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INVESTIGATION OF THE EFFECT OF CUTTING SPEED ON CHIP-TOOL CONTACT PROCESS AND TOOL WEAR FOR STEEL OF UNKNOWN COMPOSITION.

A PROJECT

By

Md. Abu Hanifa
B.Sc.Engg.(Mech.)

Submitted to the Department of Industrial and Production Engineering in partial fulfilment of the requirements for the degree of

MASTER OF ENGINEERING (IP)

1987

Department of Industrial and Production Engineering,
Bangladesh University of Engineering and Technilogy,
Dhaka

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লাইব্রেরী, ঢাকা

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DEPARTMENT OF INDUSTRIAL AND PRODUCTION ENGINEERING

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

DHAKA, BANGLADESH

#69068#

DECLARATION

I hereby declare that this thesis work was recently performed by me and has been submitted nowhere for award of any Degree or Diploma.

Supervisor

Candidate

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ABSTRACT

Cutting Speed is one of the most important factor on which Tool Wear depends. In Metal cutting operation there exists an optimum speed at which the Tool Wear is minimum. This optimum Cutting Speed maintains a definite relationship with the critical Cutting Speed from which Tool Wear starts increasing abruptly. Critical Cutting Speed can be identified amongst other methods by observing the Chip-Tool Contact Process and Chip surface finish. It is found that the critical cutting speed appears during the transition from contact process with built-up edge to contact process without built-up edge. It has been established in the present work that for single carbide tool material optimum cutting speed in machining steel of unknown composition and under any condition of cut is just below the critical cutting speed.

NOMENCLATURE

V	-	Cutting Speed
V_{op}	-	Optimum Cutting Speed
V_c	-	Critical Cutting Speed
t	-	Depth of Cut
S	-	Feed
K	-	Coefficient of Chip-Shrinkage
L	-	Length of Cut
h_f	-	Flank Wear
h_{f_o}	-	Initial Flank Wear
h_{f_1}	-	Final Flank Wear
BUE	-	Built-up-edge
BSW	-	British Standard Whitworth
NM	-	Machine RPM
N	-	Actual RPM
σ	-	Tensile stress

বাংলাদেশ প্রকৌশল বিশ্ববিদ্যালয়
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CHAPTER - 1

INTRODUCTION AND LITERATURE SURVEY

1.1. Introduction:

It has been well recognised that successful transfer of technical knowledge is essential in order to utilize the modern technology properly. Otherwise the local engineering products will not be comparable to that of the foreign products. Thus, the present study has been made with a view to enrich the technical knowledge in the field of metal cutting.

Metal cutting principles ad pted by the Machine Building Industry including different Engineering Workshops are based on mere experience due to lack of proper technical knowledge. This industry and Workshops are playing a key role to the national development and the improvement of their status is the precondition of the Socio-economic development of the country. In this industry and workshops, apart from Cast iron, steel is the most widely used material in the production of different engineering products. But the steel is available in the local market , mainly in the form of scraps, the composition of which are quite unknown before making any metallurgical test on it. Sorting of this steel as per different test results is not feasible due to the small size of the lot consumed by the end users and infact it is rarely practised. Thus it has become necessary and it has of practical importance to determine the optimum cutting conditions of such a steel material, whose composition and physico-mechanical properties are not known.

People in such a industry, namely, foremen, technicians and even a good proportion of the engineers usually use thumb-rules to determine the value of optimum cutting speed in machining operation. In most of the cases this value is far away from the optimum cutting speed. This optimum speed is to be identified from Tool Wear consideration. Tool Wear varies mainly with cutting speed due to the formation of different Chip-tool Contact Process dueing machining operations. Therefore in the present work efforts were given to identify the optimum Cutting Speed of steel of unknown composition from the consideration of Chip-tool Contact Process and Tool Wear.

1.2 Literature Survey:

Although metal cutting operations were started from the earliest stone age but upto seventeenth century there has not been any development except in the concept of three basic angles[1] - the rake angle, the clearance angle and the setting angle.

The first research period on mechanics of chip formation extended approximately from 1850 to 1900. Cocquilhat in 1851, Wiebe in 1958, Timme in 1870 and Tresca in 1873[2] worked in this field contributing on determination of cutting forces and power. Lastly Tresca proposed a different concept of chip formation describing the mechanism as a process of compression. Subsequently, it was proved that the compression process differs from the ordinary compression but Kuznetsev and Krivoukhov[3], showed that the principal laws of ordinary compression were valid for contrained compression as well and that the chip-forming process was actually the process of plaste-elastic deformation of the layer of metal being removed.

Mallock[4] made a microstructural study of polished and etched chips and vividly described the process of chip formation which is identical with the current "sliding deck of cards" analogy[1].

At the end of eighteenth century Zvorikin and Hermann[5] made an analysis on metal machining and derived a relationship comprising shear angle, rake angle and friction angle at the chip-tool interface. These relationship, with slight modifications, have remained unchanged to the present time.

Taylor[6], was probably the first person to study the speed-life relationships, including the tool shape and size of cut in 1907.

Herbert[7] and Rosenhain and Sturney[8] in around 1920 were the first user of the term "machinability" which referred specifically to the speed-life relationship and not to criteria like surface finish, chip disposal etc. However the presence of the tool-chip interface temperature was considered at this period.

Ernst and Martellott[9] in 1935 confirmed the role of built-up edge in metal cutting and described its effect on tool temperature and on surface finish. Again Ernst[10] in 1938 and Ernst and Merchant[11] in 1940 interrelated the effect of tool geometry, tool temperature, chip formation, cutting fluid and surface finish.

Merchant, Ernst and Krabacher[12] in 1952 presented a scientific method of tool life testing, specially for cemented carbide tool. Laladze[13], in 1958 presented the role of tool wear for optimization in metal cutting process.

Bekes[14] in 1967 developed a method of calculating the optimum cutting conditions, Basu[15] in the same year modified this method by developing a new approach for chosing optimum cutting variables.

Cutting speed is the most dominant factor of the cutting variables which determines the nature of chip-tool contact process and also the process of tool wear.

