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IMPROVEMENT OF PRODUCTIVITY OF A CYCLE PARTS MANUFACTURING UNIT

A thesis

By

MOHAMMAD IQBAL



A thesis submitted to the Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka in partial fulfilment of the requirements for the Degree of Master of Science in Industrial & Production Engineering.

December 21, 1993

Department of Industrial & Production Engineering
Bangladesh University of Engineering and Technology



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To
My Beloved Parents

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ABSTRACT

The improvement of productivity is a concern which involve several disciplines, including management, design engineering, ergonomics, safety engineering, etc.. Most of the cycle parts manufacturing units in Bangladesh cannot compete with the imported bicycles components. The primary reason being their higher costs of production arising due to lack of proper utilization of man, machine and raw materials, excessive consumptions of spare parts and fast moving tools and failure to meet the market demand.

In this regard the present work was conducted in a local production unit claimed to be the largest bi-cycle components manufacturer in the country. The objectives of the study were (i) to study and analyse of the existing production system, (ii) to suggest ways and means to overcome the weakness and bottlenecks to increase efficiency and productivity, (iii) to examine the scope for import substitution of some spare parts, (iv) to optimize of machine utilization and maximizing profit through optimum product-mix of selected spare parts and (v) to investigate injury occurrence profiles and their preventions. It was revealed, as usually found in similar studies elsewhere in various production systems that no scientific methodology was applied to improve the overall productivity of the unit. From its inception, as found from the study, standards of production were not set properly. In conducting this study an analysis of the production system was done with an objective to identify the factors due to which productivity suffers. In this regard idle/unproductive man and machine has been ascertained and ways have been suggested to remove the bottlenecks in the production system.

An isolated work was directed to make a feasibility study of manufacturing few selected spare parts to be used for the machineries used in the unit. The production processes were also developed. The work also concerns with the optimization of machine utilization and profit maximization for production of the selected spare parts using linear programming technique.

To increase the overall productivity and reduction of cost another isolated work was directed. An attachment was designed for drill bit resharpener which would give accurate profile of cutting edges of drill bits. Design of an industrial work station (seated worker) along with the improvement of the existing method of packing of the end products were done using ergonomic methodology.

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CHAPTER-1

INTRODUCTION

1.1 GENERAL INTRODUCTION

In the Country's industrial sector, more specifically at enterprise level, has various deficiencies in strategic planning at macro level and factory operation due to lack of technical facilities, endeavours and efforts at micro level. In the present context, strategic planning means planning of production processes, manpower utilization, control of fast moving tools and spares, production planning (Production system and capacity), working environment (includes worker's safety), manpower utilization, spare parts consumption control, lack of research, use of mathematical model in decision making and operating condition which have great effect on productivity. Research studies have shown that productivity due to human factors depends on, amongst many other important factors, the optimal working condition. Increasing efficiency and productivity in a working condition depends on a worker's health and working safety. Unplanned system of production is one of the many factors which affects adversely on increasing productivity. Therefore it requires an effective system for improve utilization of both man and machine .

Plant, equipment, spare parts and fast moving tools play an important role in a productivity improvement through following basic procedures:

- i. Good maintenance of machines and keeping their proper log books.
- ii. Operating the plant and equipments in optimum process conditions.
- iii. Increasing plant capacity by eliminating bottle necks and by taking corrective measures for reducing idle time and making more effective use of available machineries and plant capacity.

Bangladesh like other developing countries is incapable of raising the industrial growth with its own technology and limited resources. It requires substantial amount of investment to import technology, equipments, machineries and component parts. In the developing economy industrial sector /projects chronically suffer from shortage of spare parts which are obtained from the original manufacturer. The procurement of such spares is a lengthy and cumbersome process. To alleviate this situation many policies were formulated regarding import-substitution of spares in the past. But no significant improvements have been reported in the country. In this regard efforts have been given isolatedly at university and research centres to explore the feasibility of manufacturing of spare parts indigenously and substitute imports. But these are not sufficient. Moreover, research/project work and effort at enterprise level has been undertaken to manufacture spare parts locally and in-house.

1.2 BACKGROUND OF THE STUDY

In the country, interestingly, the bicycle is the next common means of transport after the boat. Figure 1.1 shows the major transport modes in 1989. Every year three times as many bicycles are produced as cars (99 million of bicycles in 1987 compared with 33 million of cars)[9]. Production of bicycle is dominated by the

Asian countries, namely China, Taiwan, Japan and India accounting for two-thirds of the world's total. Rickshaws and bi-cycles constitute the most important transport sector in Bangladesh. Relative shares of the market for rickshaw and bi-cycle components in 1988 is given in Fig. 1.2. Rickshaw spares market contain 47% cycle parts and 16% rickshaw parts; bicycles market contains 14% bicycle spares and 4% new bicycles and new rickshaws market contains 7% cycle parts and 12% rickshaw parts. The total rickshaw and bi-cycle components market in the country is worth over Tk. 200 crore annually (US\$ 63 million). There are two million bi-cycles in Bangladesh and their growth per annum is 52,500 new bi-cycles. There are 10,00,000 rickshaws and 75,000 new rickshaw are built every year. Eighty percent of components are common for rickshaws and bi-cycles. Proportion of bi-cycles components demand in the country taken by (i) Rickshaws Vs. bi-cycles, (ii) New vehicles Vs. spare parts are given in Table 1.1. Besides that Table 1.2 shows annual demand of selected cycle components in Bangladesh for the year 1988. Spokes, rims, nipples, washers, frame, front forks are the cycle components which are produced indigenously. But locally made cycle components cannot compete with the imported bi-cycles components due to the following reasons [9]:

- i. Inefficiency in overall production planning
- ii. Lack of knowledge about capacity of plant and its utilisation
- iii. Lack of know-how to make quality products
- iv. Right supply of bi-cycle components to enter the local market at right time

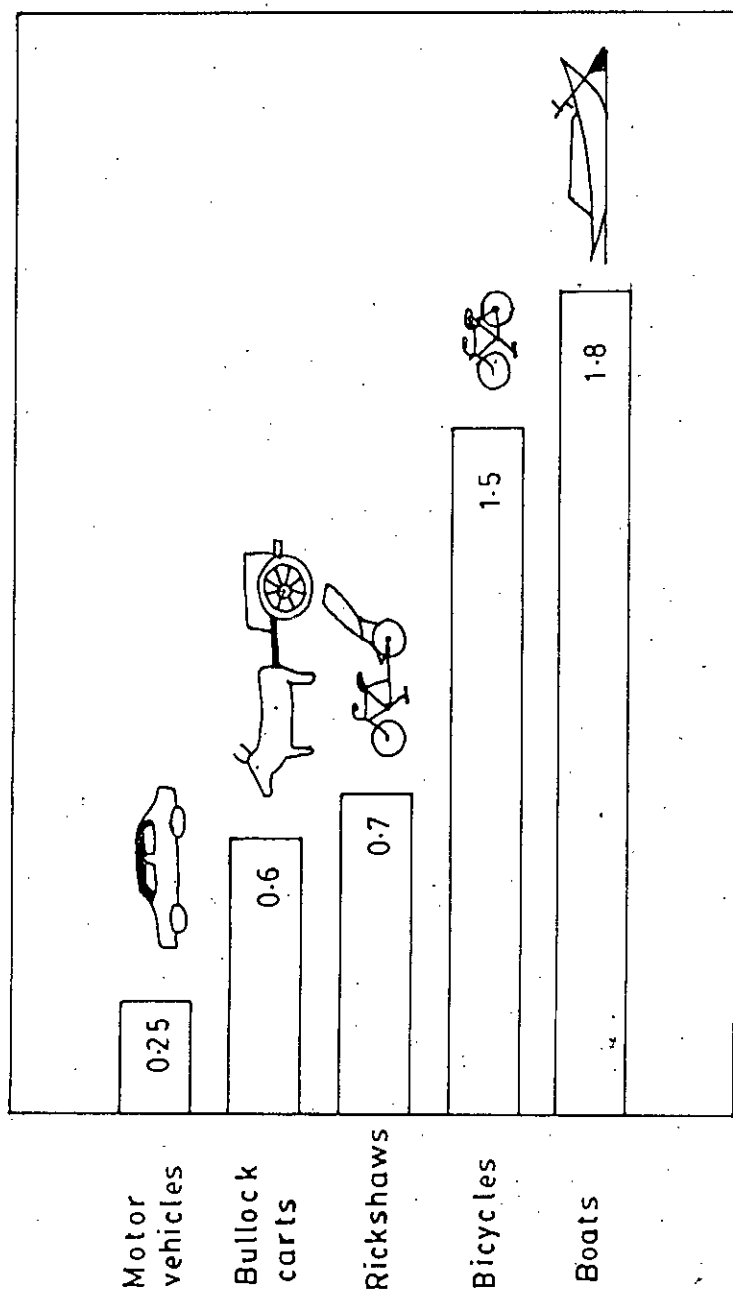


Fig.1.1 Main transport models in Bangladesh 1989 (numbers are in millions)

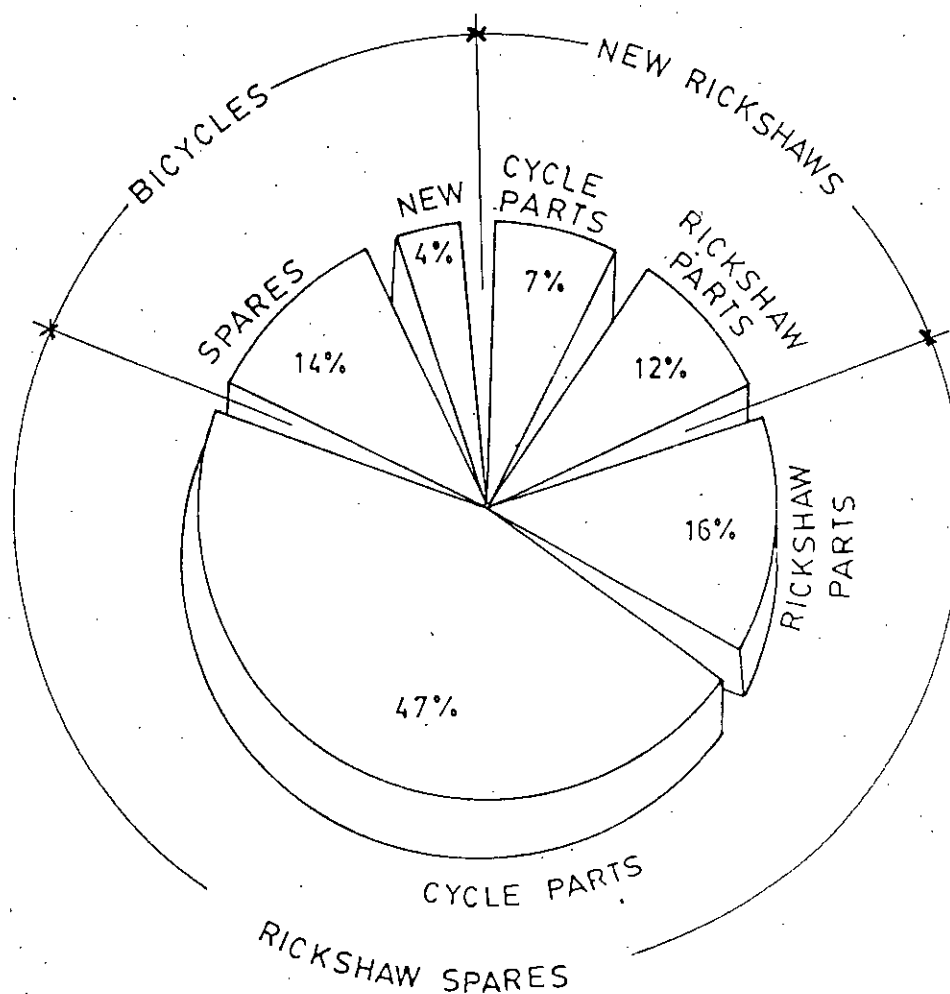


Fig. 1.2 Relative shares of the market for Rickshaw and Bicycle components (1988)

- v. Excessive cost of fast moving tools and spare parts for production of bi-cycle components which takes away lion share of the capital invested. Thus blocking the purchasing capacity for other items like chemicals and raw materials in time and delaying production of rims, spokes, washers and nipples. Lack of standardization of spare parts and tools is another problem for purchasing components in due time
- vi. Unsafe working environment which causes industrial injuries to workers thus delaying production and delivery of bi-cycle components to market in time

Table 1.1 : Proportion of Bicycle components demand taken by :

i. Rickshaws vs. Bicycles

ii. New Vehicles vs. spare parts.

Item		Rickshaws		Bicycles		Total %
		New %	Spares %	New %	Spares %	
1.	Tyres	6	75	3	16	100
2.	Rims	15	54	7	24	
3.	Chains	13	66	5	16	
4.	Chamwheel Cranks	12	55	9	24	
5.	Freewheel	12	52	8	28	
6.	Handle bar sets	17	38	12	33	
7.	Seat	22	34	16	28	
8.	Bottom Bracket Axle Set	12	52	8	28	
9.	Front Hub Barrel	10	44	7	39	
10.	Front Hub Spindle	5	49	4	42	
11.	France	19	42	14	25	
12.	Front Fork	16	42	11	31	
13.	Front Tubes	14	60	7	19	

Note : The above figures were taken when there were 665,000 rickshaw in Bangladesh at the start of 1988 with 75,000 new rickshaws added during the year (various Statistical Year Book of Bangladesh)

Source : Ref: Gallagher, Rob, 'The Rickshaws of Bangladesh', University of Press Limited, pp.416, Feb., 1992

1.3 PRESENT SITUATION OF CYCLE COMPONENTS MANUFACTURING INDUSTRY IN BANGLADESH

During the preindependence period (before year 1947), bicycles were imported from U.K. By the year 1961 there were 7 bicycle components manufacturing factories which stands now at 24. The list of such units with employees engaged are given in Table 1.3. However, its true picture is not clear from government statistics. This is because some firms are listed under other sector's, such as tyre and tube manufacturers, lock and bell makers, etc. and there are dozens of unregistered small units. Table 1.4 gives names of firms which produce various bi-cycle components.

Table 1.3 : Rickshaw and bi-cycle components industries of Bangladesh

Firm	Employees
North Bengal Cycle Industries	139
Purbadesh Cycle Industries	20
Bangladesh Cycle Industries	214
International Engineering Co.	57
Pilot Cycle Industries	13
Meghna Cycle Industries	51
Titas Cycles (Pvt) Ltd.	N/A
Dhaka Industrial Co.	40
N. Islam & Bros.	27
The Bengal National Engineering Works	41
Nurjahan Cycle Industries	31
Mannaf Cycle Industries	37
Suny Metal Industries	27
Three Star Cycle Industries	9
Karim Cycle Industries	13
Bangladesh Cycle Works	N.A
Alam and Co.	25
Rostom Traders	12
Jessore Cycle Industries	N.A
Popular Cycle and Rickshaw Industries	17

Note : All of the above firms are located within Dhaka Metropolitan Area, except North Bengal Cycles (Tangail), Alam and Co. (Comilla), Rostom Traders (Sylhet), Jessore Cycle Industries and Popular Cycle and Rickshaw Industries (Chittagong)

Source: Ref. Gallagher, 'The Rickshaws of Bangladesh, University Press Ltd., pp.419, Feb. '92

Table-1.4 : Approximate numbers of firms producing various bi-cycle components in 1991

Components	Approximate number of firms	Name of Enterprises in production
Rims	2	North Bengal Cycle Industries Meghna Cycle Industries
Tyres and Tubes	7.8	Crown Rubber Industries Bagh Rubber Industries Ibrahim Rubber Industries Haque Rubber Industries Karim Rubber Industries Bengal Rubber Industries
Spoke	7	North Bengal Cycle Industries Meghna Cycle Industries Bangladesh Cycle Industries International Engineering Pilot Cycle Industries Purbadesh Cycle Industries
Front Forks	20-30	Most of the firms listed in the Industrial Directorate and many unregistered firms situated in Dhaka
Mudguards	10-15	N & S Engineering N. Islam and Bros. Sony Metal Industries M/S. Dhaka Industrial Co.
Bell	3	Sunny Metal Industries Pilot Industries
Bicycle Seats	3	Jony Masud Cycle Industries Mohendro Bico. (Assembly only)
Cycle Locks	1	Bico.
Handle-bar Grips	40-60	Small industries (They also make low quality rubber brake shoes)
Rexene	7*	4 in Dhaka make 'Japan' quality 3 in Chittagong make low quality

Source : Interviews with traders in Bangsal and components firms.

* 8 additional units under construction.

From recent studies and Table 1.3 it becomes evident that the size of the industry is still very small. The largest industry (North Bengal Cycle Industries Ltd) in Bangladesh has only 139 employees. Most other registered factories have 2 to 40 employees while the unregistered factories usually have only a few workers.

Most of the firms are located in Dhaka and the others are located mainly in Chittagong and Jessore. There are several reasons for this locational pattern. One is historical - the early entrepreneurs migrated to Dhaka from India. Other reasons relate to already available existing facilities of production and marketing in Dhaka and Chittagong. Many firms depend on specialised inputs and services which are only available in Dhaka (e.g. imported raw materials and services such as chrome plating etc.). It is also the centre of components whole-sale business. About three hundred shops in Bangshal (an area in old Dhaka) serve customers from all over the country. The power supply and availability of raw materials are the other factors. These factors in most cases influence heavily on deciding the location of the factory. In this context an example may be forwarded - the North Bengal Cycle Industry. This was illustrated when the North Bengal Cycle Industries Ltd was originally planned to be set up in Bogra in early '80's. But considering reliability of power supply and availability of raw materials it was finally decided to set up the industry in its present location at Gorai, Tangail.

Except the North Bengal Cycle Industries Ltd. (NBCIL), all other cycle components manufacturing firms produce limited number of bi-cycle components such as spoke, washer and nipples. In addition to producing components mentioned above, these firms also import them parts alongwith other parts such as mud

guard, chain, chainwheel, front wheel hubs and many other components to meet the market demand. Recently the Meghna Cycle Industries has installed rim forming machines and is producing rims for local market in a very limited quantity.

1.4 AIMS AND OBJECTIVES

The primary purpose of the present work is to propose suggestion as to how the overall productivity of a bi-cycle parts manufacturing firm could be increased. Following are the aims and objectives of the thesis :

- i. To study and analysis of an existing production system of a bicycle parts manufacturing enterprise.
- ii. To suggest ways and means to overcome the weakness and bottlenecks to increase efficiency and productivity.
- iii. To examine the scope for import substitution of some spare parts.
- iv. To optimize of machine utilization and profit for production of the selected spare parts.
- v. To investigate injury occurance profiles and their preventions.

1.5 ORGANIZATION OF THE THESIS

The thesis is organized as follows:

In the second chapter a survey of some relevant literature on system approach and productivity improvement is presented.

Chapter Three presents a system approach to analyse the existing system of a cycle components manufacturing unit. Chapter Four presents the analysis of production system and capacity determination of the spoke section. The fifth chapter presents selection of spare parts to be produced and developing their manufacturing processes. In the six chapter, formulation of models for optimization of machine utilization & profit maximization and their solutions have been described. The seventh chapter presents design of an attachment for drillbit sharpening. Chapter Eight describes how efficiency and productivity of packing section can be increased. Chapter Nine presents investigation on injuries generally occurs at the study unit and their preventions. Conclusion and recommendations for future research are presented in chapter Ten.

CHAPTER-2

LITERATURE

2.1 INTRODUCTION

The present work as already mentioned in Chapter 1 is directed towards productivity improvement of a cycle parts manufacturing unit using system approach & scientific methodologies of industrial engineering. It has been proven that succes of an enterprise depends entirely on the systematic and system & scientific management approach.

The following section presents a review of some work on system approach & productivity improvement.

2.2 REVIEW OF SOME RELEVANT LITERATURE

The approach presented by Meredith [19] leads engineers to pose problems in greater depth, to focus on the necessary integration of the factors influencing the problem of a business firm. It also would help engineers to develop an awareness of the activities of a firm and to develop an approach to solve any problems ina manufacturing unit.

B.Wu [29] attempted to show how structured approaches in the design and evaluation of a modern manufacturing plant may be adopted, with the objective of improving the performance of the factory as a whole. The purpose is to

demonstrate the system aspects of modern manufacturing operations, including: Systems concepts of manufacturing operation; manufacturing systems modelling and evaluation; and the structured design of manufacturing systems.

The case study of Mehran [26] conducted in four major American manufacturing companies have improved substantially the operational productivity. Mehran used the combination of two approach automation (technology) and Just-in-time (organization). It is pointed out that management involvement and worker education are essential in any productivity improvement program.

Dorffment [7] reports a pilot productivity program for improving productivity of white collar personels in a mechanical engineering organization. A task form is introduced in order to give management and the engineer the better control and visibility over each project and the department workload as a whole. The analyst performing the task completes the performer's assessment. The assessment process focuses attention on the process used to do the work and the resource involved.

Ramsay [24] presents a modelling technique for examining the productivity performance of an Australian public utility which highlights the factors critical to improve performance. The "Rational Summation Model" as it is called is used to provide management with a tool capable of revealing the interrelationship of factors and the ability to simulate change and record the effect made on the overall productivity performance of the organization. Twelve inputs have been identified for analysing using this model and which form the basis of providing total productivity performance measures and partial productivity performance

measures. Using the model as a basis, future operating scenarios are also simulated.

Dehelly and Laredo [6] presented a case study for explaining the European approaches to productivity Improvement in an European company of the worlds largest electronics groups. On the basis of fine assesment of activities and arts an extensive merger of the maintenance function and the production function was made. The stock level is reduced by adopting a method which consists simply in adjusting a few con trol parameters and the Japanese style zero stock system.

Gupta [11] presents a case study on industrial experience that obtained productivity gain in the largest engineering industry in India. The salient feature of the productivity movement in the organigation were the identification of " Productivity" as the key area for organizational excellence, opening of new productivity department, formulating policy and guidelines for giving clearcut direction for proposing" productivity" concept, planning, designing, monitoring and evaluation of systems. For this objectives were identified and different approaches were taken to achieve these objectives.

Compared to the various work discussed above on system approach and productivity improvement, the present work deals with improvement of productivity of a cycle parts manufacturing unit in Bangladesh. No such study has been conducted in any cycle components manufacturing unit. This will allow to identify the major bottlenecks in the existing system and to overcome them.

CHAPTER-3

PRODUCTIVITY STUDY -A SYSTEMS APPROACH

In the chapter the productivity study of a bi-cycle components manufacturing unit by applying systems approach concepts and system description technique- IDEF was made. The term "IDEF" stands for Integrated computer-aided manufacturing DEFinition or simply "Integrated DEFinition" of a complex manufacturing system. IDEF has been applied to analyse the existing system of the North Bengal Cycle Industry to find out the bottlenecks in the system; these hamper the overall production of the enterprise.

3.1 CHARACTERISTICS OF A MANUFACTURING BUSINESS FIRM

A business firm is a system of interrelated parts working in conjunction with each other in order to accomplish a number of goals. A dynamic model of a business firm is shown in Fig. 3.1.

Manufacturing firm takes people, resources, capital and management from outside sources as inputs and transforms them into products and services which are disposed of outside its own system. When functioning properly, an open system reaches a steady state or equilibrium. Similarly a firm maintains a constant state while matter and energy which enter it keep changing (so-called dynamic equilibrium). An increase in the cost of goods forces a comparable increase in prices or decrease in operating costs. This responses gives the firm its steady state.

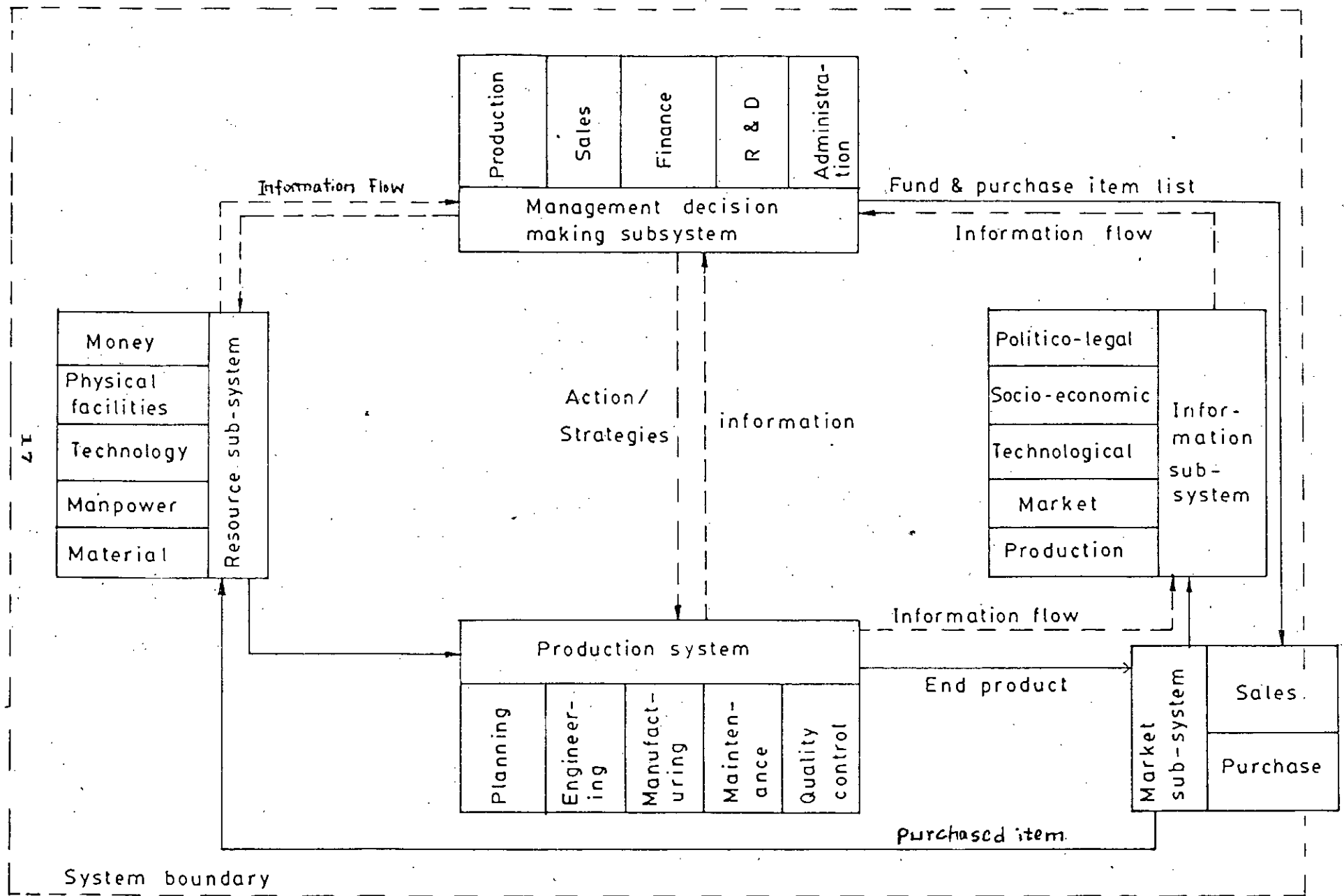


Fig.3.1: Dynamic model of a business system.

A system has elements which guides the system. These elements are known as control elements. In manufacturing business system it is the decision making subsystem that controls the pattern of activities governing input, processing, and output. Management as a decision-making body controls the inflow, handling, and outflow of activities that effect the welfare of the business. Control is carried out through management decisions on the level of production, product prices, the level of employment, the level of investment, and so on. These decisions have to be made on the basis of the performance of the organization in relation to the business target which is set for the organization. Control concept of a manufacturing business organization is given in Fig.3.2. Control in a dynamic system is achieved by feedback. Feedback provides both negative and positive information. The open system, which controls itself with the basic characteristics of feedback. Information about end products sales and market situation of a system is feedback to decision making subsystem that controls the pattern of activities governing input, processing and output. Management analyses the information and gives decision depending on other subsystems of the firm. Feedback involves communication, the transmittal of information from one place in the system to another.

3.2 SYSTEM DESCRIPTION WITH SYSTEM APPROACH

The systems approach is a philosophical orientation and a desirable goal. It receives inputs and, after a transformation of some kind takes place, it produces an output that will be an input to other systems. The input transformation-output concept is basic to systems theory.

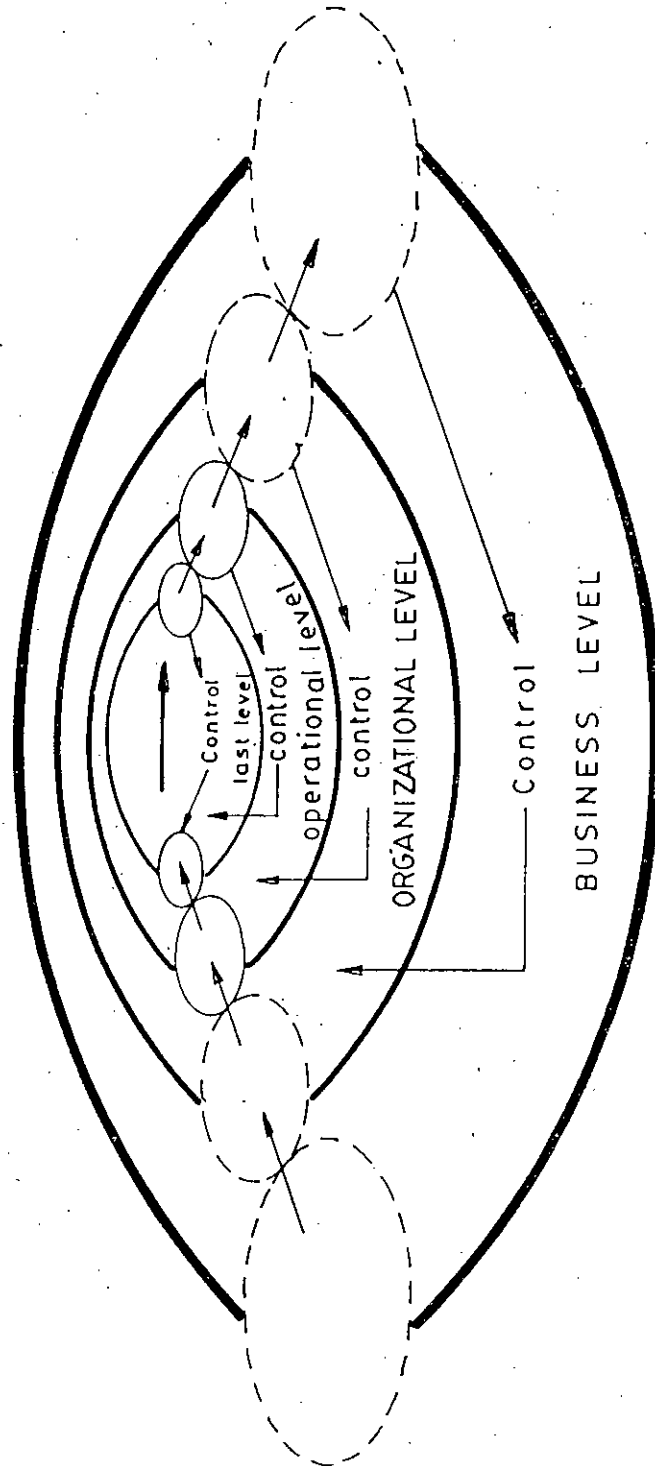


Fig.3.2:Control hierarchy of a business organization

The system approach presents the "big picture" as a way of thinking about the job of managing. It provides a framework for relating internal and external environmental factors into an integrated whole. Systems concepts help management expose and to some extent reduce this complexity. A system approach to problem - solving usually involves looking at a situation from the top down rather than from the bottom up.

Depending on the number of hierarchical levels involved, a subject system may be further divided into sub - systems and components, each of which will receive inputs and transform them into outputs. Out of different systems, modern manufacturing system embraces a wide range of applied methodologies and technologies, process a variety of material, and the rates of change are considerable. Until recently this system was analysed in traditional approach based on specialized and isolated segments. But with the development of knowledge and computational skill manufacturing system may be analysed from a systems perspective as an integrated combination of process, machine system, people, organizational structure, information flow, control systems and computers. Approach from a systems perspective has led to development of various conceptual models of manufacturing system. One such model which provides a useful way of specifying the information and organization structure within a complex manufacturing system is briefly described in the next section.

3.3 SYSTEM DESCRIPTION TECHNIQUE - IDEF SYSTEM

IDEF is one of the system description techniques. The term "IDEF" stands for Integrated computer-aided manufacturing DEFINition or simply "Integrated DEFINition" of a complex manufacturing system.

The technique consists of three basic levels. IDEF₀, IDEF₁, IDEF₂.

System Description IDEF₀:

IDEF₀: It is a technique that can be used to specify completely the functional relationships of any manufacturing environment.

System Description IDEF₁:

IDEF₁: It is used to describe the relationship between data items in the environment so that a relational data base model may be specified.

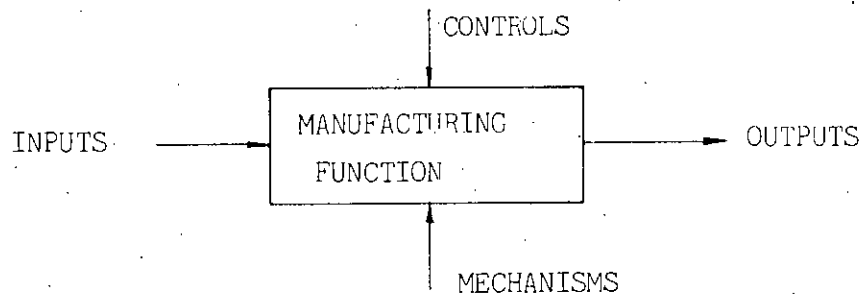
System Description IDEF₂:

IDEF₂: It is a simulation technique that can be used to investigate a system's dynamic behaviour. These three techniques may be used independently.

IDEF₀ is a systematic methodology used to produce a functional model which is a structured representation of the functions of a manufacturing system and the flow paths of information and objects which interrelate those functions. It is by nature a "top-down" approach. In this study, the IDEF₀ technique will be used to describe the functional relationships and specify the flow pattern of information and material within the system of the study unit.

The IDEF₀ function block:

The basic element of an IDEF₀ model is called a function block as shown below.



In such a model, the individual function blocks are linked together through the inputs, the outputs, the mechanism and the controls. They can be either physical objects or information. The performance of the function is carried out through a mechanism and under the guidance of the control[29].

Function decomposition

An IDEF₀ model can be expanded to any level of details. A function block in the system can be decomposed into more detailed function blocks further down the structure hierarchy. The highest level function block describes the main purpose of the subject system and the lower-level function blocks describe the supporting sub-systems which exist to serve the upper levels. In Fig.3.3 the IDEF₀ function decomposition is shown. The function and subfunction are defined as follows:

A_0 = Overall system function with system boundry { $A_1, A_2, A_3, \dots$ }

$A_1, A_2, \dots, A_n$ = Sub-Function of A_0

$A_1 = \{A_{11}, A_{12}, A_{13}, \dots\}$

$A_2 = \{A_{21}, A_{22}, A_{23}, \dots\}$ and so on.

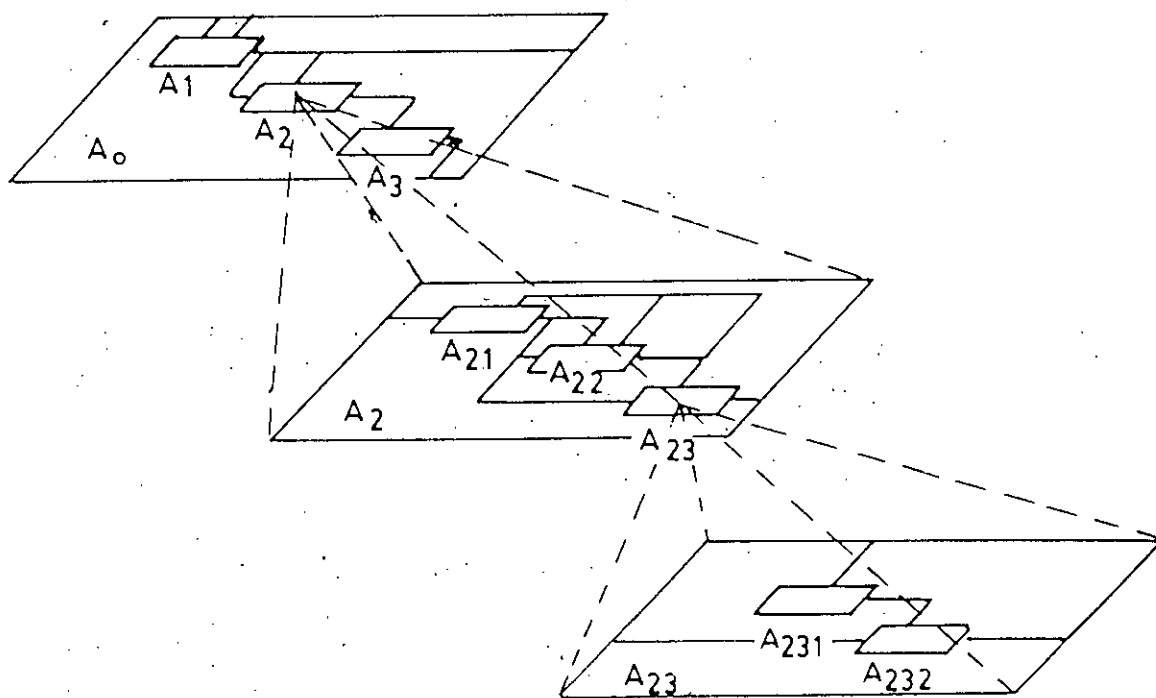


Fig. 3.3 : IDEF Function levels and decomposition

A complete IDEF₀ model provides a comprehensive description of the functions and their relationships within the manufacturing environment being modelled as shown in Fig.3.1. This technique, therefore, provides a clear specification methodology for total system description at any desired level of details.

The major advantages of IDEF₀ includes the followings:

- i. It permits an effective, standardized systems communication method whereby system analysts can properly communicate their concepts.
- ii. It permits a system to be described in as complete a level of detail as desired.
- iii. It provides a mechanism for decomposing a function into a number of smaller sub functions and verifying that the inputs and outputs of the function match those of its sub-function.
- iv. It has the potential to be used as an industry standard for manufacturing design.

3.4 DESCRIPTION OF BI-CYCLE MANUFACTURING UNIT-USING IDEF TECHNOLOGY

The North Bengal Cycle Industry (NBCIL) is a private limited company. It is an import substitute industry manufacturing bi-cycle components and capable of catering the entire demand of the country for spokes, nipples, washers and rims. Full production capacity of NBCIL is 7,20,000 grosses spoke, nipple and washer and 7,20,000 pcs. rim yearly. The industry is capable of manufacturing rims and spokes for Motor Cycles as well. Manufacturing processes of the various bi-cycle components involved in are discussed in this chapter.

The above mentioned bi-cycle components such as nipples, spokes, washers and rims are used in the following:

- i. Bi-cycles
- ii. Rickshaws
- iii. Van-carts
- iv. Wheel chairs.

The IDEF technique is now presented as used in NBCIL. Fig. 3.4 provides an overview of the bicycle components manufacturing activities. The functions of the study unit may be grouped into the following four areas, according to customer enquiry to product delivery.

1. Market(sale & purchase)
2. Management decision making
3. Resource
4. Production.

The relation between those areas are as illustrated in Fig. 3.5 which is the expansion of the bi-cycle components manufacturing model to it's first level of decomposition. Here the highest level function block is the manufacturing of bi-cycle components on customer order which is denoted by A_0 . In another words A_0 represents the overall system objectives and system boundary. The IDEF technique with system description is given below:

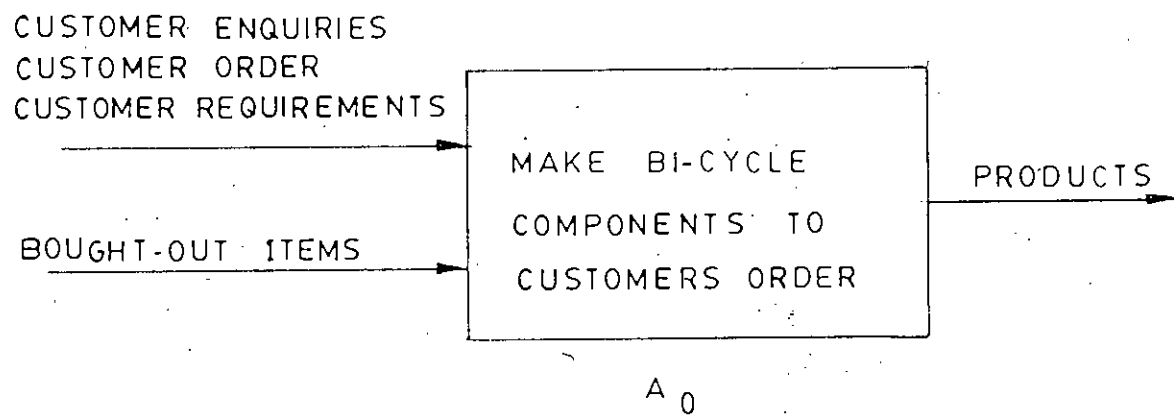


Fig. 3.4 : Simplified overview of the bi-cycle components manufacturing operation

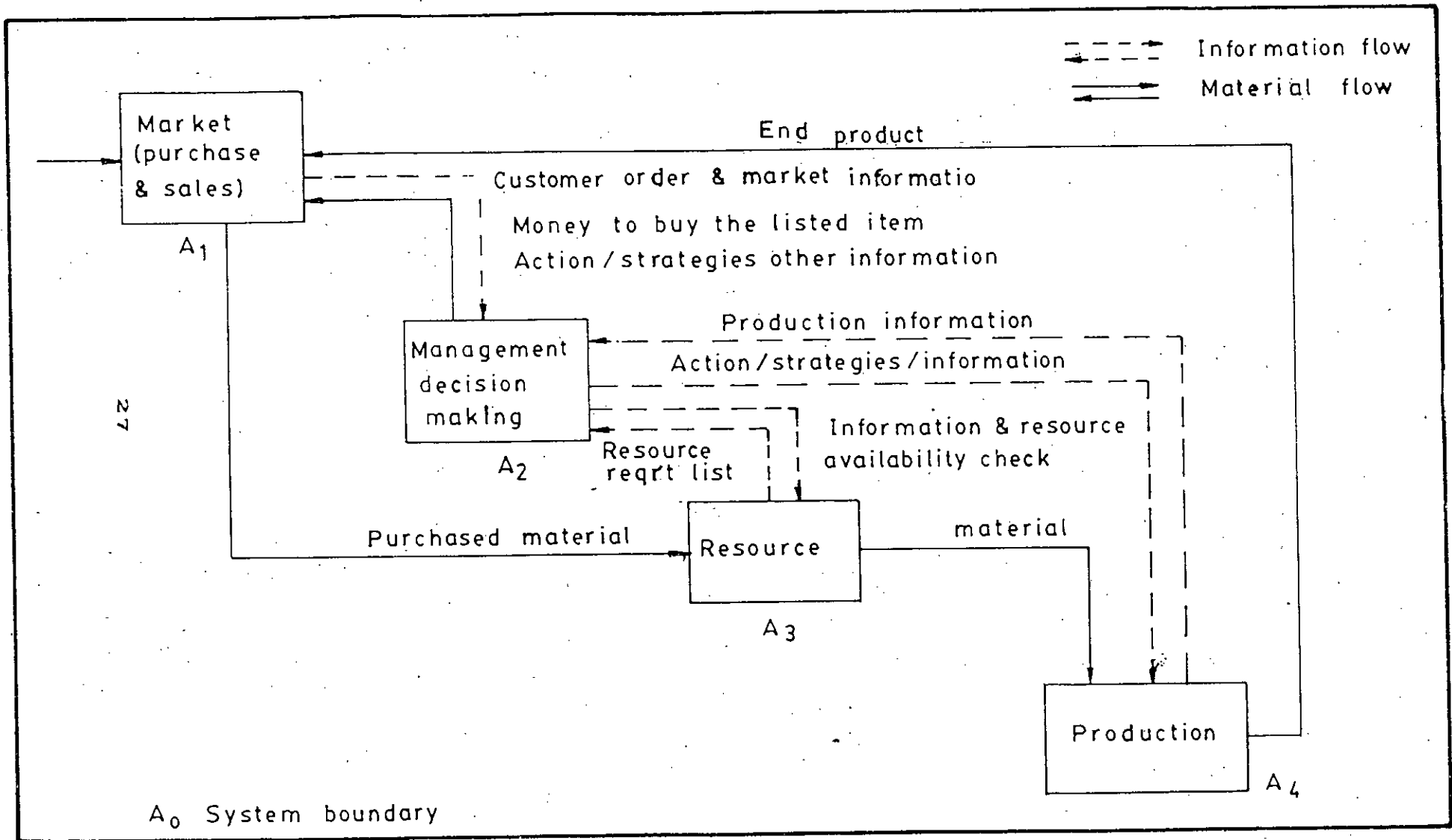


Fig.3.5:Represents bi-cycle components manufacturing system
Its first level of decomposition

A₀ : MAKE BI-CYCLE COMPONENTS TO CUSTOMER ORDER

{A₁, A₂, A₃, A₄}

Where A₁ = Sales and purchase
 A₂ = Management decision making
 A₃ = Resource
 A₄ = Production.

A₁: Sales and purchase subsystem

Sales and purchase subsystem is shown as function block A₁ in Fig.3.5. It consists of two components which are the two major tasks as shown in Fig.3.6 and Fig.3.7.

A₁₁: Sales

1. Customers make communication with the sales department to make an enquiry on bi-cycle components.
2. In response to this customer enquiry, the manufacturer will prepare a proposal including price and delivery dates.
3. The customers will carefully examine the proposal in terms of quantity, price and delivery date probably comparing it with market price.
4. If not satisfied the customer will see another company or he will contact the manufacturer again and ask for modification.
5. Through a number of iteration of stage 3 and 4 a mutually acceptance agreement may finally be reached. At this point the customer issues an order for the bi-cycle components.

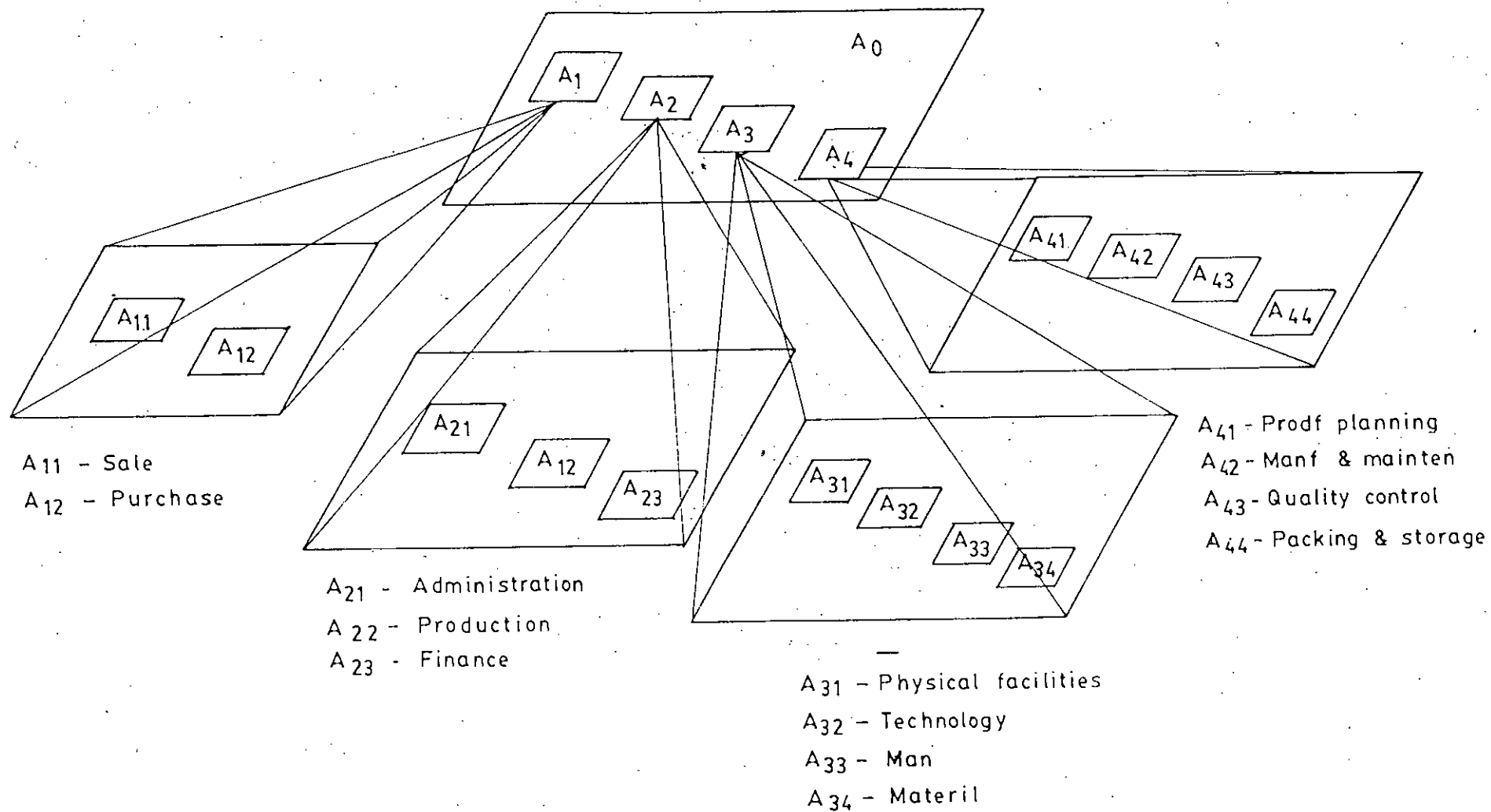


Fig.3.6: The subfunction block at next level $A_{11} \dots A_{21} \dots A_{31}, A_{32}$ and A_{41}, A_{42} shown below

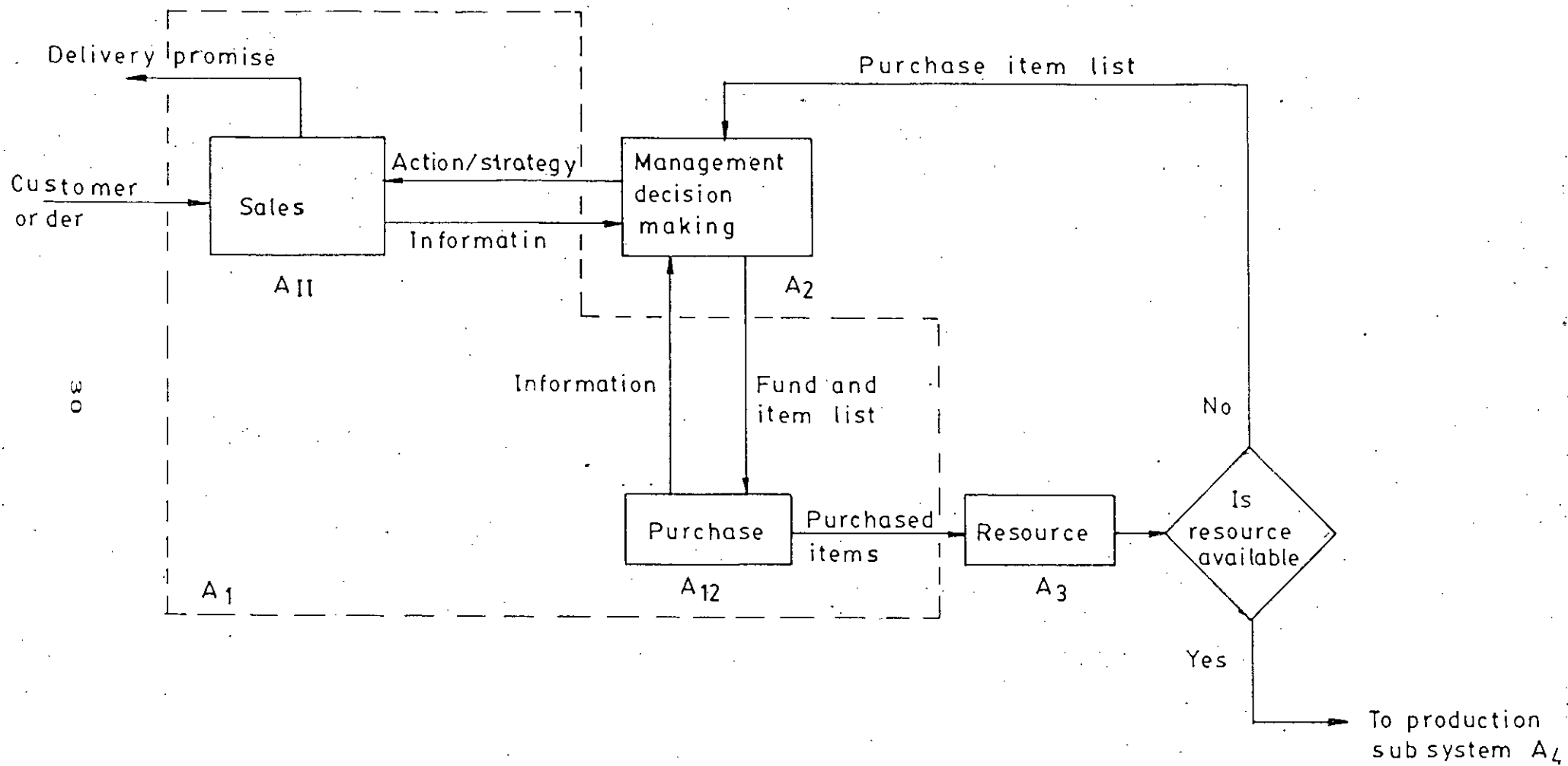


Fig 3.7: Market components and their relationship with other subsystems (A1)

It is important to recognize that, from a systems point of view, the customer act as the wider system to the manufacturer. The company has to satisfy customer's objectives in order to maintain a reasonable relationship between itself and its wider system. It is the task of the sales department to satisfy the requirement of the wider system and in doing so to secure the inflow resources by receiving orders from customers. The sales department must balance demand against its technical, capacity and cost information to determine the sales plan which best satisfies the requirements of both customers and company. It should be remembered by the manufacturer that the incoming rate of customer orders may in general be influenced by the delivery performance of the manufacturer.

A₁₂: Purchase

When the fund is released by the finance department to buy the listed items in order to produce the ordered products to deliver in time, that list is sent to purchase department. According to purchase list, purchase department buys raw material, machinery spare parts, tools, chemicals and packing materials etc. Those bought items goes to resource storage use (Fig.3.8).

A₁: Management decision making subsystem

Management decision making subsystem is shown as function block A₁ in Fig. 3.6. The components of this subsystem is described using IDEF format in Fig. 3.9.

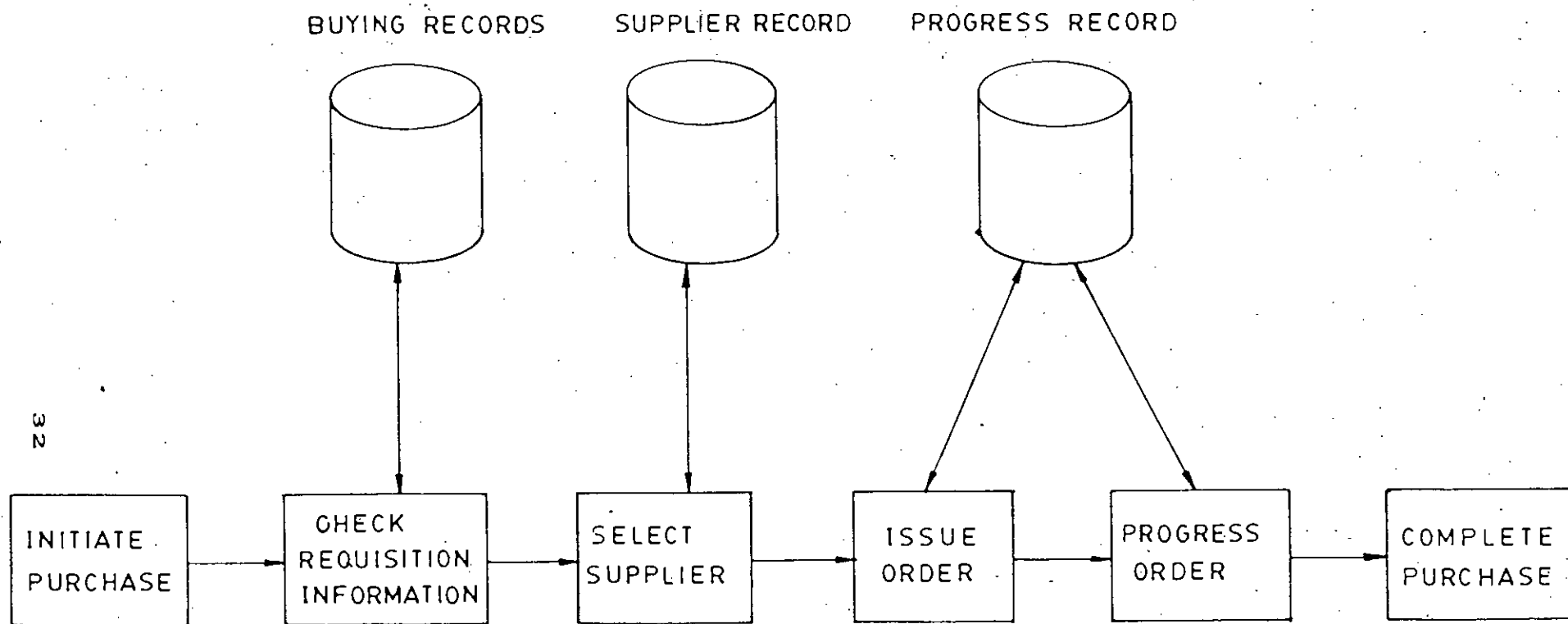


Fig. 3.8 : General purchasing procedures.

Fig.3.9; Management decision making components (A₂)

A_{21} : Administration

Administration deals with administration, direction, coordination and control of the unit. For example it's function is to receive all information and data from sales, purchase resource and production components and supply those to the respective places. Besides it recruits personnels and controls workforce in the compound of the unit and in the offices outside of the unit. It deals with the workers and officers activities.

A_{22} : Production (Component of management decision making)

Report on activities of production subsystem and its different functions are placed time to time to management decision making function which deals with production. Reports on daily production of bi-cycle components and consumption reports of chemicals, tools, spare parts and packing materials are supplied. It estimates the cost of items to be procured for producing the ordered products. Monthly reports of production of bi-cycle components, reports on consumption of chemicals, packing materials, machinery spare parts and tools are supplied from production subsystem (A_{11}) to production component (A_{22}) of Management Decision Making Sub-system (A_2).

A_{23} : Finance

The function of finance is to release a fund to buy the listed items prepared by the production function (A_{21}) of management decision making, to decide about L/C opening. These are done on the basis of quantities ordered by customers. The

sales volume is discussed by the finance. The released fund along with items list is sent to purchase department (A_{12}) through production component A_{22} for further action. Payment date of monthly salary of all personnels is decided by finance. Other functions of finance are to decide basis for the expenditure of funds to determine the financial position of the concerned by determining efficiency of the unit, and to determine product price and so on.

A_3 : Resource subsystem

Following management decision making, resource is the next manufacturing subsystem. This function can be broken down into five functions known as components (Fig.3.10). The components are described below.

A_{31} : Physical facilities

This involves machineries, tools and workshop etc. The factory has three sections namely spoke, electroplating and rim sections. (Fig. 3.11). Fig. 3.11 shows flow pattern of raw materials and components and company structure.

A_{32} : Technology

All technology in the factory are imported. Machineries were bought from Germany and U.K.

A_{33} : Manpower

At present there are 139 employees in the unit as shown in Table 3.1.

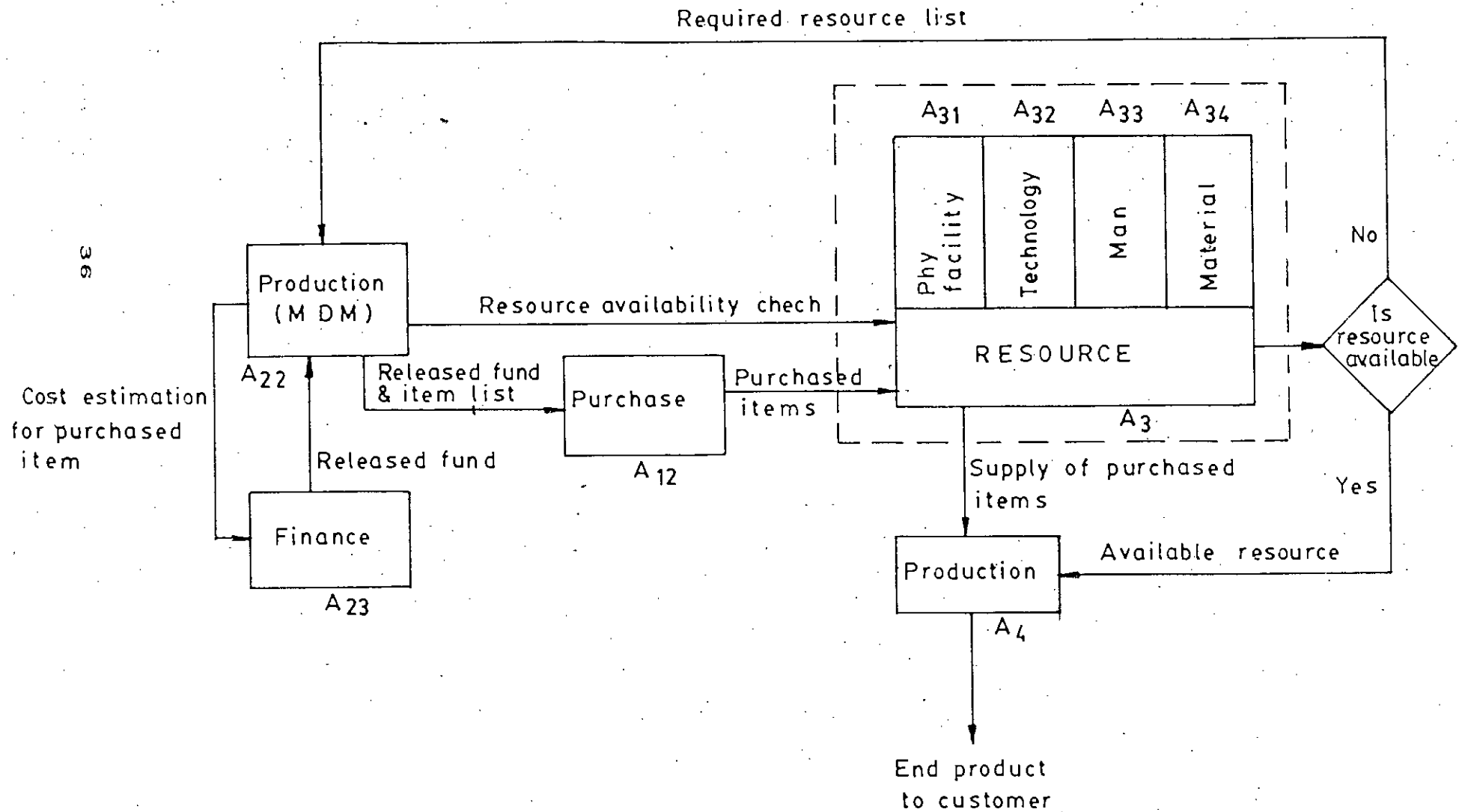
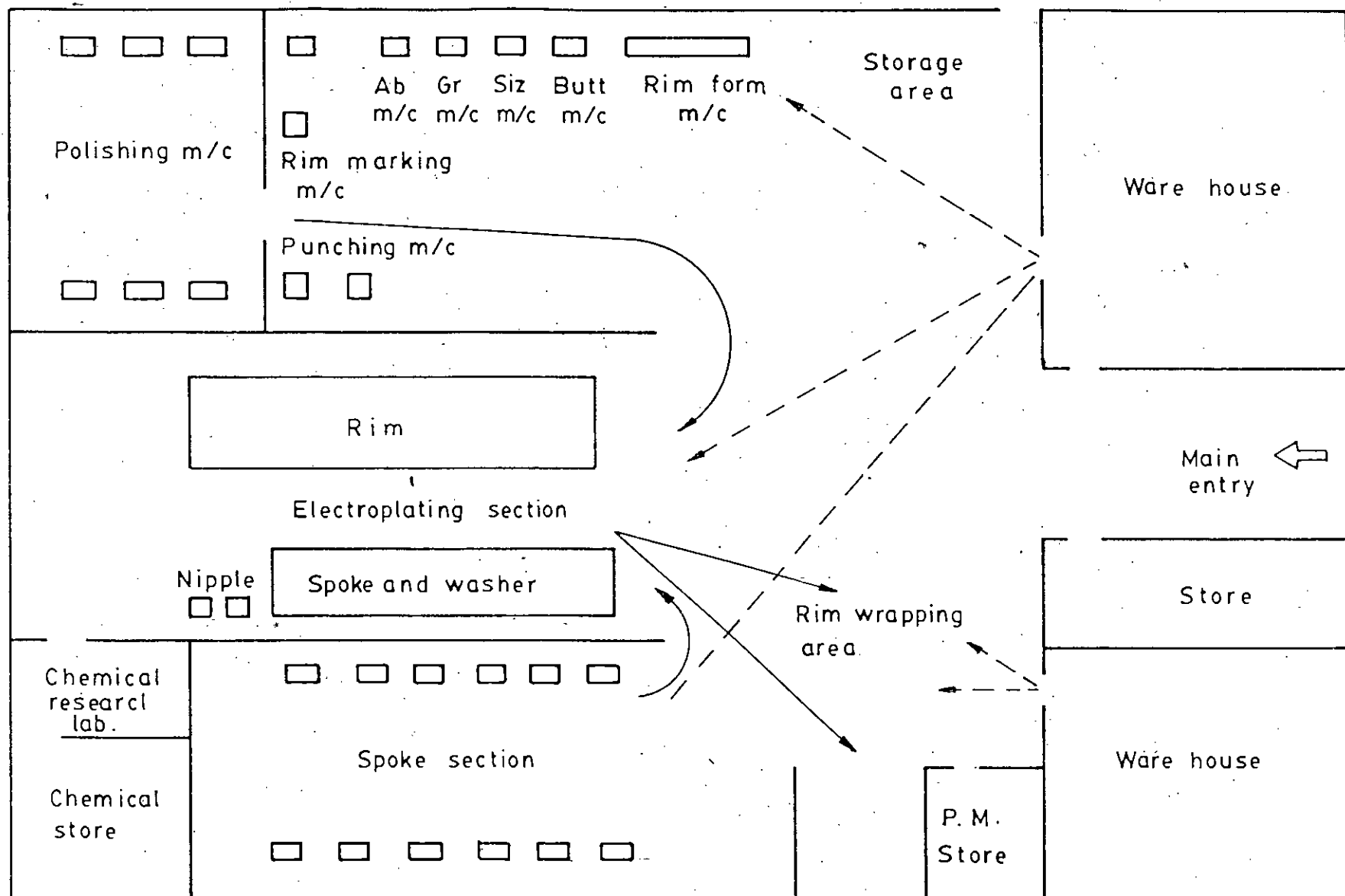


Fig. 3.10: Relation of resource subsystem with other subsystems and components.



----- Flow of raw material
 ————— Flow of finished product

Fig.3.11:Flow pattern of components and plant structure

Table 3.1

Class of Employees	Number
Admn. Officers	20
Technical Officers & staff	18
Skill, semi-skill & unskill	65
Security Guards	22
Tech. Assistants	14
	Total 139

The organization structure of NBCIL is shown in Fig.3.12.

A₃₄: Material

These are materials on which activities of production are performed. They consist of primary materials and auxiliary materials. Primary materials are to be converted into products through production processes. These include raw materials, parts and so on. Auxiliary materials are added to the primary materials (as when paint is used or electricity, lubricant oils). Most of the raw materials used for making different bicycle components are imported from U.K. and Korea and a few of them are procured from local market. Some chemicals, wrapping papers, cartoon boxes and jute twines are procured locally.

The raw materials used for manufacturing the various bi-cycle components are listed in Table 3.2 below:

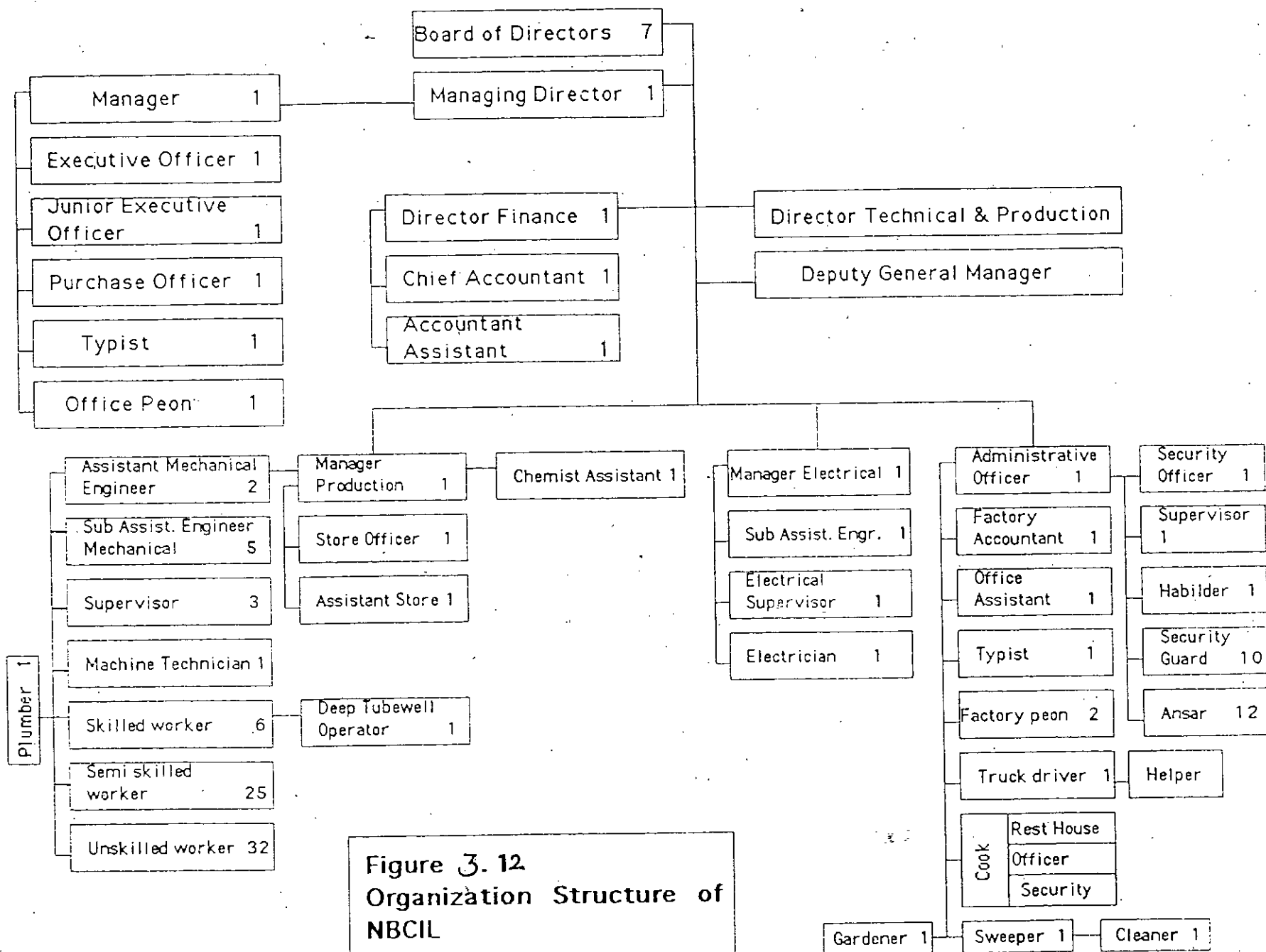


Table 3.2

List of raw materials used and their dimensions

Sl.No.	Product	Raw Material	Dimensions mm
1	Nipple	Alloy steel	Total length = 12 Dia = 3.85mm
2	Spoke	Medium Carbon Bright Steel Wire 0.10 - 0.13%	Length = 309 mm Diameter= 2.00 mm (+ 0.2 mm/ -0.00 mm)
3	Washer	M.S. Strip	Width = 70 mm Thickness = 0.5 mm
4	Rim	M.S. Strip (Heavy Strip)	Width = 79 Thickness = 1.1 mm
		M.S. Strip (Light Strip)	Width = 79 mm Thickness = 0.9 mm

Production function (A_{22}) of management decision making (A_7) checks the resource availability (A_3). If resources are available then those resources are send to production subsystem (A_1). When resources are not available then production function (A_{22}) makes a list and sends it to finance department for fund release (Fig.3.9).

A_1 : Production subsystem

Production subsystem deals with the manufacturing of ordered items by customers. The primary function of it is to gather all the resources needed to manufacture the required quantity of products. To accomplish this production subsystem has four functions which are planning, maintenance and manufacturing, quality control and packing of finished products. Fig. 3.13 shows decomposition of the production subsystem.

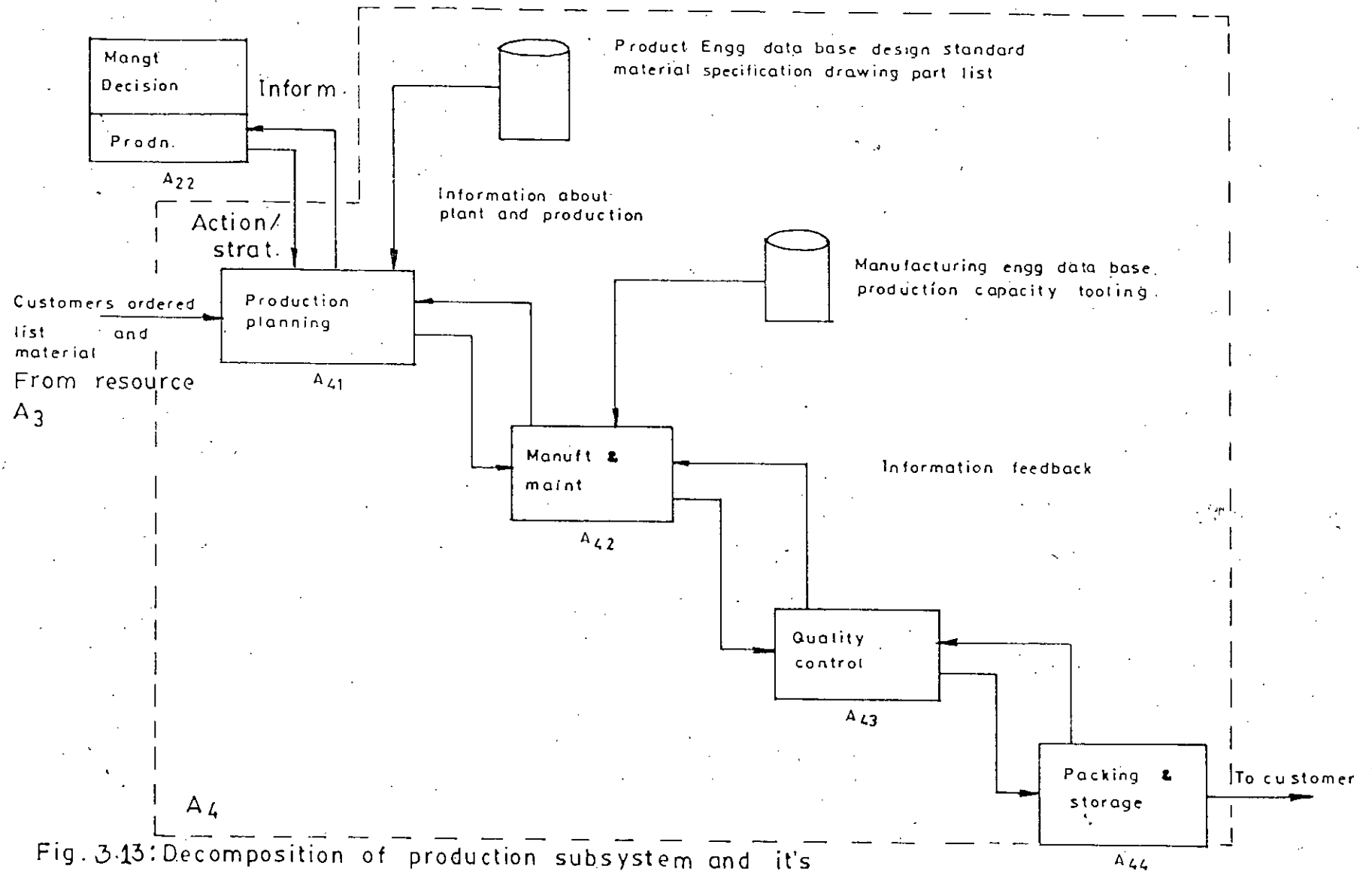


Fig. 3.13: Decomposition of production subsystem and its relationship with other sub systems (A₄)

A₁₁: Planning

It is to plan and schedule about production of nipples, spokes, washers and rims ordered. Planning involves in how many days will it take to produce; how much raw material would be required; spare parts, tools, chemicals and packing materials are required to produce the required ordered items. Also it deals with machine capacity and planning of workers duties. It supplies information to production section of management decision making subsystem.

A₁₂: Maintenance and manufacturing

The second function of production subsystem is maintenance and manufacturing. It includes cleaning of machineries and equipments, and keeping machineries operative and to check spares time to time. Proper maintenance leads to effective utilization of machineries to produce end products in due time. Also it deals with the design of end products, spare parts and rectifying breakage of spare parts and tools during manufacturing period. The order items are manufactured according to their processes in different machineries available in the plant. The production process of the bi-cycle components are described below.

PRODUCTION PROCESS OF THE BI-CYCLE COMPONENTS

The production process of cycle parts consisting of several steps and different processes involving different machines are mentioned below.

Production of nipple:

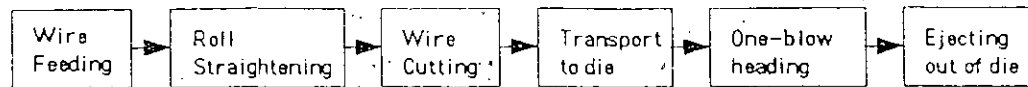
The flow diagrams of nipple production lines are shown in Fig.3.14(a) & 3.14(b) respectively.

Step-1

The production of nipple starts with Nipple-Upsetting-Machine. It is a one blow-press and makes the nipple blanks automatically from the wire coil. The wire is straightened and fed into the machine, where small wire pieces are cut and transported in front of a die. The head maker is then presses the wire into the die where it will achieve the nipple form. The finished blank is ejected. 200 pcs. of nipples are formed and upsetted per minute.

Step-2

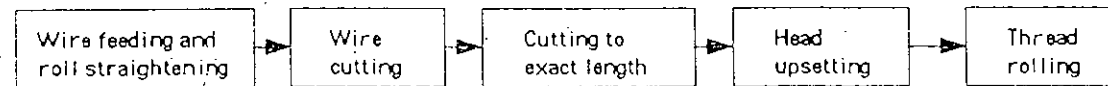
Nipple threading starts with the Nipple-Automation machine which is a round table machine and serves for machining the nipple blanks, i.e. to provide the blanks with holes, slit and thread. The blanks are filled into a hopper from which they are fed one by one into chucking tongs mounted on a revolving head



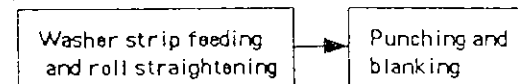
3.14(a) Flow diagram of nipple forming and upsetting by nipple machine



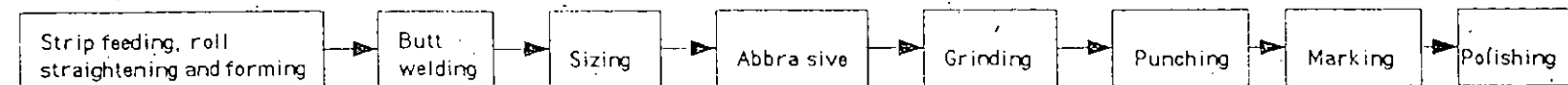
3.14(b) Flow diagram of nipple threading by nipple automation machine



3.14(c) Flow diagram of spoke forming by spoke forming machine



3.14(d) Flow diagram of washer forming by washer machine



3.14(e) Flow diagram of rim producing by various machines in rim section

Table 3.3

Standard dimension of a nipple

Before champhering		After champhering	
Total length	: 12.2 mm	Total length	: 12 mm
Shank length	: 9.2 mm	Shank length	: 9 mm
Head length	: 3 mm	Head length	: 3 mm

(See Fig.3.16)

This head indexes and takes the blanks along working stations where the different operations are executed. 43 pcs. of nipples are threaded per minute per machine. There are two alloy nipple automation machines in spoke plant.

Production of spoke

Spoke wire is straightened, sized, headed, head bended and threaded in one spoke machine in one sequence. Ninety four pcs. of spokes are produced per minute per machine. There are two spoke forming machines in spoke section. Dimension of a spoke is given in Fig.3.15. The flow diagram of spoke production lines are shown in Fig.3.14(c). Table 3.4 shows standard dimensions of a spoke.

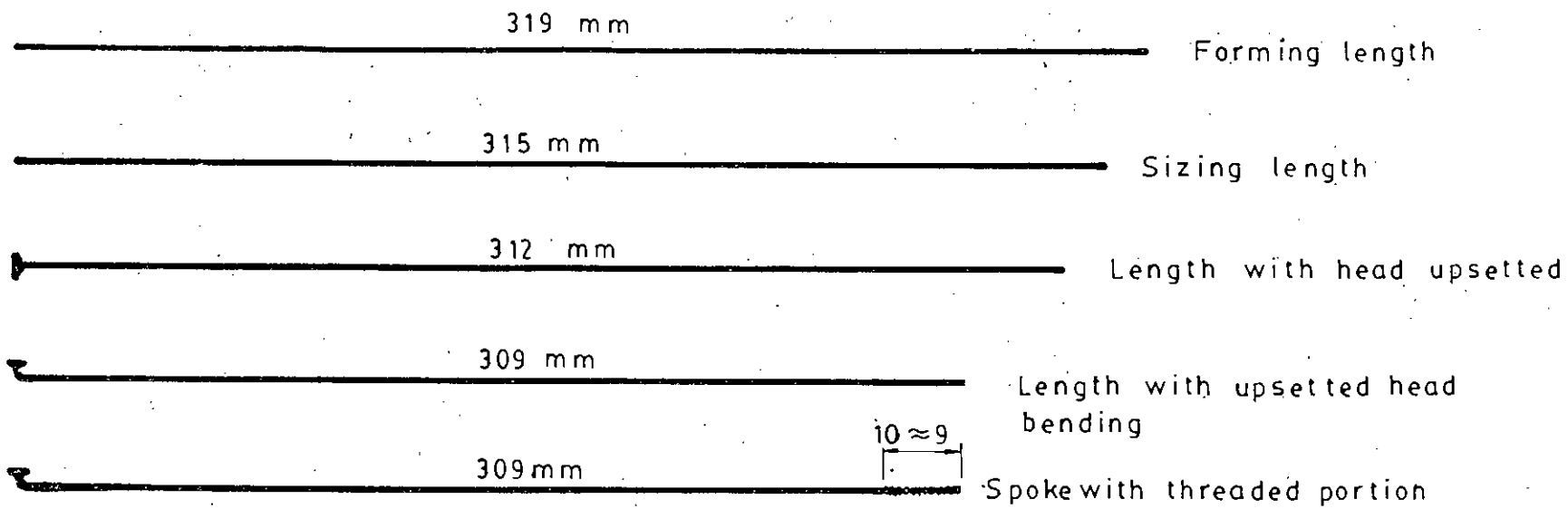


Fig.3.15:Dimension of spoke

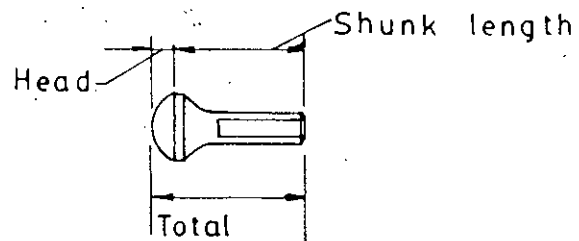


Fig.3.16:Different parts of a nipple

Table 3.4
Standard dimensions of a spoke

Before champhering		After champhering	
Forming length	: 319 mm		
Sizing length	: 315 mm		
Length with head upsetted	: 312 mm	Head upsetted	: 3 mm
Length with head upsetted and bending	: 309 mm	Bending	: 3 mm
Threaded portion of spoke	: 10 mm		

Production of washer

A punching and stamping machine is used for making washers automatically from the metal strip. 340 pcs pf washers are produced per minute by a washer machine. The flow diagram of washer production line is shown in Fig.3.14(d).

Production of rim

The flow diagram of rim production lines are shown in Fig.3.14(e).

Step-1

A forming machine is used to form a bi-cycle rim. Forming operation consist of actual form of a rim by use of 13 different rollers and Seam Welding. Then a length equal to rim length is cut off by a cut off blade. Then cut off rim is joined by a butt welding machine, size checked by sizing machine, butt welded portion is grounded by grinding and abrasive machines.

Step-2

The Rims are punched to make 32 or 40 holes using hydraulic operated punching machine.

Step-3

Rims are then polished by three polishing machines and marked by a marking machine. Table 3.5. shows rate of production by different machines of rim section.

The operation process chart for production of rim, spoke, washer, and nipple is shown in Fig.3.17. The flow process charts for the production process of nipple, spoke, washer and rim are depicted in Fig.3.18,3.19,3.20 and 3.21. respectively.