Talantov[16] in 1969 established that tool wear is a function of chip-tool contact process and minimum tool wear is observed in a definite range of cutting speed which is just below the critical speed for a single carbide tool. The same authors determined experimentally the dependence of tool wear on cutting speed. It was also established that this critical cutting speeds can be shifted to highter values[17] for steel alloyed with calcium.

Sankar[18] in 1984 experimentally determined the optimum cutting conditions for low alloywd steel. In determining the critical cutting speed the co-efficient of chip-shinkage of Nickel-chromium steel of known composition was measured and found the required speed at the maximum value of the coefficient of chip-shrinkage.

The present work attempts to identify the critical cutting speed for a steel of unknown composition from the study of the chip-tool contact process.

1.3. General Theory:

It is of immense practical importance to know the exact dependence of chip-tool contact process and Tool-wear on cutting speed. Large number of research works have been carried out in the "Volgograd Polytechnic Institute", USSR[19], to establish the exact dependence of these interrelated factors. According to the results the relationship between chip-shrinkage coefficient, K Vs. V(cutting speed) and Tool wear (flank), h_f Vs. V, can be represented graphically in figures 1 and 2 respectively. From Figure 2 it is seen that variation of tool wear with respect to cutting speed in the range upto V_c is somewhat complex in nature. This is due to the change in chip-tool contact process as a result of the formation of difference types of built-up edge (BUE) on the face of the tool adjacent to the cutting edge. The BUE is wedge shaped and consists of a part of the metal being machined. Different types of chip-tool contact process is identified from the size and nature of this BUE (Figure 3). At low cutting speed there is no BUE because of a discontinuous chip is produced and the cutting temperature is low. As the cutting speed increases the chip changes from the discontinuous type to the partially continuous and continuous types, and BUE is formed. Upto a certain range of cutting speed this BUE extends only within the (rake) face of the tool. Breaking tendency of BUE in this range causes increase in the face wear which affects the cutting