Table 3.5

Rate of Rim production by different machines
of Rim Section

Sl. No.	Name of machines		Average rate of rim production (in pcs. per hr)	Remarks
1	Forming	1	135	2.25 pcs. per minute
2	Butt welding	1	71	
3	Sizing	1	240	
4	Grinding	1	86	
5	Abrassive	1	45	
6	Spoke hole punch	2	93	
7	Polishing	6	93	Including six machines
8	Marking	1	120	

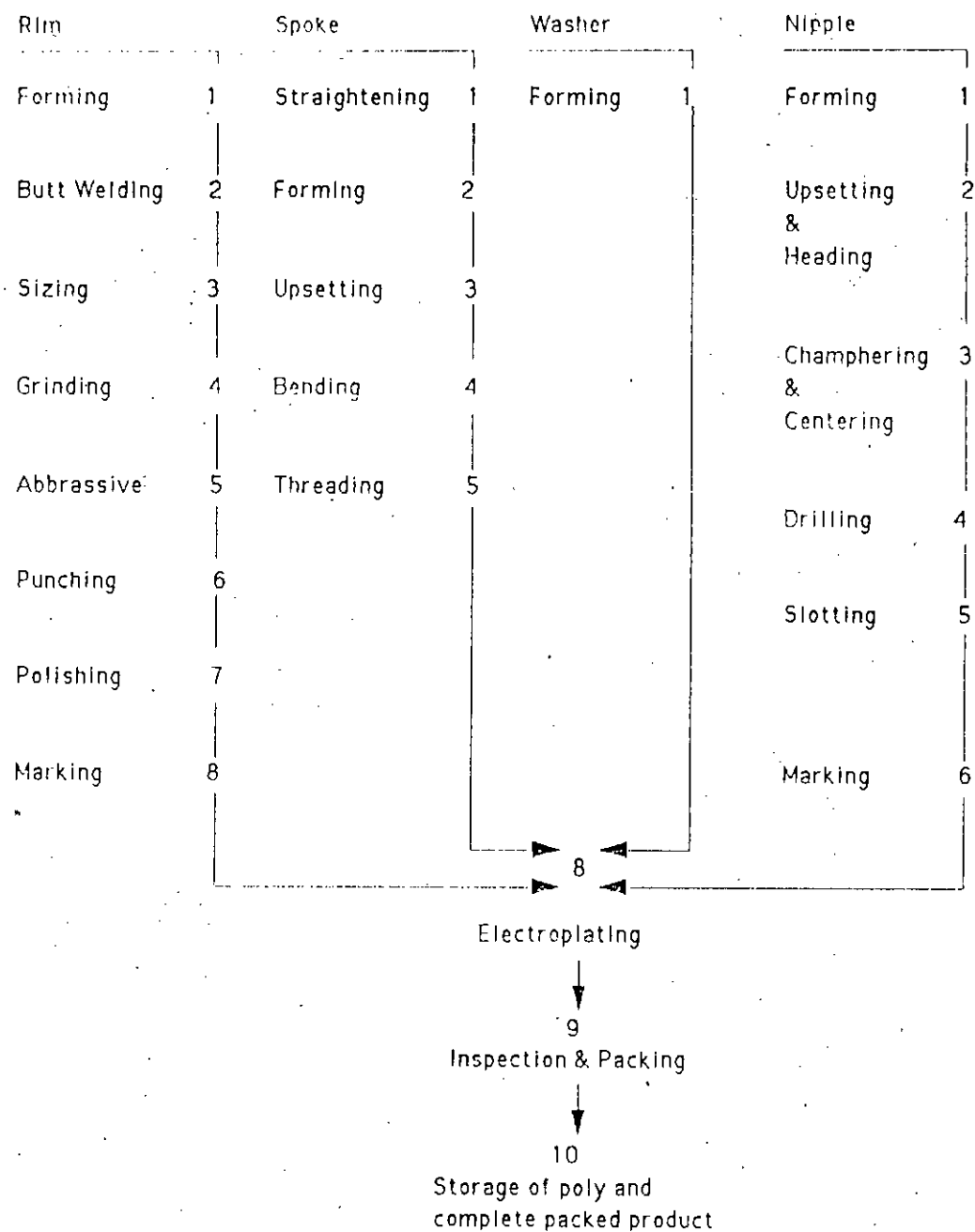


Fig. 3.17: Operation process chart

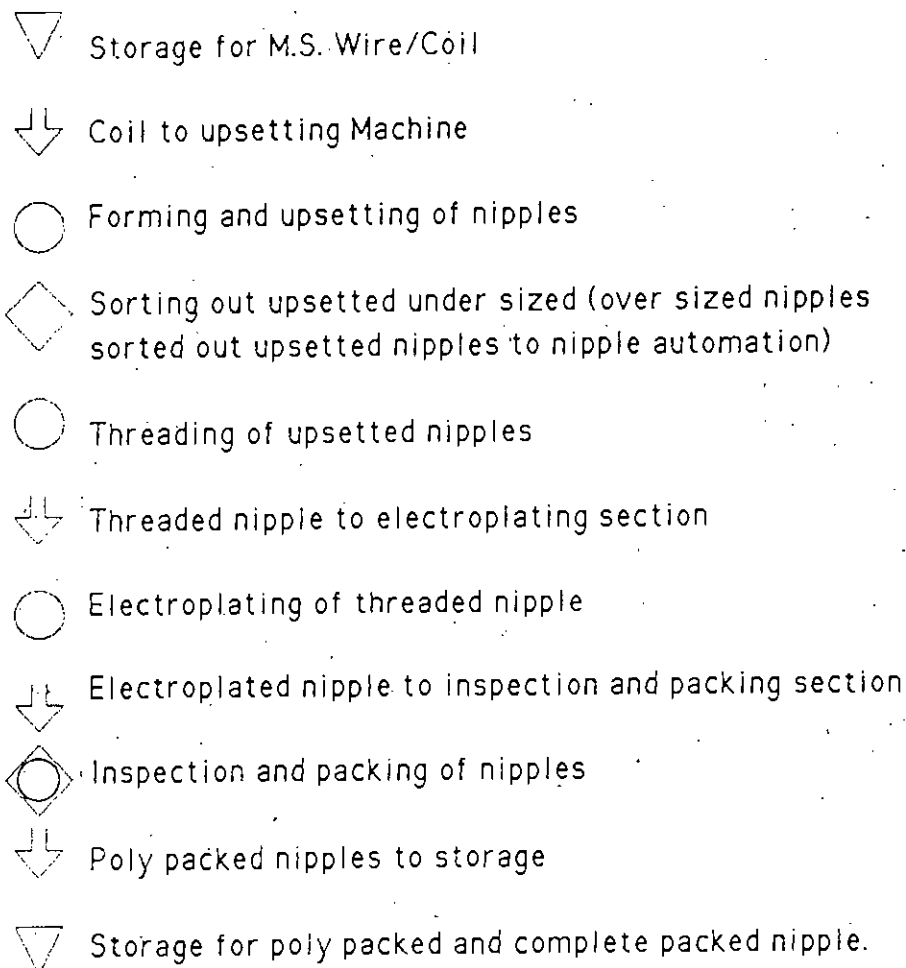


Fig.3.18: Flow process chart for the production process of nipple

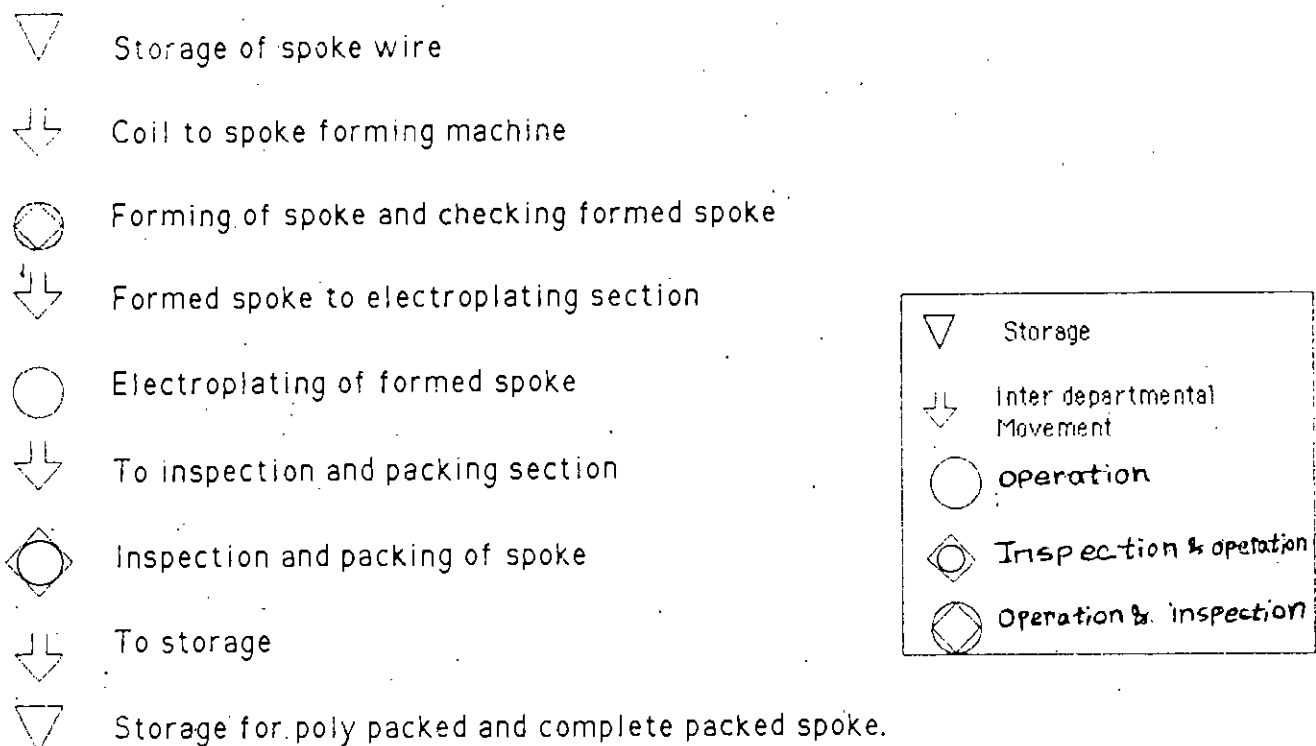


Fig.3.19 : Flow process chart for the production process of spoke



Storage of washer strip



To washer machine



Forming of washer by washer machine



Sorting out washer



To electroplating section



Electroplating of washer



To inspection and packing section



Inspection and packing of electroplating washer



To store



Storage for polypacked and complete packed washer

Fig. 3.20: Flow process chart for the production process of washer

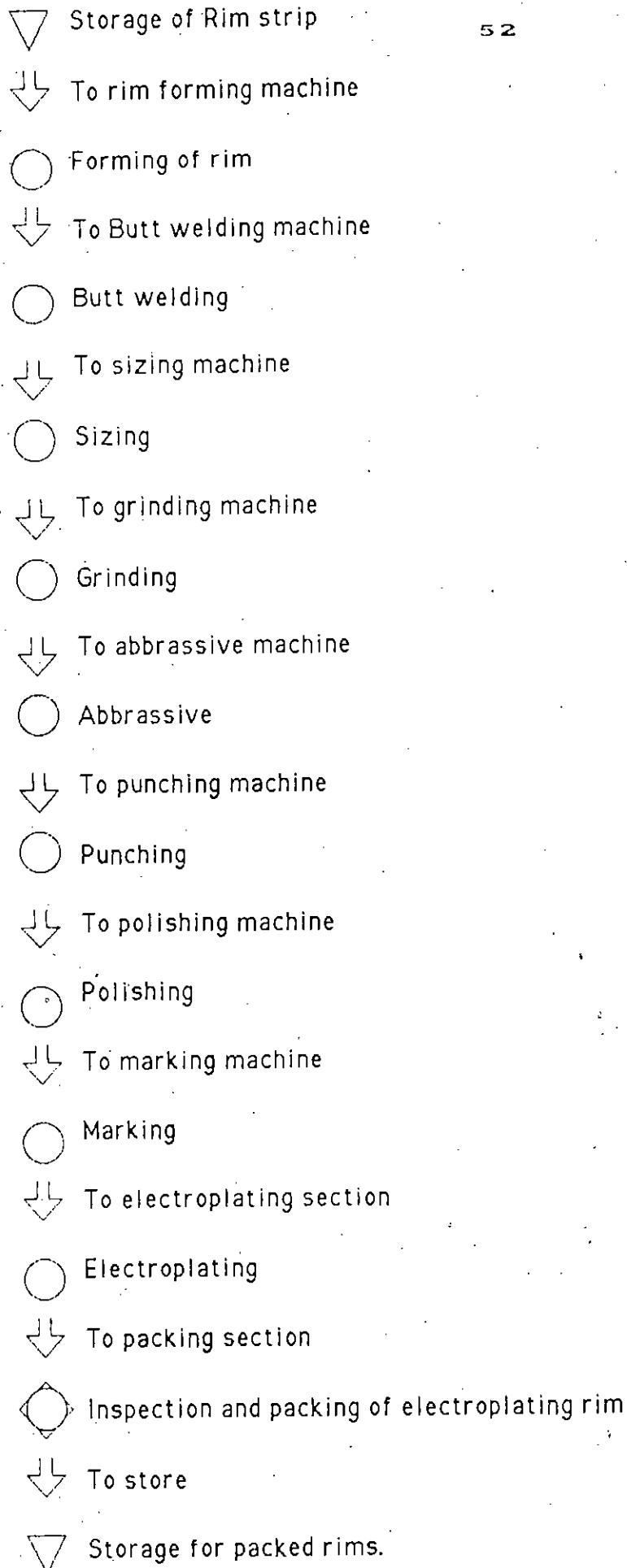


Fig.3.21: Flow process chart for the production process of rim

A₄₃: Quality control

This function of production subsystem is performed during the manufacturing processes by the concern persons. Also it is performed before packing of finished products. This includes checking length of nipples and spokes, checking rim dia and washer's size. The colour of all products are checked after electroplating is done.

A₄₄: Packing of finished product

The last function of product subsystem is packing of finished products and storage. Packing of end products are performed in two areas in the factory as shown in Fig. 3.11. Storage of packed products are done inside the plant as shown in Fig. 3.11.

The bi-cycle components manufacturing system as already defined in this section may be described from the uppermost level, A₀, down to the fourth level of decomposition, as illustrated by the complete IDEF diagram of the conceptual model Fig.3.22.

The scope of these subsystems mentioned earlier are not wide. Each of the subsystems work according to their functions. All the subsystems of the manufacturing unit are influenced by their components which influences the total manufacturing system. No subsystem can function in isolation because it is dependent on the data (inputs) it receives from other subsystems.

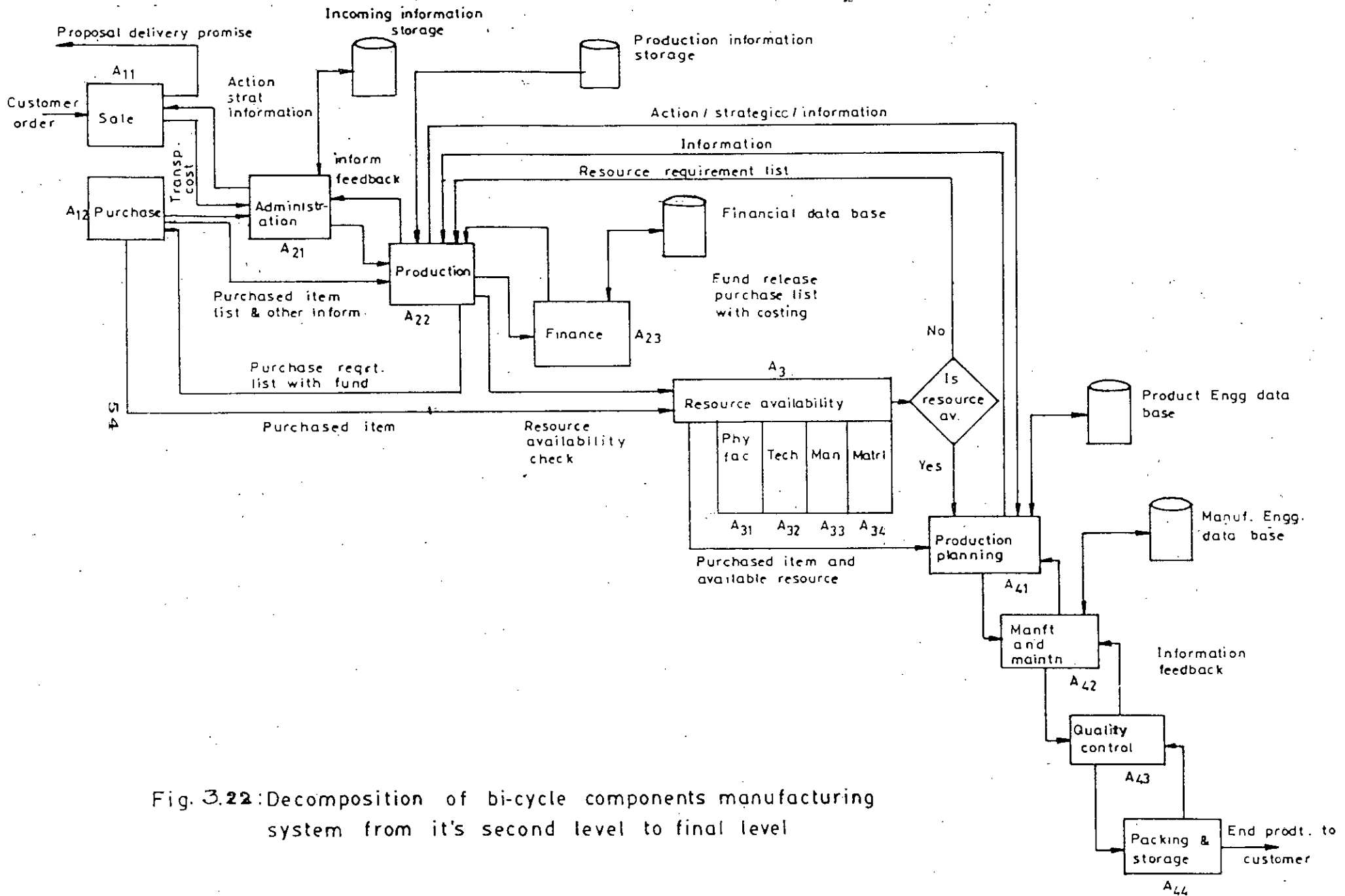


Fig. 3.22: Decomposition of bi-cycle components manufacturing system from it's second level to final level

Decision making subsystem requires information about market situation and sales which is input to decision making subsystem. All information about customer demand and market situation are given to decision making subsystem directly. Then decision making subsystem supplies those information to resource and production subsystems for their proper functions. For example, item to be produced depends on order of items given to sales department by the customers. So this information is given to finance subsystem of decision making system. Which decides how much money is to be required to purchase raw materials, chemicals, spare parts and tools to make the ordered items.

Similarly action and strategies taken by decision making subsystem is input data to production subsystem for it's output (Fig. 3.9). Output of production system are the end products (rim, spoke, nipple and washer). These end products goes to the market for sales. Information about customers need and complaint on endproducts is passed to decision making subsystem which in turn passes the information to quality function to check the quality of the end products.

3.5 PRODUCTIVITY AND ITS RELATIONSHIP WITH THE SYSTEM OF A MANUFACTURING BUSINESS FIRM

Productivity is the reduction in wastage of resource, effective use of decision making, increase sales and reduce purchase cost and increase product volume. The resource may be men, machines material, power, space, time and building etc. It is a concept that guides the management of a production system and measure its success. It is the quality that indicates how well labour, capital, material and energy are utilized. A general definition is that productivity is the relationship between the output generated by a production or service system and the input

provided to create this output [25]. The concept of productivity is also increasingly linked with quality-of output, input and the process itself. An elements of key importance is the quality of the workforce, its management and working conditions. It has been generally recognised that raising productivity and improving quality of working life do tend to go hand in hand.

Productivity is related to almost all subsystems of a business system. Management decision making subsystem is a factor which influences productivity of a business firm. It implies management techniques to control the firm as a whole. A small change in management decision making will influence other subsystems of the total system of the unit.

Production subsystem has many means which influences it's components—planning, engineering, manufacturing and quality control(also known as internal factors of the system). Improvement in any of the aforesaid means would influence the production subsystem and it's factors. Similarly market system has means which influences components of market subsystem. Advertising, quality of end products and prices have influence on market sub system and it's components. A small change in price of the end products would affect the productivity of market subsystem and it's factors.

However, there are certain external factors which influences the system as a whole and affects the productivity of the system are listed below [23].

- i. National resource and their mobility
- ii. Availability of capital
- iii. Taxation
- iv. Govt. laws and restrictions concerning business

- v. Extend of market competition
- vi. Technical and other training facilities.

Those are beyond the control of the individual enterprise.

3.5.1 State of art of productivity of components

Relationship among subsystems of the system of the study unit is shown in Fig. 3.22. Components of all subsystems of the unit has some problem in running the unit smoothly. For example, technology which is a subsystem of resource can be studied to improve productivity. Technology deals with foreign and local technology. Spare parts and tools are imported from foreign countries. Difficulties arise in the procurement of spare parts and tools. This sometime slows down the production. Maintenance of machineries and equipment is also hampered due to untimely and less supply of spare parts and tools due to high cost. The unit has no standard in some section. So manufacturing capacity of each machine need to be compared with the given one by the manufacturer of the machineries. One of the main factor of planning is work method. Work method influences the efficiency of works. Also injuries to worker influences planning. It would slow down production. Consumption of excess drill bits and threading taps leads to purchase of excess tools. This involves more money in purchase and thus blocking the money to purchase items like chemical, packing material and chemical locally. Some times imported raw material are found defective. A small portion of spoke or nipple coil is found non uniform.

Market subsystem of the unit has bottleneck both in sale and purchase. Complaints are frequently received from customer about products. Purchase of drill bits is in excess. The exorbitant Bank's interest and other charges, tax on imported raw material, spare parts, tools, equipments, working capital have adversely affected to the normal production planning. Erratic power supply and sometimes complete failure of power in the area has become a regular factor, causing inconvenience to keep up normal production. With the growing demand of bi-cycle and rickshaw there will be a crying need of cycle parts in everywhere of the country. So there is a great possibility of manufacturing proccesses for bicycle components.

3.5.2 Major Bottlenecks in the subsystems of the study unit :

The present production system planning at NBCIL does not utilize any method of industrial engineering. Machine capacity and manpower utilization need to be checked. The demand of spare parts for machineries producing cycle components amongst other important and relevant factors, depends on consumption of spare parts per month/year as imported from foreign countries. Currently no efforts has been given to manufacture machine spare parts with the available machineries such as capstane lathe, grinding machine, milling machine and drilling machine. Also the company gives no effort to assess its machinery parts. The company at present imports 80% of its machinery parts from foreign countries.

Drill bits of 2.00 mm and 2.38 mm diameters are sharpened by different operators which causes frequent resharpenering thus hampering production. Present method of drill bit sharpening also causes injuries to hand. Besides that workers of

different sections are injured by different tools used by them. This too hamper the factory efficiency.

The existing packing method of spokes, nipples and washers are not systematically done. While packing workers do not use any tray for putting the weighted sealed polypacked nipples & washers.

Spokes are counted for 144 pieces and sealed in a polythene packet. Sitting arrangement and work distribution are not done systematically. Also the table and tools used does not suits the workers.

No effort has been given to improve the aforesaid situations.

3.5.3 Scope of the present work :

The various problem areas in the subsystems of the system of the manufacturing business firm have been discussed and identified in the previous sections. The management would be able to priorities the above problem areas. A possible rational approach may be such as follows:

- i. An effort to increase production and to set a target of production.
- ii. Economic analysis of the spare parts to be manufactured locally.
- iii. Utilization of machineries available in the unit to manufacture selected spare parts with maximum profit.
- iv. An effort to improve the existing working methods in order to increase efficiency and productivity.

CHAPTER-4

ANALYSIS OF THE PRODUCTION SYSTEM AND CAPACITY DETERMINATION OF THE SPOKE SECTION

4.1 INTRODUCTION

Capacity is defined as the limiting capability of a productive unit to produce within a stated time period, normally expressed in term of output unit per unit of time. Capacity is related to the intensiveness with which a facility is used. Capacity could be increased by increasing the limit by working overtime, adding a second shift. Another way of increasing a capacity limit is to engage in subcontracting when it is feasible [5].

When the output units are relatively homogeneous, the capacity calculation is simple. For example, steel plant produces tons of steel, a nuclear power plant produces magawatts of electricity and an auto plant produces numbers of autos. Maximum rate of output from each machine (output per hour/shift), normal machine running hours per shift, skilled machine operators are the basic factors in calculating capacity of the plant in North Bengal Cycle Industries Limited. Understanding the concept of capacity and how to increase capacity an effort has been given to achieve the following goals in order to improve the existing production capacity of the different products in the spoke section of case production unit.

- i. To achieve shiftwise production target (Standard)
- ii. To implement a system of maintaining records on (a) daily production of nipples, (b) causes for unsatisfactory production of nipples, and (c) machinery faults, to find shift-in-charge efficiency.
- iii. Plan and estimate of manpower.

At present there is no production standard for machines in spoke section. Daily production of nipples, causes of unsatisfactory production of nipples and machinery faults are not recorded properly. Manpower resource is not distributed properly shiftwise and this hampers the production of the spoke section time to time.

4.2 ACTUAL SHIFTWISE PRODUCTION CAPACITY IN THE SPOKE SECTION

At present the manufacturing unit does not have any standard for production volume of nipples. Present production volume per minute was calculated for each of the end product in each section of the unit. Table 4.1 indicates capacity of machines producing different end products and actual volume of production. It was found from the table that actual volume of production of nipple is lower than the machine capacity as given by the manufacturer of the machine.

Table 4.1
Machine output capacity Vs. Actual production
per minute of various machine in NBCIL unit

Name of machines	Machine output capacity per minute Pcs	Present production volume by machine per minute Pcs.
Nipple automation machine	43	39 - 40
Nipple upset machine	215	212 - 215
Spoke forming machine	94	94
Washer forming machine	350	350
Rim forming machine	2	2

To ascertain the reasons for the above unsatisfactory production than the production capacity of nipple machines a step was taken by management. Two production sheets were developed and used.

Advantages of such production sheets would be as follows:

- i. Causes of unsatisfactory production would be known.
- ii. Machine running hour per shift can be found.
- iii. Actual machine utilization would be known.

The two production sheets namely production sheet-1 and production sheet-2 were used for 2 months experimentally. After running for 2 months, average production of nipples per shift and average machine running hours per shift were found using table 4.2. These sheets are given in next pages respectively.

PRODUCTION SHEET - 1
Production quantities, production times
and reasons for stoppage

Date : _____

Shift : _____

(1)	(2)	(3)	(4)	(5)
Machine start time, hr/min.	Meter reading of nipples, pcs.	Machine stoptime hr/min.	Meter reading of nipples, pcs.	Reasons for produc- tion stoppage
10 : 45	5000	11.05	7100	EP
10 : 06	7100	12.00	9111	EP

Checked by : AME

Signature, Shift-in-Charge

List of factors for production stoppage

Electrical problem = EP
Mechanical problem = MEP
Labour unrest = LU
Power failure = PF
Political problem = PP
Raw material problem = RP

Lack of spare parts = LP
Manpower problem = MPP
Breakage of
threading tap = BT
Breakage of drill bit = BD

PRODUCTION SHEET-2
Machine Utilization

Date : _____

Shift : _____

Date (1)	Shift (2)	Total machine hour per shift (3)	Actual machine hour (Actual production) (4)	Machine Utilization in % = (4) - (3) (5)	Reasons for under utilization (6)
1-6-93	A	8	7	87.5	MEP, BT
	B		6	75	PF, EP

Checked by : _____
AME

Signature : _____
Shift-in-Charge

List of factors for under utilisation

Electrical problem	= EP	Lack of spare parts	= LP
Mechanical problem	= MEP	Labour unrest	= LU
		Power failure	= PF
Manpower problem	= MPP	Breakage	
Political problem	= PP	of threading tap	= BT
Raw Material problem	= RP	Breakage of drill bit	= BD

Production sheet-1 was prepared based on a stop-watch time study. In the study various times were measured by taking times continuously using stop watches. Actual production quantities per shift were known from production sheet-1. The difference between actual production and theoretical production capacity per shift would be known. Production sheet-1 also provide the reasons for production stoppages during a shift. Production sheet-1 could be explained below. Machine starting time and production quantity at machine starting time were written in columns (1) and (2) respectively. Suppose machine is stopped for some failure. Then machine stopping time and production volume at the time of switching off machine were noted in columns (3) and (4) respectively. Also reasons for stopping of machine are recorded in column (5) of production sheet-1. The sheet was signed by shift-in-charge (Sub-Assistant Engr.) at the end of each shift. Production sheet-2 was used to find out machine utilization in each shift which would give actual machine running hour per shift.

Table 4.2
Average production of nipples and machine
running hours per shift

A	B	C	D	E	F	G
Total Production of nipples in two months by the two machines	Total shifts in 2 months	Average production of nipples per shift per machine = $(A-B) \times$ $(144-2)$	Standard production per shift as per machine hand book	Total machine running hrs. in 2 months	Hrs. per shift	Average actual machine running hrs./shi ft $G =$ $E - B$
23470	101	16731 pcs	18060 pcs (116.19 gross)	607	8	6

1 Gross = 144 pcs

It was found from table 4.2 that average nipple production per shift by the automatic machine is 16731 pieces against standard production of 18060 pcs. Average loss of time per shift is 2 hours due to the factors mentioned in production sheet 1 and 2. The production capacity of the nipple automatic machine is 43 nipples/min. or 125 grosses (18060 pcs of nippls). Hour lost per shift is two. One hour is used up for machine cleaning at start and at the end in each shift and time for setting and changing fast moving tools. Another working hour is lost due to the factors such as mentioned in the production sheet-1. Amongst all the major causes for loss of time during production the time lost due to abnormal breakage of drill bit (2.00 mm and 2.38 mm dia) and threading taps is highly significant.

4.3 DEFECTS IN THE PRODUCTION PROCESS

4.3.1 Abnormal breakage of drill bits are listed below:

Following are the reasons for abnormal breakage of drill bits:

- i. Inaccurate dimension of upsetted nipple: Dimension of upsetted nipple is a factor for drill bit breakage. If the length of upsetted nipple is not adjusted correctly then champhering and centering could not be properly done. This would lead to having improper dimensions of upsetted nipple and would cause non straight drilling by 2.38 mm drill bit. Table 5.3 shows standard dimension of nipple after upsetting. This defective non-straight drilling done by 2.38 mm dia drill bit leads to breakage of 2.00 mm dia drill bit and itself.

- ii. **Improper material for drill bits:** For drilling holes in alloy steel the correct material of drill bit should be high speed steel. Drill bits actually used were of high carbon steel
- iii. **Improper resharpener of drill bits:** Unplanned resharpener of drill bits that is not resharpener at right time leads to continued drilling with the blunt drill. This results to excessive friction evolving excessive heat and drill bit lossing its hardness. This causes complete destruction of the cutting edges. The buckling of the drill bits due to excessive cutting force resulting from improper point angle of the drill bit causes the hole becoming larger beyond tolerance limits.
- iv. **Wrongly positioned coolant supply pipe :** Coolant supply pipe positioned far away from nipple . The pressure of coolant inside the nipple hole was not enough to remove chips formed during drilling (2.00 mm dia.).
- v. **Improper setting of centering and champhering tools:** This causes shift of guide hole from the centre of the nipple for drill bits (2.00 mm x 2.38 mm).
Table 4.4 shows actual dimensions of a nipple after champhering.

Table - 4.3
Dimension of an upsetted nipple after champhering
(all dimensions in mm.)

STANDARD DIMENSIONS		ACTUAL DIMENSIONS
Total length	: 12.2	11.7
Shank length	: 9.2	8.7
Head length	: 3.0	3.0

Table 4.4
Standard dimension of upsetted nipple
after champhering

STANDARD DIMENSIONS (mm)		ACTUAL DIMENSIONS (mm)
Total length	: 12.0	11.5
Shank length	: 9.0	8.5
Head length	: 3.0	3.0

4.3.2 Abnormal breakage of threading taps:

- i. Improper setting of drill bits in collet: Due to this improper setting resulting to non straight drilling of nipples would make the threading non-straight. This results to breakage of the front portion of the taps shorting their lives drastically.
- ii. Wrongly positioned coolant supply pipe: Wrongly positioned coolant supply pipe makes the chips flow inside the threaded nipple difficult. It's because force of oil flow inside the nipple is not sufficient to remove chips formed by slit cutting saw and threading tap. Some chips remains inside the hole thus blocking the passage through which threading tap is supposed to be moving. The blockade results in threading tap's front portion breakage.
- iii. Improper selection of taps : The flutes of theading taps used are found to be faulty. The flute groove are not large enough for smooth flow of chips. Usually threading taps are to be changed after production of every 6000-7000 nipples. But it is found that a threading tap breaks after producing only 3000-4000 pcs. of nipples. This is due to use of Korean threading taps whose dimensions found to be improper.

Effect of abnormal breakages of drill bits and threading taps are as follows:

- i. Loss of production time and loss of production during each shift.
- ii. Increased tool costs for drill bits and threading taps.
- iii. Customer dissatisfaction on defective nipples.

4.4 SUGGESTED IMPROVEMENT IN PRODUCTION PROCESS TO REDUCE BREAKAGE OF DRILL BITS AND THREADING TAPS

On undertaking a study as depicted in secs 4.3.1 & 4.3.2 the following steps were taken to prevent breakage of drill bits and threading taps:

- i. Dimensions checking of first 10-15 upsetted nipples after initial start up of the upsetting machine.
- ii. Skilled operators were assigned for setting up champhering and centering tools and resharpening of drill bits.
- iii. A study period of 2 months was considered. During the study, it was found that drill bits should need resharpening after every 4 hours 5 hours as currently being considered. It was found that drill bits start becoming dull after 4 hours, thus causing the nipples move out of the chucking tong. As a result drill bit slips and breaks after hitting the chucking tong.
- iv. Position of coolant flow pipe was set very close to nipple head. Thus making coolant flow speed through nipple hole and threading taps

increased and removing broken chips to allow drill bit movement inside the nipple more easy.

- v. Checking of drill motor and threading tap motor alignment for straight drilling and thereby straight threading of nipples in every shift at the start of the machine.
- vi. Using High Speed Steel (H.S.S) drill bit instead of high carbon steel (H.C.S).

The causes of excessive breakage of drill bits and threading taps and their preventive steps can be shown in the form of cause-and-effect diagram as shown in the Figure 4.1. to 4.3. It is a diagram which shows the relation between a quantity characteristic and factors.

4.4.1 RESULTS DUE TO THE IMPROVEMENT IN PRODUCTION PROCESS

Excessive breakage of drill bits and threading taps have been reduced after implementation of suggested steps as described earlier. A comparative study of consumption of drill bit, threading taps, production of nipples and number of shifts before and after implementation of suggested steps were made Table 4.5 and Table 4.6 show consumption of threading taps, drill bits, production of nipple and number of shifts before and after implementation of the steps mentioned earlier respectively. Preventive steps were implemented from June, 1992. It is seen in Tables 4.5 and 4.6 that production of nipple has increased gradually and consumption of drill bits and threading taps have started to fall from that

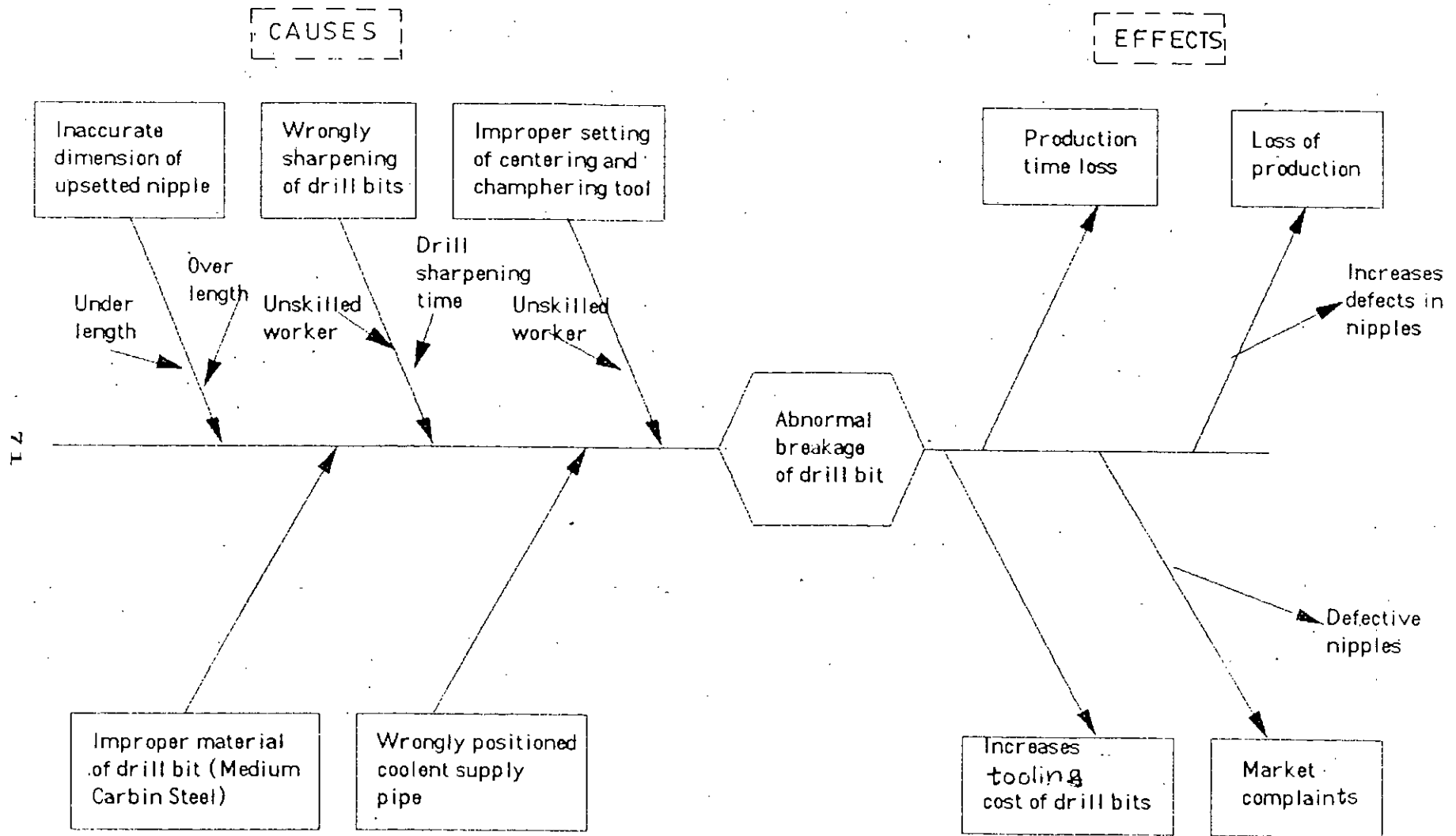


Fig. 4.1 : Cause and effect diagram for drill bit breakage before the proposed solution

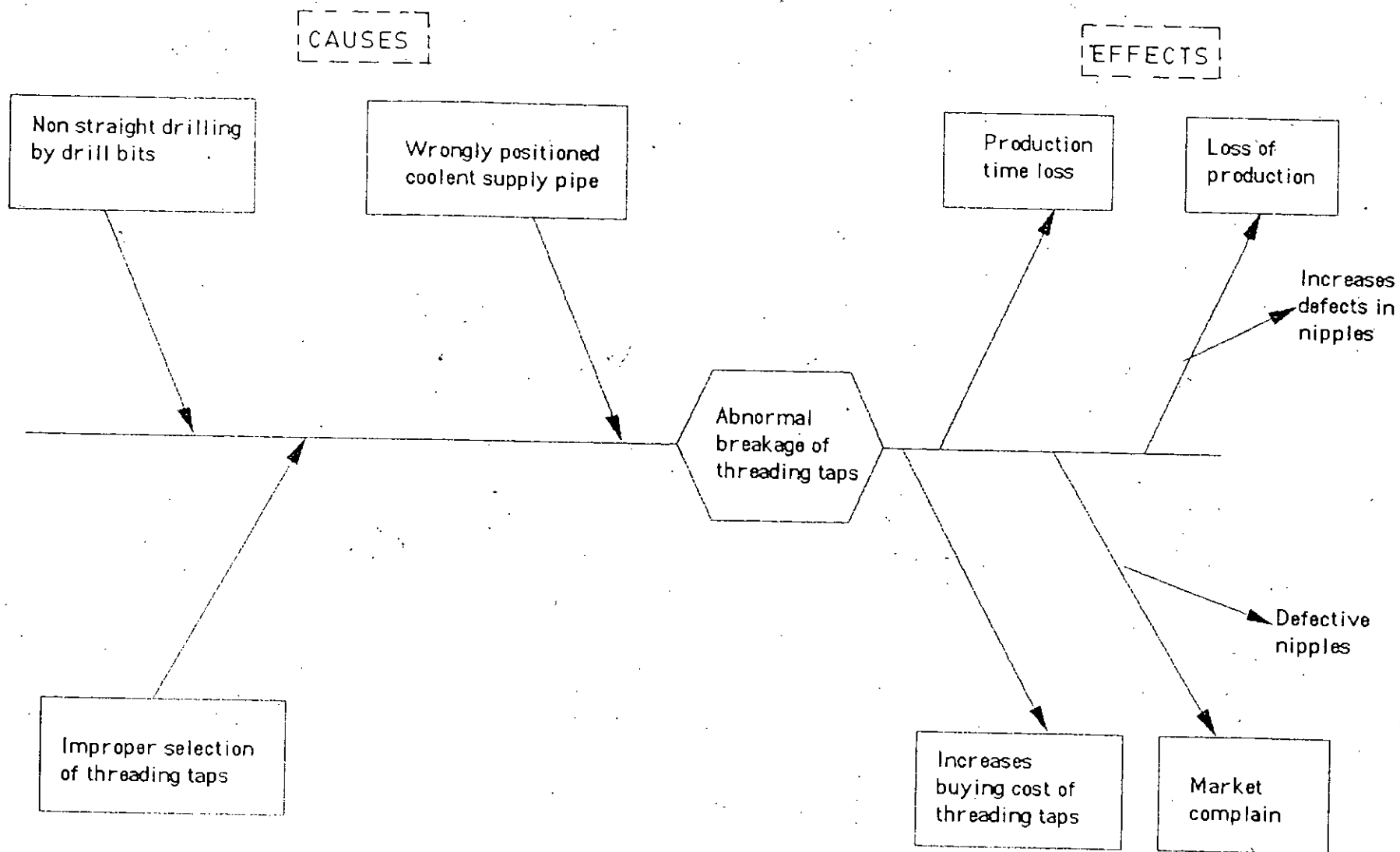


Fig. 4.2 : Cause and effect diagram for threading tap breakage before the proposed solution

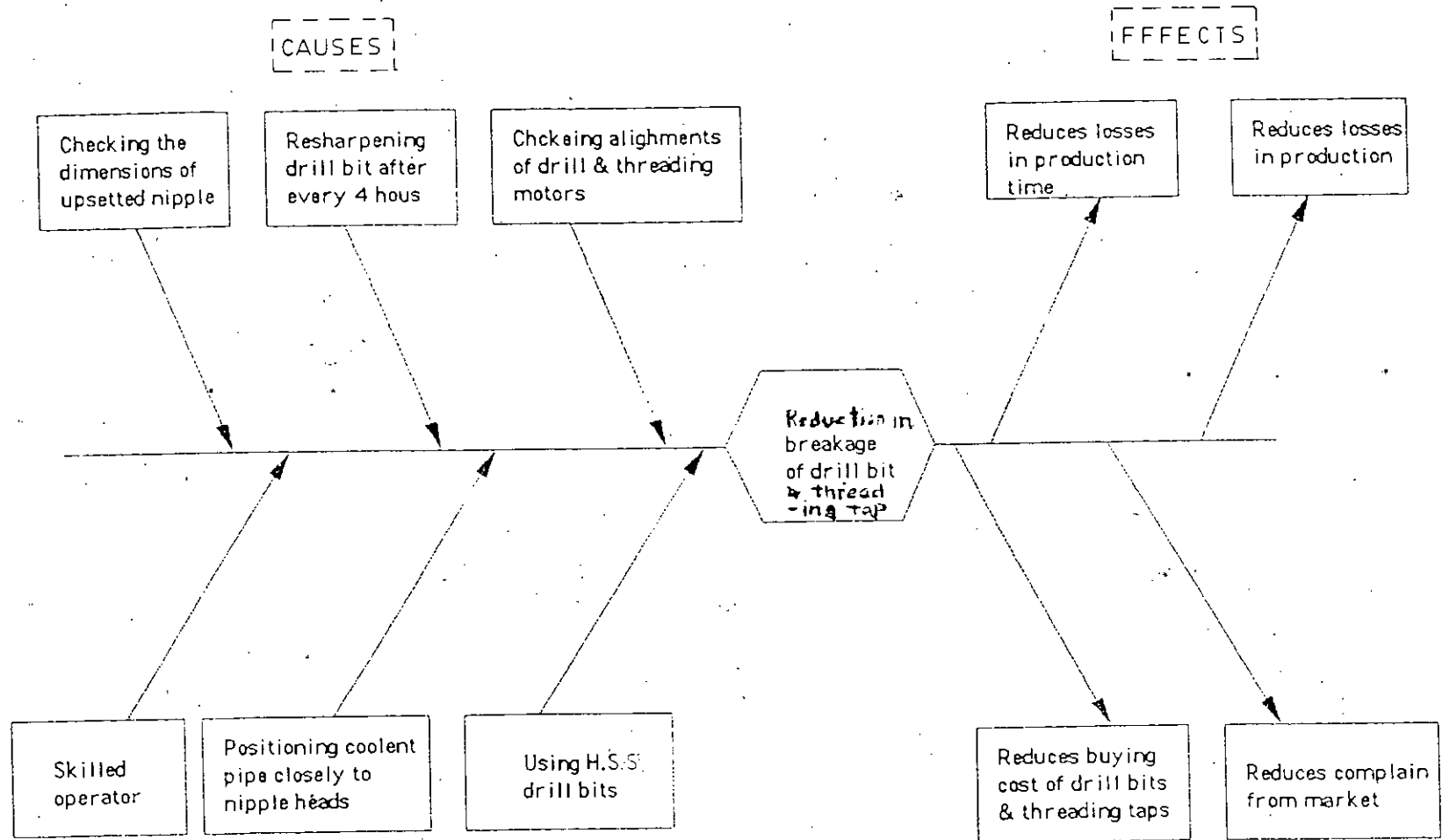


Fig. 4.3 : Cause and effect diagram for reduction of breakage of drill bits and threading taps

period. Yet a complete and satisfactory performance could not be achieved after implementing the preventive steps. The reason is that the wire quality (raw material) of the nipple could not be obtained at 100%. Previously the average nipple production per machine per shift was 116.19 grosses as shown in Table 4.2. But after implementing the steps for preventing excessive breakage of fast moving tools the average per shift production of nipple has increased to 247 grosses by 2 machines equivalent to 123.5 grosses per machine. Table 4.8 shows consumptions of drill bits and nipples along with nipple productions per shift before and after implementing the aforesaid preventive steps.

Table 4.5

Nipple production, consumption of drill bits and threading taps by the two nipple automation machines before implementation of preventive steps

Month Year	Shift	Nipple production in grosses		Threading tap consump- tion in pcs.	Drill bit (2.00 mm) consump- tion in pcs.	Drill bit (2.38 mm) consump- tion in pcs.
		Actual production	Std. production			
Jan, 1990	48	11200	12000	240	440	135
Feb, 1990	38	9100	950	200	430	120
Mar, 1990	33	7572	8250	160	356	115
Apr, 1990	50	10250	12500	260	480	145
May, 1990	47	11100	11750	260	470	135
Jun, 1990	45	7426	11250	270	450	133
Jul, 1990	47	7572	11750	250	475	133
Aug, 1990	44	9100	11000	265	440	130
Sep, 1990	43	10250	10750	220	400	127
Oct, 1990	50	11900	12500	255	490	145

Nov, 1990	48	11800	12500	235	440	135
Dec, 1990	49	11300	12250	248	450	140
Jan, 1991	52	12000	13000	250	490	140
Feb, 1991	47	11200	11750	230	390	135
Mar, 1991	33	7572	8250	160	356	115
Apr, 1991	43	10250	10750	220	395	125
May, 1991	49	11100	11562	240	480	140
Jun, 1991	31	7426	7626	150	279	100
Jul, 1991	33	7572	8250	160	290	115
Aug, 1991	38	9100	9500	200	380	120
Sep, 1991	49	11300	11562	245	470	130
Oct, 1991	50	11900	12500	250	490	145
Nov, 1991	50	11800	12500	255	490	145
Dec, 1991	52	12400	13000	250	450	145
Jan, 1992	49	11450	11562	240	440	140
Feb, 1992	51	12054	12750	250	440	143
Mar, 1992	52	12760	13000	260	460	150
Apr, 1992	50	11470	12500	240	455	135
May, 1992	51	12000	12750	255	440	135

Table 4.6

Nipple production, consumption of drill bits and
threading taps by the two nipple automation machines
after implementation of preventive steps

Month Year	Shift	Nipple production in grosses		Threading tap consump- tion in pcs.	Drill bit (2.00 mm) consump- tion in pcs.	Drill bit (2.38 mm) consump- tion in pcs.
		Actual production	Std. production			
Jun, 1992	38	9200	9500	135	340	88
Jul, 1992	32	7800	8000	109	276	79
Aug, 1992	33	8000	8250	110	284	75
Sep, 1992	44	10990	11000	142	380	95
Oct, 1992	47	11600	11750	152	359	109
Nov, 1992	45	11190	11250	146	370	100
Dec, 1992	52	12670	13000	160	426	110
Jan, 1993	44	10990	11000	142	370	93
Feb, 1993	49	11990	12250	160	400	102
Mar, 1993	50	12300	12500	166	360	101
Apr, 1993	45	11200	11250	146	371	99
May, 1993	47	11700	11750	152	358	100
Jun, 1993	44	10991	11000	141	370	93

Table 4.7
Average nipple production, drill bit and threading
taps consumption per two machine per shift

Month Year	Nipple prodn. by 2 machin e per shift in gross	Nipple prodn. by 1 machine per shift	Drill bit (2.00 mm) consumption by 2 machine per shift	Drill bit (2.38 mm) consumption by 2 machine per shift	Threading taps consumption by 2 machine per shift
Jan-Jun 1990	217	108.5	10.6	3	5.3
Jul-Dec 1990	220.36	110.16	10	3	5.24
Jan-Jun 1991	233.52	116.76	9.3	3	5
Jul-Dec 1991	236.2	118.1	9.4	3	5
Jan-Jun 1992	236.10	118.05	8.8	2.7	4.9
Jul-Dec 1992	245.5	122.7	8	2	3
Jan-Jun 1993	247	123.5	8	2	3

From table 4.7, above, it is found that average production of nipple and fast moving tools consumptions are 247 grosses (nipple), 3pcs threading tap, 8pcs drill bit(2.00mm) and 2pcs drill bit(2.38mm) by two machines after implementation of the preventive steps.

Table 4.8

Shiftwise standard nipple production of drill bits
and threading taps and machine running time by two
automation machines

Standard production of nipple per machine per shift	Machine running hr. per shift	Consumption per two machines per shift		
		Threading tap in pcs.	Drill bit (2.00 mm in pcs.)	Drill bit (2.38 mm) in pcs.
247 grosses (246.70)*	7	3.0 (3.26)*	8 (8.18)*	2 (2.13)*

* Figure in parenthesis indicates actual performances after preventive steps taken.

Table 4.8 indicates standard nipple production, standard drill bits and threading taps consumptions per shift. Production sheets for spokes and washers were maintained and relevant information were collected. It was found that the actual production quantity of these products were almost comparable to standards. Therefore, a further study was not done. Standard production volumes of nipples, spokes and washers per month are shown in Table 4.9.

Table 4.9

Monthly production of nipple, washer and spoke

Working days	Working shifts per day	Working time per shift,hrs	Machine running time per shift,hrs	Nipple gross	Spokes gross	Washers gross
26	2	8	7	12350	27416	51040

4.5 WASTAGE OF NIPPLES, SPOKES AND WASHERS

Reasons for wastage of nipples, spokes and washers during production are as follows:

REASONS

- Nipple : Small broken portions of drill bits and threading taps locked inside the nipple after their breakage.
- Spoke : Due to non uniformity of wire thickness portion of spoke wire is reject. Normally this rejection is about 2 feet.
- Washer : Wastage of washer when punching stops due to sudden power failure and due to poor quality of raw material of washer.

Average wastage per shift of the above items are as follows:

- Nipple 10 pcs
- Spoke 1 kg.
- Washer 1 kg.

4.6 IMPLEMENTATION OF A RECORDING SYSTEM FOR FINDING THE EFFICIENCY OF SHIFT-IN-CHARGES

A monthly observation sheet was developed to record the production status under the shift-in-charge.

The reasons for developing such a monthly observation sheet are:

- i. The existing shiftwise production report for the spoke section does not provide sufficient information to prepare the report of production per shift and finally the monthly report of production by each machine.
 - ii. Reasons for consumption of fast moving tools and for any unsatisfactory production could not be ascertained.
 - iii. Information on types of drill bits consumed are not clearly mentioned.
- Tables 4.10, and 4.11 show the existing shiftwise production report for various machines in the spoke section.

Table 4.10
Existing shiftwise production report for upsetting and
automation machines for production of nipples

UPSETTING MACHINE	SHIFT	A		B	
	Production in coil				
	Machine running hour				
	Wastage in kg.				
	Spare needed				
	Signature of Shift-in-Charge				
NIPPLE AUTOMATION MACHINE	Machine No.	1	2	1	2
	Production in nipple (No)				
	Machine running hour				
	Wastage in kg.				
	Spare needed				
	Tap Drill				
Signature of S.A.Engr.					

Table 4.11

Existing shiftwise production report for
washer and spoke machines

WASHER FORMING MACHINE	SHIFT	A		B	
	Production in coil				
	Machine running hour				
	Wastage in kg.				
	Spare needed				
	_____ Signature of Shift-in-Charge				
SPOKE FORMING MACHINE	Machine No.	1	2	1	2
	Production in spoke (No)				
	Machine running hour				
	Wastage in kg.				
	Spare needed Tap Drill				
	_____ Signature of S.A.Engr.				

PERFORMANCE REPORT OF S.A.E.

Month of _____

Date _____

Automation machine _____

Table: 4.12

Shiftwise production of nipples, machine running hours,
Name of S.A.Engr. and consumption of drill bits & threading taps

Date	Shift	Name of S.A.Engr	Prod- uction Nipples	Nipple Auto machine				Remarks
				Running time Hrs.	Consumption			
					Threa- ding tap	Drill bit (2.00 mm)	Drill bit (2.38 mm)	
1.1.93	A							
	B							
	C							
2.1.93	A							
	B							

Table - 4.13

MONTHLY STANDARD & ACTUAL BREAKAGE OF TOOL BITS

S.A.E	Total Prodn. Nipple		Machine running time Hrs.		Consumption						Total shift per month	
	Stan dard	Actual	Stan dard	Actual	Threading tap pcs		Drill bit (2.00 mm) pcs		Drill (2.38 mm) pcs.		Stan dard	Actual

Signature of A.K.E.

Table 4.14
Recording system in a Log Book for each
nipple automation machine

Date	Shift	Nipple prodn. in pcs	Machine Faults		Action taken for rectification	Test results	Time takenf or repair	Remarks by S.A.E.
			Details	Other probable causes				
	A							
	B							
	C							

Table 4.15
Monthly production sheet for spoke & washer

Date	Shift	Name of S.A.Engr.	Prodn. in kgs.	Machine running time Hrs.	Wastage in kgs.	Spare parts consumed	Remarks by S.A.E.
	A						
	B						
	C						

Table 4.12 is a proposed performance report which indicates consumption of drill bits, threading taps, nipple production, machine running hrs. per shift by each Sub-Assistant Engineers during the whole month. Performance of Sub Assistant Engineers involved in individual shift can be determined by analysing total production of nipples, total machine running hours, total consumption of drill bits and threading taps, total shifts in Table 4.13. Standard production of nipple and breakage of drill bits and threading taps, machine running hours, number of shifts are also given in Table 4.13 to compare with actual performance by individual Sub-Assistant Engineer.

Maintenance of auto machines and their details are recorded in a log book for each nipple automation machine. Format of one such log book for each machine has been suggested as shown in Table 4.15. These log books are maintained by S.A.Es and they discuss every week with shift-in-charges. This function of S.A.Es could be made a responsibility for assessing their performance. Table 4.15 shows the monthly production sheet which could be used for both spoke forming and washer producing machines.

4.7 MANPOWER ESTIMATION FOR THE SPOKE SECTION

Utilization of man and machine is not ascertained in isolation since these are complementary to one another. An example could explain this interrelationship. The capacity of two spoke forming machine is 27416 grosses per month (50 shifts). The average monthly demand for spoke is 15000 grosses. So the two spoke forming machine can produce 15000 grosses in 27 shifts. Thus spoke forming machine operator along with the machine is in idle state for some days.

The effect of this idle and nonproductive time leads to loss of production. The manpower utilization figure of spoke section can be seen from Table 4.16. which shows manpower strength before the study. The total number of workers in spoke section is 13. Before the study the two nipple automation machine were having difficulties in operation due to excessive breakage of threading taps and drill bits, centering and champhering setting in machines by inefficient operators. Thus additional workers were required to sort the products to separate the out defective products. This problem was overcome as explained at the beginning of this chapter. The production of nipple has been achieved to 123.5 grosses an average per machine per shift which was 114.31 grosses before the study. Where the target production is 125 grosses and considering the improvement in production process a revised manpower requirement has to be made. A work study method was applied for this purpose used for 1 month. In this work study, job done by each machine operator is observed per shift. Table 4.17 indicates various tasks done by a machine operator during a shift.

Table - 4.16
Machinewise manpower distribution chart per
shift in spoke section before the study.

NO. of m/c	Machine name	No. of operatorp er machine	Workers for checking the prodn.	Total manpower
1	Spoke forming machine 1	1	1	13
2	Spoke forming machine 2	1	1	
3	Nipple automachine 1	1	1	
4	Nipple automachine 2	1	1	
5	Upsetting machine	1	1	
6	Washer machine	1	1	
7	Lathe machine	1	0	

Table 4.17
Task of a operator in operating a
machine in spoke section

Machine Name	Operator	Operator's Tasks		
		1	2	3
Spoke forming machine	1	To check machine before starting & clearning	To start machine and checking and threading spoke	Put the machine in auto and checking the end product during machine running time
Nipple automation machine	1	To check machine before starting & cleaning and then setting drill and threading tap	To start machine and checking threaded nipple and switching the machine to auto	Sharpening drill time to time and changing threading tap timely
Nipple upset machine	1	To check machine and clearning before starting	To start machine and checking the length head of the first 10-15 upsetted nipples	Starting the machine in auto system
Washer forming machine	1	To check machine and to clean before starting	To start machine and checking the washer formed	Shorting the washer

Table 4.18
Modified machinewise manpower distribution chart
for Shiftwise requirement in spoke section
after the study

No. of machine	Machine Name	No. of operators per machine	Extra workers for shorting out defective end product	Total manpower
1	Spoke forming machine 1	1	0	9
2	Spoke forming machine 2	1		
3	Nipple auto machine 1	1	1	
4	Nipple auto machine 2	1		
5	Upsetting machine	1	1	
6	Washer forming machine	1	0	
7	Lathe	1	0	

According to the proposed manpower distribution (Table 4.18) one worker has been engaged for sorting the defective nipples from the two nipple automation machine. Similarly one worker is needed to sort out the products after upsetting operation and deliver the sorted products to the nipple automation machine.

Utilizing the proposed manpower distribution in the spoke section the production output of 98.8%, 99.5% & 99.5% of the standard production capacity was achieved for nipples, spoke and washers respectively.

CHAPTER-5

SELECTION OF SPARE PARTS TO BE PRODUCED AND DEVELOPING THEIR MANUFACTURING PROCESSES

5.1 JUSTIFICATION OF THE PRESENT WORK

Various studies on import substitution have clearly and strongly suggest that this process of indigenous manufacturing of spares and tools should be given high consideration. It has been found that country's industrial sector cannot achieve a steady growth with import dependency for the supply of it's machine tools, spare parts, raw materials etc.

The bi-cycle manufacturing factory under consideration of the present work, currently manufactures rim, nipple, washer and spoke for bi-cycle and rickshaws. Presently most of the spare parts are imported from Korea and Germany thus making the factory entirely dependent on procurement and availability of these parts from imports. Moreover, huge amount of foreign currency is to be spent for the procurement of those spare parts listed in Table 5.1. It has also been observed that the procurement process is complex and lengthy. With these considerations possibility of indigenous and in-house manufacture of some selected spare parts was explored.

Table 5.1

List of imported spare parts

Sl. No.	Spare parts name	Annual requirement pcs.	Imported price			Country of origin	Remarks
			Qty c s	Rate Tk.	Total cost Tk.		
1	Grinding gib with cover	-	01	19,320	19320	Germany	Imported after every 4 years
2	Feeding segment	12	01	8,000	96000	Germany	For two automation machines
3	Segment finger	36	01	500	18000	Germany	
4	Upset cutter	24	01	18,000	43200	Germany	
5	Grinding dies	216	02 1 set	11,500	124000	Korean	
6	Thread rolling dies	216	02 1 set	2,000	216000	Korean	
7	Upset head punch	48	01	2,500	120000	Korean	
8	Upset ejector pin	36	01	1,500	54000	Korean	
9	Upset die	02	01	45,000	90000	Korean	
10	Straightening roller	24	01	12,000	288000	Korean	Imported after every two years
11	Slit cutting saw	24	01	1,000	24000	Korean	For two automation machines
12	Centering and champhering tools	36	03 1 set	4,077	48924	Korean	
13	Spoke head punch	72	01	2,600	187200	Korean	
14	Automation ejector pin	36	01	1,125	40500	Korean	

5.2 SELECTION CRITERIA FOR SPARE PARTS

Some criteria for the selection of the spare parts to be manufactured in-house are listed below [12]:

- i. Simplicity in construction
- ii. Availability of raw material at reasonable cost
- iii. Availability of technology, production cost and usage value.
- iv. Availability of machine in the factory for manufacture of selected spares.
- v. Relative importance of the spare parts in their demand.

There are three production sections namely, spoke, electroplating and rim manufacturing sections. The spare parts required per month to produce 12000 - 15000 grosses of nipples, washers and spokes per month are list in Table 5.2.

Some of the spare parts are taken under consideration to be manufactured locally according to the selection criteria mentioned earlier are shown in the Table 5.2.

Machines available for manufacture of spare parts are as follows:

1. Lathe machine
2. Drilling machine
3. Grinding machine
4. Milling machine.

Yearly consumption of selected spare parts and their imported cost are also given in Table 5.2. Total imported cost per year is also shown in the same table.

Table 5.2
Cost of Selected spare parts

Sl.N o.	Spare parts name	Annual requireme nt pcs.	Imported cost	
			Cost per pcs. or per set,TK	Imported cost per year,TK
1	Feeding segment	12	8,000	96,000
2	Upset head punch	48	2,500	1,20,000
3	Upset ejector pin	36	1,500	54,000
4	Spoke head punch	72	2,600	1,87,200
5	Automation ejector pin	36	1,125	40,500
6	Gripping die	216 (108 sets)	11,500 1 set	12,42,000

5.3 MANUFACTURING PROCESSES OF SELECTED SPARE PARTS

Function, design dimensions and materials for the selected spare parts are presented in Appendix-A. In this section manufacturing processes for those parts are suggested.

a. Process planning in manufacturing the spare parts in NBCIL:

The task of process planning is to translate design data to work instruction to produce a part or a product. It is the systematic determination of the methods by which a product is to be manufactured economically and competitively. It synthesizes into a plan of manufacturing which includes such factors as mentioned below:

- i. Volume of output needed
- ii. Operations
- iii. Estimated manufacturing costs
- iv. Production capacity of the machines (availability of tools and other conditions under which the parts are to be machined)

The plan provides specifications for the proposed manufacturing process on process sheets which designate, in appropriate details, the proper sequence of operations, facilities and tools requirements.

b. Initial data required for process design:

The following principal data and information are required to plan a manufacturing process.

- i. Working drawing of the part machined and other manufacturing specifications for finished part.
- ii. Monthly requirement of the product.

c. Production process:

The production process of the parts depends on the lot size and type of the product. The production process of manufacturing the parts for job-shop or batch production is quite difficult from that of the process for mass production. Process for the selected spare parts to be manufactured are shown in the following operation sheets. The basic requirements of the jobs which could be obtained from the detailed drawing of the parts are to be determined before the actual operations for the batch production is achieved [12]. To produce a workpiece by machining, the following factors should be considered.

- i. Size and shape of the workpiece.
- ii. Tolerance
- iii. Surface finish
- iv. Material from which part is to be machined
- v. Number of pieces to be produced.

Production process for the selected spare parts to be manufactured are shown one by one respectively in the following operation sheets.

Fig. 5.1 : PROCESS SHEET - 1
Master operation sheet for ejector pin of nipple automation m/c.

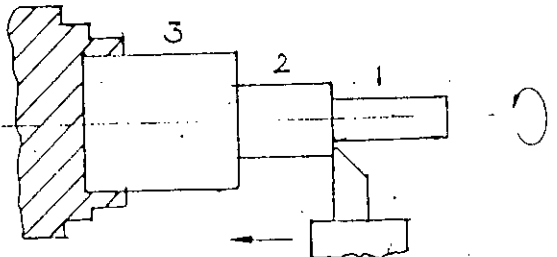
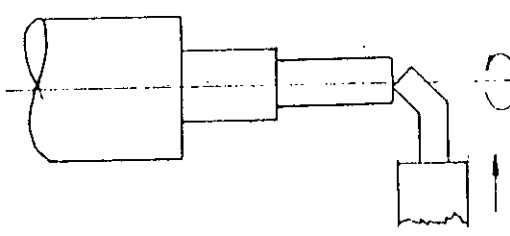
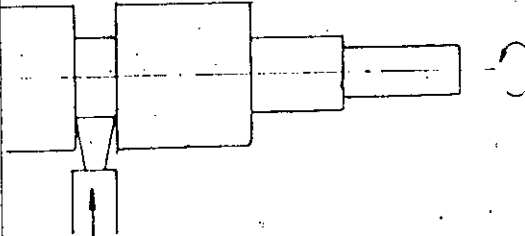
OP No	Operation	Sketch	Machine & Tools	M/c time min	Total time min
1	Clamping & Turn a. Surface-1 b. Surface-2 c. Surface-3		Lathe a. Straight cutting tool for surface 1, 2 and 3 with $\phi 90$	20	50
2	Facing		Lathe Single point cutting tool (H.S.S)	4	15
3	Parting off		Lathe parting off tool (H.S.S)	8	20

Fig-5-2: PROCESS SHEET - 2
Master operation sheet for ejector pin of nipple upset m/c.

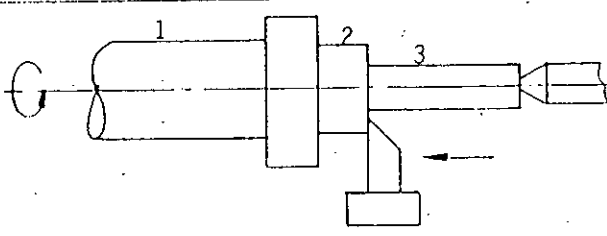
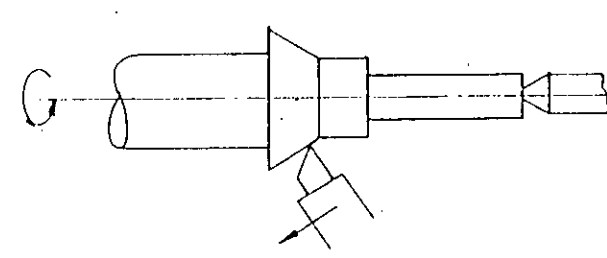
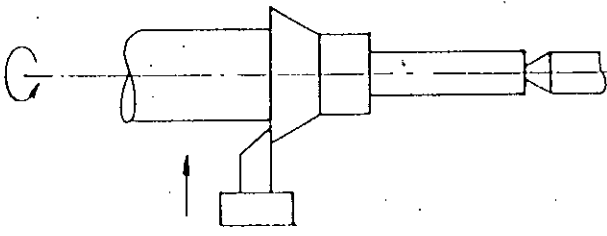
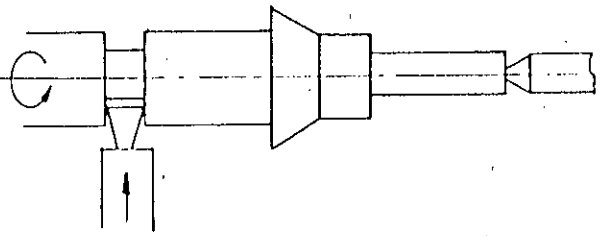
OP No	Operation	Sketch	Machine & Tools	Machine time min	Total time min
1	Turning Longitudinal turning for surface 1, 2 & 3		Lathe Operation for surface 1, 2 & 3 done by straight cutting tool (H.S.S)	20	50
2	Angular Turning		Lathe Angular turn. done by straight turning tool (H.S.S)	6	15
3	Facing		Lathe Straight cutting tool (H.S.S)	5	15
4	Parting off		Lathe parting off tool (H.S.S)	3	10

Fig. 5.3: PROCESS SHEET - 3

Master operation sheet for head punch of nipple upset m/c.

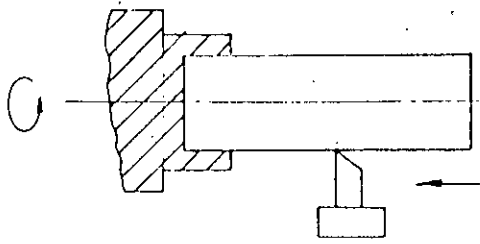
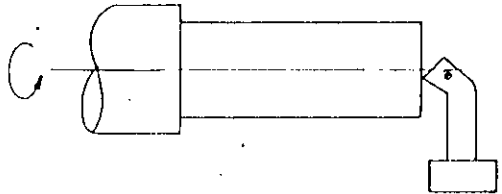
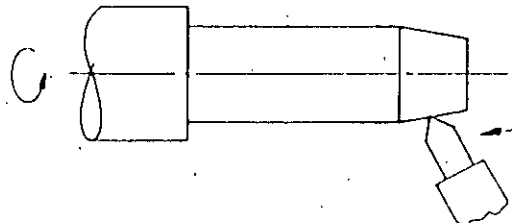
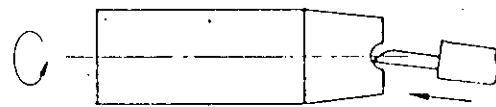
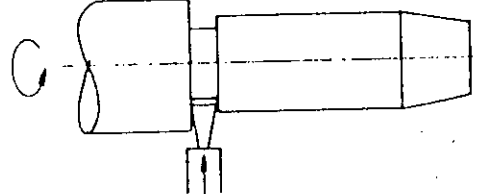
OP No.	Operation	Sketch	Machine & Tools	Machine time min	Total time
1	Clamping & Turning		Lathe Straight cutting tool (H.S.S)	20	80
2	Facing		Lathe Single point cutting tool	7	30
3	Taper turning		Lathe Taper turning done by straight cutting tool	10	24
4	Grooving		Lathe Single point tool	6	14
5	Parting off		Parting done to acquire the required length	7	17
6	Heat Treatment		Heat treating furnace & bath	60	

Fig.5.4:PROCESS SHEET - 4
Master operation sheet for spoke head punch

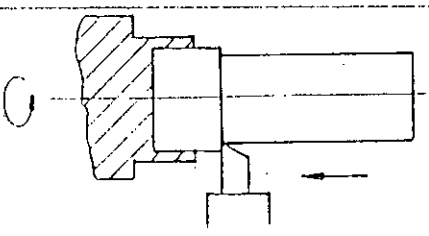
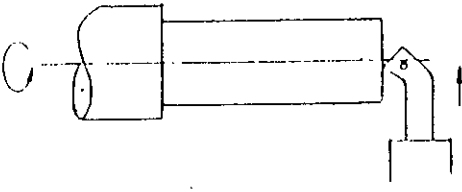
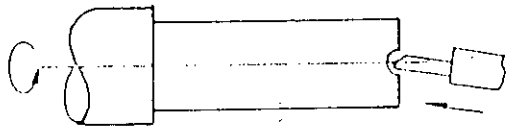
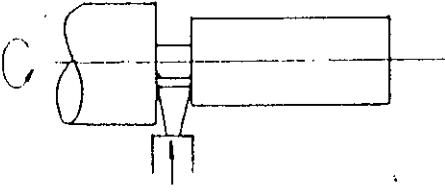
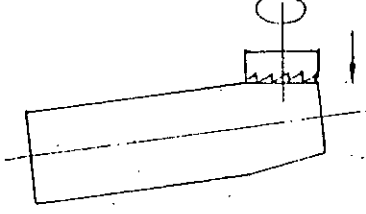
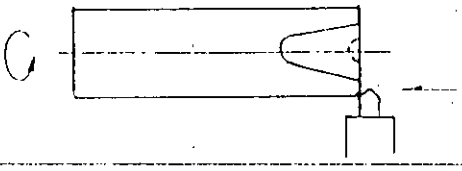
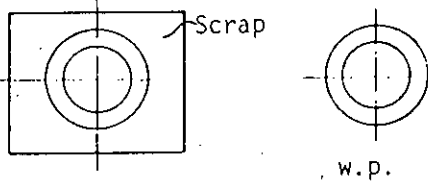
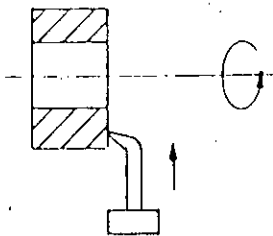
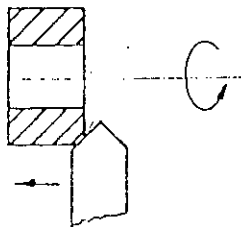
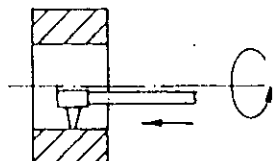
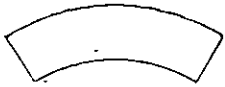
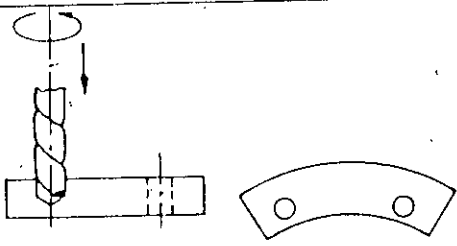
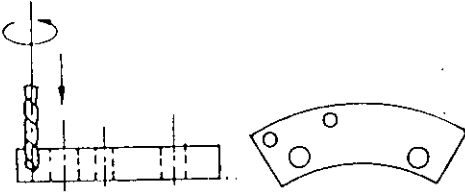
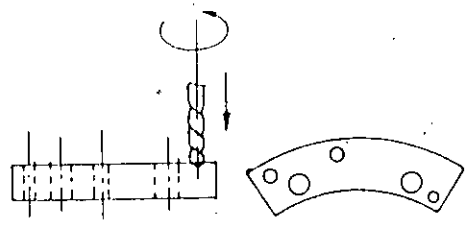
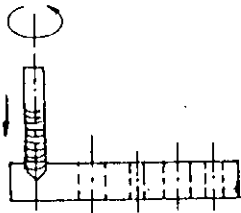
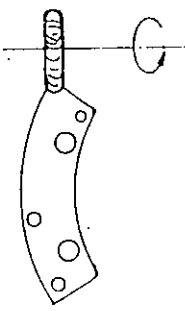
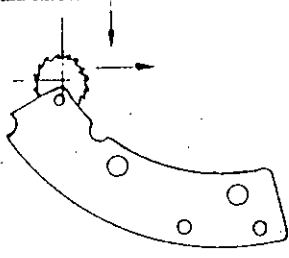
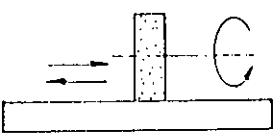
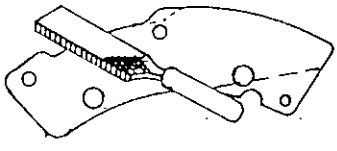
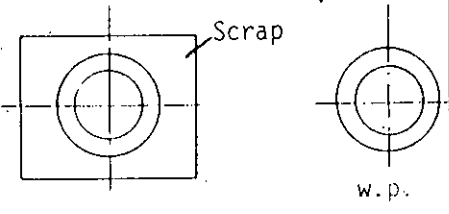
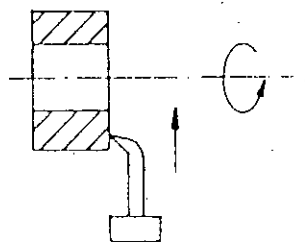
OP No.	Operation	Sketch	Machine & Tools	Machine time min	Total time min
1	Clamping & Turning		Lathe Straight cutting tool (H.S.S)	17.	39
2	Facing		Lathe Single point cutting tool (H.S.S)	6	14
3	Grooving		Lathe Single point cutting tool (H.S.S)	5	12
4	Parting.		Lathe Cutting off tool (H.S.S)	6	17
5	Milling Surface milling		Milling m/c Three sides to be milled	20	46
6	Chamfering		Lathe Cutting off tool (H.S.S)	9	29
7	Heat Treatment		Heat treating Furnace & bath	60	

Fig. 5.5: PROCESS SHEET - 5
Master operation sheet for feeding segment production

OP No.	Operation	sketch	Machine & Tool	Machine time min.	Total time min.
1	<u>Part 1</u> Gas cutting		Gas cutter	20	30
2	Facing		Lathe Single point tool (H.S.S)	4	10
3	Turning		Lathe Straight turning tool	3	5
4	Boring		Lathe Boring tool	4	5
5	Sawing (Two faces)		Hacksaw (Manually)	25	30

OP No.	Operation	Sketch	Machine & Tool	Machine time min	Total time min
6	Drilling (Two holes)		V.milling machine H.S.S. drill bit Ø 7 mm.	4	6
7	Drilling (Two hole)		V.milling H.S.S. drill bit Ø 4 mm	4	6
8	Drilling (One hole)		V.milling H.S.S. drill bit Ø 3 mm	4	6
9	Tapping (Two holes)		Hand tap	2	3
10	Grooving (Two grooves)		V.milling End mill Cutter	8	18

11	Sawing		H.Milling Saw (Circular)	5	10
12	Grinding (Two faces)		Surface grinding G. wheel	15	30
13	Filing		File	40	45
	<u>Part 2</u>				
1	Gas cutting		Gas cutter	5	10
2	Facing (Two faces)		Lathe Single point H.S.S. tool	5	10

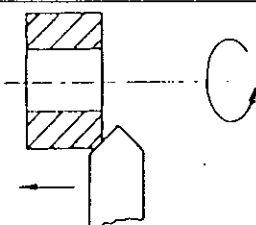
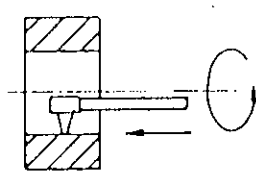
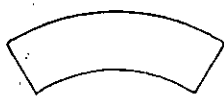
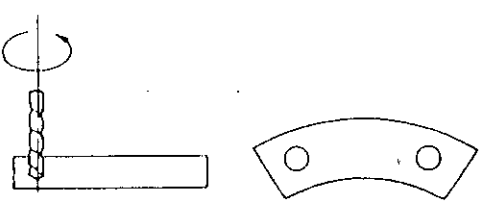
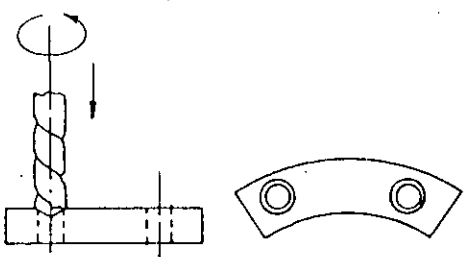
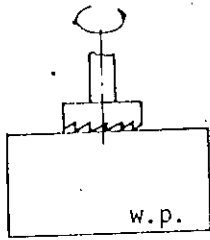
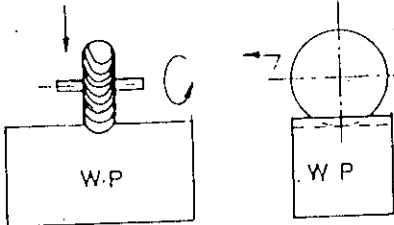
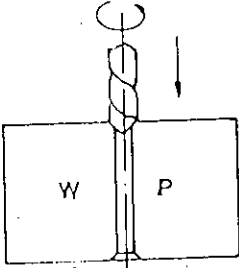
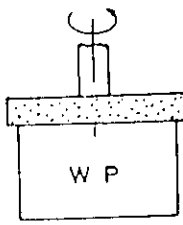
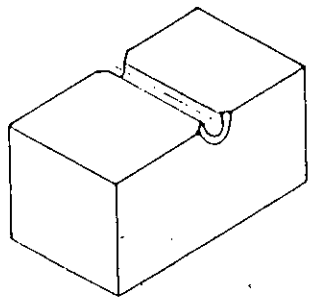
OP No.	Operation	Sketch	Machine & Tool	Machine time _{min.}	Total time _{min.}
3	Turning		Lathe Straight Turning tool	3	5
4	Boring		Lathe Boring tool	3	5
5	Sawing (Two faces)		Hacksaw	8	10
6	Drilling (Two holes)		Drill machine H.S.S. Drill bit bit $\varnothing 4$	3	5
7	Chamfering (Two faces)		Drill machine H.S.S. Drill bit $\varnothing 6$ mm	3	4
8	Heat Treatment part 1 & 2		Heat treating Furnace and bath	60	

Fig. 5-6: PROCESS SHEET -6
Master operation sheet for gripping die production

OP No.	Operation	Sketch	Machine & Tools	Machining time min.	Total time min.
1:	Milling Surface milling		Milling m/c. End milling c cutter is used At first milling is done on all six sides of the block	200	343
	Face milling		Then slotting is done on one side of the block using form cutter (H.S.S)		
	Chamfering		Lastly chamfering is done on one side using T slot cutter (H.S.S)		
2.	Surface grinding		All six sides are surface grinded	40	120
					
3	Heat treatment		Heat treating furnace & bath	60	

5.4 ECONOMIC ANALYSIS

Economic analysis should be done to calculate the production cost of different components selected to be manufactured locally. Local production will be justified only if the production cost of those components is below the imported ones available in the local market. Production cost includes raw material cost, manufacturing cost and other non manufacturing cost (administrative and miscellaneous cost). For NBCIL non manufacturing cost was estimated as Tk. 10.50 per hour.

a. Cost Factors:

Complete costs incurred in the manufacturing enterprise are usually segregated into two broad groups: (i) manufacturing cost (the cost of actual fabrication of the product, elements of which are material, labour, factory expense) and (ii) non manufacturing cost (those further costs incident to business operations such as selling or distribution, legal, financial, and administration expenses)[12]

Manufacturing costs: Elements of manufacturing cost are:

- i. Material cost (direct and indirect)
- ii. Labour cost (direct and indirect)
- iii. Manufacturing overhead.

Explanation of these cost elements could be found in any standard text book on accountancy.

Besides, administration, selling and distribution, transportation and finance expenses are common to all manufacturing firms.

If manufacturing costs are added together with the administration, selling and distribution, and finance expenses, the resulting figure is known as total cost.

b. Manufacturing time and machining time:

When the tools have been selected feeds, speed, setup times, cutting times, tool changing times have to be determined. Those parameter will be affected by the material to be cut, the cutting tool, machining parameter, and the design of the machine tool. The cutting speed, feed and depth of cut to be used can be obtained from various handbooks.

Manufacturing time is the time required for producing a workpiece in accordance with the capacities of the machine tools.

The Manufacturing time (per piece) is determined from the following formula.

$$T_p = T_m + T_h + T_t + T_f$$

where,

T_p = Manufacturing time (per piece), min

T_m = Machining time, min.

T_h = Work handling time, min.

T_t = Tool changing time, min.

T_f = Fatigue allowance, min.

T_m is the time, during which machining is being performed to change the size and form or the state of the workpiece surface.

T_h is the time required to control the machine tool, for loading and unloading the workpiece, to make measurements and for advancing and retracing the tools for certain elements.

T_c is the time required to change tools for different operations.

T_r is the time required for rest and personal needs of the operator, is promised for all kinds of jobs.

For batch production machining time (T_m), work handling time (T_h), tool changing time (T_c) and fatigue time (T_r) may be taken as 30-40%, 50-70%, 6-8% and 4-2% of Manufacturing Time T_p respectively.

In lathe work T_m can be calculated by the formula [10]:

$$T_m = \frac{L}{ns} i \text{ min.}$$

where L = travel of the tool in the direction of the feed motion,
mm

n = speed of the workpiece (spindle), rpm

s = rate of feed, mm per rev.

i = number of passes, or cuts.

Tool travel is made up of

$$L = l + Y + \Delta \text{ mm}$$

where l = length of machined surface in the direction of feed motion, mm

Y = tool approach, mm

Δ = tool overtravel and approach mm, $\Delta = 1$ to 2 mm.

The approach Y in feeding the tool into the work is determined by the formula

$$Y = t \cot \theta$$

Where t = depth of cut, mm

θ = plan approach angle

Machining time in any type of milling operation is determined from the formula:

$$T_m = \frac{L_i}{S_m} \text{ min}$$

in which : L = length of table (or cutter) travel in the direction of the feed, mm

i = number of cuts

S_i = rate of feed, mm per min.

Machining time for surface grinding is determined from the formula:

$$\frac{2 \times L \times i}{V \times 1000}$$

where L = grinding length (l + overtravel)

l = length of workpiece

i = number of cuts

v = speed of table in m/min.

Calculation of the machining time for drilling operations is determined from the formula mentioned below:

$$T_m = \frac{L}{s \times n} \text{ min}$$

where L = feed distance of the drill
= depth of hole + drill point
= $L + 0.3 \times d$
 l = depth of hole
 d = diameter of drill in mm
 n = numbers of revolutions of drill per min.
 s = feed of drill in mm/rev.

Production time was calculated on the basis of the formulas mentioned above.

c. Assumptions in cost analysis:

Although in real situations, factors such as the spare parts demand per month, price of raw materials, production rate, etc. may vary, yet for simplicity these are assumed fixed for a certain time period. Thus, the following factors are to be considered fixed in the present work.

- i. Spare parts demand
- ii. Cost of raw material
- iii. Labour rate

- iv. Production rate
- v. Bank interest
- vi. Building rent
- vii. Administration cost
- viii. Price of machineries and equipmen

d. Determination of costs of production of selected spare parts

The production costs of the selected spare parts have been determined. Work handling, tool changing and fatigue allowance are added to machining time for obtaining total time, while the cost estimation are done according to market rate for various operations. Cost of raw material & manufacturing have been taken on the basis of 1992 market cost. The detailed scheme of determination of production cost and their estimations are given in Appendix-B. Production quantities of various products using locally made spare parts is given in Table 5.3. Table 5.4 gives a comparison of production quantities per spare parts produced locally and imports. Cost comparison is given in the Table 5.5. Cost advantage per year by spare parts manufactureed locally over imported are in Table 5.6.

Table 5.3
Performance of the selected spare parts produced locally

Sl No	Spare part's name	Qty. Used	Local Manufacturing Capability		Production quantities per month
			Cost per pc.	Total cost Tk.	
1	Feeding segment	1	985	985	4,000 nipples
2	Auto ejector pin	2	250	500	5,000 nipples
3	Upset ejector pin	2	259	518	6,000 nipples
4	Upset head punch	2	859	1718	4,000 nipples
5	Spoke head punch	2	992	1984	1,800 spoke
6	Gripping die	4 (2sets)	449	1796	3,168 spoke

Table 5.4
Production given by a foreign made and a local made spare parts

Part's name	Imported no.	Production in grosses	Local made No.	Production in grosses
Feeding segment	1	15,000	1	4,000 nipples
Ejector pin (Upset machine)	1	5,000	1	2,675 nipples
Ejector pin (Auto machine)	1	6,000	1	2,500 nipples
Upset Head Punch	1	4,000	1	2,000 nipples
Spoke Head Punch	1	2,500	1	1,200 spokes
Gripping die	1	1,760	1	1,584 spokes

Table 5.5

Cost comparison of the selected spare parts produced locally and imported on the basis of production of 15000 grosses of spokes and nipples per month

Spare part's name		Cost/pc. Tk.	Profit per pc. Tk.	Total spare parts demand per month pcs.	Total cost Tk.	Cost advantage of locally produced spares per month Tk.
Feeding segment	Imported	8,000	7015	1	8,000	4,060
	Locally	985		4	3,940	
Ejector Pin (Upset machine)	Imported	1,500	1,242	3	4,500	2,946
	Locally	259		6	1,554	
Ejector Pin (Auto machine)	Imported	1,125	875	3	3,375	1,875
	Locally	250		6	1,500	
Upset Head Punch	Imported	2,500	1,641	4	10,000	3,128
	Locally	859		8	6,872	
Spoke Head Punch	Imported	2,600	1,608	6	15,600	3,996
	Locally	992		12	11,904	
Gripping Die	Imported	5,750	5,301	18	103,500	94,520
	Locally	449		20	8,980	

Table 5.6

Profit per year by manufacturing imported spare parts locally

Part's name	Imported spare parts		Locally manufactured spare parts	
	Annual requirement pcs.	Total cost Tk.	Annual requirement pcs.	Total cost Tk.
Feeding segment	12	96,000	48	47,280
Ejector Pin (Upset machine)	36	54,000	72	18,576
Ejector Pin (Auto machine)	36	40,500	72	18,000
Upset Head Punch	48	1,20,000	96	82,464
Spoke Head Punch	72	1,87,200	144	1,42,840
Gripping Die	216	12,42,000	240	1,07,760
Total cost = Tk. 1739,700/-			Total cost= Tk.4,16,928/-	
Profit	=	Imported cost - Locally manufacturing cost		
	=	Tk. 17,39,700 - Tk. 416,928		
	=	Tk.13,22,772 per year		

CHAPTER-6

OPTIMIZATION OF MACHINE UTILIZATION AND PROFIT FOR PRODUCTION OF SELECTED SPARE PARTS

6.1 INTRODUCTION

Selection of spare parts and the economics of their production with the available machineries in the factory have been presented. Appropriate manufacturing processes have been discussed in the previous chapter. In the present chapter application of quantitative techniques of operations research have been used for optimization of machine utilization and maximization of profit through production of the selected spare parts. In this regard a linear programming technique (LP) has been presented in this chapter. used and two models have been developed for maximizing the total machine utilization and maximizing the profit through manufacturing of the selected spare parts.

The drilling machine, vertical milling machine, grinding machine (horizontal), lathe machine (capstan) remain idle for one shift per day in the factory. They have been in idle position during one shift per day since the start of the factory. In the other shift small parts, tools and etc. are manufactured. Thus if those machines are utilised to manufacture the selected spare parts for the machines which produce bi-cycle parts then the factory can get the following benefits.

- Utilization of the idle machines and their operator
- In-house manufacture of the selected spare parts thus reducing transport and import cost.

Linear programming models are the most frequently utilized mathematical programming models. In this case, the objective function for Model-1 is to maximize the total machine utilization for the machines used. This is dependent on the machining time and spare parts demand. It is found that whatever capacity is used by a particular product in say Machine-1, it becomes unavailable for the others. Similarly for model-2 the required number of spare parts for profit maximization taking into account the maximum machine utilization. So the problem is a linear programming of the class product mix type.

In problem formulating using linear programming, the following assumption must be satisfied [16]:

1. Proportionality
2. Divisibility

1. Proportionality: The assumption is that the measure of effectiveness and uses of each resource are directly proportional.

In the existing problem effectiveness $Z = TR_{ij} X_i$ and the available machine time for each resource (use of each resource) is equal to $TA_j X_i$. The difference between those two is only the sign of summation which is

$$Z = \sum_j^J \sum_i^N T_{ij} X_i \quad \dots \quad (a)$$

$$\text{and} \quad \sum_{i=1}^N TR_{ij} X_i \leq TA_j \quad J=1 \dots j \quad \dots \quad (b)$$

from this we see that they are directly proportionate.

2. Disvisibility : Disvisibility assumption implies that noninteger values for the decisions variable are permissible. In our problem decision variable is X_i , quantity of spare parts of type i to be produced which can have fraction of values.

6.2 MODEL FOR MAXIMUM MACHINE UTILIZATION (Model-1)

Decision Variables:

Primarily two types of variables are considered as the decision variables. These are as follows:

TR_{ij} = Time required for spare parts i in machine j .

X_i = Quantity of spare parts of type i to be produced.

Data :

Constant and parameters :

TA_j = Time available in machine j

D_i = Demand for spare parts i per month

N = Total number of spare parts

J = Total number of machines.

Formulation :

The objective function for the model is to maximize the total machine utilization for all the machines.

$$\text{Maximize, } Z = \sum_{j=1}^J \sum_{i=1}^N TR_{ij} X_i \quad \dots \quad (6.1)$$

The objective function Z , could be expanded as follows:

$$Z = \sum_{j=1}^J \sum_{i=1}^N TR_{ij} X_i$$

$$\sum_{j=1}^J (TR_{1j} X_1 + TR_{2j} X_2 + TR_{3j} X_3 + TR_{4j} X_4 + TR_{5j} X_5 + TR_{6j} X_6) \dots \quad (6.2)$$

The objective function stated above is subject to the following constraints:

1. Constraint for maximum available machine time:

The total time required to produce the selected spare parts should not exceed the maximum available machine time for each machine. Thus the constraint becomes:

$$\sum_{i=1}^N TR_{ij} X_i \leq TA_j \quad j = 1 \dots J \quad \dots \dots \quad (6.3)$$

2. Constraint for the fulfilment of demand

The number of spare parts produced should be such that they fulfill the minimum required demand. If spare parts are manufactured below the required demand then the company will be unable to supply 15000 grosses of nipples and spokes to fulfill market demand. So x_i should be greater or atleast equal to demand D_i . Thus the constraint becomes:

$$X_i \geq D_i \quad i = 1 \dots N \quad \dots \dots \quad (6.4)$$

Variable Bounds:

The variables have the following bound:

$$\begin{aligned} X_i &\geq 0 && \text{for all } i \\ TR_{ij} &\geq 0 && \text{for all } j \end{aligned} \quad \dots \quad \dots \quad (6.5)$$

6.2.1. Input Data for Model-1

The following data has been collected from the NBCIL. These are given in Table 6.1 and 6.2.

Table 6.1 : Time available in each machine per month

Machine running time per shift	7 hours
Shifts allocated per day	2 shifts
Shifts remain idle per day	1 shift
Working days per month	26 days
Machine running time per month	Machine running time pre day x working days per month = 7 x 1 x 26 = 182 hrs/month = 182 x 60 min/month = 10920 minutes/month

Table 6.2 : Machining time and demand of selected spare parts

Spare parts name	Demand per month pcs	Machining operation time per piece					
		Lathe min	Milling min	Grinding min	Drilling min	H.T. min	Filing min
Ejector pin (N. auto)	8	85	-	-	-	-	-
Ejector pin (Upset machine)	8	90	-	-	-	-	-
Upset head punch	8	165	-	-	-	60	-
Spoke head punch	12	157	50	-	-	60	-
Feeding segment	4	40	45	30	10	60	45
Gripping die	20	-	343	120	-	-	-

The objective function is,

$$Z = \sum_{j=1}^J \sum_{I=1}^N TR_{Ij} X_j \quad \dots \dots \quad (6.6)$$

$$Z = \sum_{j=1}^J (TR_{1j} X_1 + TR_{2j} X_2 + TR_{3j} X_3 + TR_{4j} X_4 + TR_{5j} X_5 + TR_{6j} X_6)$$

$$\text{or, } Z = 85X_1 + 90X_2 + 225X_3 + 267X_4 + 175X_5 + 523X_6$$

Constraints of type-1 becomes

$$85X_1 + 90X_2 + 165X_3 + 157X_4 + 40X_5 \leq 10920 \quad \dots \quad (i)$$

$$50X_4 + 45X_5 + 343X_6 \leq 10920 \quad \dots \quad (ii)$$

$$40X_5 + 120X_6 \leq 10920 \quad \dots \quad (iii)$$

$$10X_5 \leq 10920 \quad \dots \quad (iv) \quad \dots \quad (6.7)$$

$$60X_3 + 60X_4 + 60X_5 + 60X_6 \leq 10920 \quad \dots \quad (v)$$

$$45X_5 \leq 10920 \quad \dots \quad (vi)$$

Comparing the two equation (iv), equation (vi), equation (iv) is omitted because it is redundant.

Constraint of type-2

$$\begin{array}{rclcl}
 X_1 & \geq & 6 & & \\
 X_2 & \geq & 6 & & \\
 X_3 & \geq & 8 & \dots & (6.8) \\
 X_4 & \geq & 12 & & \\
 X_5 & \geq & 4 & & \\
 X_6 & \geq & 20 & &
 \end{array}$$

6.2.2 Result of Model-1

By solving the Model-1, the maximum number of each type spare parts are obtained given in Table 6.3.

The plant is producing 15000 gross of spokes and nipples currently. It is observed from Table 7.3 that the company can manufacture the aforesaid demanded spare parts in one shift which remain idle at present.