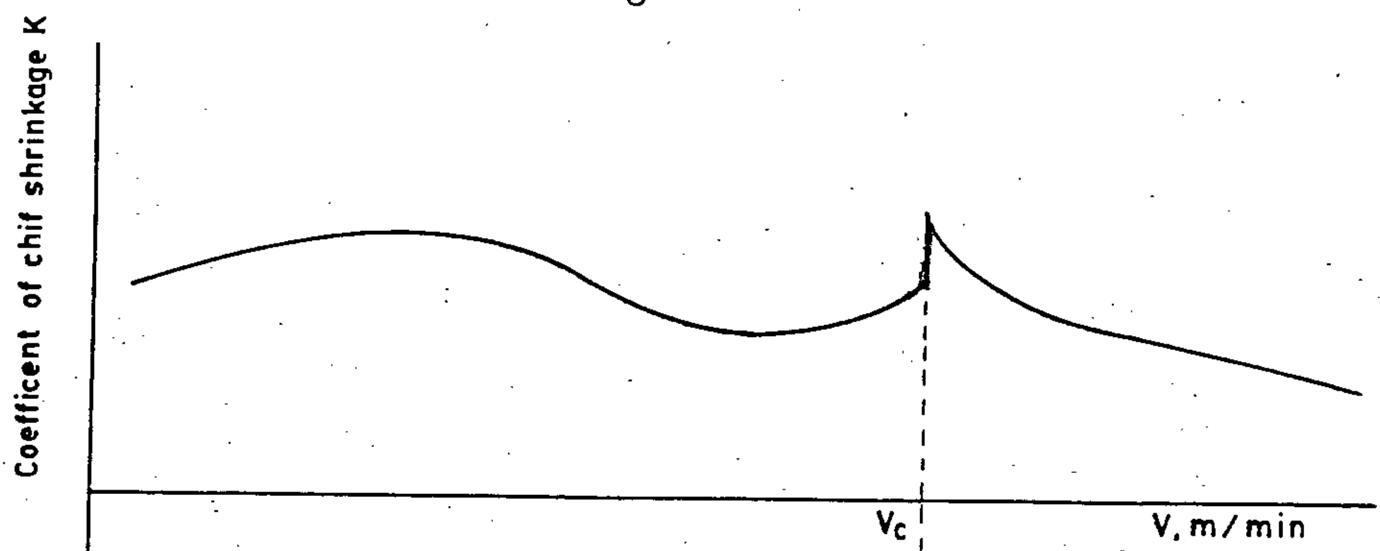

Figure-1 Typical curve K Vs. V

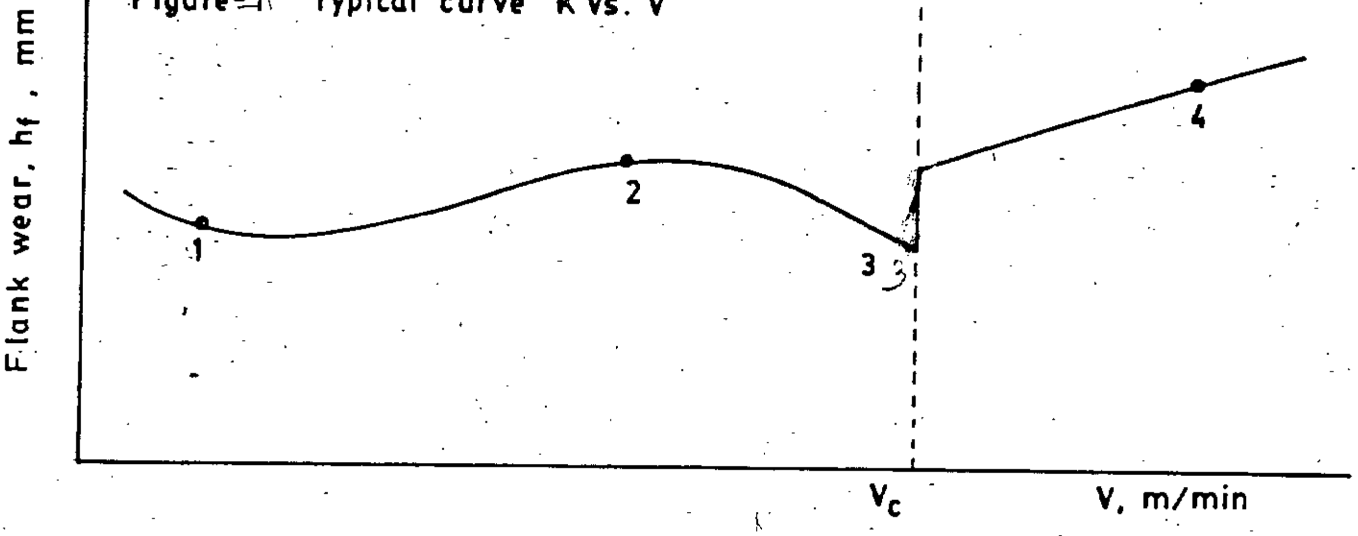

Figure-2 Typical curve, hf Vs. V

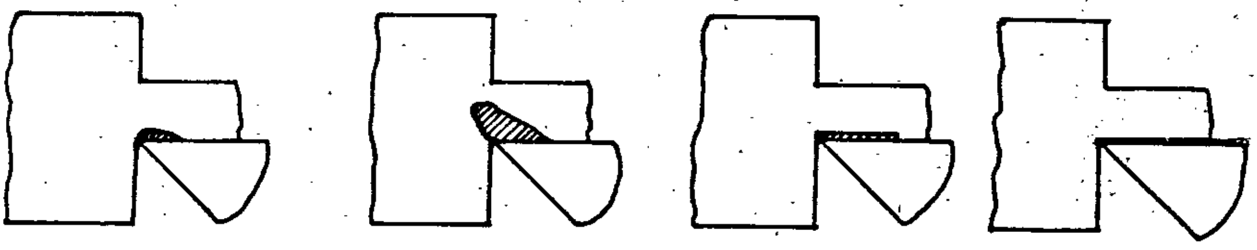

Figure-3 Typical view of BUE

process to a smaller degree and cannot be taken as optimum wear. BUE in this range is called BUE of Type-A (Figure-3a). After this range BUE extends beyond the rake surface and overhanges the tool. In case of its fracture the entire material of the hardened BUE is dragged along the flank surface of the tool causing intensive wear of the tool flank. It is well-known that flank wear affects the accuracy of cutting process and for this reason it is taken as the limiting criteria of Tool wear. BUE in this range is called BUE of Type-B (Figure-3b). It is important to note that BUE of Type-B and specially its instability increases the flank wear whereas BUE of Type-A saves the tool from flank wear. However, further increase in cutting speed causes rise in temperature, consequently BUE is softened and its size is reduced to a thin layer called BUE of Type-C (Figure-3c). It is unstable in nature and sometimes called "Pulsation Contact Process". "Tool Wear is always minimum at this range. Beyond this range the BUE disappears completely, a continuous contact of chip and tool is observed causing abruptly increase in tool wear. Figure-2 & 3 d illustrate this phenomenon. This transition from contact process with BUE to contact process without BUE occurs at a definite cutting speed (point V_c of Figure-1 & 2) which is known as critical cutting speed, V_c. It has been established by Talantov[16] that for a single carbide tool material the optimum cutting speed (cutting speed corresponding to minimum tool-wear) is usually just below the critical cutting speed, V_c.

One method of determining V_c is from the study of chip shrinkage coefficient, K[18]. Figure-1[19] shows the variation of 'K' with respect to cutting speed. Critical cutting speed 'V_c' is observed to be the point where 'K' becomes maximum. However this is an indirect method for estimating 'V_c' which is not reliable for all the time as it is seen in some cases that 'K' is increasing even after 'V_c'. For exact estimation of 'V_c' study of chip-tool contact process is one of the most reliable methods. The main problem of this study is the instant "freezing" of the cutting process and collection of chip-tool contact region, for which special experimental set up is required.

Sen and Bhattacharyya[20] in 1965 suggested different methods for this purpose. But details of design and fabrication of an apparatus as well as the systematic procedure of studying the chip tool contact process for a material of unknown composition is very rare. So the present work attempted to design and fabricate a simple and less expensive apparatus for this purpose, which is known as Dropping Tool Apparatus.

1.4 Aims and Objectives:

i) To design and fabricate the Dropping Tool Apparatus for the study of Chip-tool contact process.

ii) To determine the optimum cutting speed of a material (Steel of unknown composition) for which the tool-wear is minimum.

CHAPTER - 2

DESIGN AND FABRICATION

OF

DROPPING TOOL APPARATUS

2.1 Dropping Tool Apparatus:

Design of Dropping Tool Apparatus mainly depends on the type and size of the machine on which it is to be used. In this study the apparatus was designed for a lathe machine*, having a square turret. Tool fixing space (x,y,z) in the turret and the distance from the base of the turret to the center line of the lathe(s) as shon in Figure 4 were the main criteria which determined the dimensions of different parts of the apparatus.

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* Lathe machine of size 4½ feet bed length and maximum machinable job diameter 150 mm.