Table 6.3 : Maximum number of selected spare parts by the available machines in NBCIL

Sl.No.	Spare part's name	Computer result	
		Variable	No. of spare parts (each type)
1	Nipple automation ejector	X_1	6.0
2	Upset ejector pin	X_2	6.0
3	Upset head punch	X_3	29.76
4	Spoke head punch	X_4	12.0
5	Feeding segment	X_5	76.8
6	Gripping die	X_6	20.0

THE MAXIMUM OBJECTIVE FUNCTION VALUE = 32174.51
ELAPSED CPU SECOND = 0.71875

Table 6.4 indicates maximum utilization time for producing spare parts listed in Table 6.3.

Table 6.4 : Maximum utilised time for operation

Sl.No.	Name of different operation/machine	Maximum utilized time (min)	Maximum time available (min)
1	Lathe	10920	10920
2	Milling	10920	
3	Grinding	4706.67	
4	Drilling	768.89	
5	H.T.	8318.90	
6	Filing	3460	

6.3 MODEL FOR PROFIT MAXIMIZATION (MODEL-2)

The model has been developed to determine the product mix of the selected spare parts for profit maximization. In this case the total maximum demand, maximum machine capacity, maximum spare parts on hand (inventory) and production constraints have been taken into account.

The terminology used to formulate the model is described below.

Decision variable:

Only one type of decision variable has been identified

X_i = Maximum number of spare parts i to be produced for profit maximization.

Formulation

The objective function for the model is to maximize the total machine utilization for all the machines.

$$\text{Maximize, } Z = \sum_{j=1}^J \sum_{i=1}^N TR_{ij} X_i \quad \dots\dots\dots (6.9)$$

The objective function Z , could be expanded as follows:

$$\sum_{j=1}^J (TR_{1j} X_1 + TR_{2j} X_2 + TR_{3j} X_3 + TR_{4j} X_4 + TR_{5j} X_5 + TR_{6j} X_6)$$

The objective function stated above is subject to the following constraints:

1. Constraint for maximum available machine time:

The total time required to produce the selected spare parts should not exceed the maximum available machine time for each machine. Thus the constraint becomes:

$$\sum_{i=1}^N TR_{ij} X_i \leq TA_j \quad j = 1 \quad \dots J \quad \dots\dots\dots (6.10)$$

2. Constraint for the fulfilment of demand. The number of spare parts produced should be such that they fulfill the minimum required demand. If spare parts are manufactured below the required demand then the company will be unable to supply 15000 grosses of nipples and spokes to fulfill market demand. Thus the constraint becomes:

$$X_i \geq D_i \quad i = 1 \dots N \quad \dots \quad (6.11)$$

Input data :

- a. Objective function coefficient

M_i = Import cost for product i

C_i = Local manufacturing cost for product i

H_i = Holding cost for product i

- b. Constraint and parameter

D_i = Total demand for product i $i = 1 \dots 6$

η = Percentage/fraction value of total profit

N = Total number of various types of spare parts

FORMULATION

The objective function is formulated as profit maximization all the spare parts into consideration. Should excess piece of spare parts produced are not sold then holding costs for those excess pieces are taken into consideration. Thus for profit maximization this holding cost for spare parts is subtracted from the unit profit margin.

Thus, the objective function becomes:

$$\text{Maximize, } Z \sum_{i=1}^N (M_i - C_i) X_i - \sum_{i=1}^N (X_i - D_i) H_i \quad \dots \quad (6.12)$$

1. Constraint for fulfilment of total demand

The number of each type of spare parts produced should be such that they fulfil the minimum total demand. If spare parts are manufactured below the required demand then the company will be unable to produce the target 15000 grosses of nipples and spokes to fulfil the market demand per month. Thus, the constraint becomes:

$$\sum_{i=1}^N X_i \geq D_T \quad \dots \dots \dots (6.13)$$

2. Constraint for maximum available machine time

The spare parts produced should be such that they are produced within the machine available time. The company cannot make profit by making spare parts beyond the capacity of the machines in the available shifts. At present the company operate on two shifts basis. Only one shift is free for machining operation. Thus the constraint becomes,

$$\sum_{i=1}^N TR_{ij} X_i \leq TA_j \quad J = 1 \dots 6 \quad \dots \dots \dots (6.14)$$

3. Constraint for inventory

The company made decision that each type of spare parts should be produced such that on hand should be greater than or equal to zero. Thus the constraint becomes,

$$(X_i - D_i) \geq 0 \quad \dots \quad (6.15)$$

4. Production decision constraint

The management decided that if the difference between import cost and local manufacturing cost for each type of spare parts should equal to or greater than certain percentage (η) of profit (z). Only under this condition those particular spare parts can be considered for production.

Thus the constraint becomes

$$(M_i - C_i) X_i \geq \eta * (Z) \quad \dots \quad (6.16)$$

The variable is subject to the following bounds

$$X_i \geq 0 \quad \text{for all } i \quad \dots \quad (6.17)$$

6.3.1 Input Data for Model-2

The data for profit of each selected spare parts manufactured locally are obtained from the previous chapter as given in Table-6.5.

Table 6.5 : Profit for each selected spare parts manufactured in the factory

Spare parts name	Import cost Tk.	Local manf. cost Tk.	Cost advantage = (Import cost - local cost) Tk
Nipple automation ejector pin	1125	250	875
Upset ejector pin	1500	259	1241
Upset head punch	2500	859	1641
Spoke head punch	2600	992	1608
Feeding segment	7015	985	7015
Gripping	5750	449	5301

Holding cost = Tk.10 for each type of spare parts.
Percentage/fraction value of total profit = 0.1.

The objective function is,

$$Z = \sum_{i=1}^N (M_i - C_i) X_i - \sum_{i=1}^N (X_i - D_i) H_i$$

$$\begin{aligned}
 \text{or } Z &= (1125 - 250)X_1 + (1500 - 259)X_2 + (2500 - 859)X_3 \\
 &\quad + (2600 - 992)X_4 + (7015 - 985)X_5 + (5750 - 449)X_6 \\
 &\quad - [(X_1 - 6) + (X_2 - 6) + X_3 - 8) + X_4 - 12) + (X_5 - 4) \\
 &\quad + (X_6 - 20) \times 10 \\
 &= 875X_1 + 1241X_2 + 1641X_3 + 1608X_4 + 7015X_5 + 530X_6 \\
 &\quad - 10X_1 + 60 - 10X_2 + 60 - 10X_3 + 80 - 10X_4 + 120 - 10X_5 \\
 &\quad + 40 - 10X_6 + 200 \\
 &= 865X_1 + 1231X_2 + 1631X_3 + 159X_4 + 700X_5 + 529X_6 + 560 \quad \dots \quad (6.18)
 \end{aligned}$$

Constraint of type-1

$$\sum_{I=1}^N X_I \geq D_T$$

$$= X_1 + X_2 + X_3 + X_4 + X_5 + X_6 \geq 56 \quad \dots \quad (6.19)$$

Constraint of type-2

$$\sum_{I=1}^N TR_{IJ} X_I \leq TA_J \quad J = 1 \dots 6$$

$$\begin{aligned} 85X_1 + 90X_2 + 165X_3 + 157X_4 + 40X_5 &\leq 10920 \quad \dots \quad (i) \\ 50X_4 + 45X_5 + 343X_6 &\leq 10920 \quad \dots \quad (ii) \\ 30X_5 + 120X_6 &\leq 10920 \quad \dots \quad (iii) \\ 10X_5 &\leq 10920 \quad \dots \quad (iv) \quad \dots \quad (6.20) \\ 60X_3 + 60X_4 + 60X_5 + 60X_6 &\leq 10920 \quad \dots \quad (v) \\ 45X_5 &\leq 10920 \quad \dots \quad (vi) \end{aligned}$$

Constraint of type-3

$$\begin{aligned} (X_1 - D_1) &\geq 0 \\ (X_1 - 6) &\geq 0 \quad \dots \quad (i) \\ (X_2 - 6) &\geq 0 \quad \dots \quad (ii) \\ (X_3 - 8) &\geq 0 \quad \dots \quad (iii) \quad \dots \quad (6.21) \\ (X_4 - 12) &\geq 0 \quad \dots \quad (iv) \\ (X_5 - 4) &\geq 0 \quad \dots \quad (v) \\ (X_6 - 20) &\geq 0 \quad \dots \quad (vi) \end{aligned}$$

Constraint of type-4

$$\begin{aligned}
 (M_1 - C_1) X_1 &\geq \eta.(Z) \\
 (1125 - 250) X_1 &\geq (0.1).Z \quad \dots \quad (i) \\
 (1500 - 259) X_2 &\geq (0.1).Z \quad \dots \quad (ii) \\
 (2500 - 859) X_3 &\geq (0.1).Z \quad \dots \quad (iii) \\
 (2600 - 992) X_4 &\geq (0.1).Z \quad \dots \quad (iv) \\
 (8000 - 985) X_5 &\geq (0.1).Z \quad \dots \quad (v) \\
 (5750 - 449) X_6 &\geq (0.1).Z \quad \dots \quad (vi)
 \end{aligned}$$

or,

$$\begin{aligned}
 875X_1 &\geq 86.5X_1 + 123.1X_2 + 163.1X_3 + 159.8X_4 + 700.5X_5 + 529.1X_6 + 56 \quad (i) \\
 1241X_2 &\geq 86.5X_1 + 123.1X_2 + 163.1X_3 + 159.8X_4 + 700.5X_5 + 529.1X_6 + 56 \quad (ii) \\
 1641X_3 &\geq 86.5X_1 + 123.1X_2 + 163.1X_3 + 159.8X_4 + 700.5X_5 + 529.1X_6 + 56 \quad (iii) \\
 1608X_4 &\geq 86.5X_1 + 123.1X_2 + 163.1X_3 + 159.8X_4 + 700.5X_5 + 529.1X_6 + 56 \quad (iv) \\
 7015X_5 &\geq 86.5X_1 + 123.1X_2 + 163.1X_3 + 159.8X_4 + 700.5X_5 + 529.1X_6 + 56 \quad (v) \\
 5301X_6 &\geq 86.5X_1 + 123.1X_2 + 163.1X_3 + 159.8X_4 + 700.5X_5 + 529.1X_6 + 56 \quad (vi)
 \end{aligned}$$

or,

$$\begin{aligned}
 789X_1 - 123X_2 - 163.1X_3 - 159.8X_4 - 700.5X_5 - 529.1X_6 &\geq 56 \quad (i) \\
 -86.5X_1 + 1117.9X_2 - 163.1X_3 - 159.8X_4 - 700.8X_5 - 529.1X_6 &\geq 56 \quad (ii) \\
 -86.5X_1 - 123.1X_2 + 1477.9X_3 - 159.8X_4 - 700.5X_5 - 529.1X_6 &\geq 56 \quad (iii) \\
 -86.5X_1 - 123.1X_2 - 163.1X_3 + 1448.2X_4 - 700.5X_5 - 529.1X_6 &\geq 56 \quad (iv) \dots (6.22) \\
 -86.5X_1 - 123.1X_2 - 163.1X_3 - 159.8X_4 + 6314X_5 - 529.1X_6 &\geq 56 \quad (v) \\
 -86.5X_1 - 123.1X_2 - 163.1X_3 - 159.8X_4 - 700.5X_5 + 4771.9X_6 &\geq 56 \quad (vi)
 \end{aligned}$$

6.3.2 Result of Model-2

By solving Model-2, the maximum number of selected spare parts tube produced for maximum profit per month have been determined as shown in Table 6.6. Computer output result of Model 1 and 2 are given in Appendix-D.

Table 6.6 : Maximum spare parts to be produced for maximum profit per month

Sl.No.	Name of spare parts	No. of spare parts
1	Nipple ejector pin	33.16
2	Upset ejector pin	23.39
3	Upset head punch	17.69
4	Spoke head punch	18.05
5	Feeding segment	6.0
6	Gripping die	25.05

THE MAXIMUM OBJECTIVE FUNCTION VALUE = TK. 28981.0
ELAPSED CPU SECOND = 0.769531

6.3.3 Sensitivity Analysis

This section presents the sensitivity analyse comparison by reducing the machine available time to 1%, 5%, 8% and 10% from the actual value and keeping other constraints unchanged in Model-2.

Table 6.7, 6.8 & 6.9 indicates different values of selected spare parts by reducing machining time to 1%, 5% and 8% respectively.

Table 6.7 : Value of variables by reducing available machine time to 1%

Sl.No.	Variable	Value	Shadow price
1	X_1	32.82	0
2	X_2	23.15	+27.189075
3	X_3	17.51	0
4	X_4	17.87	0
5	X_5	6.00	0
6	X_6	24.71	0

MAXIMUM OBJECTIVE FUNCTION VALUE = TK. 286828.50
ELAPSED CPU SECOND = 0.7695313

Table 6.8 : Value of variables by reducing available machine time to 5%

Sl.No.	Variable	Value	Shadow price
1	X_1	31.47	0
2	X_2	22.20	+27.189075
3	X_3	16.79	0
4	X_4	17.18	0
5	X_5	6.00	0
6	X_6	23.36	0

MAXIMUM OBJECTIVE FUNCTION VALUE = 274774.10
ELAPSED CPU SECOND = 0.7695313

Table 6.9 : Value of variables by reducing available machine time to 8%

Sl.No.	Variable	Value	Shadow price
1	X_1	30.45	0
2	X_2	21.48	+27.189075
3	X_3	16.24	0
4	X_4	16.58	0
5	X_5	6.00	0
6	X_6	22.34	0

MAXIMUM OBJECTIVE FUNCTION VALUE = 266056.00
ELAPSED CPU SECOND = 0.7734375

It is seen from those tables that the values of the profit function vary but the values of variables do not indicate any notable variation. This due to increase in the holding costs. When available machine time is reduced to 10% then the result becomes in feasible. Thus the company has to utilize the available machining time fully in order to make maximum profit.

CHAPTER-7

DESIGN OF AN ATTACHMENT FOR DRILL BIT SHARPENING

7.1 EXISTING METHOD OF DRILL BIT SHARPENING IN SPOKE SECTION

This chapter deals with the design of an attachment for sharpening of drill bits. At present, sharpening of drill bits are done manually which takes away production time, makes injuries to workers who sharpen the drill bits and the resharpen is not done accurately. This effects the overall production of estimated nipple per shift. Besides a big amount of company fund is spent for buying excess drill bits per month. If an attachment is designed to sharpen the drillbits then it would have the following benefits.

- i. Production of nipples per shift would be increased.
- ii. Reduction in consumption of drill bits per shift.
- iii. It would reduce workers injuries.
- iv. The purchasing cost of drill bits would be reduced.
- v. The designed attachment can be moved from one place to another.
- vi. The parts of the attachment can be removed easily for maintenance.

Thus it would increase productivity of the plant. In the spoke section drill bits of 2.00 mm and 2.38 diameter are sharpened by nipple automation machine operators. Each nipple automation machine has separate tool post for four drill bits of which three are of 2.00 mm dia and one of 2.38 mm dia. Purpose of the 2.38 mm diameter drill bit is to make guide hole in the nipple for further drilling

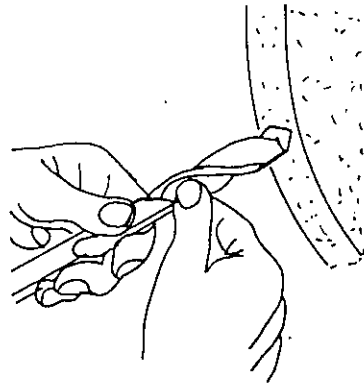


Fig. 7.1: Grinding by hand

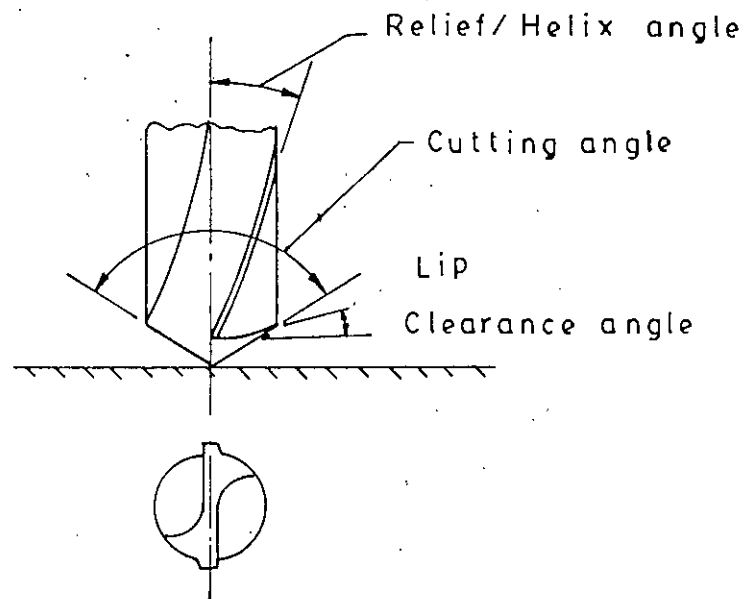


Fig. 7.2: Cutting Relief and Lip clearance angle

by 2.00 mm diameter drill bits. Usually drill bits are resharpened after every two hours depending upon their working conditions. An automation machine operator checks the sharpness of each drill bit in after every $1\frac{1}{2}$ hours. Existing method of drill bits resharpening is shown in Fig. 7.1. Drill bits are dipped in water frequently during resharpening time.

Table 7.1 : Shows resharpening time difference for 2.00 mm and 2.38 mm diameter drill bits per shift

Type of drill bit size in mm	Hours of operation between successive resharpening of drill bits	No. of resharpening time per shift,	Average resharpening time per shift,min	Average time needed for resharpening drill bit per shift, mm
2.00	2	4	10	16
2.38	6	1	1	2

Previously only four drill bits were sharpened before setting them in four drill chucks. When a drill bit being is sharpened and is posioned in place of the broken one it takes away some time. So to save the sharpening time, presently eleven drill bits are sharpened after setting the four drill bits in drill chucks.

7.2. PROBLEM CAUSED FROM PRESENT METHOD OF DRILL BIT SHARPENING

It was observed that the process of resharpening of drill bits by different operators and their performancy were poor; this required additional resharpening. This serious affected production and productivity. If drilling is continued with a blunt drill, excessive friction causes excessive heat and the drill losses its hardness. This results intensive tool wear. Often mistakes occurs

during resharpening of drill bit by hand, which results variation of point angle of drill bits. Clearance angle (fig.7.2) will vary from its designed value due to variation of point angle. Here the material to be drilled is alloy steel. If point angle is not 118° then after sometime part of drill bit may break and would be left inside the nipple to damage it. The existing method also causes hand injuries. The drill bit of nearly 1.5 inches long has to be held close to grinding wheel and finger tips. Finger tips becomes hot in short time due to friction caused by grinding wheel and drill bit. Drill bits are dipped frequently in a pot full of water. The injuries are caused also due to the wrong holding of drill bits by hand which sometimes shakes. Again when drill bits become dull, it pushes nipple away from the tongs which hold the nipple instead of drill cutting.

7.3 SCIENTIFIC METHOD OF DRILL BIT SHARPENING

It is very important that drill are properly ground by grinding the clearance surfaces of the drill point. Various methods are employed either using special attachment or with conventional universal tool grinders. These sharpening techniques are[2]:

- i) Conical sharpening method
This method includes
 - a) Washburne's method of conical grinding.
 - b) Weisher's method of conical grinding.
 - c) Blowa's method of conical grinding.
- ii) Flat plane grinding
- iii) Oliver's method of grinding
- iv) Suchow's method of planetary sharpening.

i. Conical Sharpening method:

In this method each chip clearance surface of the twist drill is part of a conical surface. The above mentioned three different methods for conical grinding differs from one another only in position of the location of the imaginary cone in reference to the drill is given by the following particulars:

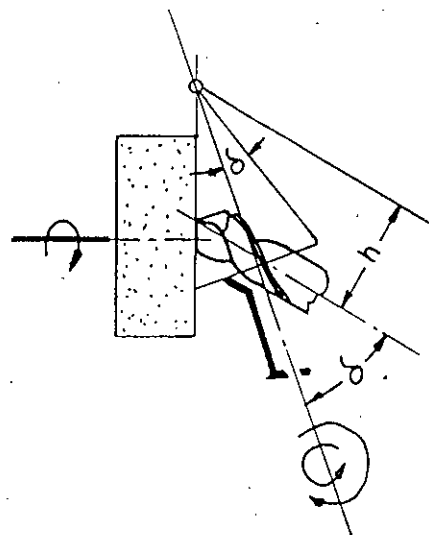
- a) the angle, σ , between the axis of the cone and the drill axis (Fig.7.3).
- b) the distance, h , from the vertex of the cone to the drill axis (Fig.7.3).

Washburne method : In the washburne method of conical grinding, the vertex of the imaginary cone is above the point of the drill (apex up) and its axis makes an acute angle δ (usually 20° or 45°) with the drill axis [Fig.7.3(a)].

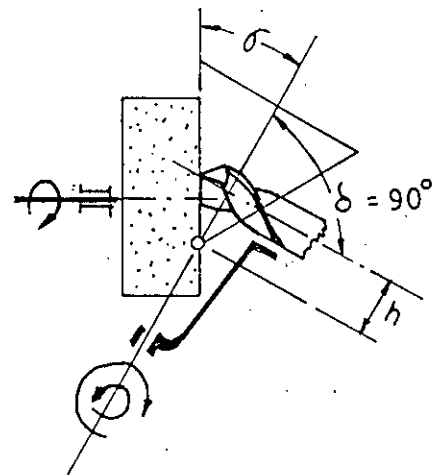
Weisker method : In this method of grinding, the vertex of the imaginary cone is below the drill point (apex down) and the cone axis is at right angles to the drill axis i.e. 90° .

Blow method : In this method of grinding, the cone is parallel to the surface of the grinding wheel. In such cases, the grinding cone becomes a round straight cylinder, i.e. $\sigma = 0$ [fig.7.3(c)].

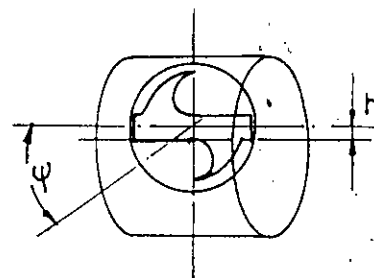
Working principal of conical grinding : In this method the clearance surface of each lip is ground in separate settings by indexing the drill through 180° . The side face of the grinding wheel coincides with an element of the imaginary cone where grinding is carried out. The drill is mounted in a holder in a definite position which is, in turn, mounted on a spindle whose axis coincides with that



(a) Washburne method



(b) Weisker method



(c) Blow's method of conical sharpening

Fig. 7.3: Drill sharpening method

of the imaginary cone. With an oscillating motion of the drill holder about the spindle axis, the clearance surface moves in reference to this side at the wheel along a conical surface. The tool holder setup for three methods are shown in Fig. 7.3.(a),(b) & (c).

ii. Flat plane grinding : Flat plane grinding of clearance surface of twist drill can be carried out in one or two planes as shown in Fig. 7.4. Single plane grinding is used for small drills upto 3 mm in diameter. Larger drill is ground by 2-plane method.

iii. & iv. Grinding method of grinding twist drill :

Sucherw's and Oliver's method of grinding twist drills are based on sharpening on helical surfaces. In Oliver's method, the drill is held and slowly rotated about axis I as shown in Fig. 7.5(a). The grinding wheel rotates about axis II. The wheel axis is offset to the axis of a sleeve which is given an independent rotation thus providing planetary rotation about axis III. The wheel is also given an axial reciprocation iv with the help of a cam. All the relative motions of the drill and wheel are interrelated in such a manner that the grinding of the lip clearance is carried out on a helical surface. In the suchow method of helical grinding as shown in Fig. 7.5(b), the tool is ground by the side of a grinding wheel trued to a part of a cone with an included angle of 156° . All other motions given to the system are similar to those given in Oliver's method.

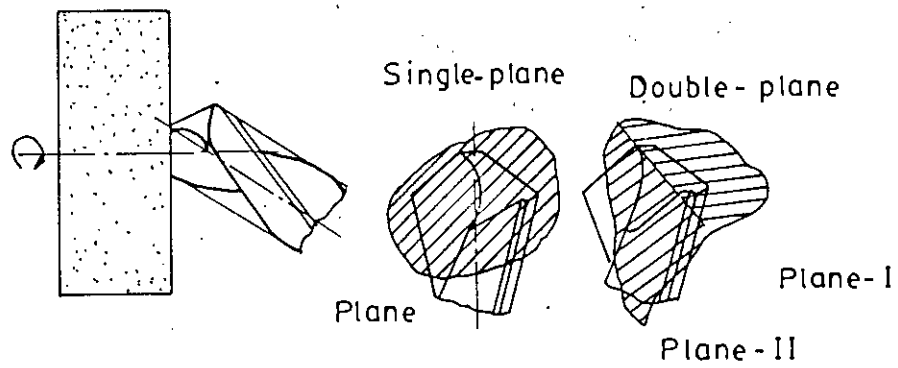
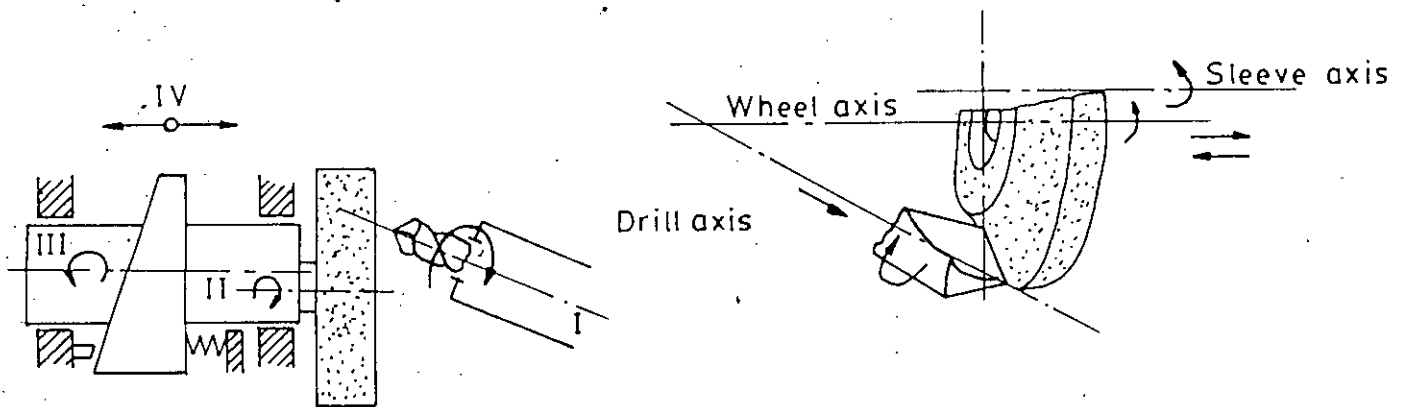


Fig.7.4: Flat drill point grinding



(a) Oliver's method

(b) Suchow's method

Fig.7.5 :Drill sharpening method

7.4 PROPOSED ATTACHMENT FOR DRILL BIT RESHARPENING

From the study of the existing methods of drill bit resharpener mentioned in the previous paragraph, a new idea has been conceived for the design of an attachment for drill bit resharpener. In designing a attachment, there is no rigid rule. The problem may be attempted in several ways. However, the general procedure to solve a design problem is as follows [14].

- i. To make a complete statement of the problem, indicating the purpose for which the attachment is to be designed.
- ii. To select the possible group of mechanism which will give a desired motion.
- iii. To select the material best suited for each member of the machine.
- iv. To find the size of each member on the basis of operation.
- v. Consideration of friction.
- vi. Safety of operation.
- vii. Detail drawing of the attachment to be designed.

With the above points in mind design of an attachment has been done as shown in Fig. 7.8.

7.5 WORKING PRINCIPLE OF THE PROPOSED ATTACHMENT

The working principle of the proposed attachment is shown in Fig. 7.8. The drill to be ground is clamped in a chuck 12. The chuck is mounted on a shaft 19. The angle between grinding wheel and drill bit axis is 59° which is half of point angle 118° as shown in Fig. 7.6. Grinding wheel 2 is rotates in the direction of b. Then

the whole attachment is moved forward in the direction of e towards the grinding wheel 2. This is done by rotating the handle 16. The rotation of handle 16 controls the forward and backward movement of attachment. Then the drill bit is set in rotation in the direction of arrow a by rotating handle 9 manually. At the sametime shaft 4 and cam 7 rotates in the direction of c as cam is fixed to the shaft by screw. Spring 6 controls push pin movement when the cam's outer edge touches the push pin, the drill bit moves forward in the direction of arrow. Again when the cam's inner edge comes in contact with the push pin 8 then spring 6 pushes the plate 5 towards push pin 8 in the direction of arrow f. This occurs due to gap created by inner edge of cam 7 and the push pin 8. This makes the drill bit to move backward. A complete revolution in the direction of the arrow c makes one complete sharpening of drill bit. After two-three rotation of handle 21, point angle of drill bit is checked by drill point counter gauge shown in Fig. 7.7.

When the handle 16 is rotated which moves the whole attachment forward, at that time left hand is used to rotate the handle knob 33 such that its displacement is one division (0.0012 mm) on the circular scale 32. Then the box plate 29 moves forward toward the grinding wheel 34 over the top rail 30 . Thus making the whole unit to move forward. Again the process is repeated for sharpening of drill bit. The attachment consists of the following parts as given in Table 7.2.

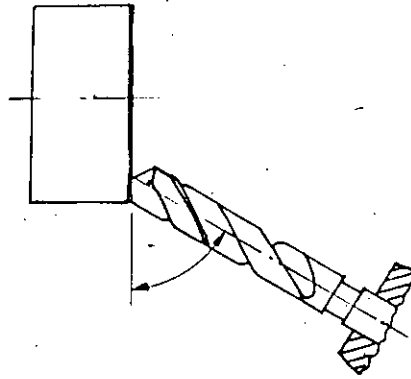


Fig.7.6: Setup for sharpening 2.00 dia twist drill



Fig.7.7 :Drill bit point counter gauge

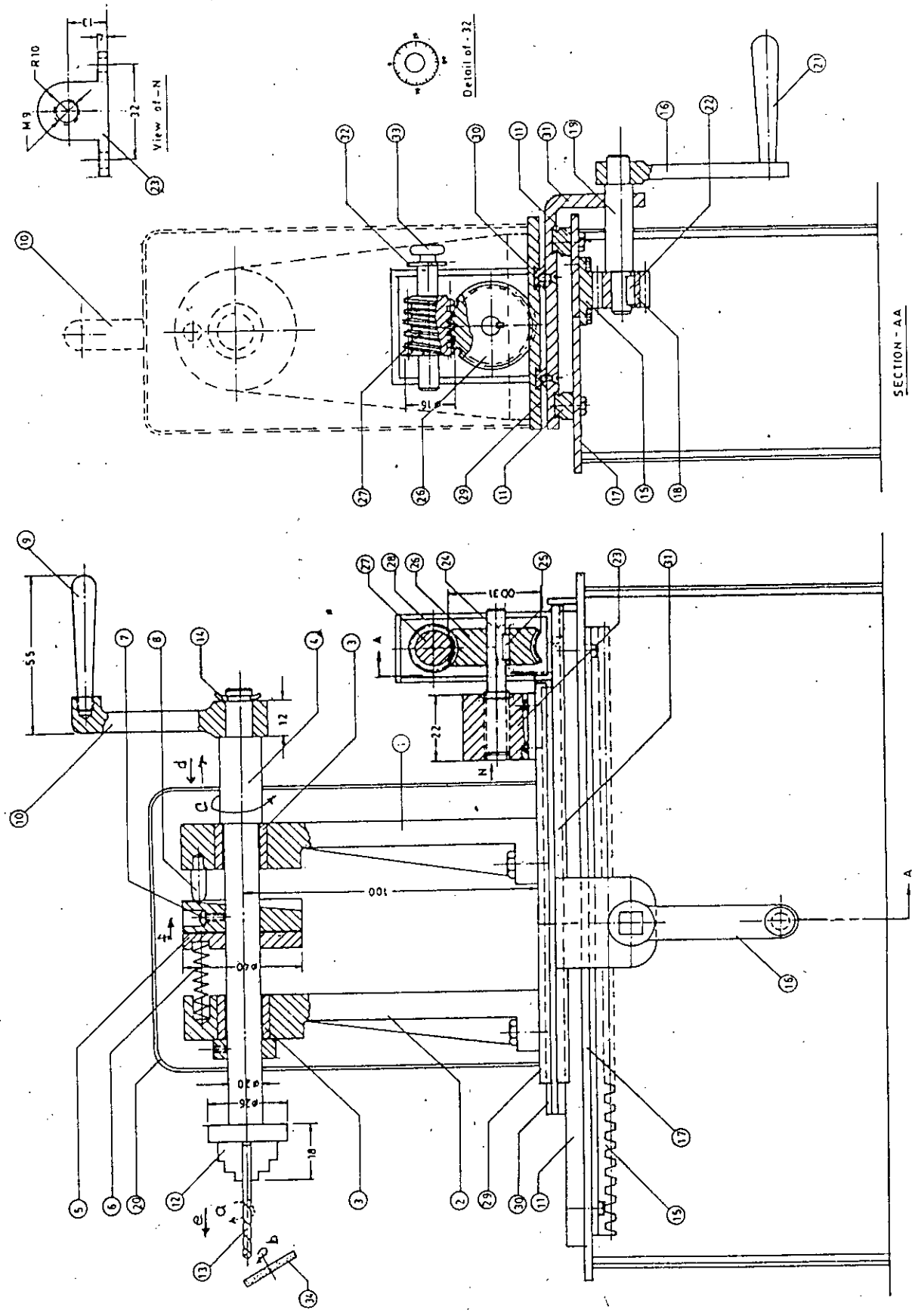


Fig. 7.8: ASSEMBLY DRAWING OF DRILL SHARPENING ATTACHMENT

Table 7.2 : Part list of drill sharpening attachment

Sl.	Part Name	Quantity pcs	Material
1	Leg	1	C.I. (cast iron)
2	Leg	1	C.I.
3	Bush	1	Brass
4	Shaft	1	M.S. (Mild steel)
5	Plate	1	M.S. (Mild steel)
6	Spring	1	Carbon steel
7	Cam	1	M.S. hard
8	Pushpin	1	M.S. (Mild steel)
9	Handle	1	M.S. or wood
10	Handle arm	1	C.I. (cost inn)
11	Rail	1	M.S. (Mild steel)
12	Drill chuck	1	M.S. hard
13	Drill	1	H.S.S.(High Speedsteel)
			M.S. (Mild steel)
14	Lock pin	1	M.S. (Mild steel)
15	Rack	1	C.I or M.S
16	Handle arm	1	M.S. (Mild steel)
17	Table	1	C.I. (Cast iron)
18	Rack pinion	1	M.S. (Mild steel)
19	Shaft	1	M.S. (Mild steel)
20	Safety guard	1	M.S. (Mild steel) M.S.
21	Handle	1	(Mild steel) M.S.
22	Key	1	(Mild steel) M.S.
23	Nut	1	(Mild steel) M.S.
24	Lead screw	1	(Mild steel)
25	Key	1	Brass
26	Worm wheel	1	M.S. (Mild steel) M.S.
27	Worm	1	(Mild steel) M.S. (Mild steel)
28	Wear box	1	steel)
29	Box plate	1	M.S. (Hard)
30	Top rail	1	M.S. (Mild steel)
31	Main base plate	1	Aluminium
32	Circular scale	1	Plastic
33	Handle knob	1	Stone
34	Grinding stone	1	

The cam is the rotating element which gives reciprocation motion to the push pin. The cam shown here is of cylindrical type. Maximum rise of the cam is equal to the cam relief value. This cam relief value is calculated from the formula given below [14].

$$\tan x = \frac{KZ}{2 \pi R}$$

where,

K = cam relief value

z = no. of teeth

R = Radius of the drill

x = cam relief angle

here value of Z & R are taken from the existing drill bit dimension and X from machine design book given as follows:

Z = 2

R = 1 mm

X = 8°

So from the formula mentioned above, value of K is found as shown below:

$$\tan x = \frac{KZ}{2 \pi R}$$

or,

$$K = \frac{2 \pi R}{Z} \tan x$$

or,

$$K = \frac{2 \times 2.3 \times \tan 8^\circ}{2}$$

or,

$$K = 0.44 \text{ mm.}$$

$$K = \frac{2 \times 3.14 \times 0.144}{2}$$

So value of cam relief, $k = 0.44$ mm.

Lead Screw mechanism

The kinematic equation for lead screw movement is given as follows:

1 revolution of hand wheel $\times \frac{1}{Z} \times$ displacement of lead screw

Where $Z =$ no. of teeth of wheel $= 30$

lead screw movement/displacement $= 6$ mm.

$$= 1 \times \frac{1}{30} \times 6$$

$$= 0.12 \text{ mm.}$$

A circular scale 32 containing 100 divisions is attached where each division is equal to $0.12/100 = 0.0012$ mm movement for lead screw which leads to 0.0012 mm forward movement of drill bit 13 as shown in Fig. 7.8.

Diameter of wheel

$$\text{Module, } m = D/Z$$

where $m =$ module

$Z =$ no. of teeth of wheel

$D =$ Wheel pitch circular diameter.

Therefore $D = mz$

Here $m = 1$

$z = 30$

$D = 1 \times 30 = 30 \text{ mm}$

So wheel diameter = $D + \text{Addendum}$

$$\begin{aligned}\text{and Addendum} &= 1 \text{ m} \\ &= 1 \times 1 = 1 \text{ (: m = 1)}\end{aligned}$$

$$\begin{aligned}\text{wheel diameter} &= D + \text{Addendum} \\ &= 30 + 1 = 31 \text{ mm.}\end{aligned}$$

Worm diameter has been assumed of 16

From the above calculation the following dimensions have been determined and which have been used in the design shown in Fig.7.8.

Cam relieve value, $k = 44 \text{ mm}$

Worm diameter = 16 mm

Wheel diameter = 31 mm

7.6 ADVANTAGES OF THE DESIGNED ATTACHMENT

Advantage of the designed attachment for drill bits sharpening is mentioned below:

- i. Using the designed attachment, drill bit point angle can be produced more accurately than by hand operation.
- ii. It would reduce frequent sharpening of drill bit used in nipple automation machines. Thus increasing machine running time and production.
- iii. The designed attachment would prevent workers from getting injuries in fingers directly from grinding wheel.

- iv. Eye stress of the operator is reduced as he does not have to hold the drill bit close to grinding wheel and finger tips.
- v. This method of drill bit sharpening would reduce consumption of drill bit per shift.

In this chapter a drill bit resharpener attachment has been designed. It has been proposed that it would replace the existing manual hand operation of drill bit resharpener process. Only technical aspect and design details were included in this chapter. Advantages of this attachment from technical view were mentioned; an economic analysis was not made. This analysis is not worth considering that technical advantages would be far more higher than economic costs in its design and prototyping.

CHAPTER-8

INCREASING EFFICIENCY AND PRODUCTIVITY OF THE PACKING SECTION

8.1 INTRODUCTION

A well designed work can make the best use of worker's skills and abilities and unnecessary difficulties can be avoided. Improvements in work organization and workstation design are particularly closely related. This can improve productivity, for example by eliminating or combining tasks. This would permit more rapid task execution, by shortening handling distances and by reducing likelihood of errors.

A workstation is a place which a worker occupies when performing a job. It may be occupied only occasionally or all the time. A workstation often contains a work stand or work table for machine operation, packing, assembly or inspection. At workstations, people repeat similar operations many times. It is therefore important to keep good people work relationships so that work is done smoothly and without unnecessary disruptions. It often happens, however, that manual controls are placed inconveniently far away, that the work table wobbles, that the worker's body is twisted each time an operation is done, or that the worker is easily confused when reading a meter or moving a control. Each of those inappropriate situation can easily lead to wasted production time, increased fatigue and a fall in product quality or packing quality. The worker may suffer from bodily troubles due to work, such as low back pain. Even accidents may result due to improper workstations. If work is done effectively and easily, productivity will be higher and quality will be better.

Each workstation presents a unique combination of workers and tasks. It is important to design the work station with both workers and tasks in mind. Also work stations should be adjusted to the capacity and needs of individual workers. For examples the work table height should correspond to body height. It is also important to make sure that the strength and skills required by the job are appropriate to individual workers who do the work. This is the reason why modifications are often needed when machines are imported or work stations designed without much attention to the specific abilities and needs of local people [20].

8.2 ERGONOMICS OF WORKSTATIONS DESIGN

The objectives of ergonomics in workstation and work organization design, are as follows:

- i. To promote efficiency, safety and comfort at work situation through better relationship between man his tools and the work environment.
- ii. To develop the optimal conditions for the workers, to reduce physical workload, to improve working postures and to facilitate psycho-sensorial functions in instrument handling and to assist inworker's job.
- iii. Working out proportions and conditions at the work place to ensure correct body posture.
- iv. To improve the quality of working life, maximize the efficiency of production operators and to minimize human error.

The systematic application of ergonomics in industry can contribute to higher quality, more efficient production and a safer working environment. This can be best be achieved through deduction of systems functions from system objectives, detailed analysis of human tasks and true operator involvement through out the design process.

The interaction of the operator with the immediate workspace around him is influenced by many factors. These includes items such as the seat design, the working desk, the controlling buttons and adjacent machines. These immediate work tools may affect the position and postures of the workers and their comfort and efficiency. Backaches, neckaches and other musculus strains due to bad seating and incorrect working posture are common in industry. Ergonomics has been focused on fitting the workplace to operator in such a way that the operator will be able to function efficiently.

In view of the above an ergonomical study was conducted in the packing section of NBCIL and some modifications/improvements were suggested to improve the present working condition. The purpose of those modifications was to develop better workplace for workers for their comfortable conditions. Those will (i) reduce musculo skeletal strain (ii) increase productivity (iii) increase work efficiency.

8.3 ANTHROPOMETRY AND ITS APPLICATION

Anthropometry is the engineering measurement of human body. Anthropometry and the closely related field of biomechanics has been concerned with the

measurement of physical dimensions of the static human body. Fig. 8.1 and 8.2 shows examples of some common body dimensions and their names are given in Table 8.1 [17].

Table 8.1
Common Body Features

Item	Body Feature
1	Height
2	Sitting height, erect
3	Shoulder breadth
4	Chest depth
5	Hip breadth, seat and standing
6	Shoulder height; sitting
7	Back height
8	Shoulder-elbow
9	Forearm length
10	Arm reach
11	Arm span
12	Elbow height; sitting
13	Buttock-knee length
14	Seat length
15	Knee height; sitting
16	Seat height (popliteal height)
17	Knee breadth
18	Foot length
19	Foot breadth
20	Hand breadth

From various items of anthropometric data, the following 14 (fourteen) items have been chosen for design purpose. (Table 8.2 and Figure 8.3 and 8.4).

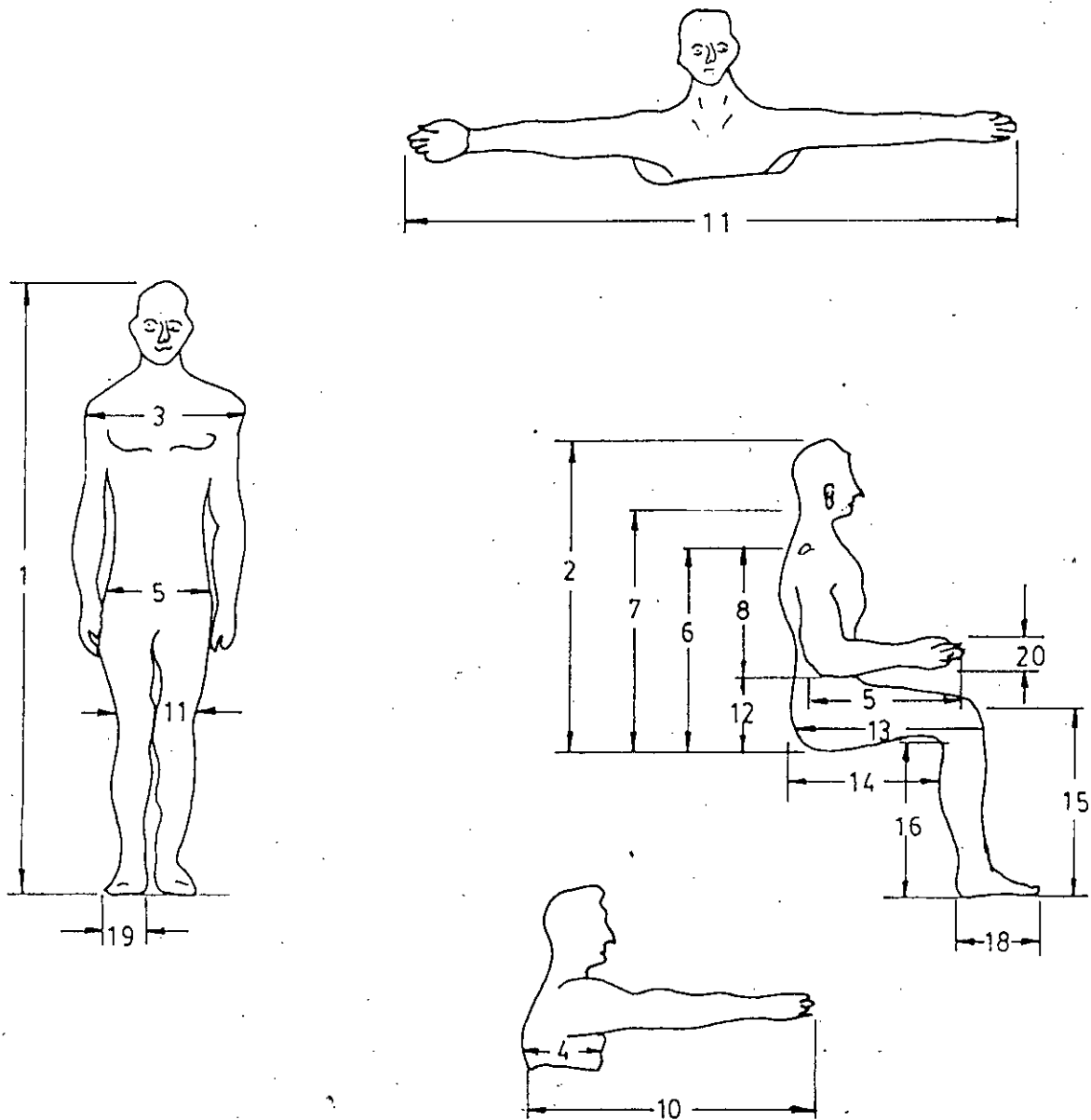
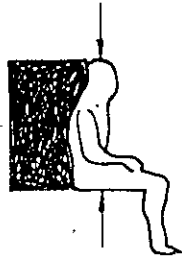
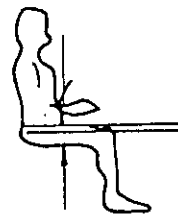


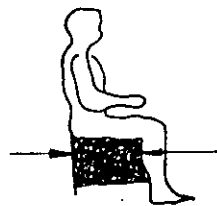
Fig.8.1: Examples of some common body dimensions



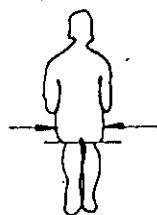
Sitting height normal



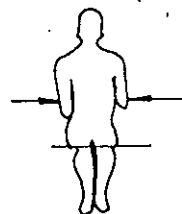
Thigh clearance height



Buttock - popliteal length



Seat breadth



Elbow-to-elbow breadth

Fig.8.2: Example of some common body dimensions

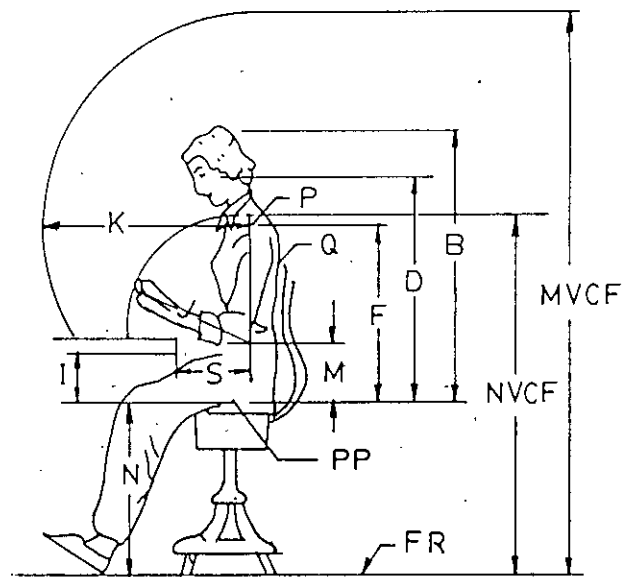


Fig.8.3: Normal and maximum working areas and clearances in the vertical plane for a sit-stand operator.

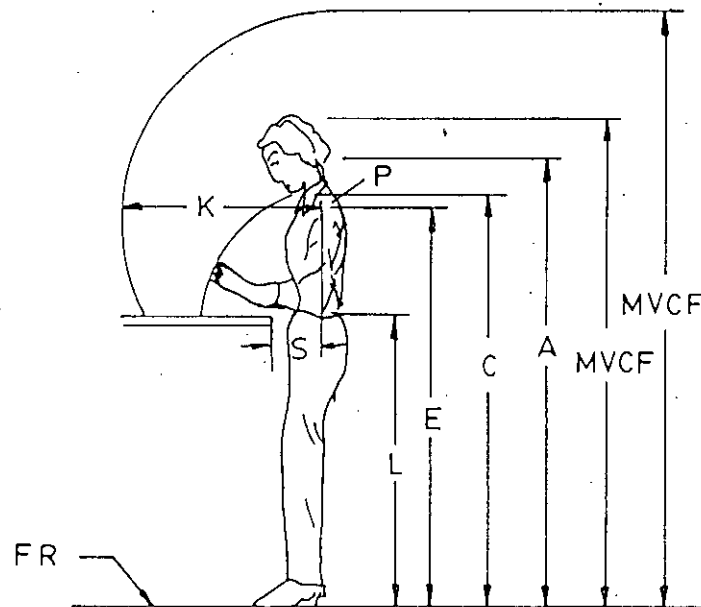


Fig.8.4: Normal and maximum working areas and clearances in the vertical plane for a standing operator.

Table 8.2

Selected Body Features

Item	Body Feature
A	Total height (Slump)
B	Body height (sitting, slump)
C	Eye height (slump)
D	Eye height (sitting, slump)
E	Shoulder height
F	Shoulder height (sitting)
G	Body depth
H	Elbow-to-elbow
I	Thing clearance
J	Forearm length
K	Arm length
L	Elbow height
M	Elbow height (sitting)
N	Popliteal height (sitting)

Figs. 8.3 and 8.4 show normal and maximum working areas and clearances in the vertical plane for a seated operator and for a standing operator respectively.

8.4 DESIGN DIMENSIONS BASED ON FARLEY'S AND SQUIRE'S CONCEPTS

A study by Farley [8] gave only one work area for male operators and one for female operators based on the average physical dimensions of men and women. He determined the normal working area as being equal to the volume circumscribed by the horizontal arm pivoting about a relaxed vertical arm. The maximum working area was represented by the volume circumscribed during the movement of the fully extended arm pivoting about the shoulder pivot point. The results reported by Farley are probably the most widely used by designers presently. Squires [27] pointed out that the elbow does not stay at a fixed point

but moves out and away from the body as the forearm pivots. He determined only the normal working area in the horizontal plane based on the existing anthropometric data. Farley's concept was selected over Square's not because it is precise; but due to the reason that Farley's concept is applicable in determining both the top layout and also the height of the work table.

Fig. 8.5 show normal and maximum working areas in horizontal plane as proposed by Farley, with normal work area proposed by Squires superimposed to show differences (Fig.8.6).

8.4.1. Design Dimensions (Layout of Workplace) Based on Farley's Concept

The horizontal and vertical clearances are imperative to apply the concept and they are explained below:

i. Horizontal Clearances :

a. NORMAL FARLEY or NORMAL HORIZONTAL CLEARANCE FARLEY, (NHCF).

The formula required for calculating NHCF is:

$$NHCF = (J - S) + G; \quad \text{where, } S = 0.5G$$

n. MAXIMUM FARLEY or MAXIMUM HORIZONTAL CLEARANCE FARLEY, (MHCF)

$$MHCF = (K - S) + G$$

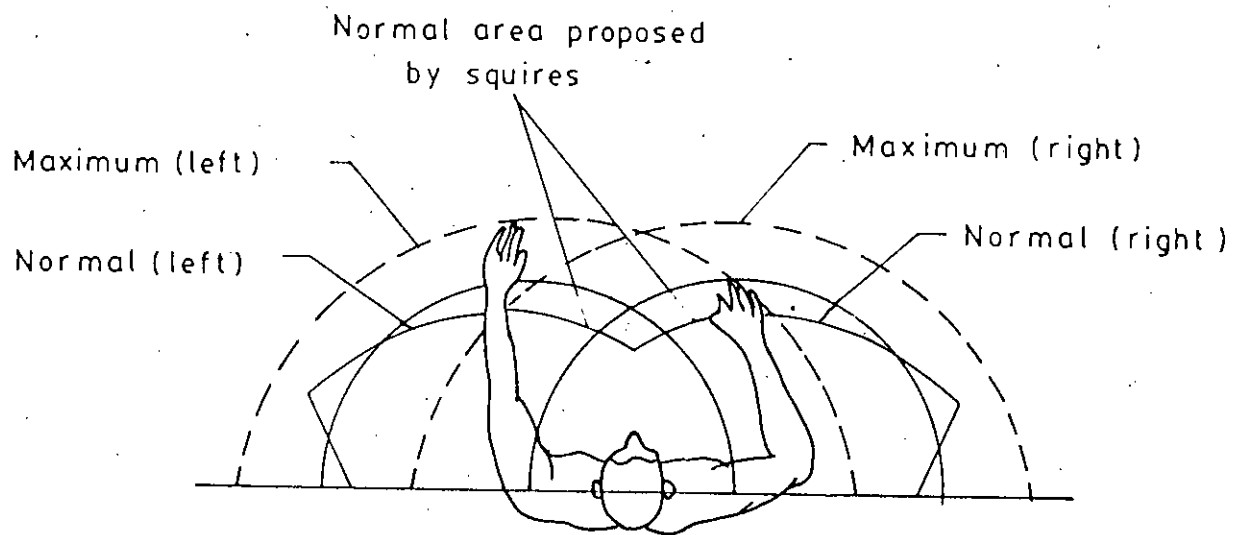


Fig.8.5: Normal and maximum working areas in horizontal plane as proposed by Farley with normal work area proposed by Squires superimposed to show difference

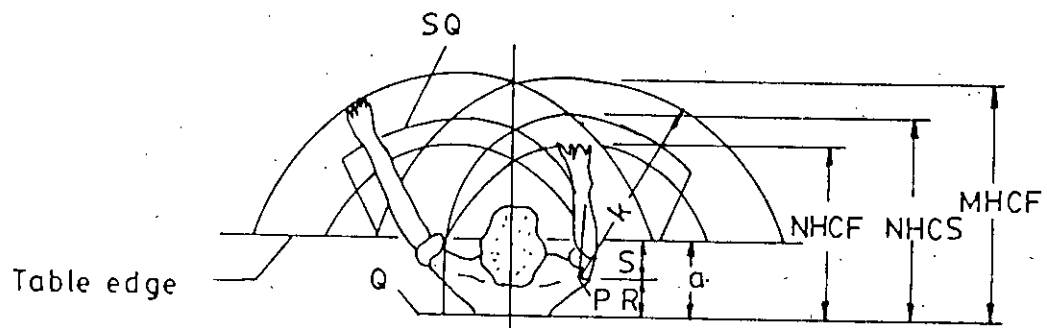


Fig.8.6: Normal and maximum working areas and clearances for a seated (also for standing and sit-stand) male operator

ii. Vertical Clearances :

a. NORMAL VERTICAL CLEARANCE FARLEY, (NVCF)

$$NVCF = N + M + J$$

b. MAXIMUM VERTICAL CLEARANCE FARLEY, (MVCF)

$$MVCF = N + F + K$$

8.4.2 Design dimensions (Layout of workplace) based on
Squire's concept

Squire's concept deals only with the horizontal clearances as it deals with the movement of elbow and forearm and their variation occurs dynamically only on the horizontal plane[27].

The existing wrapping system of rim fulfills the requirement. Eight workers are involved in wrapping of rims in each shift. The rims average wrapped per shift by those eight workers are 700 pcs.

The problem comes from packing of nipples, spokes, and washers. The present packing method of spokes, washers and nipples are described in the following section.

8.5 EXISTING PACKING SYSTEM OF NIPPLES, WASHERS AND SPOKES

In NBCIL's packing section, spokes are brought from electroplating section and put in a box. Spokes are counted for 1 gross (144 pcs.) and are put in a plastic packet and the opening is sealed using heater. The sealed plastic packet containing 144 pcs. of spoke (1 gross weighs 1.099 kg) is dump in one corner of the packing section. This polythene packing is known as polypacked spoke. Similarly washers and nipples are brought from electroplating section and stored in separate boxes. Then workers weighs 1 gross of nipples (1 gross nipple weighs 203 gm) and 1 gross washers (1 gross weighs 57.97 gm). All those polypacked nipples, washers, nipples are kept on the floor separately.

On placement of demands from the market, those poly packed nipples, washers and spokes are put in paper cartoons. Each paper cartoon contains one gross of polypacked nipple and one gross of polypacked washer. Fig. 8.7 shows polythene packed and cartoon packed nipple spoke and washer.

Working height when seated

In the packing section, packing is done on the table shown in Fig. 8.8. The workers sit by the side of the table on a long bench. The height of the working table of packing section is 32.5 inches and the length is 156 inches when seated. The hands are at their best in terms of both power and precision if the elbows are at the sides

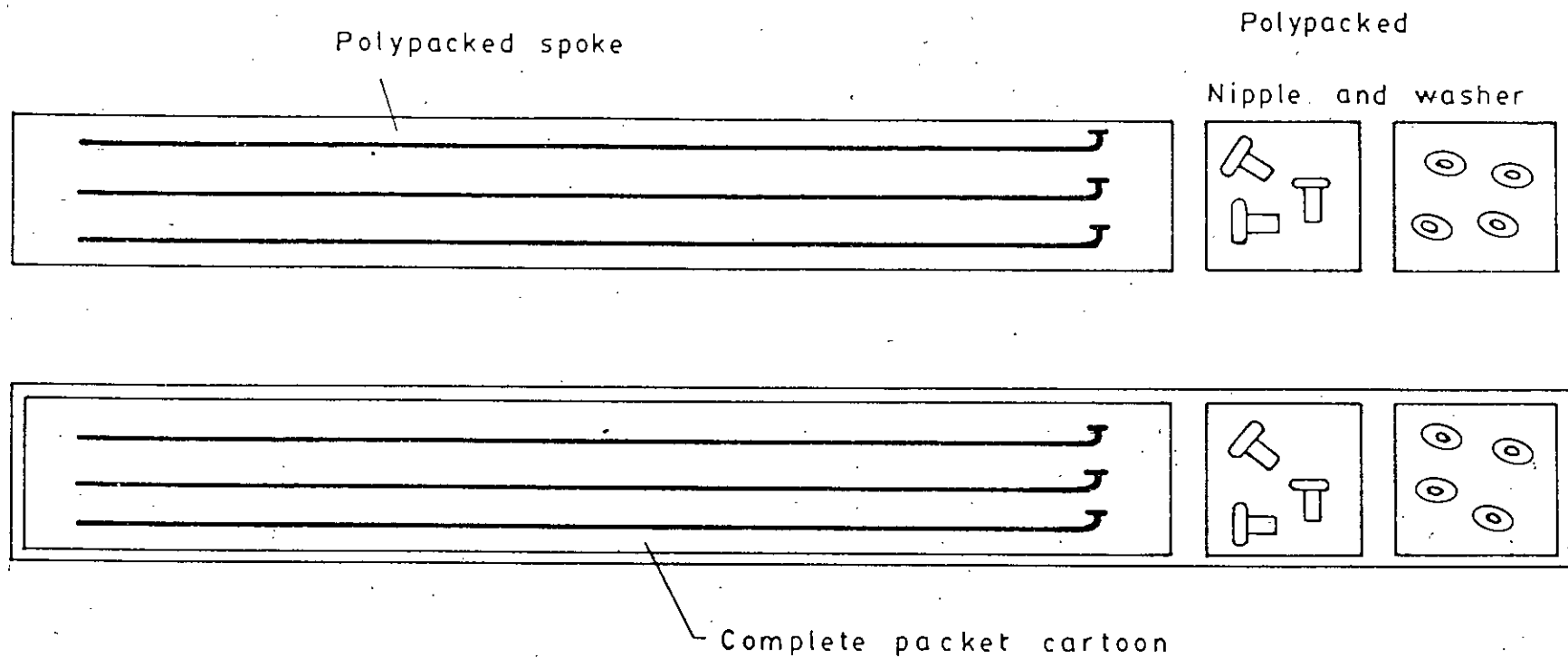


Fig.8.7 : Poly packed and complete packed spokes nipple and washers

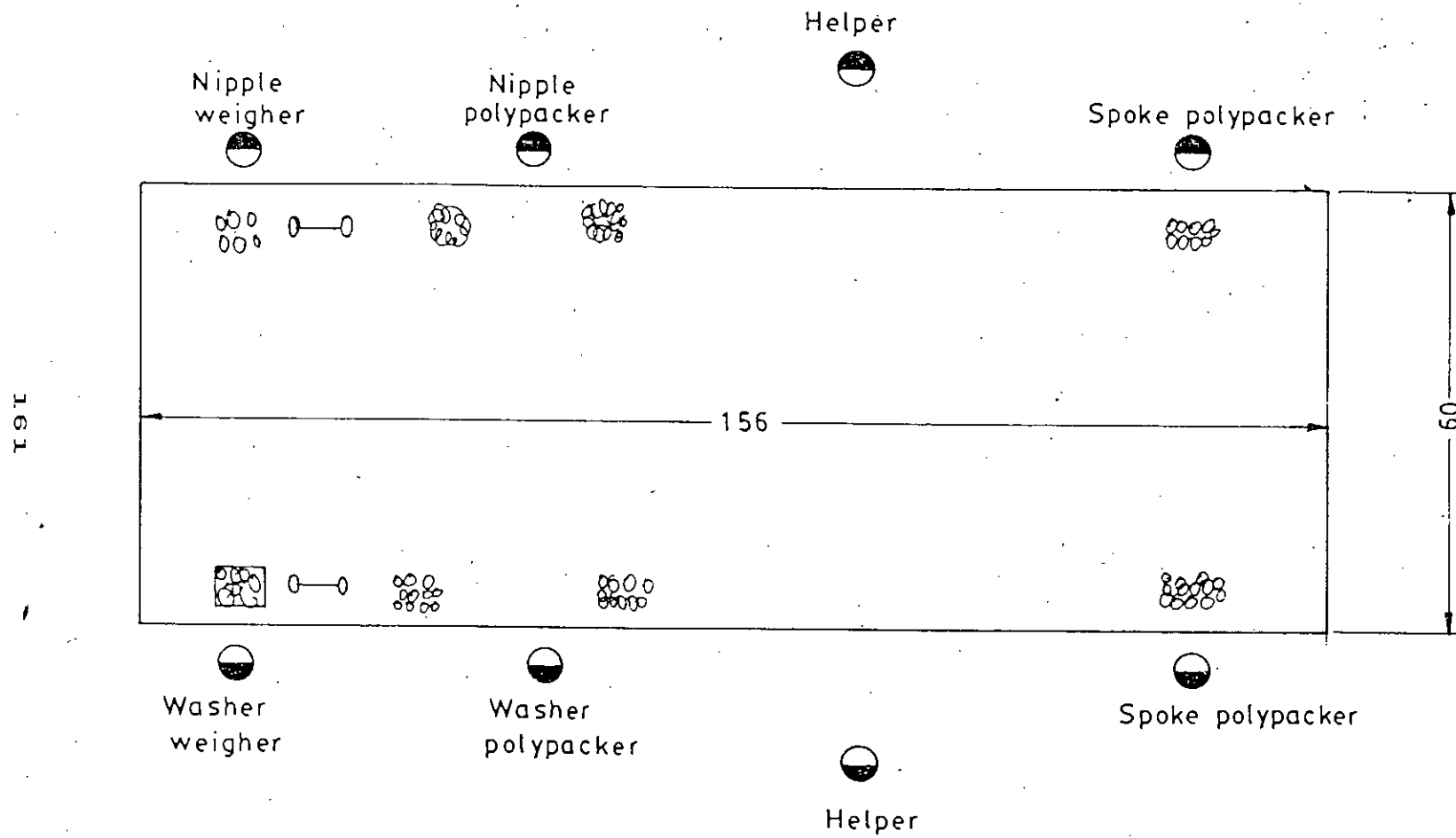


Fig.8.8:Top layout of the existing table used in packing section

and bent at right angles. When the height of seat, the elbow height and the height of the knee beneath the table are considered, it is recommended that tables for skilled work (drawing, writing, reading) should have an optimum height for men of 74-78 cm and for women of 70-74 cm and for manual work (assembly work or type writing) the optimum height for men of 68 cm and that for women 65 cm.[20].

Disadvantages of the present method packing of nipple, spoke and washer :

The packing of nipples, spokes and washers are performed in two shifts per day. The Table 8.3 indicates the volume of polypacked and complete cartoon packed products per day.

Table 8.3
Value of polypacked and complete cartoon packed products per day

Shift	Workers per shift	Polypacked product			Complete cartoon packed product			Working hours per shift
		Nipple	Spoke	Washer	Nipple	Spoke	Washer	
1st	8	600	500	600				8
2nd	8				400	400	400	8

Packing workers do not use any trays for putting the weighed sealed polypacked nipples, washers, and spokes, Usually sealed polypacked nipples, washers and spokes are placed on the table. Besides no standard was set for work volume of polypacking or cartoon packing of the products. The polypacking of spokes, washers and nipples do not synchronize with the packing of completed cartoons. The present working height of wooden table for packing does not satisfy working

height for sitting position. The tool height and the table height do not match each other.

The problem caused by the existing height of the table and the tool are:

- i. Back pain due to continuous bending
- ii. Leg pain
- iii. Spinal pain and excessive muscles stress
- iv. Shoulder pain
- v. Fatigue.

8.6 DESIGN OF THE PROPOSED WORKSTATION

Concepts on height of workstations

The efficiency of workers to a large extent depends on the height of workstations; thus the effect of height of the workstation on productivity of workers requires more closer investigation.

There are three approaches available for designing the height of the worktable:

- i. To make available several workplaces or work surface heights
- ii. To adjust the operator's elbow rather than the height of workplace, using an adjustable chair.
- iii. To adjust the height of work on the worktable

Height of workstation is an important criteria to decide as it has effects on productivity of workers. It will be emphasized that work height is not the same as table height since most items have a thickness of 25 to 50 mm.

Design Guide :

A general rule is : Design so that the small women can reach and the large man can fit or to ensure that smallest man can reach, while the largest man can fit comfortable in the design workstation[13]. A good workplace layout for industrial workstations should fulfill the following requirements:

- i. Improve worker productivity by maximizing effective motions.
- ii. Reduce operator fatigue.
- iii. Increase operator stability and equilibrium.

Data Collection

For the designed workstations, a brief but relevant set of local population (packing section workers) anthropometric data of 10 (ten) males were collected at random. The anthropometric data of the local population is supplied in Table 8.4.

Table 8.4

Anthropometric data of local population (workers) dimensions
in inches (for A .. N, see Table 8.2)

Specimen No.	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	65	30	62	25	54.3	21	10.6	17	5	15	24	40	6.8	16
2	67	31	63.5	27.5	56	20	10.4	16	6.5	15.6	26	44	7	17
3	68	32	64	27	57	21	10.5	15.5	6.5	16	25.5	45	8	18
4	67.5	31.5	63	27	56.5	21.5	10.5	15.6	6	15.6	25.5	44	7.5	17.5
5	66.3	31	62.5	26	56	20.5	10.4	16	5.8	15.6	26	43	6.5	16.5
6	64	30	61.8	26	56.2	20.5	10.4	15.3	5.5	15.5	25.5	42.5	6.4	16.25
7	66	31	62	27	55	21.5	10.5	15.5	5.8	15.5	25.5	42.5	7.5	16.5
8	62	29	61	24	54	19.5	10	15.5	5.7	15.5	25	40.5	7	16
9	65.2	30.2	63.1	26	55	21.1	10.3	15.7	5.2	15.6	25	42	7	17
10	66.2	31	63.3	26.8	56.2	20.7	10.4	15.7	5.2	15.6	25.1	42	7.2	17.1

Table Height :

Now for finding elbow height (sitting) the following formula has to be used.

Elbow height (sitting) = M + N + allowance for the foot rest (5 inches).

The following Table 8.5 gives the factors for computing percentiles from the standard deviation (Source, Reobuck, 1957).

Table 8.5

Percentiles	Factor
0.5/99.5	2.576
1/99	2.326
2.5/97.5	1.960
5/95	1.645
10/90	1.282
15/85	1.036
20/80	0.842
25/75	0.674
30/70	0.524

The formula to be used to determine the required dimension of body feature is given below.

$$X = \bar{X} \pm (S.D) \times (Factor) \dots\dots\dots (i)$$

where,

x = represents the required dimension of body feature corresponding to percentiles determined by factors and sign (+ or -) of the equation.

$\bar{x}$ = mean value of the required parameter from population data.

S.D. = Standard Deviation.

Table 8.6
Elbow height for specimen 1 to 10

Specimen (workers)	Elbow height (inches) sitting M + N + Allowance (5 inches), x
1	27.8
2	29
3	31
4	30
5	28
6	27.65
7	29
8	28
9	29
10	29

$$\bar{x} = \frac{\sum x}{n} = \frac{288.45}{10} = 28.845 = 28.85$$

$$S.D = \sqrt{\frac{\sum (x - \bar{x})^2}{n}} = 1.001$$

Now from the Table 8.5, factor for 5th or 95th percentile equals to 1.645

So, the table height corresponding to 95th percentile, using eqn (i) is,

$$\begin{aligned} X \text{ (95th percentile)} &= \bar{x} + (S.D.) (\text{Factor}) \\ &= 28.85 + (1.001 \times 1.645) \\ &= 28.85 + 1.64 \\ &= 30.49 \text{ Approx. 30 inches.} \end{aligned}$$

Therefore, by rounding off, H becomes 30 inches.

It has been mentioned earlier that work height is not the same as table height since most packing items have a thickness of 1 inch(25mm). Thus the table height is taken as 29 inches.

Width of the table (W):

The measurement used for determining the width is based on Farley's concept as stated earlier. The measurement used is MHCF (Maximum Horizontal Clearance Farley) which is measured from the backrest of the operator including the dimensions of the body depth G, arm length k and elbow to shoulder projection distance S (Fig. 8.6). The values of G and K are taken from the local population data (Table 8.4) and S is taken as half of G.

$$\begin{aligned}\text{Thus, MHCF} &= (K - S) + G \\ &= (66 - 0.5 \times 26.7) + 26.7 \\ &= 79.35 \\ &= 79 \text{ cm} \\ &\text{i.e. 31 inches.}\end{aligned}$$

Now to find the width W, G was subtracted from MHCF and then a clearance of more than 25 cm (12 inches) was added for convenience of placing packing items.

Therefore width, W is,

$$\begin{aligned}W &= \text{MHCF} - G + \text{clearance} \\ &= 79 - 26.7 + 82.3 \\ &= 82 \text{ cm} \\ &\text{i.e. 32 inches.}\end{aligned}$$

The width of a table when used by one worker is 32 inches. When two workers are sitting opposites to each other, the width of the table will be

$$\begin{aligned} W' &= 2W \\ \text{or } W' &= 2 \times 32 \text{ inches} \\ &= 64 \text{ inches.} \end{aligned}$$

Tool height :

The height of the tools presently used is 22.5 inches. It is the height from the factory floor to the top surface of the tool which is equal to popliteal height, (sitting), N. Figure 8.9 shows detailed layout of workstation for seated packing worker-wise view. Various dimensions taken for the proposed workstation are given in Table 8.7. The proposed height of the tool is 21 inches as shown in Fig. 8.9.

Table 8.7
Dimensions for a seated worker

Body Feature	Dimension inches
Popliteal height N	16
Foot rest from floor	5
Thigh clearance I	8
Arm reach K	26
Elbow to shoulder project distance	5.2
Eye height	27

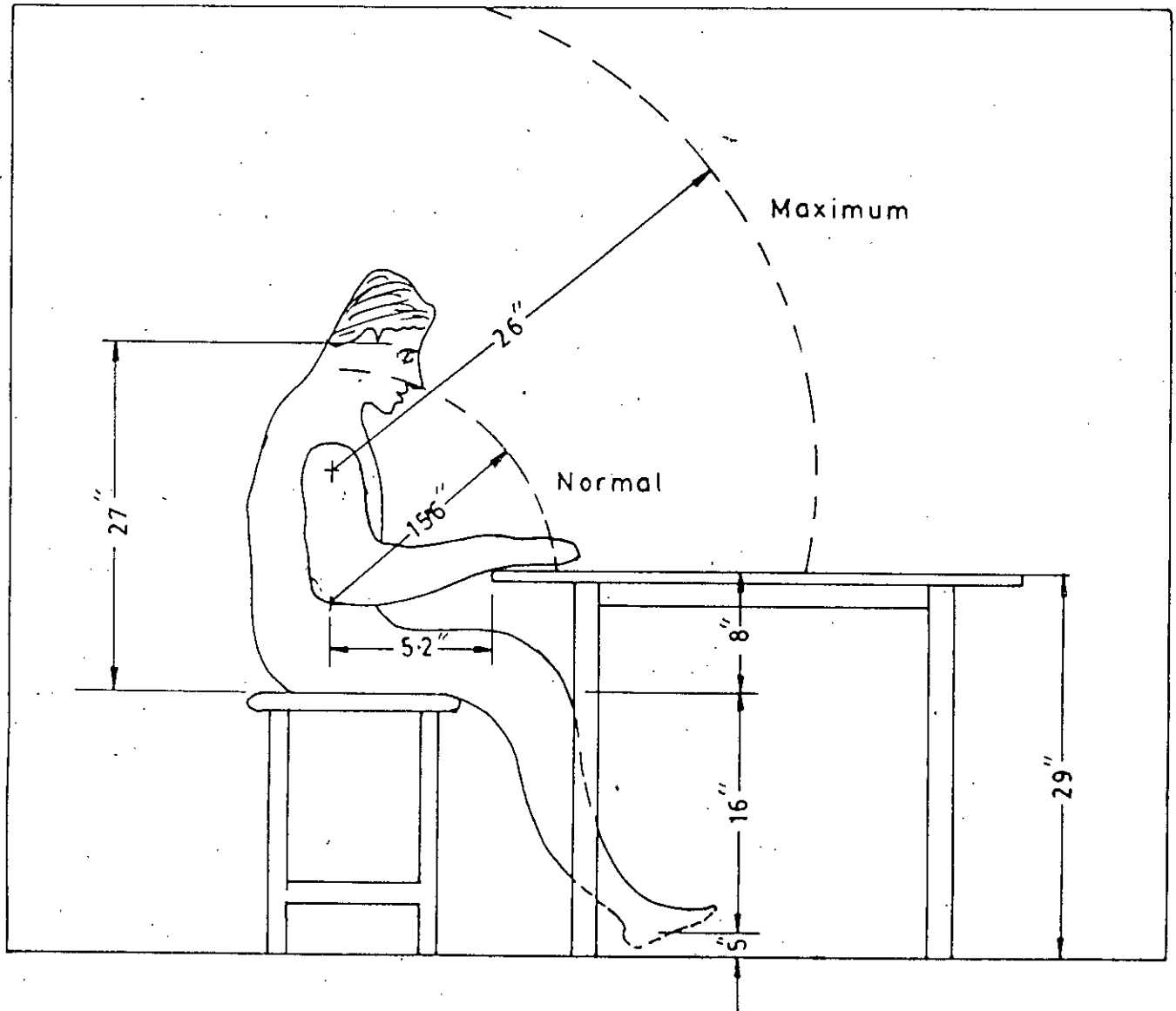


Fig.89: Detail layout of workstation for seated operator
side view

Length of the table for a seated packing worker :

The length of the proposed table has been taken into consideration depending on each workers normal working area. Normal area has been shown in Fig. 8.5. In the proposed workstation six packers have been employed for proper method of packing electroplated nipples, spokes and washers. Previously eight workers were employed for packing the above mentioned items.

A ninetyfive percentile (majority) worker's data from Table 8.5 used to determine the length of the proposed table.

Thus table length, L is given as,

$$L = H + 2J$$

where H = elbow to elbow length = 15.5" or 40 cm

$$J = \text{Arm length} = 15.6" \text{ or } 39.6 \text{ cm.}$$

$$L = 40 + 2 \times (39.6)$$

$$L = 119.2 \text{ cm. or } 46 \text{ inches.}$$

This 46 inches is the length of a table used by 1 packing worker for normal reach. Fig.8.10 shows the proposed method of packing end products with table dimensions.

8.7 PROPOSED PACKING METHOD OF NIPPLES, WASHERS AND SPOKES

In the proposed method six workers are employed to polypack spokes, washers and nipples(Fig.8.10). A worker is employed as a helper to those six workers from time to time. In addition to that the helper removes the polypacked

products from the table and puts them in the given space of packing section. The nipple weigher takes loose nipples from tray-1. He weighs them and puts them in a polythene packet and places the polythene packet in tray-4. Nipple polypacker takes the weighted packet from tray-4. Nipple polypacker takes the weighed packet from tray 4 and seals the opening of the packet and puts them in a polythene packet and places it in tray-5. Similarly the washer weigher takes washers from tray-2, weighs them and puts them in a polythene packet and places it in tray-3. Then washer polypacker takes the weighed polypacked washer from tray-3. Then washer polypacker takes the weighed polypacked washer from tray-3 and seals the opening of the polythene packet and places it in tray-6. Spoke poly packers takes the loose spokes from tray-8 and tray-7, counts the spokes for 11 gross and puts them in a polythene and seals it. These are then placed in tray-9 and 10 respectively.

In the case of a complete packed cartoon, six workers are assigned to do the complete packing in the next shift. The seventh worker helps the other six workers in supplying the polypacked products. The top layout of the proposed table with sitting arrangement and job distribution is shown in Fig. 8.11. In this arrangement worker-1 puts the polypacked spoke inside the cartoon (tray-1) and puts the cartoon in tray-2. Worker-2 takes an empty nipple cartoon from tray-3 and puts into it a polypacked nipple packet from tray-4. Then the small cartoon with nipples is put inside the larger cartoon taken from tray-2 containing polypacked spoke and places it in tray-5. The third worker picks up an empty washer packet from tray-7 and finally puts into cartoon containing a spoke and a nipple packet and then places the cartoon in tray-8. Similarly workers 4, 5 and 6 would repeat the job parallelly.

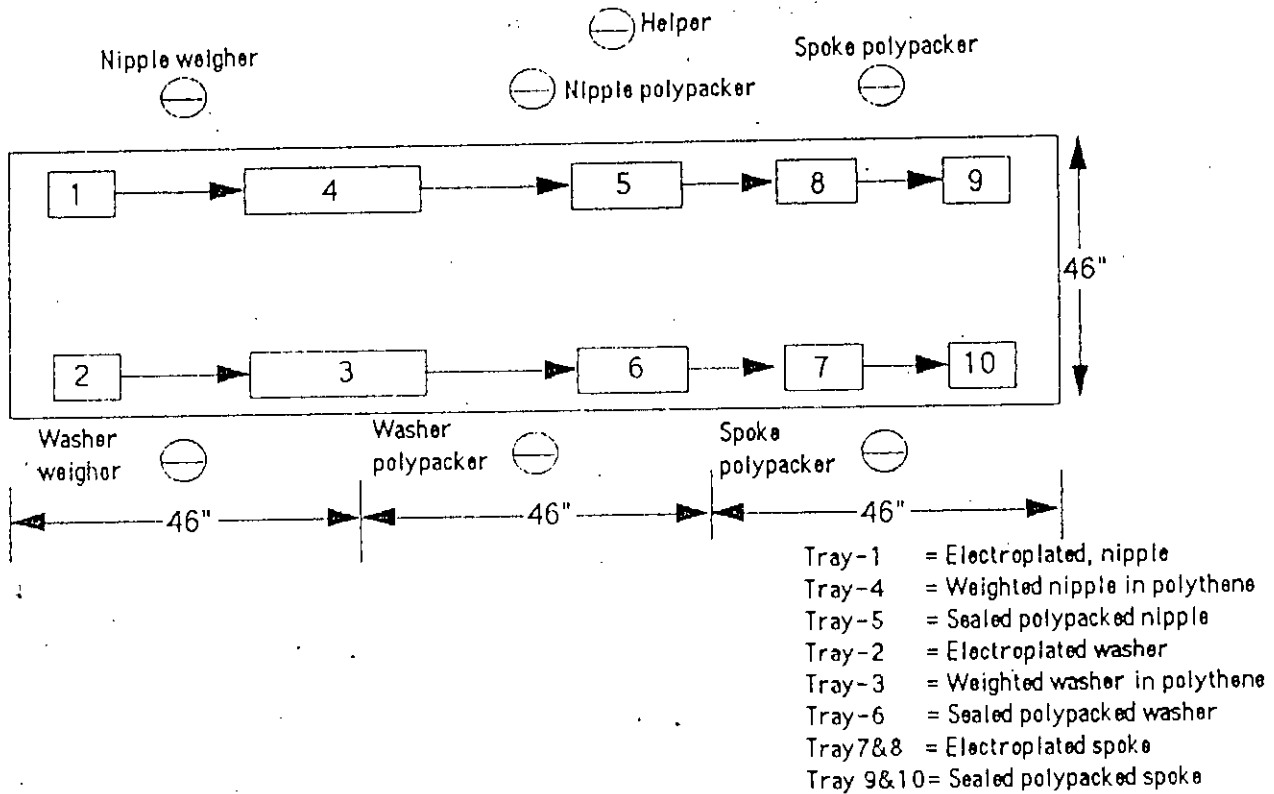


Fig.8.10 : Top layout of the proposed table in packing section
 (All dimensions in inches)

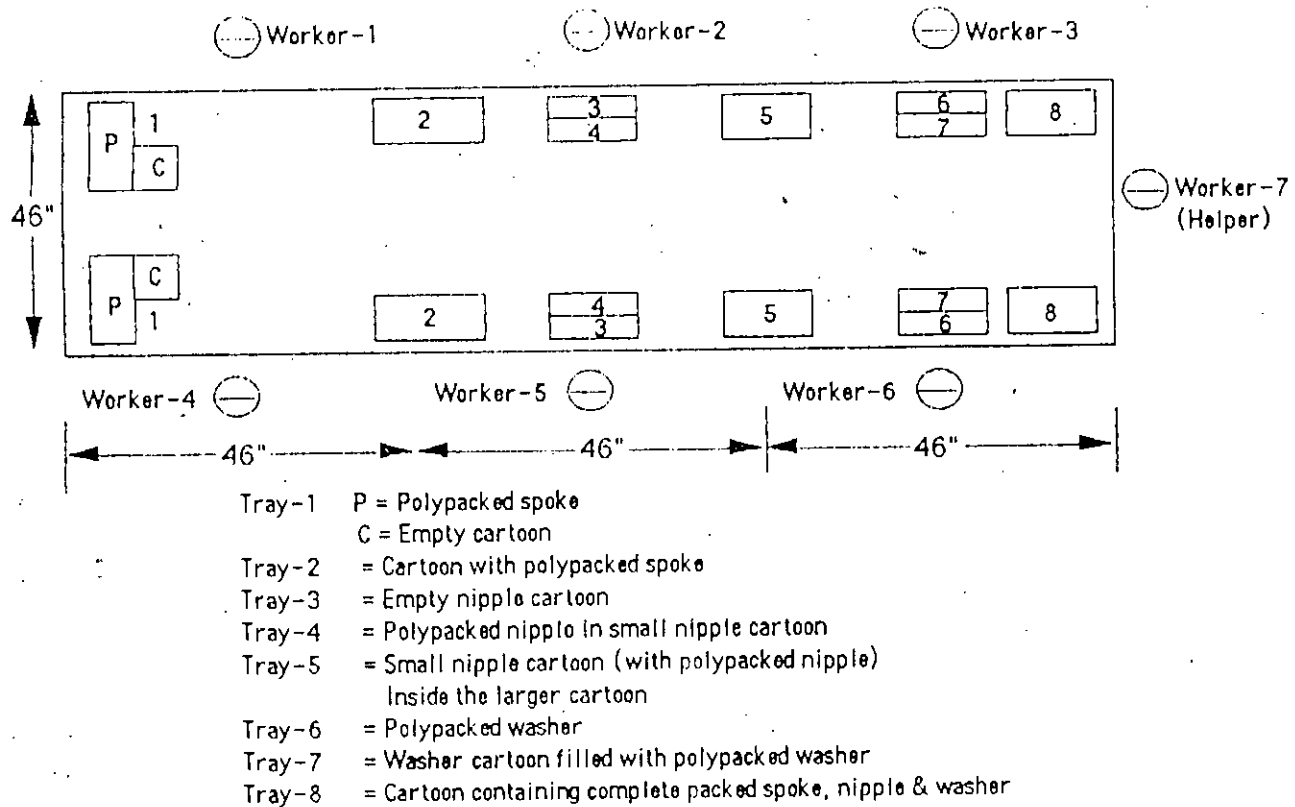


Fig.8.11 : Top layout of the proposed table for proposed method of complete packing

8.8 ADVANTAGES OF THE PROPOSED METHOD OF PACKING END PRODUCTS (Nipple, Washer and Spoke):

The worker's working efficiency have been improved as shown in Table 8.8 below:

Table 8.8

Shift	Workers per shift	Polypacked product			Complete cartoon packed product			Working hours per shift
		Nipple	Spoke	Washer	Nipple	Spoke	Washer	
1st	7	700	600	700				8
2nd	7				500	500	500	8

Two workers have been reduced from 2 shifts, 7 workers in each shift can polypack 700, 600 and 700 grosses of each product nipples, spokes and washers in one shift. Similarly 7 workers can give 500 completed sets of the products.

8.9 ADVANTAGES OF THE PROPOSED TABLE AND TOOL :

Following are the advantages,

- i. The proposed table and tool would given comfort to workers thus increasing their packing efficiency and productivity.
- ii. Packing workers are reduced from eight to seven.
- iii. The proposed method of packing spokes, nipples and washer and the arrangement of seven workers give more number of polypacked and complete cartoons of packed spokes, nipples and washers per shift.

CHAPTER-9

INVESTIGATION AND ANALYSIS OF INJURIES GENERALLY OCCURS AND THEIR PREVENTIONS

9.1 INTRODUCTION TO ERGONOMIC INJURIES

Injuries in industries causes great human suffering and lead to extensive leaves of absence from work, expensive medical treatment and reduces productivity. This chapter includes the causes of common injuries in NBCIL and future needs to prevent those injuries and recommendations.

In a third world country, like Bangladesh, every year about 5,000 industrial accidents occurs out of which 6% are fatal and 20% are of serious nature. The average incidence rate of accidents is 7.89 per thousand workers[21]. As a result the victims, their dependents, the firms and the whole nation have to pay a very high price. In term of human suffering, it is of course, a wide spread and uncompensable loss which includes deaths disablement, social burden and so forth. Research finding shows that about 98% of the accident could be prevented by rectifying the causes and conditions thereof[21].

9.2 ERGONOMIC INJURIES

An ergonomic injury is one which results from the nature of person's working task-most commonly, when the demand of that task exceeds the person's working capacities. Ergonomic injuries are work-related musculo-skeletal disorders such as back pain, neck and shoulder pain, conditions affecting the upper limb which

are referred as repetitive strain injuries. Conditions of those are consequence of physical risk factors in person's work such as working posture, repetitive or awkward patterns of movement, forceful exertion, lifting and handling loads. The term 'ergonomic injury' would not only due to conditions resulting from exposure to hazard but also due to environmental conditions such as heat or cold may diminish a person's working capacities and are factors which influences an ergonomic injury[3].

Back pain occurs to those people who spend most of their times in a sitting position and do very little physical work. Whereas people whose job is flexible that is who are free to alternate between standing and sitting at work are unlikely to have trouble with their backs. Women suffers more in back pain than men due to sedentary work in third world. Examples are women working in garment industries in Bangladesh, packing and production sections workers of different industries. According to official sources, about 60 million working days were lost, in the UK last year, due to back pain sickness absence[23].

Causes behind back pain in industries are listed below :-

1. Heavy work - lifting and handling, forceful exertions, bending twisting, etc.
2. Prolong sedentary work.
3. Prolong work in a stopped position.
4. Vibration.
5. Psychological stress.

Repetitive strain injury [RSi] is applied to a set of work-related musculo skeletal disorders affecting the hand, wrist and forearm. Other lesser affected portions are upper arm, shoulder and neck. Mostly packing section workers, typist and keyboard operators are likely to suffer from these conditions.

According to ROSPA, the Royal Society for the Prevention of Accidents, work accidents fall into three broad groups[1]:

- i. General Accident
- ii. Process Accident
- iii. Disasters.

- i. General Accident: It can happen anywhere and constitute half of the work injuries reported. Most of them cause slight injuries but so men can be serious. Movement of them cause slight injuries but some can be serious. Movement of the person is the main cause.
- ii. Process Accident : It is linked with the technicalities of production and with the work going on the factory. Injuries can be both slight and serious but cause proportionately more serious injuries and permanent disablement than do the general type of accidents.
- iii. Disaster: It occurs when an accidental situation gets out of hand and develops on a large scale.

According to the factory Rules, 1979, industrial accidents in Bangladesh are classified as:

- i. Fatal
- ii. Serious
- iii. Minor.

A Fatal one is self-explanatory, A "Serious accident" will seem to have occurred if "There is no reasonable prospect that he (the worker) will be able to resume his employment in the factory within 20 days". If the duration of absenteeism is more than 48 hours after the accident occurred, such accidents shall be termed "Minor accidents".

9.3 TYPES OF INDUSTRIAL INJURIES

- a) Occupational disease : It is a disease caused by the exposure to environmental factors associated with employment.
- b) Disabling injuries : Is one which results in death or permanent impairment or which renders the injured person unable to work for a full day or any day after the day of injury.

Disabling injuries are of four classes, as follows[18]:

- i. Death: Is any fatality resulting from a work injury, regardless of the time intervening between injury and death.
- ii. Permanent total disability: Is an injury other than death which permanently and totally incapacitates an employee for following any gainful occupation or which results in loss of any of the following in one accident: (a) both eye (b) one eye or one hand or arm or foot or leg (c) Any two of the following limb, hand, arm, foot and leg.

- iii. Permanent partial disability: Is an injury other than death or permanent total disability which result in the complete loss or loss of use of any member of the body, or any permanent impairment of functions at the body or past thereof, regardless of any preexisting disability of the injured member of impaired body function.
- iv. Temporary total disability: Is any injury which does not result in death or permanent impairment but which results in one or more days of disability.

Besides there are other minor injuries which are not included in the above mentioned groups because they do not hamper a full day work. Fig. 9.1 shows probable places of injuries to human body[21].

9.4 CAUSES OF INDUSTRIAL INJURIES

Injuries results from deficiencies in people, in tools and in environment (Most injuries deficiencies in all three) as shown in Fig. 9.2. But more importantly, injuries results from interactions like an over tired young machine operator, focusing his mind at home while operating a machine. His hand may get in contact with a moving part of the machine and he is injured.