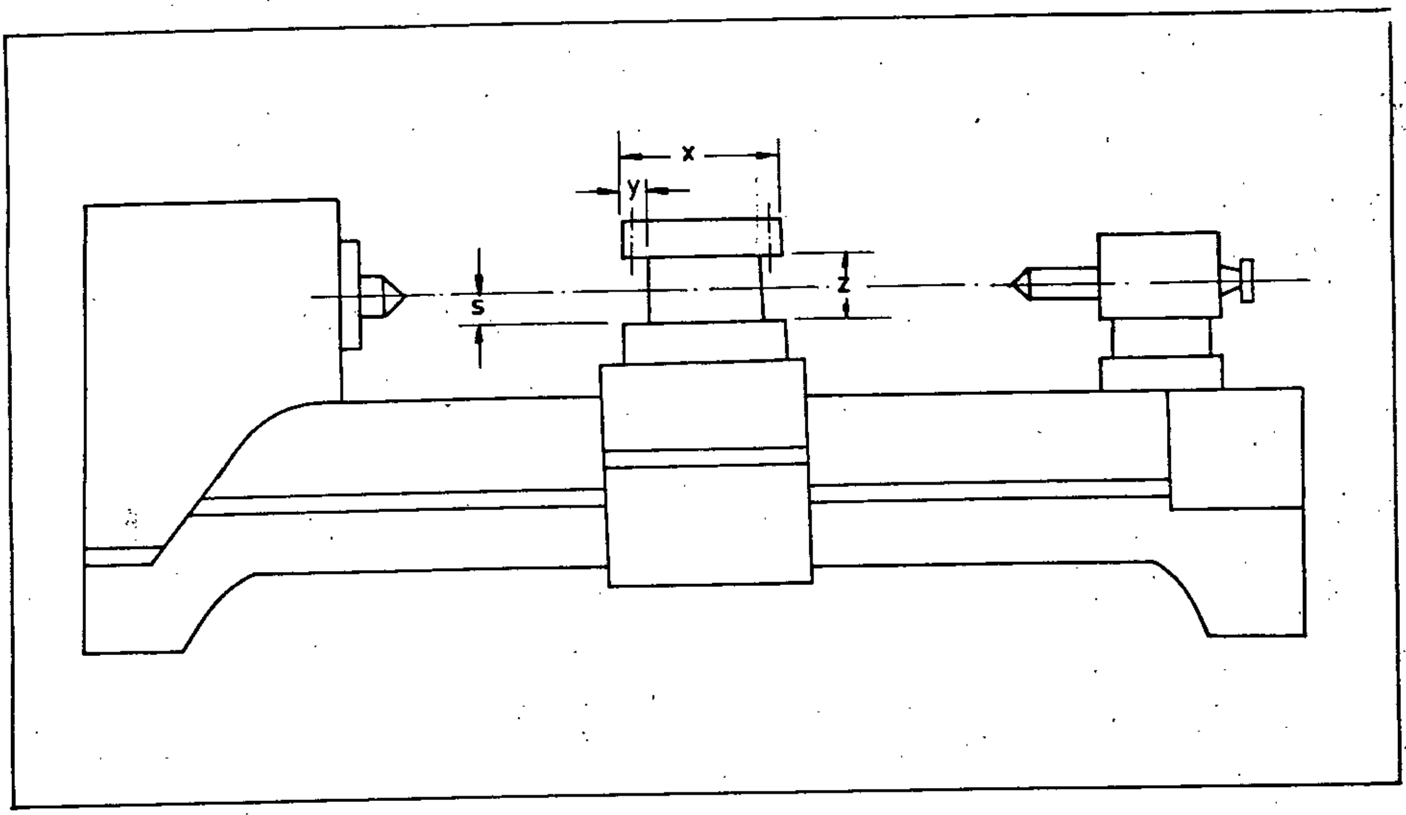


Figure - 4 Sketch of lathe

Figure -5. Shows the different parts of Dropping Tool Apparatus.

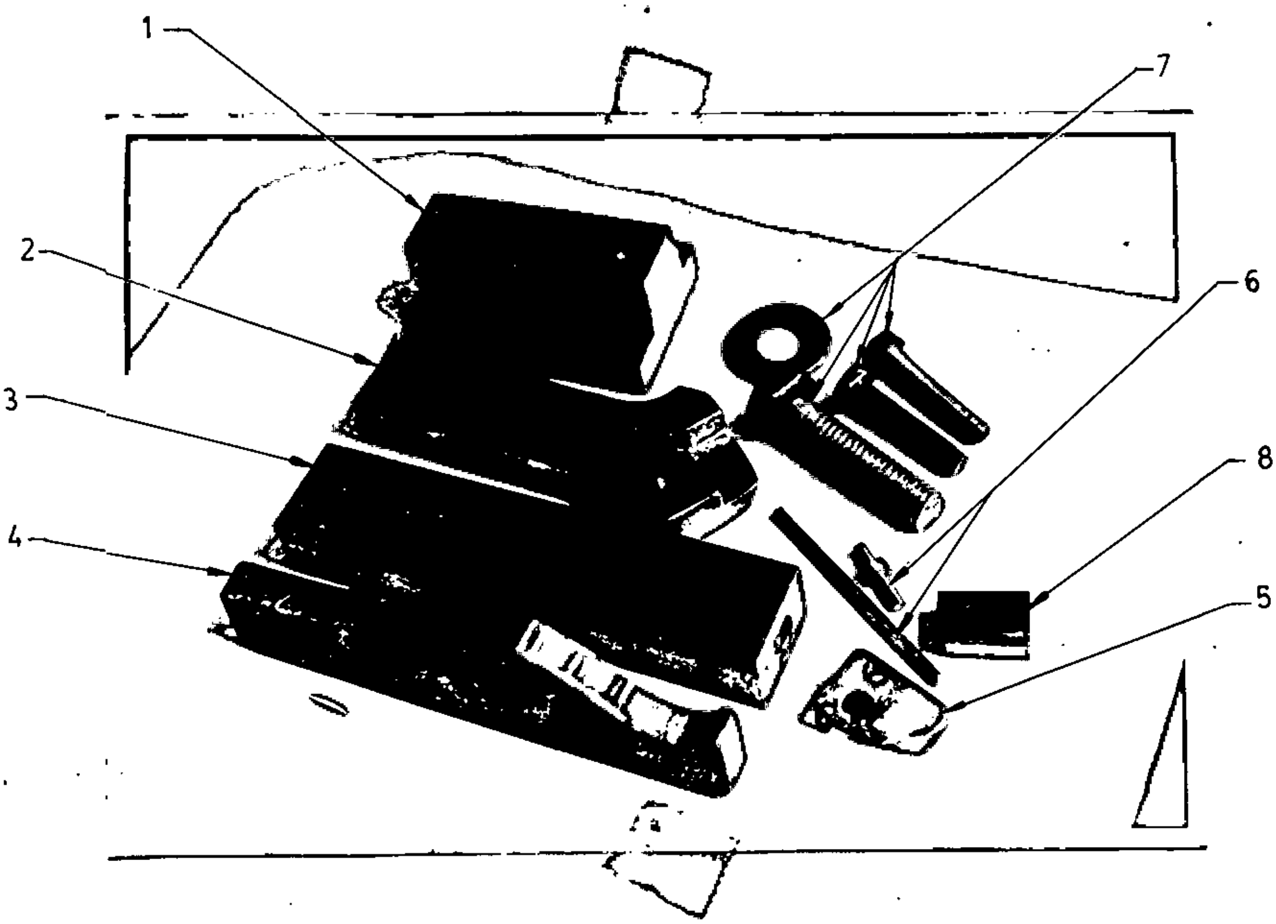


Figure -5.