Causes of industrial injuries are classified in the following manner:

- i. Mechanical failure
- ii. Defective material
- iii. Electrical failure
- iv. Faulty design of equipment
- v. Environmental conditation

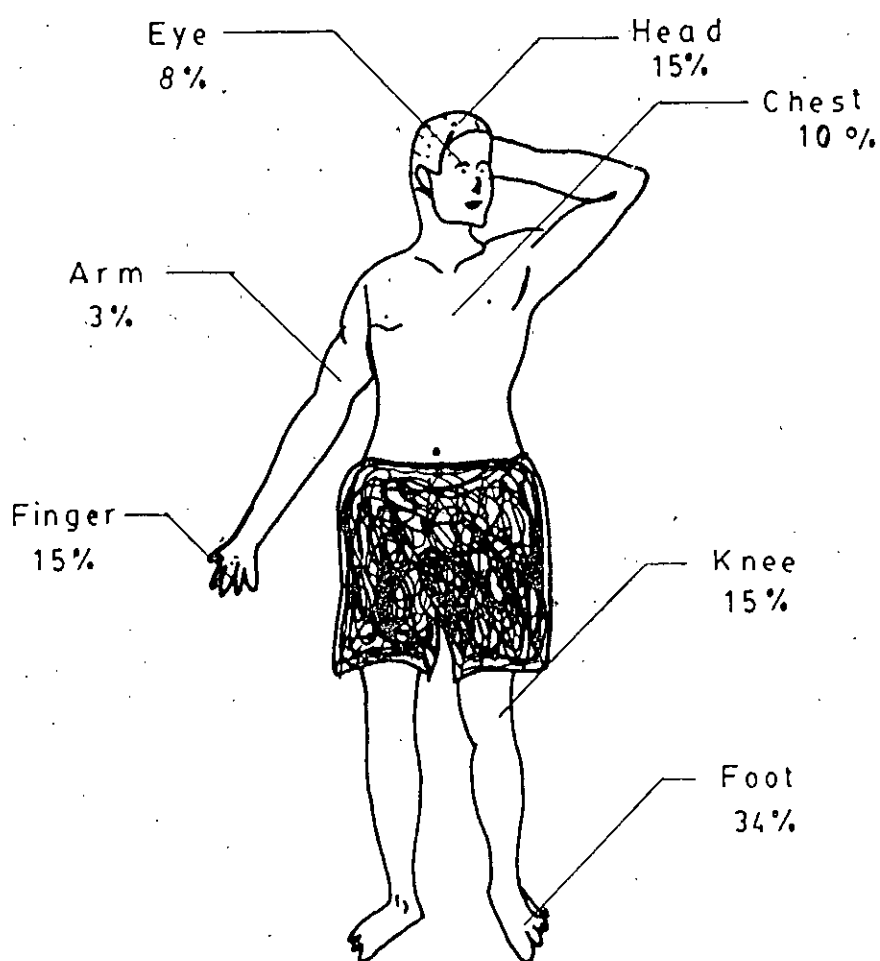


Fig.9.1:Places of injuries to workers (in percentage)

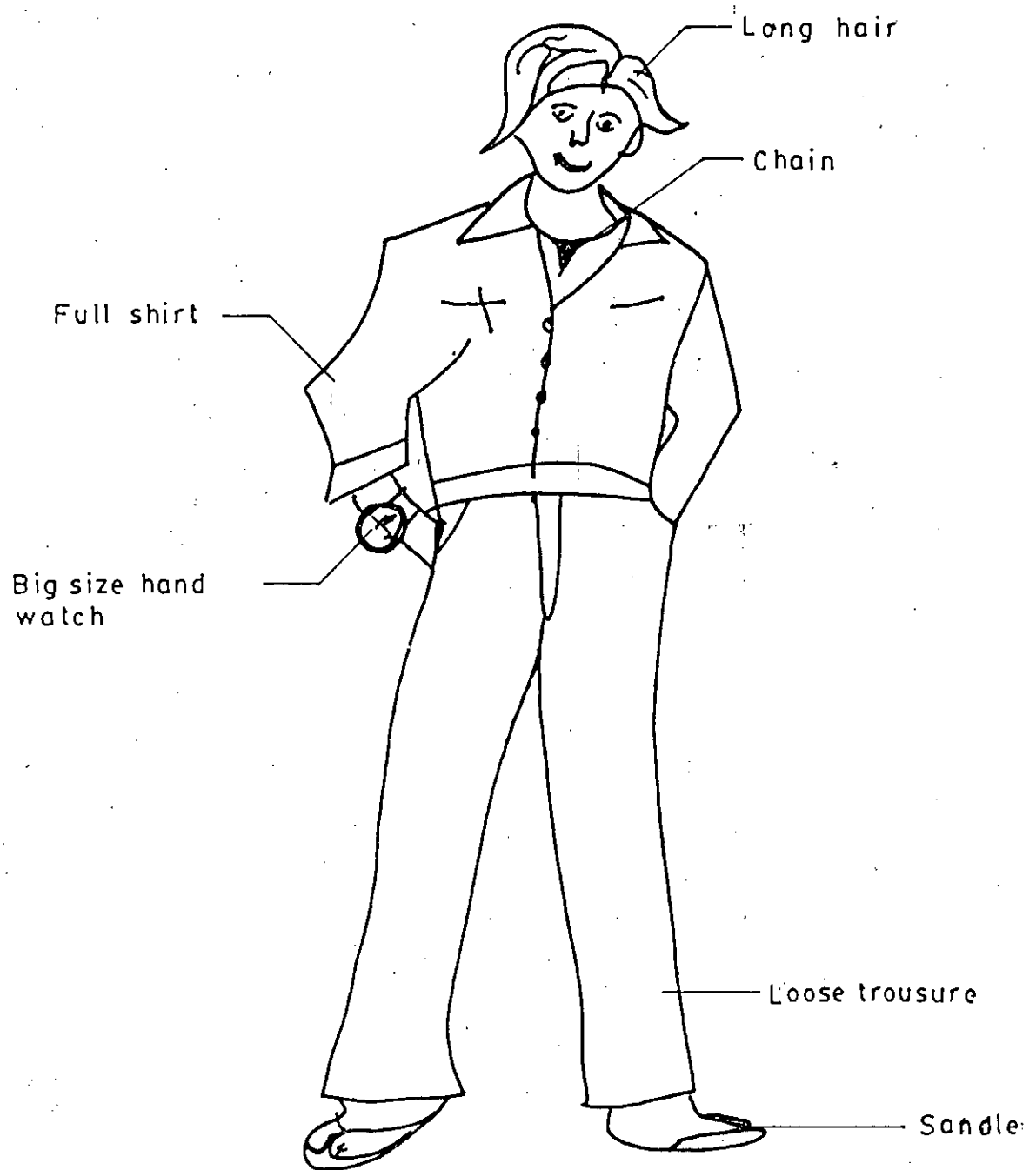


Fig.9.2: Risky, dressing in an Industry

- vi. Human failure
 - vii. Working condition
 - viii. Accident.
-
- i. Mechanical failure: It is the failure caused by breakdown of machine parts and tools which causes injuries to workers or to operator.
 - ii. Defective material: This includes improper size of raw material, which can cause injuries to the workers.
 - iii. Electronic failure: This includes electric short circuit, electrical sparking, leakage or burning of electric coil, unstable power supply etc. which cause injuries to workers or to m/c operators.
 - iv. Faulty design of equipment: This covers sharp edges equipments. Equipment/device designed without safety to workers while working.
 - v. Environmental condition: This covers poor lighting, floor condition, temperature, workplace, ventilation, humidity, colour, noise, etc. which can cause a great deal of injuries to the workers.
 - vi. Human failure: This includes age, curiosity, fatigue, indolence, worry, anger, lack of skill, poor physical condition, poor dressing (Fig.9.3).
 - vii. Working condition: Working condition also affects the work, when a worker is allowed to work in good working conditions then his efficiency increases a lot and reduces the frequency of injuries.
 - viii. Accident: An accident is another major cause of industrial injuries. An accident has been defined as " an unexpected, unplanned event in a sequence of events that occurs through a combination of causes. It results in physical harm (injury or disease) to an individual, damage to property, a loss or any combination of these effects".

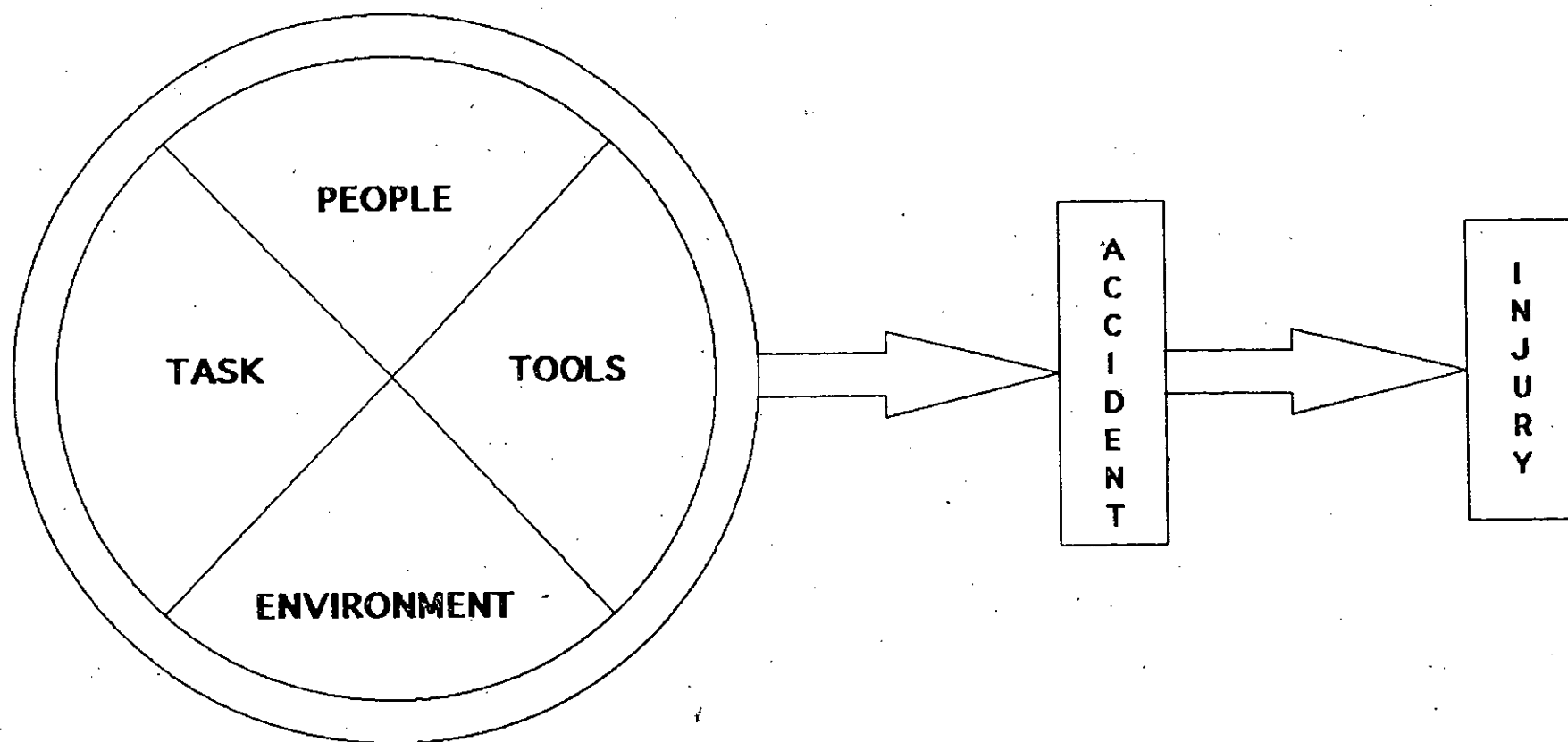


Fig.9.3: Causes of Injury. An injury results from accident. An accident may cause from deficiencies in people, tools, environment and/or task. Most accidents have deficiencies in people, tools and environment.

9.5 IDENTIFICATION OF FACTORS CAUSING INDUSTRIAL INJURIES IN NBCIL UNIT

Causes of injuries in NBCIL have been identified by using chart. NBCIL does not keep any record of workers accidents or injuries inside the factory. The Chart-1 includes worker's name, age, section, part of body, caused by, reasons for injuries, days on leave, year and type of injuries.

CHART-1

Name	Age	Section	Part of body	Caused by	Reasons for injuries	Days on Leave	Year	Type of injuries
Kandicar Hossain	28	Rim	Right hand's finder (thumb) cut	By copper disc of seam welding Machine	While cleaning the disc during machine running period with-out using gloves	7	1991	TTD
Siddik	28	Rim	Left hand's one finger was cut into two pieces	By compressor belt	By keeping the finger on running belt unmindfully	10	1990	PPD
Nurul Hoque	27	Spoke	A cut in left hand palm	While filling a machine parts	Slip of filing tool from hand	2	1991	TTD
Rahim	30	Rim	A portion of left thumb was burned	Done by butt welding machine	Not using gloves	3	1992	TTD
Jalil	31	Packing	Forehead deep cut	By wooden bar during pressing of 20 rims together	Slipping of wooden bar (handle) from workers hand	10	1991	TTD
Karim	27	Packing	Forehead deep cut	Do	Do	10	1992	TTD
Jalil	29	Packing	Forehead deep cut	Do	Do	9	1990	TTD
Rahim	29	Spoke	Back pain	Rolling spoke coils to machine	For bending downward	3	1991	PTD
Babul	27	Spoke	Back pain	Do	Do	4	1991	PTD
Nuru	25	Spoke	Left hand's finder cut	By gear	While cleaning gears	2	1990	TTD

CHART-1 contd..

Name	Age	Section	Part of body	Caused by	injuries	Days on Leave	Year	Type of injuries
Mesher Ali	23	Spoke	Left eye	By chips while looking into the m/c by bending the body	Curiosity	5	1992	TTD
Samad	25	Spoke	Left hand's one finger was stamped	By punch tool of washer m/c	Putting finger between punch and die	10	1992	PPD
Babul	27	Spoke	Right hand's one finger stamped	By punch tool of washer m/c	Putting finger between punch and die	10	1992	PPD
Sultan	25	Electro plating	Left shoulder	While carrying 300pcs spoke on shoulder	Not using Trolley	3	1991	PTD
Anish	26	Do	Right shoulder	Do	Do	4	1992	PTD
Babul	27	Spoke	Right hand's thumb	By grindwheel while grinding a tool	Putting finger on grinding wheel	3	1992	PTD
Selim	28	Spoke	Left eye cut	By chips while looking into the m/c during m/c running time	curiosity	3	1992	TTD

It is observed from the Chart-1 that temporary total disability (TTD) occurrence in NBCIL is the highest, and permanent total disability (PTD) and permanent partial disability (PPD) are second and third places in % occurrence rank. This ranking is done based entirely on number of occurrences. In NBCIL distribution of number of occurrences of TTD, PTD, and PPD cases are shown below:

Type of Injury	Number of Occurrence	% Occurances
TTD	9	52.94
PTD	5	29.41
PPD	3	17.65
Total= 17		100.00

This distribution is shown pictorially in Fig.9.4(a). This procedure obviously gives equal weightages to the varies types of injuries. But from rational point of view and considering the damage to a person the types of injuries should be ranked as follows:

Rank	Types of Injuries
1	PTD
2	PPD
3	TTD

To overcome this difficulty in ranking, it is therefore suggested that number of days lost due to injuries should be considered. With this procedure the modified distribution of injuries would be as follows:

Type of Injuries	Days lost man-days	% Days lost
TTD	51	52.04
PPD	30	30.61
PTD	17	17.35
Total = 98		100.00

This distribution is shown in Fig. 9.4(b).

Different types of injuries (in percentage) and injuries occurred in the different sections of the bi-cycle components manufacturing unit is shown in Fig. 9.5. It is seen from the Fig. 9.5 that most injuries occur in the spoke section. Fig. 9.6 indicates that most injuries occurred in fingers which is 47.05% of the total percentage of injuries. Other common risky places of machineries causing injuries to operators is shown in Fig. 9.7.

TTD = Temporary total disability
 PTD = Permanent total disability
 PPD = Permanent partial disability

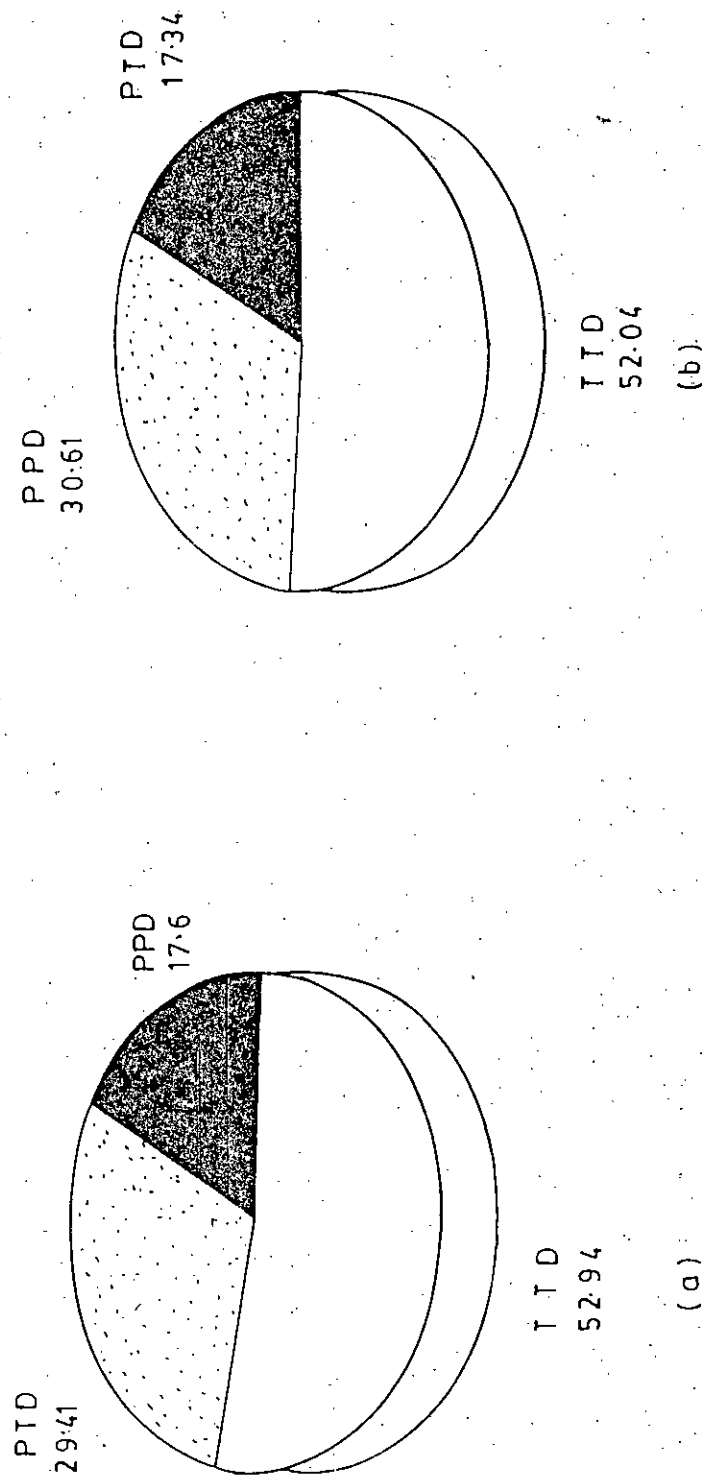
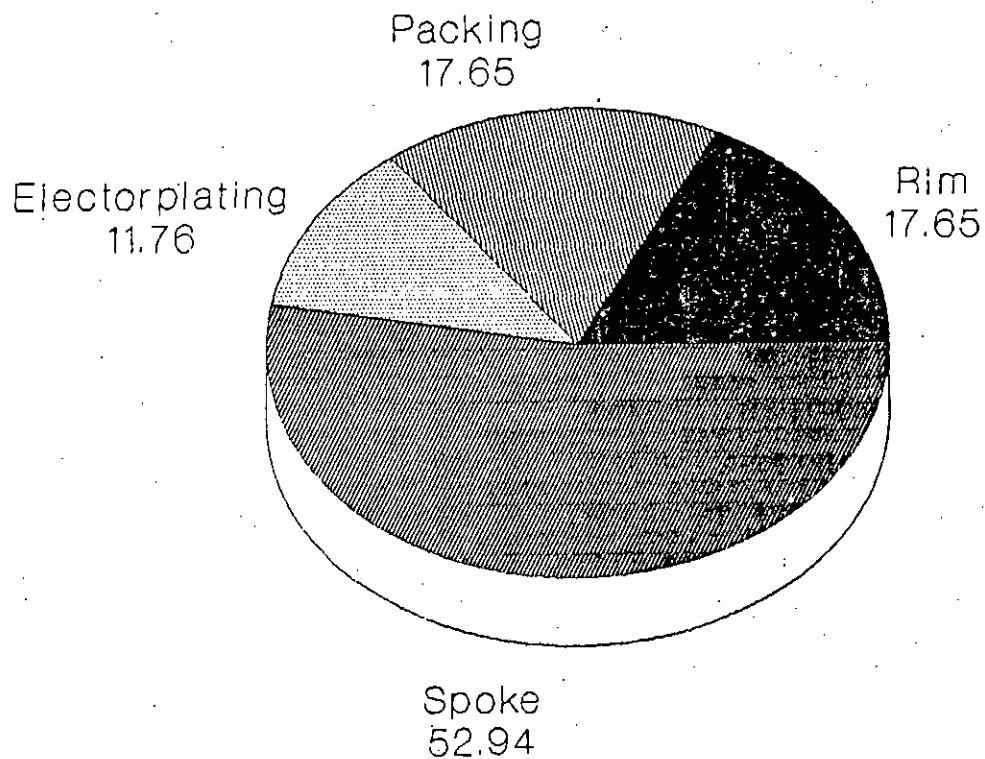


Fig.9.4: a) Different types of injuries occurred in a by-cycle components manufacturing unit (in percentage)
 b) Different types of injuries occurred in respect to days lost (in percentage)

Figure -9.5

**Injuries occurred in different sections of
a bi-cycle components manufacturing unit
(in percentage)**



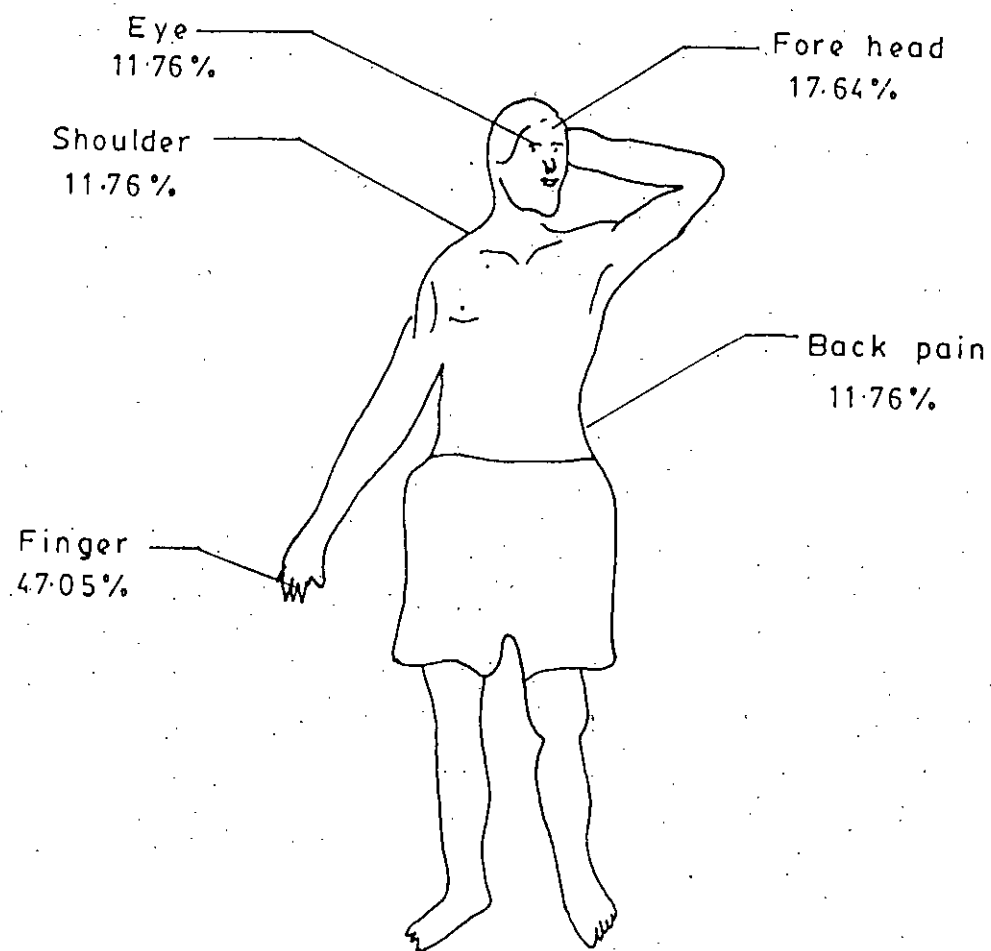
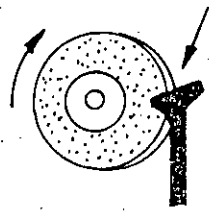
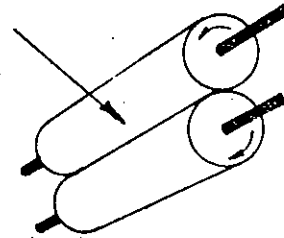


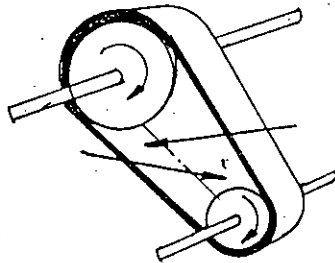
Fig.9.6: Places of injuries to workers in a cycle components manufacturing unit (in percentage)



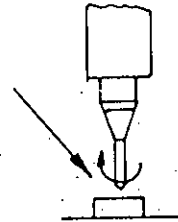
Grinding



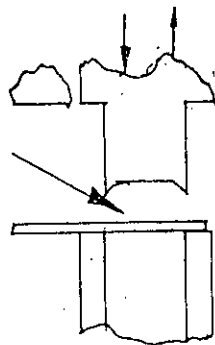
Rollers



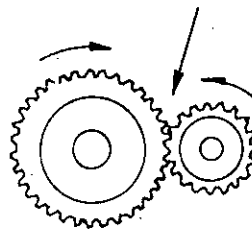
Pulley



Drilling



Punching



Gear

Fig. 9.7: Risky places of machineries causing injuries to machine operators and workers (indicated by thick arrows)

9.6 EFFECT OF INJURIES IN NBCIL PLANT

The effect of industrial injuries occurred in NBCIL Plant are listed below:

- i. Reduced output
- ii. Absenteesm
- iii. Go slow in production on the part of the workers
- iv. Effect of one injury becomes the cause of next injury.
- v. Workers reluctance to carryout their works due to fear of recurrent injuries.
- vi. workers in the packing section sometime hesitate to work where 20 rims are to be packed at a time.
- vii. When a worker suffers injuries on shoulder or forehead he has to leave that particular job for several subsequently he losses interest in that job.
- viii. Besides those above effects the worker and his familysuffer economic losses. The economic consequences affect the worker, his family, his employer and the society. The worker and his family suffers two types of economic losses : (a) a loss of earnings and (b) extra expensesfor treatment.

9.7 MEASURES TAKEN TO PREVENT INDUSTRIAL INJURIES

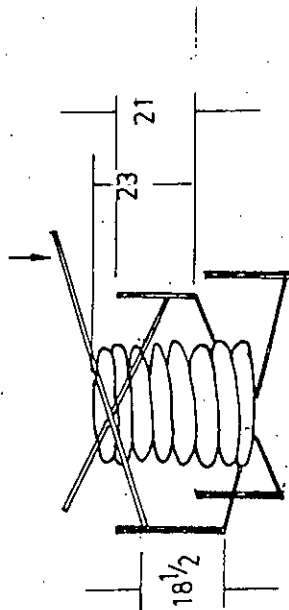
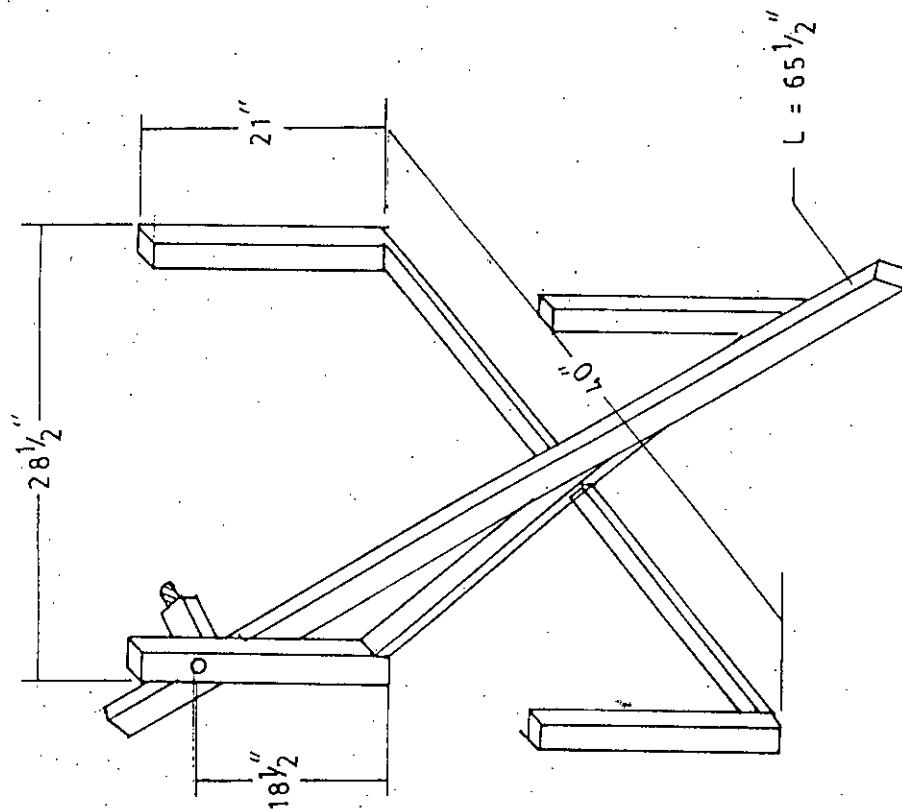
The injuries could be either prevented or atleast minimised by taking proper and timely measures. From experience it is realized that the company management should pay attention into this area and should formulate safety programmes.

The management of NBCIL has decided to implement the necessary safety programme by taking action into any of the three following schemes.

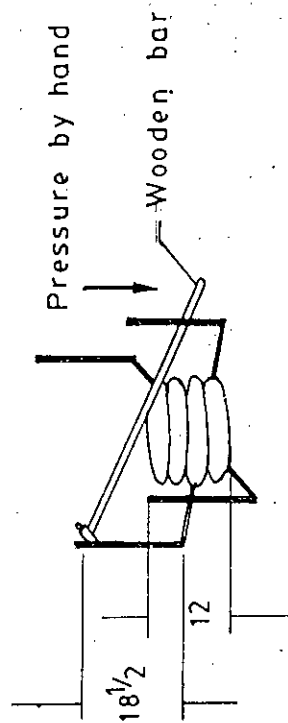
- i. Human safety : Human safety is the safety of the employee exposure to injury.
- ii. Work method safety : It is the safety of the working system.
- iii. Work environment safety : It is the safety of the working environment of a worker.

9.7.1 Present method of tightenning twenty rims together durinnng packing

It is found that during packing of rims slip of a wooden bar from a worker and striking on the forehead of another worker is the mostly occured injury in NBCIL. The weight of the wooden bar is 8 kg. Thus injury caused due to this bar would be serious. This prioritywise prevention of such an injury has to be considered first. Four workers are employed to do the job of tightening of 20 rims together with the wooden bar. The process is described in Table 9.1 and shown in Fig.9.8.



Before pressing 20 rims downward



Height of rims after pressing the wooden bar.

Fig. 9.8 : Existing wooden equipment's dimension and its working method

Table 9.1.Distribution of workers for the tightening
of 20 rims by jute twin

No. of workers engaged	Job element
2	holding 20 rims tightly downwards
1	pressing wooden bar downward
1	tightening 20 rims by jute twine.

9.7.2 Proposed method for tightening of rims

The primary drawback arises in the existing method from the wooden bar and number of workers involved as shown in Fig. 9.8. The wooden bar often slips from the workers hand. A new & improved mechanism and a method has been developed as shown in Fig. 9.9.

From the study of the existig wooden equipment used for pressing 20 rims down a new idea has been conceived for the design of the proposed equipment with safety device.

The following points have been taken into consideration for the design of the proposed equipment for pressing of 20 rims downward.

- i. Selection of material best suited for each member of the machine.
- ii. Selection of each member size on the basis of operation.
- iii. Consideration of friction.
- iv. Safety of operation.
- v. Detailed drawing of the equipment to be designed.

The main components and elements of the proposed pressing equipment are as follows:

- i. Rack and pinion mechanism
- ii. Safety device of operation
- iii. Locking system for handle

9.7.3 Working principle of the proposed equipment

The design of the proposed equipment is shown in Fig. 9.9. In this design, rack and pinion have been used to convert linear motion into rotary motion and vice versa. The rack is attached to a dove tailed slot 4. The slot is connected with the support 2. When the handle 20 is rotated in the clockwise direction the pinion also rotates in the same direction. The pinion makes the rack 3 to move downwards. The downward displacement of the rack is 11 inches. One end of rack is joined with a circular rod which is connected to padastal 7. Initially the padastal 7 with the circular rod 25 is 5 inches above the 20 rims. When the rack moves downward gradually,

the padastal also moves downward then the pressure on rim is considered. When the handle 20 is rotated in clockwise direction, the padastal 7 gives pressure on the rims. When the rack moves 10"-11" downwards, the handle 20 is locked for safety purpose. The worker tightens the 20 rims together by Jute rope. Then the handle 20 is unlocked and is rotated anticlockwise. So that the padastal along with the rack moves upward. The handle is rotated until the rack comes to it's top most position. The hundle of 20 rims are removed from the platform 9 when the rack comes to it's topmost postion then the handle 20 is put in locking positon by pulling the handle 20 backward which leads a portion of the pin to move inside the groove as shown in Fig.9.9. In this position the handle will not rotate downwards. The handle 20 is pushed forward for unlock. The pin 12 comes out at the groove.

Table 9.2:Part list of rim pressing equipment

Sl.No.	Part list	Material
1	Column/stand	MS (angle)
2	Support	MS
3	Rack	MS (Hard)
4	Dove tail rail	MS (Hard)
5	Pinion	CI
6	Support	MS
7	Padastal	CI
8	Nut	MS
9	Platform	MS
10	Shaft	MS
11	Casing	CI
12	Pin	MS
13	Bush	Brass
14	Support	CI
15	Lock pin holder	CI

16	Key	MS
17	Arm	CI
18	Locking pin	MS
19	Shaft	MS
20	Handle	Wood
21	Spring	Carbon steel
22	Lock pin	MS
23	Bolt	MS
24	Cover	CI
25	Circular rod	MS

Detail design calculation of this mechanism is given in Appendix-c.

A safety programme is sometime not enough to be implemented by the company. Safety must be built into every process or product design and into every operation. It must be a integral part of company operations. The prevention of accidents and injuries is basically achieved through control of workers environment and control of people in actions. Only management can implement such control. It is found that much of the safety to prevent injuries of employees in BNCIL depend upon their own attitude. The workers have to be properly dressed as shown in Fig. 9.10.

The new mechanism in pressing of twenty rims together for tightening by jute rope have been made with safety device. This new way of pressing and packing of 20 rims would increase job satisfaction of workers, reduce the rate of accidents and would raise productivity of the plant.

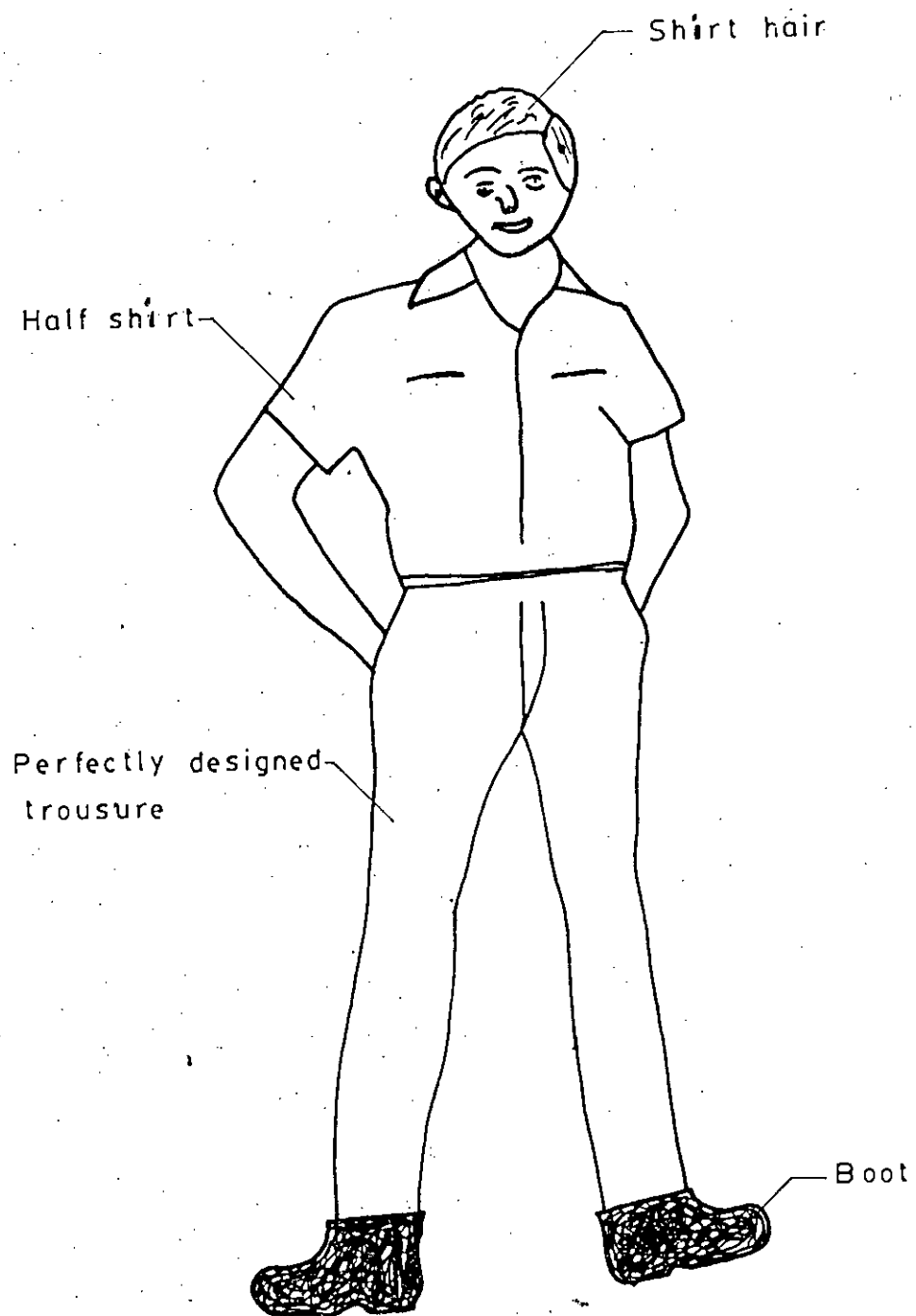


Fig.9.10: Proper and safety dressing in an industry

9.7.4 Other preventive measures for injuries in NBCIL

They are to be carried out as following way:

- i. Increasing awareness and improving the attitudes of workers are necessary as a part of injury/accident prevention programme. The programme includes safety training of employees which can foster safe attitude and motivation among employees. Production Manager, Plant Engineers and Supervisors can participate in different course on industrial safety.

Activity to foster safe attitudes are of three kinds as follows:

- a) Training or education activities in which formal teaching is done. Enforcement of safety rules is actually a matter of education. Employee must understand the rules and the importance in following them. To set a good example of employee education. Top management, supervisors must know, believe in the rules, and must regorously follow them.
 - b) Co-operative programme in which the employees actively participate in the safety programme.
 - c) General safety publicity or propaganda. Information concerning unsafe conditions is important in the prevention of future industrial injuries.
- ii. Inspection of safety measures should be carried out by the plant-in-charge and section-in-charge every month.

- iii. It is recommended that a Committee should be formed with the personnel from various departments in NBCIL to undertake the responsibility of applying ergonomics to enhance productivity. Ergonomics can be applied to any system involving human and their machines.
- iv. Section-in-charge should deliver lectures on industrial safety measure to his section workers and machine operators atleast once in every month.

CHAPTER-10

CONCLUSION AND RESEARCH FOR FUTURE WORK

10.1 CONCLUSION

In the light of the present research work the following conclusion can be drawn:
A Study of the existing production system of a Bi-cycle component manufacturing company has been made. Various production bottlenecks which prevent the normal production of bicycle components and hamper productivity were identified.

The major and solvable problems were considered. These were as follows:

- i. To increase production and to set a target of production.
- ii. Economic feasibility analysis of some of the spare parts to be manufactured (in-house).
- iii. Utilisation of machineries available in the unit to manufacture the selected spare parts with maximum profit.
- iv. To improve the existing working methods in order to increase efficiency and productivity.

The present work is a composite of various isolated problem areas of operations management. In this regard various techniques have been used with a view to

improve productivity of the production enterprise. Productivity outcomes from the work are as follows:

- a. Output of spoke section has been increased. The production of nipples have been increased to 123.5 grosses from 116 grosses per shift.
 - b. Consumption of drill bits and threading taps have been reduced from 5.3(2.05 mm) threading taps, 10.6(2.00 mm) drill bits & 3(2.38 mm) drill bits to 3(2.05 mm) threading taps, 8(2.00 mm) drill bits & 2(2.38 mm) drill bits.
 - c. Machine running hours have been increased from 6 hours to 7 hours per shift by reducing breakage of drill bit and threading taps.
 - d. Production volume per shift has been standardized as 247 grosses, 1054 grosses and 1963 grosses for nipples, spokes and washers respectively.
 - e. Monthly production observation sheets have been developed for systematic recording of production of different products in order to find the efficiency of shift-in-charges (S.A.Engineers). Approximate manpower distribution has been designed in various production sections.
 - f. An attachment has been designed for drill bit sharpening, would give desired sharpening accuracy and increase its life.
 - g. Design of an industrial workstation (seated worker) has been completed. The existing methods of packing nipples, spoke and washer have been improved.
- ii. Six spare parts for various machineris have been manufactured indigenously in the factory by the available machineries. On their performance test it was observed that the spares were functioning properly.

An economic analysis was done on these indigenous manufactured selected spare parts. It was observed that an economic profit of Tk. 13,23,000 (Thirteen lac twenty three thousand) only can be obtained annually by manufacturing the above mentioned spare parts.

- iii. Optimization of machine utilization and profit maximization for production of the six selected spare parts were determined by using linear programming technique.
- iv. Investigation on injuries generally occur at a bicycle components manufacturing unit has been done. Causes of industrial injuries were identified and preventive measures were taken to reduce the injuries.

10.2 RECOMMENDATIONS FOR FUTURE WORK

Further study can be done on productivity improvement of the bicycle parts manufacturing unit in different dimensions. Some of them are listed below:

- i. The production system of spoke section could be analysed and various weakness and faults of system could be identified and solved. Effectiveness of the system can be further strengthened by developing a decision making system to accomodate any change in production planning factors such as planning periods, products, raw materials and labour hour. Besides that computer can be used for storing various data of production, tools spare parts and raw materials.

- ii. Various spare parts could be manufactured in the industry if a shaper machine (horizontal) is included with the available machines. In this regard economic analysis may be made. Feasibility study could be carried out to set up a workshop for producing other spare parts economically.
- iii. In the distant future further development of drill bit sharpening can be done by introducing automatic feed mechanism.
- iv. A further study can be done, on motivation and human behavior to improve the efficiency of workers.
- v. Future work on causes and preventions of industrial injuries have to be carried out using modern techniques. Besides that personnel training and attitude are the two important factors that must be taken into consideration in the prevention industrial injuries.
- vi. IDEF (Integrated Computer-Aided Manufacturing DEFinition) system description technique can be further used for detail study of the existing system.

References

REFERENCES

1. A. Nizamuddin; "Industrial Architecture for Developing Countries", Vikas Publishing House Pvt. Ltd., New Delhi, India., pp.429, 1992.
2. Amitabha, Bhattacharyya; "Metal Cutting Theory and Practice", Central Book Publisher, pp. 105-111, 1984.
3. Arshinow, V.; "Metal Cutting Theory and Cutting Tool Design ", Mir Publishers, Moscow, pp. 286-287, 1976.
4. Barnes, M.R.; "Motion And Time Study: Design and Measurement of Work", John Wiley & Sons, Inc., pp.260-261, 1968.
5. Buffa S. Elwood; "Modern Productivity/Operation management", Eighth edition, Willy Eastern Limited, India, pp.127-128, 1993.
6. Dehelly, C. & Laredo; "European Approaches to Productivity Improvement: Application at Thomson Selnor", International Industrial Engineering Conference, pp-56, USA, 1987.
7. Dorfmont, Linda; "Productivity and Quality Improvement in Engineering", International Industrial Engineering Conference, USA., pp.75, 1987.

8. Farley, R.R.; "Some Principles of Methods and Motion Study as Used in Development Work", General Motors Engineering Journal, 1955.
9. Galleangher, Rob; "The Rickshaw of Bangladesh", First edition. The Unniversity Press Limited, Dhaka, pp.386-420, 1992.
10. Gerling, Heinrich, "All About Machine Tools ", Willey Eastern Limited, Seventh Edition, pp.86,1990
11. Gupta,K.T.; "Industrial Experiences that Produced Productivity Gain ", International Industrial Engineering Conference, pp.51, USA, 1987.
12. Karim, S.m.j.; "Feasibility of Local Manufacture of Spares for Fertilizer Factories of Bangladesh", An unpublished M.Engg. thesis, Deptt. of Industrial and Production Engg. B.U.E.T., October, 1990.
13. Konz Stephan; "Work Design: Industrial Ergonomics", Horizon Inc. Columbus, USA, PP.178-181,1987.
14. Kurmi, R.S. & Gupta, J.K.; "Machine Design", Eurasia Publishing House, pp.994-1010, 1988.