Different parts of Dropping Tool Apparatus

1. Fixture Body	5.Clamping Plate
2.Tool bit holder	6. Pins
3.Dropper Plate holder	7. Standard Fasteners
4.Dropper plate	8. Tool bit

Figure-6. Shows the Dropping Tool Apparatus in sub-assembled condition, ready for mounting on the square turret of the lathe machine.

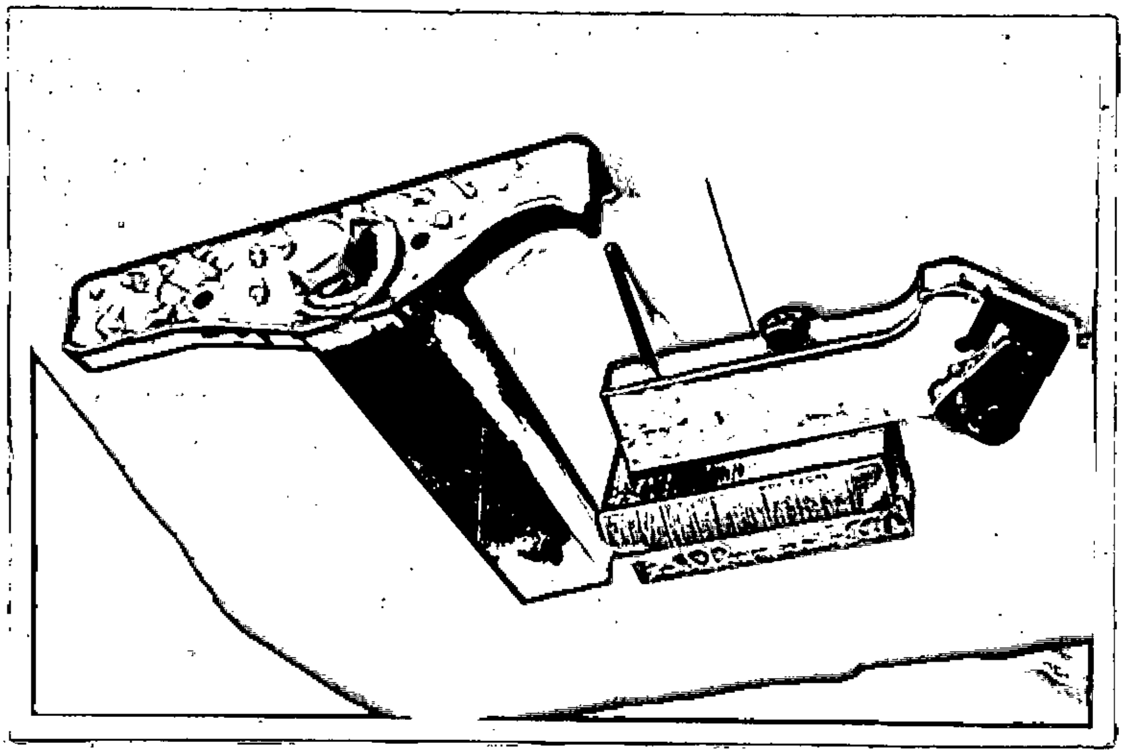


Figure-6

Sub-Assemblies of the Dropping Tool Apparatus.

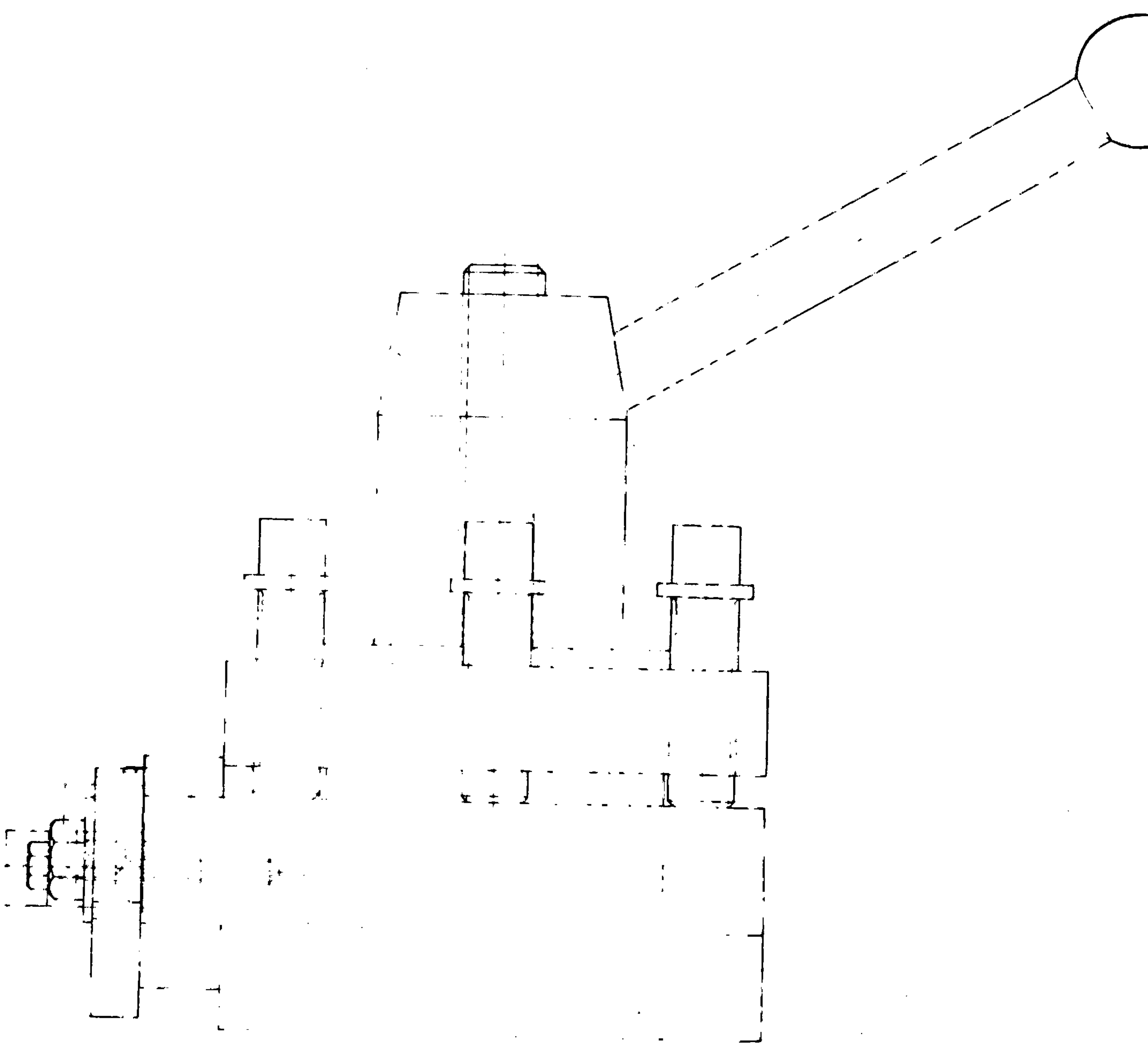
2.2. Details of Fabrication:

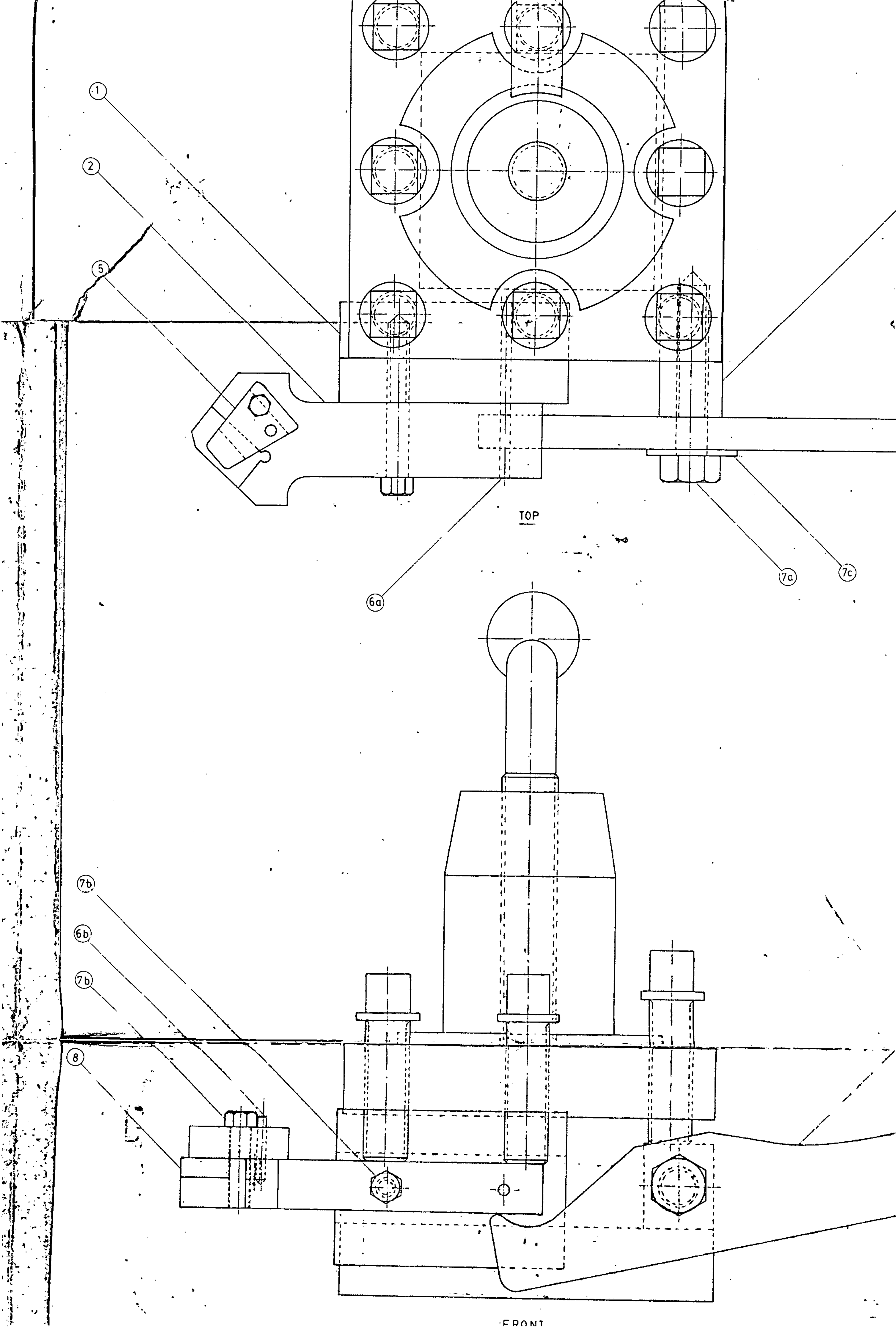
Figure-7 shows the assembly drawing of the apparatus fitted in the lathe-turret.

BILL OF MATERIALS

Parts identification no.	Name of the parts	Materials	Quantity
1	Fixture body	Medium carbon steel	1
2	Tool bit holder	,,	1
3	Dropper plate holder	,,	1
4	Dropper plate	,,	1
5	Clamping plate	,,	1
6a	Pin	Cast iron	4
6b	Pin	Steel	1
7a	Bolt	Medium carbon steel	1
7b	Bolt	,,	2
7c	Washer	,,	1
8	Tool bit	Single carbide (92% Wc 8% Co)	4

FIGURE – 7 ASSEMBLY DRAWING OF DROPPING TOOL APPARATUS FITTED IN THE LATHE-TURRET




1
2
5
6a
7a
7c
TOP
7b
6b
7b
8
FRONT

In order to make fabrication work easy detailed drawing as well as master operation sheet for each of these parts are shown in figures 8 to 15.