15. Laufe; "Production and Operations Management", South-Western Publishing CO., pp27-28, 1984.
16. Lieberman, Hillier; "Operation research", CBS Publishers & Distributer, Delhi, 1987.
17. Lund, Chapanis, Cook. and Morgan; "Human Engineering Guide To Equipment Design", Mc-Graw Hill Book Company, pp.494, 1963.
18. McElroy Frank; "Accident Prevention Manual for Industrial Operations", National Safety Council, Chicago, USA, 1974.
19. Meredith, D. Dale; "Design and Planning of Engineering Systems", prentice - hall, INC., New Jersey, U.S.A, 1973.
20. More, j., Howard; Impact of science on society : Ergonomics, UNESCO and Taylor & Frances Ltd., London. pp.3-21, 41, 1992.
21. Nasiruddin, M.; "Industrial, Safety", Productivity Services Wing, Bangladesh Association UNDP/ILO Project, pp.5, May, 1991.
22. Palay, M.; "Metal Cutting Tool Production ", Mir Publishers, Moscow, pp. 260-264, 1968.
23. Prokopen, Joseph; "Productivity management", International Labour Organization Geneva, pp.9-10, 121-148, 1987.

24. Ramsay, M.R.; "Productivity Performance Measurement in An Australian Public Utility", International Industrial Engineering Conference, pp.10, USA, 1987.
25. Riggs, L.James; "Production System:Planning Analysis and Control", John Wiley & Son, Newyork,pp. 27-32, 1976.
26. S. Mehran; "Case Studies of Manufacturing Productivity Improvement", pp.35, USA, 1987.
27. Squires, P.C.; "The Shape of the Normal Working Area", U.S. Navy Department, Bureau of Medicine and Surgery, Medical Research Laboratories, New London, Connecticut, 1956..
28. Whybark, Berry, Vollmann; "Manufacturing, Planning and Control System", Galgotia Publications Pvt. Ltd., 1989.
29. WU,B.; "Manufacturing Systems Design and Analysis, Chapman & Hall, U.K.

Appendices

APPENDIX-A

FUNCTION, DESIGN DIMENSIONS AND MATERIALS FOR SELECTED SPARE PARTS

a. Function of the selected spare parts:

Ejector pin for upsetting machine: The function of ejector pin is to eject upsetted nipple from die. The ejected nipple falls in a bucket through a hole. The ejector pin ejects 214 nipples per minutes. The movement of ejector pin is to and fro motion in the horizontal direction.

Ejector pin for nipple automation machine: Nipples from the upset machine are put in the hopper. Then nipples from hopper goes down through a guiding rail. A machine part named feeding segment holds the nipple from the end of guiding rail and places it in a chucking tong mounted on a revolving head. Then various operation namely champhering, drilling, slotting and threading are performed. Lastly that nipple is ejected from the chucking tong through the rail. Forty three nipples are ejected by the ejector pin per minute.

Spoke Head Punch: Its function is to make mark like "N", "B" or "C" on the upsetted head of spoke after performing straighting, sizing, bending and upsetting operation. 94 spokes are marked by the spoke head punch per minute. The marking of each spoke is very important as only marked spokes are supplied in the market.

Nipple Upset Head Punch: It is a part of nipple upset machine. Nipples are sized, upsetted, marked and ejected. The purpose of nipple upset head punch is to make mark like "N", "B" or "C" on each nipple head. 214 nipples are marked by an upset head punch per minute.

Feeding Segment: It is a part of nipple automation machine. In nipple automation machine, the nipples from upset machine is fed into hopper. Then nipples passes through guiding rail towards downward from gib. The feeding segment holds the nipple firmly which falls from the guiding rail. Then feeding segment places the nipple in a chucking tong mounted on a revolving head. The head moves in circular motion and various operations namely champhering, drilling, slotting, threading are performed. The feeding segment has significant importance for nipple automation machine. It's because feeding segment carries the nipples from hopper to 8 chucking tongs respectively for several operations to be performed on upsetted nipples.

Gripping Die of Spoke Machine: The function of gripping die is to grip a spoke while upsetting and marking of a spoke is done at the same time. The spokes are sized at first, then upsetting, marking, bending and threading operations are done respectively. Two pieces of gripping dies are required in one spoke machine.

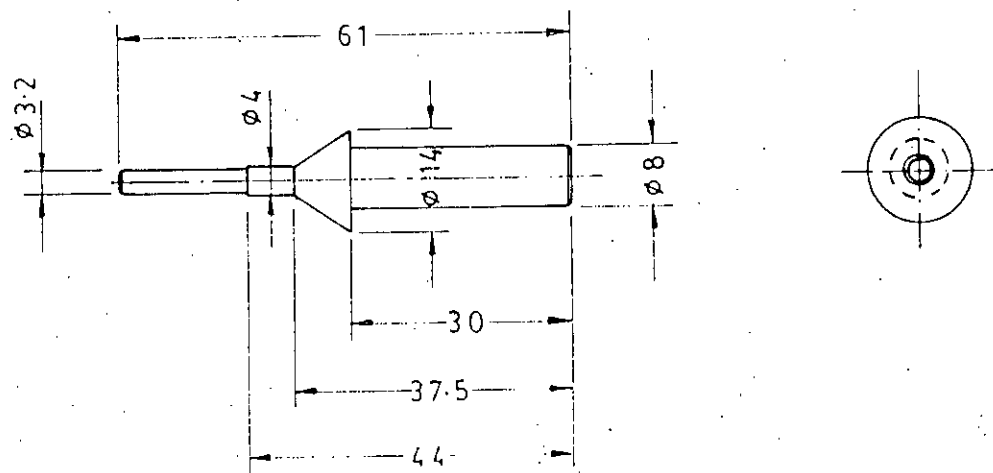


Fig. A1 : Dimensions & different views of a upset ejector pin

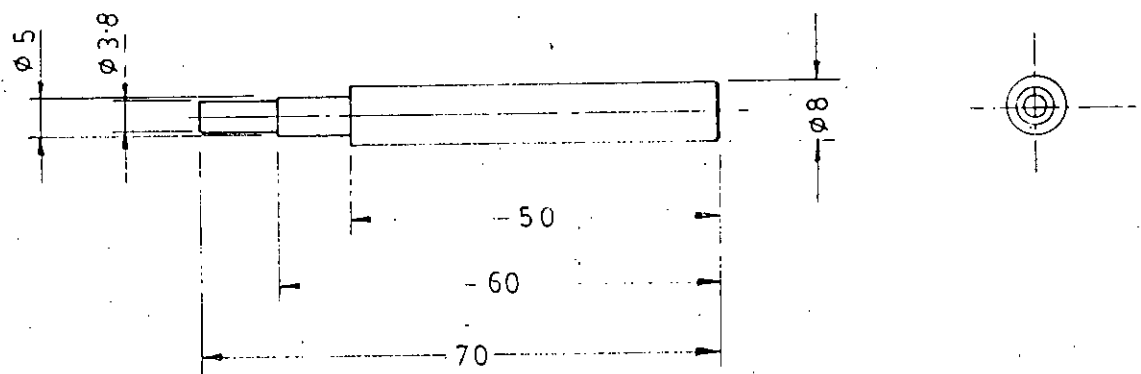
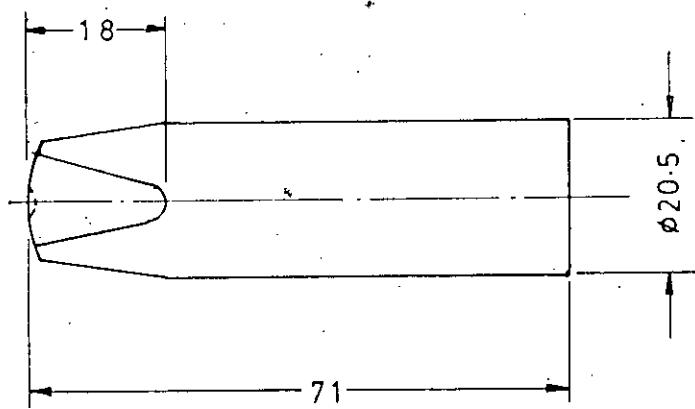
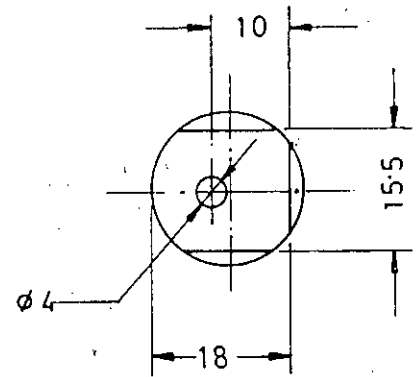


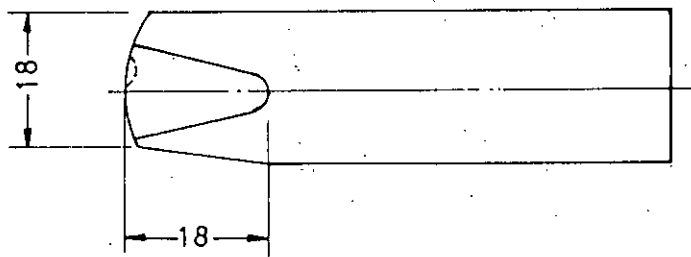
Fig. A2 : Dimensions and different views of a nipple ejector pin



FRONT VIEW



L.H.S VIEW



TOP VIEW

Fig.A3:Dimensions and different views of a spoke head punch.

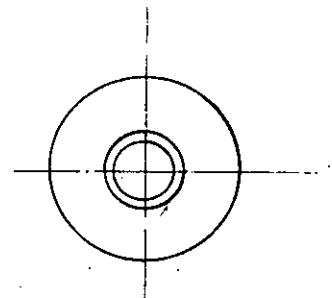
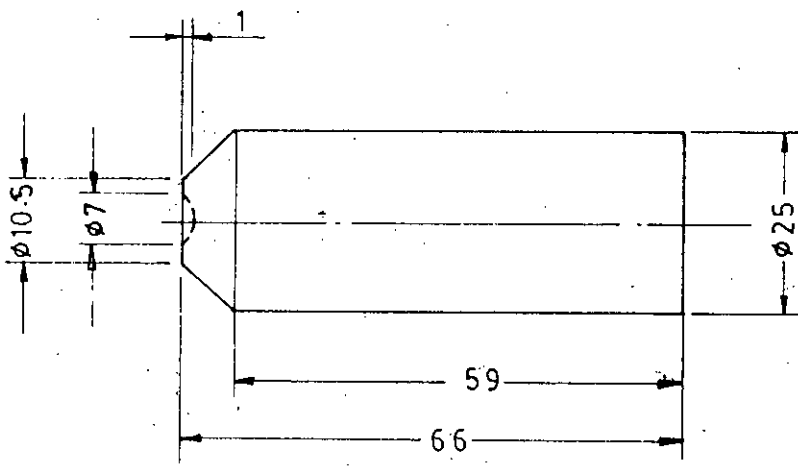


Fig.A4:Dimensions and different views of a upset head punch

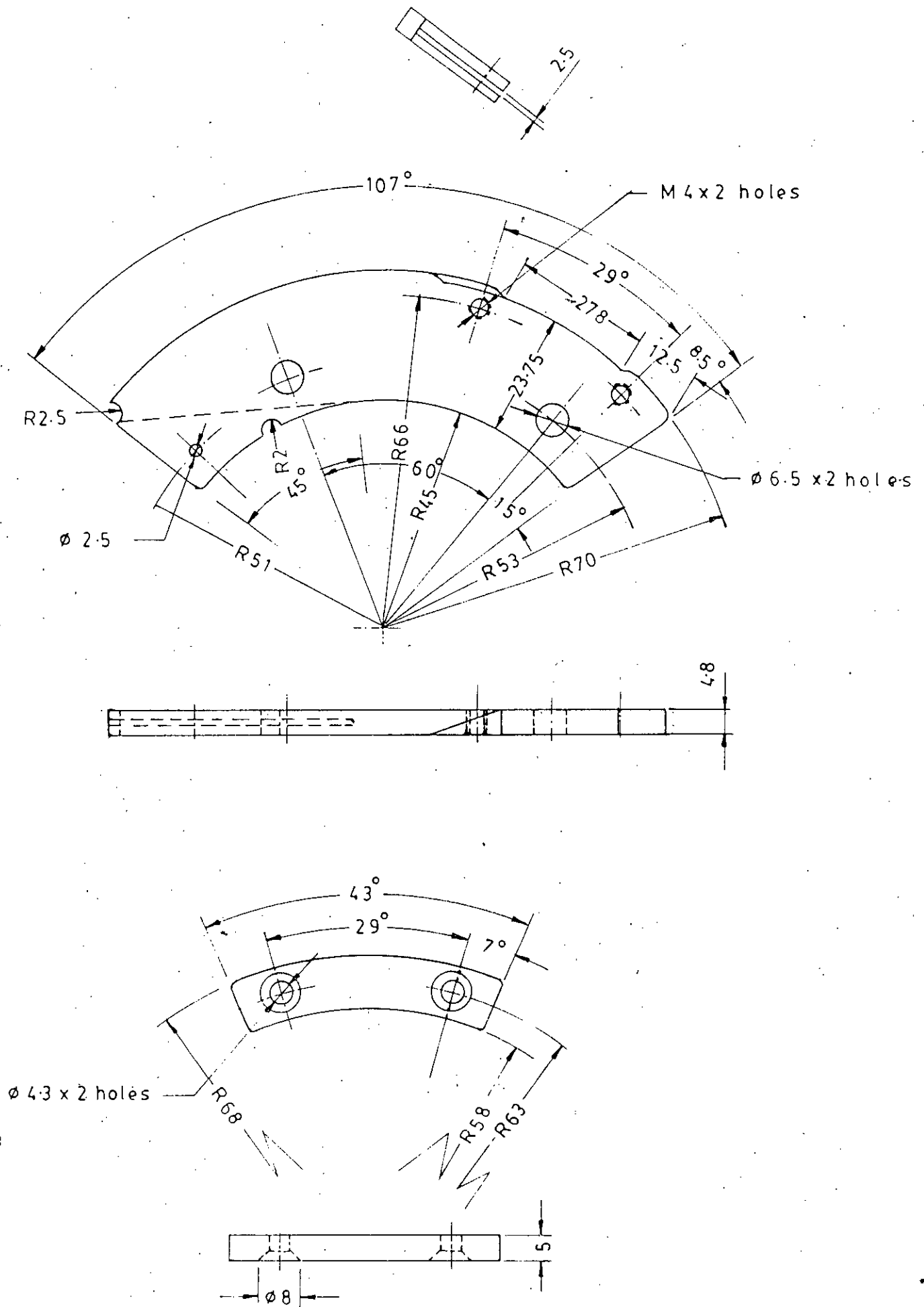


Fig. A5: Dimensions and different views of a feeding segment

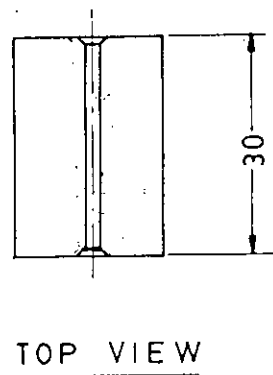
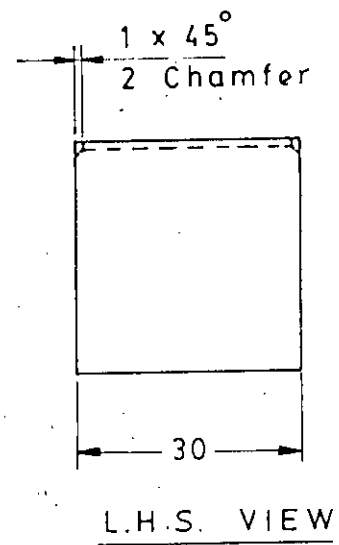
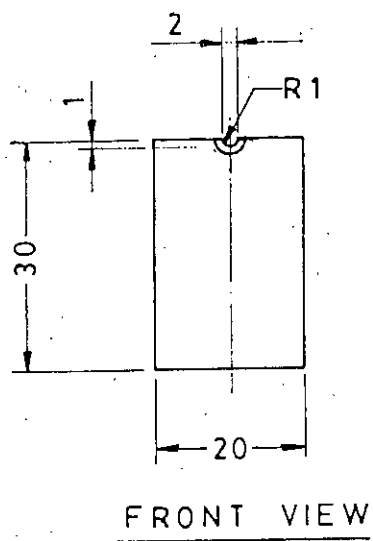


Fig. A6: Dimensions and different views of a gripping die.

b. Design dimensions and materials for selected spare parts:

Detailed drawing of all imported spare parts are not supplied to NBCIL by the suppliers. So for required dimensions (length, width, height, angle, etc.) of selected spare parts were measured by using the following instruments:

- i. Digital slide calipers
- ii. Micrometer
- iii. Digital height gauge
- iv. Scale.

c. Material Selection Criteria:

In selecting material for the production of a specific spare parts the following factors are to be taken into consideration [12]:

- i. Functional requirements
- ii. Machinability
- iii. Availability
- iv. Cost.

Function requirements: The functional requirements are satisfied by

certain mechanical and physical properties such as:

- | | |
|-----------------------|---|
| i. Strength, | vi. Resistance of wear,
corrosion, friction and heat |
| ii. Toughness | |
| iii. Ductility | vii. Electrical and Thermal
Conductivity |
| | viii. Machinability |
| iv. Impact resistance | ix. Castability |
| v. Weight | x. Formability etc. |

Machinability: Machinability is defined as the ease with which the metal is cut satisfactorily for the purpose intended. In general good machinability is associated with the removal of material with moderate forces, the formation of rather small chips, not excessive tool wear and good surface finish.

Availability of the raw material for selected spare parts: When an imported machine parts or tools are to be manufactured locally then raw material plays a great role. Raw materials are available in market as scrap. And the quality of raw materials are of inferior quality as they are not fresh.

In the present work, selection of raw materials for the spare parts were done on the basis of the following considerations:

- i. Raw material should be available in plenty
- ii. Cost of raw material should be low
- iii. Raw material selected must be met with the desired functional requirements
- iv. The material should be such that it can be machined with local facilities at the minimum cost.

Raw materials for selected spare parts are listed below:

Table A1

Raw material selection for selected spare parts

S1.No.	Spare's name	Raw material name
1	Automation ejector pin	M.C.S.
2	Upset ejector pin	H.S.S.
3	Spoke head punch	H.S.S.
4	Nipple upset head punch	H.S.S.
5	Feeding segment	M.C.S.
6	Gripping die	H.S.S.

APPENDIX-B

DETERMINATION OF COSTS OF PRODUCTION OF SELECTED SPARE PARTS

Determination of cost for the production of ejector pin
for nipple automation machine

1. Raw Material Cost: Material required for 1 piece is 1 lb.
Cost of 1 lb Medium Carbon Steel (MCS) = Tk. 80/-

So cost for 2 lbs Medium Carbon Steel (MCS) = Tk. 160/-

2. Manufacturing Cost :

a. Lathe operation

Time for turning, facing and parting = 85 minutes

Manufacturing Overhead Cost = Tk. 30/hr.

Direct Labour = Tk. 20/hr.

Total Tk. 53/hr

So the total cost for
lathe operation = $53 \times 85/60 = 75 = \text{Tk. } 75/-$

- b. Other Non-manufacturing Cost
(Administrative and Miscellaneous cost):

Non-manufacturing cost = Tk. 10.50/hr.

So total non-manufacturing cost for manufacturing
ejector pin for nipple automation machine is

$$10.5/60 \times 85 = 15$$

Total cost for manufacturing of one ejector pin

= Material Cost + Machining Cost +
Non-manufacturing cost

$$= 160 + 75 + 15$$

$$= \text{Tk. } 250/-$$

Determination of cost for the production of a ejector pin of Upsetting machine

1. Raw material cost : Raw material required for 1 piece ejector pin is 2 lbs.

Cost of 1 lb. MCS = Tk. 80/-

So, Cost for 2 lbs. MCS = Tk. 160/-

2. Manufacturing Cost :

a. Lathe operation

Turning, facing and parting time = 90 minutes

Manufacturing overhead cost = Tk. 30/hr

Direct Labour Cost = Tk. 25/hr.

Total Tk. 55/hrs

So, total cost for lathe operation = $55 + 90/60 =$ Tk. 83/-

b. Other non-manufacturing cost

(Administrative and miscellaneous cost):

Non-manufacturing cost = Tk. 10.50/hr.

Total non-manufacturing cost for manufacturing of upset ejector pin

= $10.5 \times 90/60 =$ Tk. 16/-

Hence total cost for manufacture of one ejector pin of upsetting machine

= Material Cost + Machining Cost +
Non-manufacturing Cost

= $160 + 83 + 16$

= Tk. 259/-

Determination of cost for manufacturing of nipple upsetting head punch

1. Raw material Cost : Raw material required for one piece is 2 lbs.

Cost of 1 lb. High Speed Steel (HSS) = Tk. 193/-

So cost of 2 lbs High Speed Steel (HSS) = Tk. 386/-

2. Manufacturing Cost :

- a. Lathe operation:

Turning, facing, parting time = 165 minutes

Manufacturing Overhead Cost = Tk. 45/hr

Direct Labour Cost = Tk. 100/hr.

Total Tk. 145/hr:

So total cost for lathe operation = $165/60 \times 145 = \text{Tk. } 399/-$

- b. Heat treatment:

Time required for heat treatment = 60 minutes

Heat treatment cost/piece = Tk. 28/hr.

So heat treatment cost for upset head punch = Tk. 28/-

- c. Non-manufacturing Cost:
(Administrative and miscellaneous cost):

Non-manufacturing cost per hour = Tk. 10.50/hr.

Total non-manufacturing cost = $10.50 \times 220/60 = 39/-$

Hence total cost for manufacturing of one piece nipple upset head punch

= Material Cost + Machining Cost +
Non-manufacturing Cost

= 386 + 399 + 28 + 39

= Tk. 859/-

Determination of Cost for manufacturing of spoke head punch

1. Raw Material Cost:

Cost of 1 lb. H.S.S. = Tk. 190/-

So cost for 2 lbs. H.S.S = Tk. 380/-

2. Manufacturing Cost :

a. Lathe operation

Turning facing champhering and growing time = 157

Manufacturing Overhead Cost = 45/hr.

Direct Labour Cost = Tk.100/hr.

Total Tk. 145/hr.

So total cost for Lathe operation = $157/60 \times 145$ = Tk. 378/-

b. Milling Operations

Time take for milling operation = 50 minutes

Manufacturing Overhead Cost = Tk. 40/hr.

Direct Labour Cost = Tk.150/hr.

Total Cost= Tk.190/hr.

So total cost for milling operation = $50/60 \times 190$ = Tk.158/-

c. Heat treatment

Time for heat treatment = 60 minutes

Cost per hour for Heat treatemtn = Tk. 28/-

So heat treatment cost for Spoke Head Punch = Tk.28/-

d. Non-manufacturing Cost

(Administrative and miscellaneous cost):

Non-manufacturing cost per hour = Tk.10.50/hr.

Total non-manufacturing cost = $10.50 \times 277/60$
= Tk.48/-

Hence total cost for manufacturing of a Spoke Head Punch

$$= \text{Material Cost} + \text{Machining Cost} + \text{Non-machining cost}$$

$$= 380 + (378 + 158 + 28) + 48$$

$$= \text{Tk. } 992/-$$

Determination of cost for the production of feeding segments

1. *Raw material Cost:*

Raw material required for 1 piece	=	3 lbs.
Cost per pound of Medium Carbon Steel	=	Tk.80
Cost of raw material for feeding segment	=	Tk.320/-

2. *Cost of Gas Cutting:*

Gas Cutting Cost of one ring for part 1	=	Tk.80/-
Gas Cutting Cost of one ring for Part 2	=	Tk.80/-

Total Cost	=	Tk.160/-
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3. *Manufacturing Cost :*

For Part 1 and 2

a. Lathe Operation

(Turning, facing, Boring)	=	40 minutes
---------------------------	---	------------

Manufacturing Overhead	=	Tk.45/hr.
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Direct Labour Cost	=	Tk.100/hr.
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Total	Tk. 145/hr.
-------	-------------

Hence total cost for Lathe operation = 145×0.66

= Tk.96.6

Approx. Tk.97/-

b. Milling operation (for Part 1)

Time taken	=	45 minutes
Manufacturing Overhead	=	150/hr.
Direct Labour Cost	=	Tk.150/hr.
Total		Tk.190/hr.

So total cost for Milling operation = 190×0.45
= 142.5
Approx. 143/-

c. Grinding operation (both sides of Part 1 and 2)

Grinding time	=	30 mintes
Manufacturing Overhead Cost	=	Tk.40/hr.
Direct Labour Cost	=	Tk.100/hr.
Total		Tk. 140//hr.

Hence total cost for grinding operation

$$= 30/60 \times 140/-$$

$$= \text{Tk. } 70/-$$

d. Drilling Operation

Drilling time	=	10 minutes
Manufacturing Overhead Cost	=	Tk.80/hr.
Direct Labour Cost	=	Tk.20/hr.
Total		Tk.100/hr.

Total cost for drilling = $100 \times 10/60 \times \text{Tk.16.6}$
= Tk.17/-

e. Heat treatment

Time for heat treatment = 60 minutes
Heat treatment cost/pieces = Tk.28/hr.

d. Filling Operation

Filling time = 45 minutes
Manufacturing Overhead cost = Tk.50/hr.
Direct Labour cost = Tk.60/-

Total Tk.110/-

Total Cost for filling = Tk. 110/-

Other non-manufacturing cost
(Administrative and miscellaneous cost)

Non-manufacturing cost = Tk.10.50/hr.
Total non-manufacturing cost = Tk.10.50 x 230/60
= Tk. 40

Total cost per piece of feeding segment

= Material cost + Gas cutting cost + Machining Cost
+ Non-manufacturing cost.
= 320 + 160 + (97 + 143 + 70 + 17 + 28 + 110) + 40
= Tk. 985/-

Determination of cost for the production of one
set gripping die

1. *Raw material cost :*

Raw material for 1 piece

= 1 kg. of H.s.S. (High Speed Steel)

Cost per kg. = Tk.160/-

Weight of one piece of gripping die = 350 gm.

Raw material required for one piece gripping die

= 500 gm. or 0.5 kg.

So Raw material cost for one piece gripping die

= Tk.80/-

2. *Manufacturing cost :*

a. Milling operation :

Surface milling is done on all six sides of a gripping die

Tool setup time for all six sides = 60 minutes

Surface milling time for six sides
= $30 \times 6 = 180 \text{ min.}$

Then slotting and champhering is done respectively.

A slot of 1 mm deep is to be made by form cutter.

The slot is 20 mm long, 2 mm wide and 1 mm deep.

Chaphering is required at two end of the block.
Both ends are opposite to each other.

Champhering is done by using 1 slot cutter.

Tool setup time for slotting and champhering
= $20 + 10 = 30 \text{ minutes}$

Time required for making slot = 43 minutes

Time required for making champhering = 30 minutes.

Total milling time
= $60 + 180 + 43 + 30 + 30 = 343 \text{ minutes} = 5.71 \text{ hrs.}$

Manufacturing Overhead = Tk. 15/hr.

Direct Labour cost = Tk. 20/hr.

Total Tk. 35/hr.

Milling Operation cost per piece =

$$343/60 \times 35 = \text{Tk. } 200/-$$

So cost for surface grinding operation =

$$120/60 \times 140 = \text{Tk. } 280/-$$

c. Heat treatment cost

Heat treatment time = 1 hr.

Cost for heat treatment = Tk. 28/hr.

So heat treatment cost = Tk. 28/-

d. Other non-manufacturing cost
(Administrative and miscellaneous cost):

Non-manufacturing cost = Tk. 10.50/hr

So total non manufacturing cost =

$$10.50 \times 523/60 = \text{Tk. } 91/-$$

Total manufacturing cost per piece

= Material cost + Machining cost +
Non-manufacturing cost

$$= 80 + 200 + 280 + 28 + 91$$

$$= \text{Tk. } 449/-.$$

Hence cost for 2 piece of gripping dies (1 set)

$$= 449/- \times 2 = \text{Tk. } 898/-.$$

The spare parts listed before in Table 5.2 selected for manufacture in the industry by the available machines were experimentally manufactured and were given trial.

APPENDIX—C

DESIGN CONSIDERATION FOR GEARS

Both rack and pinion are gears. Rack is the straight line gear and the circular one is called pinion. The following requirements must be met in the design of the gear drive.

- i. The gear teeth should have sufficient strength so that they will not fail under static or dynamic loading during normal running condition.
- ii. The gear teeth should have good wear characteristics so that their life is satisfactory.
- iii. The use of space and material should be economical.
- iv. The alignment of the gears and shaft's deflection must be considered because they effect on; the performance of the gears.

Beam Strength of Gear Teeth

In 1892, Wilfred Lewis investigated for the strength of gear teeth. He derived an equation which is now extensively used in determining the size and proportion of the gear. Luwis assumed that as the load

is being transmitted from one gear to another, it is all given and the load is distributed among several teeth. When contact begins, the load is assumed to be at the end of the driven teeth and as contact ceases, it is at the end of the driving teeth. This may not be true when the number of teeth in a pair of mating gear is large, because the load may be distributed among several teeth. But it is almost certain that at some time during the contact of teeth, the proper distribution of load does not exist and that one tooth must transmit the full load. In any pair of gears having unlike number of teeth, the gear which have the fewer teeth (i.e. pinion) will be the weaker, because the tendency toward undercutting of the teeth becomes more pronounced in gears as the number of teeth becomes smaller.

Lewis equation is as follows:

$$W_T = f_w \cdot b \cdot P_c \cdot Y = f_w \cdot b \cdot m \pi \quad \dots \quad (i)$$

where

W_T = Beam strength of the teeth

f_w = Permissible working stress = $f_0 C_v$

f_0 = allowable static stress

C_v = Velocity factor

b = width of gear face

P_c = $m \pi$

m = module

Y = Lewis form factor or tooth form factor.

Application of Lewis equation in the design of wheel/gear are as follows:

- i. The Lewis equation is applied only to the weaker of the two wheels (i.e. pinion or rack)
- ii. When both the pinion and the gear are made of the same material, then pinion is the weaker.

Values of Y in terms of the number of teeth are expressed as follows:

- a. $Y = 0.124 - 0.684/T$, for $14\frac{1}{2}^\circ$ composite and full depth involute system ... (ii)
- b. $Y = 0.154 - 0.912/T$, for 20° full depth involute system ... (iii)
- c. $Y = 0.175 - 0.841/T$, for 20° stub system ... (iv)

Values of C_v are:

- a. $C_v = 3/3+V$ for ordinary cut gears operating at velocities up to 12.5 m/sec. ... (v)
- b. $C_v = 4.5/4.5+V$, for carefull cut gears operating at velocities upto 12.5 m/sec.... (vi)
- c. $C_v = 6/6+V$, for very accurately cut and ground metallic gears operating at velocities upt 20 m/sec. ... (vii)
- d. $C_v = 0.75/1+V + 0.25$, for non-metallic gears ... (viii)

In the above expression, V is the pitch line velocity in metres/second. V can be found by using the following formula,

$$V = \frac{\pi D_p N}{60}$$

where

D_p = Pitch circle diameter of pinion

= $m T_p$

T_p = No. of teeth on pinion

m = Module

N = Speed in r.p.m.

And allowance static stress f_0 value depends on material of pinion.

W_T is taken as tangential tooth load for the design of pinion for the proposed equipment.

Data for the design of pinion are as follows:

Tangential tooth load, W_T = 28 kg.

Rotation of pinion, N = 40 r.p.m. (assume)

Allowable static stress, f_0 = 120 kg./mm²

No. of teeth on pinion, T_p = 30 (assume)

Face width, b = 10 m (assume)

We know that pitch line velocity,

$$\begin{aligned}
 V &= \frac{\pi D_p N}{60} \\
 &= \frac{\pi m T_F N}{60} \\
 &= \frac{\pi \times m \times 30 \times 40}{60} \text{ m/sec} \\
 &= \frac{\pi \times m \times 30 \times 40}{60 \times 1000} \\
 &= 0.0628 \text{ m m/sec.}
 \end{aligned}$$

here,

D_p = pitch circle diameter of the pinion in mm

m = module.

Taking value of tooth form factor, for the pinion,

$$\begin{aligned}
 Y &= 0.154 - 0.912/30 \quad [\text{from equation (iii)}] \\
 &= 0.1084.
 \end{aligned}$$

Now using the Lewis equation to pinion, we have

$$\begin{aligned}
 W_T &= f_y \cdot b \cdot P_c \cdot Y \\
 &= f_0 C_y \cdot b \cdot P_c \cdot Y \quad (\because f_y = f_0 C_y) \\
 &= f_0 C_y \cdot b \cdot \pi m \cdot Y \quad (\because P_c = \pi m)
 \end{aligned}$$

Now putting the value of f_0 , C_v , b and Y in the above equation, we get,

$$W_T = \left(120 \times \frac{3}{3 + 0.0628}\right) \times 10m \times \pi m \times Y$$

$$28 = \left(120 \times \frac{3}{3 + 0.0628}\right) \times 10m \times \pi m \times 0.1048$$

$$28 = \left(120 \times \frac{3}{3 + 0.0628}\right) \times 10 \times \pi \times 0.1084 m^2$$

$$28 = \frac{1225.35 \times m^2}{3 + 0.0628m}$$

$$\frac{28}{1225.35} = \frac{m^2}{3 + 0.0628m} \text{ or } 0.0228 = \frac{m^2}{3 + 0.0628m}$$

Using trial and error method

$$m = 0.26$$

For the proposed design module m of the pinion is taken equal to 2.

$$\begin{aligned} \text{So face width, } b &= 10m \\ &= 10 \times 2 = 20 \text{ mm} \end{aligned}$$

but as the diameter of the circular rod 25 is 25 mm so for the proposed design face width, b is taken as 30 mm

and pitch circle diameter of the pinion,

$$D_p = mT_p$$

here m is taken as 2 mm for convenient of pinion design

$$\begin{aligned} D_p &= 2 \times 30 \\ &= 60 \text{ mm} \end{aligned}$$

Thus rack width is also taken as 30 mm.

DESIGN OF LOCK PIN

A locking device has been designed with the handle for safety purpose. The reason for such safety precaution is that after pressing the padastal 7 on 20 rims downwards the padastal may move reversely due to counter force. Thus may hurt any workers who would tighten the 20 rims.

The formula used is as follows:

$$D = \sqrt{\frac{4P}{\pi \times F_s \times N}} \dots (i)$$

where,

D = Diameter of the pin

P = Shearing load carried by the pin

F_s = Allowable shear stress (depend on material)

N = Number of pins

Data given,

Diameter of the pin, d = 10 mm = 1 cm

Shearing load carried by the pin, P = 38 kg.

Allowable shearing stress = 100 kg/cm²

Number of pins = 1

Using the above formula (i), we get

$$D = \sqrt{\frac{4 \times 38}{\pi \times 100 \times 1}} = \sqrt{\frac{158}{313}} = \sqrt{0.5} = 7 \text{ mm}$$

But the existing dia is 10 mm. so dia of pin taken is correct.

APPENDIX-D

COMPUTER OUTPUT RESULT OF MODEL-1 AND MODEL-2

Computer output (Result) of MODEL-1

Summarized Report for T4						Page : 1
Number	Variable	Solution	Opportunity Cost	Objective Coefficient	Minimum Obj. Coeff.	Maximum Obj. Coeff.
1	X1	+6.0000000	0	+85.000000	- Infinity	+115.90909
2	X2	+6.0000000	0	+90.000000	- Infinity	+122.72727
3	X3	+29.760269	0	+225.00000	+165.00000	+294.46246
4	X4	+12.000000	0	+267.00000	- Infinity	+309.04041
5	X5	+76.888893	0	+140.00000	+123.16061	+ Infinity
6	X6	+20.000000	0	+523.00000	- Infinity	+651.35352
Maximized OBJ = 32174.51 Iteration = 9 Elapsed CPU second = .7089844						

Summarized Report for T4						Page : 2
Constr.	Status	RHS	Shadow Price	Slack or Surplus	Minimum RHS	Maximum RHS
1	Tight	<+10920.000	+1.3636364	0	+7329.5557	+18072.891
2	Tight	<+10920.000	+1.8989899	0	+7640.0000	+13495.040
3	Loose	<+10920.000	0	+6213.3335	+4706.6665	+ Infinity
4	Loose	<+10920.000	0	+10151.111	+768.88867	+ Infinity
5	Loose	<+10920.000	0	+2601.0505	+8318.9492	+ Infinity
6	Loose	<+10920.000	0	+7460.0000	+3460.0000	+ Infinity
7	Tight	>+6.0000000	-30.909088	0	0	+48.240524
8	Tight	>+6.0000000	-32.727272	0	0	+45.893826
9	Loose	>+8.0000000	0	+21.760269	- Infinity	+29.760269
10	Tight	>+12.000000	-42.040401	0	0	+43.899311
11	Loose	>+4.0000000	0	+72.888893	- Infinity	+76.888893
12	Tight	>+20.000000	-128.35355	0	+10.920169	+29.562683
Maximized OBJ = 32174.51 Iteration = 9 Elapsed CPU second = .7089844						

Computer output (Result) of MODEL-2

Summarized Report for iqbal10						Page : 1
Number	Variable	Solution	Opportunity Cost	Objective Coefficient	Minimum Obj. Coeff.	Maximum Obj. Coeff.
1	X1	+33.167255	0	+865.00000	-7890.0000	+4004.9214
2	X2	+23.398815	0	+1231.0000	-11179.000	+4279.0303
3	X3	+17.695265	0	+1631.0000	-14779.002	+7805.0791
4	X4	+18.058415	0	+1598.0000	-14482.001	+7409.4146
5	X5	+6.0000000	+1087.5634	+7005.0000	- Infinity	+8092.5635
6	X6	+25.057148	0	+5291.0000	+4539.8901	+ Infinity
Maximized OBJ = 289819.3 Iteration = 5 Elapsed CPU second = .7695313						

Summarized Report for iqbal10						Page : 2
Constr.	Status	RHS	Shadow Price	Slack or Surplus	Minimum RHS	Maximum RHS
1	Loose	>+56.000000	0	+67.376900	-11.376900	+ Infinity
2	Tight	<+10920.000	+27.189076	0	+9933.7832	+11907.233
3	Loose	<+10920.000	0	+1134.7825	+9785.2178	+ Infinity
4	Loose	<+10920.000	0	+7733.1426	+3186.8574	+ Infinity
5	Loose	<+10920.000	0	+10860.000	+60.000000	+ Infinity
6	Loose	<+10920.000	0	+6911.3506	+4008.6494	+ Infinity
7	Loose	<+10920.000	0	+10532.623	+387.37695	+ Infinity
8	Tight	>+56.000000	-2.6397161	0	-6404.5713	+6324.6016
9	Tight	>+56.000000	-1.9718105	0	-7628.8018	+7471.1001
10	Tight	>+56.000000	-2.7338192	0	-6269.4746	+6175.9746
11	Tight	>+56.000000	+2.6546547	0	-6176.8862	+7852.0449
12	Loose	>+56.000000	0	+13052.073	-12996.073	+ Infinity
13	Loose	>+56.000000	0	+103793.02	-103737.02	+ Infinity
Maximized OBJ = 289819.3 Iteration = 5 Elapsed CPU second = .7695313						

Computer output (Result) of MODEL-2 AFTER REDUCING AVAILABLE M/C TIME TO 1%

Summarized Report for iqbal10						Page : 1
Number	Variable	Solution	Opportunity Cost	Objective Coefficient	Minimum Obj. Coeff.	Maximum Obj. Coeff.
1	X1	+32.825645	0	+865.00000	-7890.0000	+4004.9214
2	X2	+23.157816	0	+1231.0000	-11179.000	+4279.0303
3	X3	+17.513010	0	+1631.0000	-14779.002	+7805.0791
4	X4	+17.872419	0	+1598.0000	-14482.001	+7409.4146
5	X5	+6.0000000	+1087.5634	+7005.0000	- Infinity	+8092.5635
6	X6	+24.716162	0	+5291.0000	+4539.8901	+ Infinity
Maximized OBJ = 286828.5 Iteration = 5 Elapsed CPU second = .7109375						

Summarized Report for iqbal10						Page : 2
Constr.	Status	RHS	Shadow Price	Slack or Surplus	Minimum RHS	Maximum RHS
1	Loose	>+56.000000	0	+66.085052	-10.085053	+ Infinity
2	Tight	<+10810.000	+27.189076	0	+9933.7832	+11811.536
3	Loose	<+10810.000	0	+1151.2227	+9658.7773	+ Infinity
4	Loose	<+10810.000	0	+7664.0601	+3145.9399	+ Infinity
5	Loose	<+10810.000	0	+10750.000	+60.000000	+ Infinity
6	Loose	<+10810.000	0	+6843.9048	+3966.0952	+ Infinity
7	Loose	<+10810.000	0	+10423.915	+386.08496	+ Infinity
8	Tight	>+56.000000	-2.6397161	0	-6498.1694	+5625.4194
9	Tight	>+56.000000	-1.9718105	0	-7740.1362	+6644.0405
10	Tight	>+56.000000	-2.7338192	0	-6361.1157	+5493.3696
11	Tight	>+56.000000	+2.6546547	0	-5481.6875	+7964.9912
12	Loose	>+56.000000	0	+13351.152	-13295.152	+ Infinity
13	Loose	>+56.000000	0	+102284.52	-102228.52	+ Infinity
Maximized OBJ = 286828.5 Iteration = 5 Elapsed CPU second = .7109375						

Computer output (Result) of MODEL-2 AFTER REDVCING AVAILABLE
M/C TIME TO 5%

Summarized Report for iqbal10						Page : 1
Number	Variable	Solution	Opportunity Cost	Objective Coefficient	Minimum Obj. Coeff.	Maximum Obj. Coeff.
1	X1	+31.471624	0	+865.00000	-7890.0000	+4004.9214
2	X2	+22.202583	0	+1231.0000	-11179.000	+4279.0303
3	X3	+16.790619	0	+1631.0000	-14779.002	+7805.0791
4	X4	+17.135204	0	+1558.0000	-14482.001	+7409.4146
5	X5	+6.0000000	+1087.5634	+7005.0000	- Infinity	+8092.5635
6	X6	+23.364616	0	+5291.0000	+4539.8901	+ Infinity
Maximized OBJ = 274974.1 Iteration = 5 Elapsed CPU second = .7695313						

Summarized Report for iqbal10						Page : 2
Constr.	Status	RHS	Shadow Price	Slack or Surplus	Minimum RHS	Maximum RHS
1	Loose	>+56.000000	0	+60.964649	-4.9646492	+ Infinity
2	Tight	<+10374.000	+27.189076	0	+9933.7832	+11432.227
3	Loose	<+10374.000	0	+1216.3860	+9157.6143	+ Infinity
4	Loose	<+10374.000	0	+7390.2456	+2983.7544	+ Infinity
5	Loose	<+10374.000	0	+10314.000	+60.000000	+ Infinity
6	Loose	<+10374.000	0	+6576.5737	+3797.4263	+ Infinity
7	Loose	<+10374.000	0	+9993.0352	+380.96484	+ Infinity
8	Tight	>+56.000000	-2.6397161	0	-6869.1592	+2854.1104
9	Tight	>+56.000000	-1.9718105	0	-8181.4258	+3365.8718
10	Tight	>+56.000000	-2.7338192	0	-6724.3477	+2787.7678
11	Tight	>+56.000000	+2.6546547	0	-2726.1682	+6919.4043
12	Loose	>+56.000000	0	+14536.597	-14480.597	+ Infinity
13	Loose	>+56.000000	0	+96305.422	-96249.422	+ Infinity
Maximized OBJ = 274974.1 Iteration = 5 Elapsed CPU second = .7695313						

Computer output (Result) of MODEL-2 AFTER REDUCING AVAILABLE

M/C TIME TO 8%

Summarized Report for idbal10						Page : 1
Number	Variable	Solution	Opportunity Cost	Objective Coefficient	Minimum Obj. Coeff.	Maximum Obj. Coeff.
1	X1	+30.453005	0	+865.00000	-7890.0000	+4004.9214
2	X2	+21.483969	0	+1231.0000	-11179.000	+4279.0303
3	X3	+16.247170	0	+1631.0000	-14779.002	+7805.0791
4	X4	+16.580601	0	+1598.0000	-14482.001	+7409.4146
5	X5	+6.0000000	+1087.5634	+7005.0000	- Infinity	+8092.5635
6	X6	+22.347858	0	+5291.0000	+4539.8901	+ Infinity
Maximized OBJ = 266056.1 Iteration = 5 Elapsed CPU second = .7734375						

Summarized Report for idbal10						Page : 2
Constr.	Status	RHS	Shadow Price	Slack or Surplus	Minimum RHS	Maximum RHS
1	Loose	>+56.000000	0	+57.112602	-1.1126022	+ Infinity
2	Tight	<+10046.000	+27.189076	0	+9933.7832	+11146.874
3	Loose	<+10046.000	0	+1265.4080	+8790.5918	+ Infinity
4	Loose	<+10046.000	0	+7184.2568	+2861.7432	+ Infinity
5	Loose	<+10046.000	0	+9986.0000	+60.000000	+ Infinity
6	Loose	<+10046.000	0	+6375.4629	+3670.5371	+ Infinity
7	Loose	<+10046.000	0	+9668.8877	+377.11230	+ Infinity
8	Tight	>+56.000000	-2.6397161	0	-7148.2520	+769.27356
9	Tight	>+56.000000	-1.9718105	0	-8513.4043	+899.72803
10	Tight	>+56.000000	-2.7338192	0	-6997.6045	+752.36206
11	Tight	>+56.000000	+2.6546547	0	-653.20966	+5705.3008
12	Loose	>+56.000000	0	+15428.398	-15372.398	+ Infinity
13	Loose	>+56.000000	0	+91807.391	-91751.391	+ Infinity
Maximized OBJ = 266056.1 Iteration = 5 Elapsed CPU second = .7734375						