Part No. 1

Material - Medium Carbon Steel

Scale- Full Size

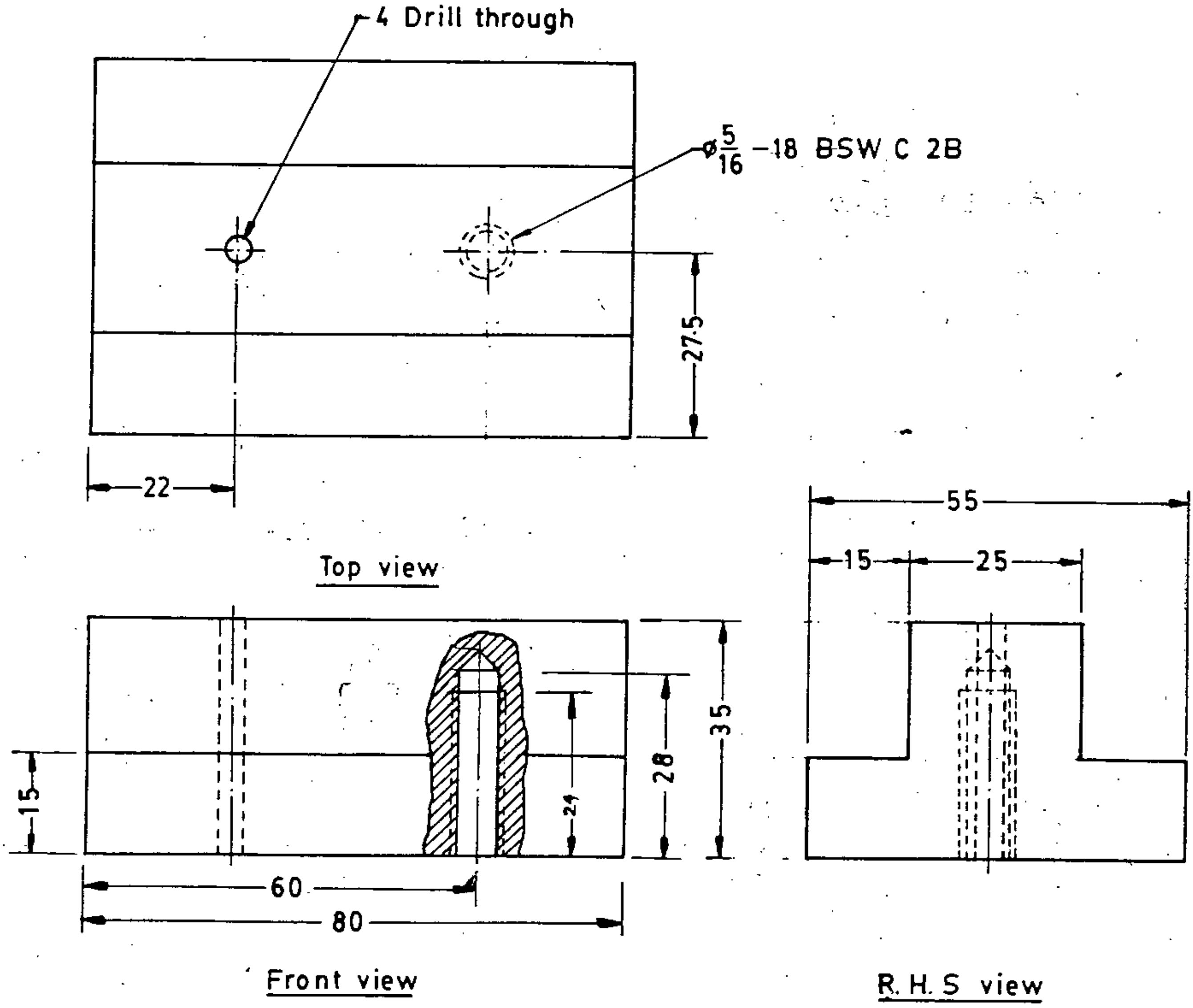
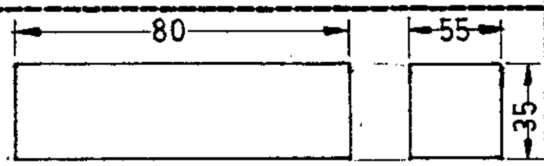
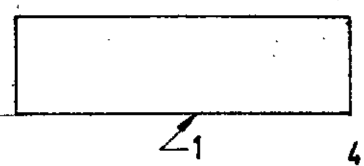
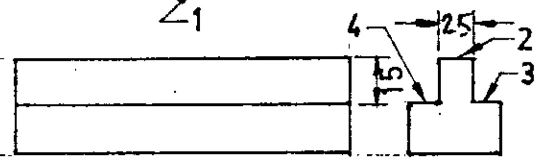
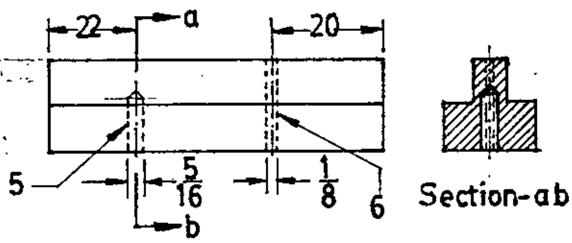


Figure- 8

Detail drawing of Fixture body

Master Operation Sheet :

Operation No.	Description	Sketches	Machine, Fixture, Tools & Gauges
1	Cutting off the blank		Power saw Machine vise, scale.
2	Machining face 1		Shaper, Machine vise.
3.	Machining faces 2 3 and 4		Shaper Machine vise scale, center punch, hammer
4	Drilling holes 5 & 6		Drill machine Drill bit Machine vise center punch hammer.
5	Cutting of thread in hole 5		Thread Cutter vise
6	Cleaning and chamfering		Brush and files.

Part No.2

Material-Medium Carbon Steel

Scale - Full Size

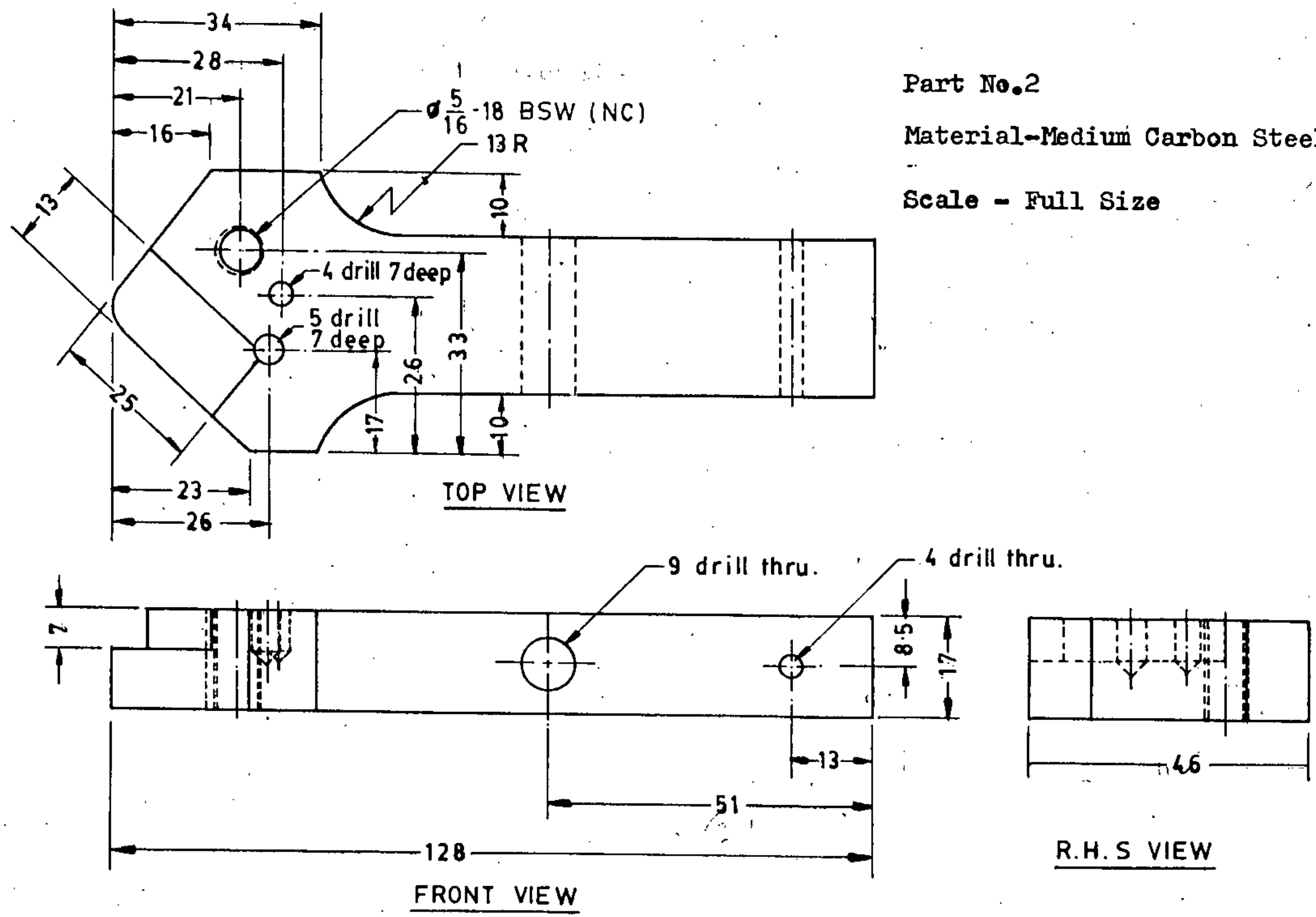
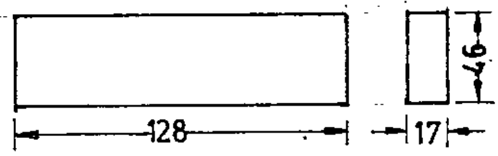
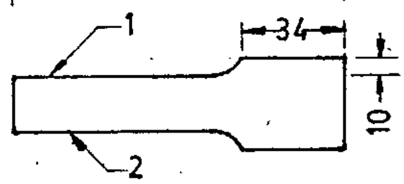
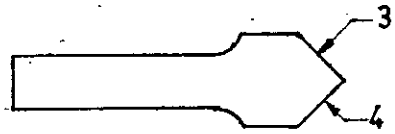
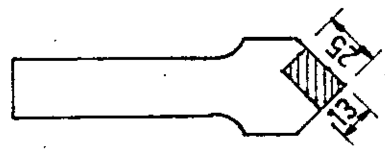
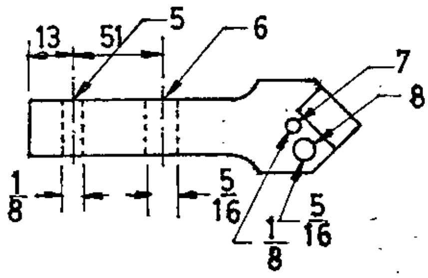


Figure - 9

Detail drawing of Tool bit holder

Master of Operation Sheet :

Operation No.	Description	Sketches	Machine Fixture Tools and Gauges
1	Cutting off the blank		Power saw Machine vise scale
2	Machining faces 1 and 2		Shaper Machine vise, Center punch hammer, scale.
3	Machining faces 3 and 4		Do
4	Milling for tool housing		Milling machine machine vise scale.
5	Drilling holes 5 6 7 and 8		Drill machine Drill bit Machine vise center punch hammer scale
6	Cutting of Thread in hole 8		Thread cutter vise.
7	Cleaning and Chamfering		Brush and Files.

Part No.3

Material-Medium Carbon Steel

Scale - Full Size

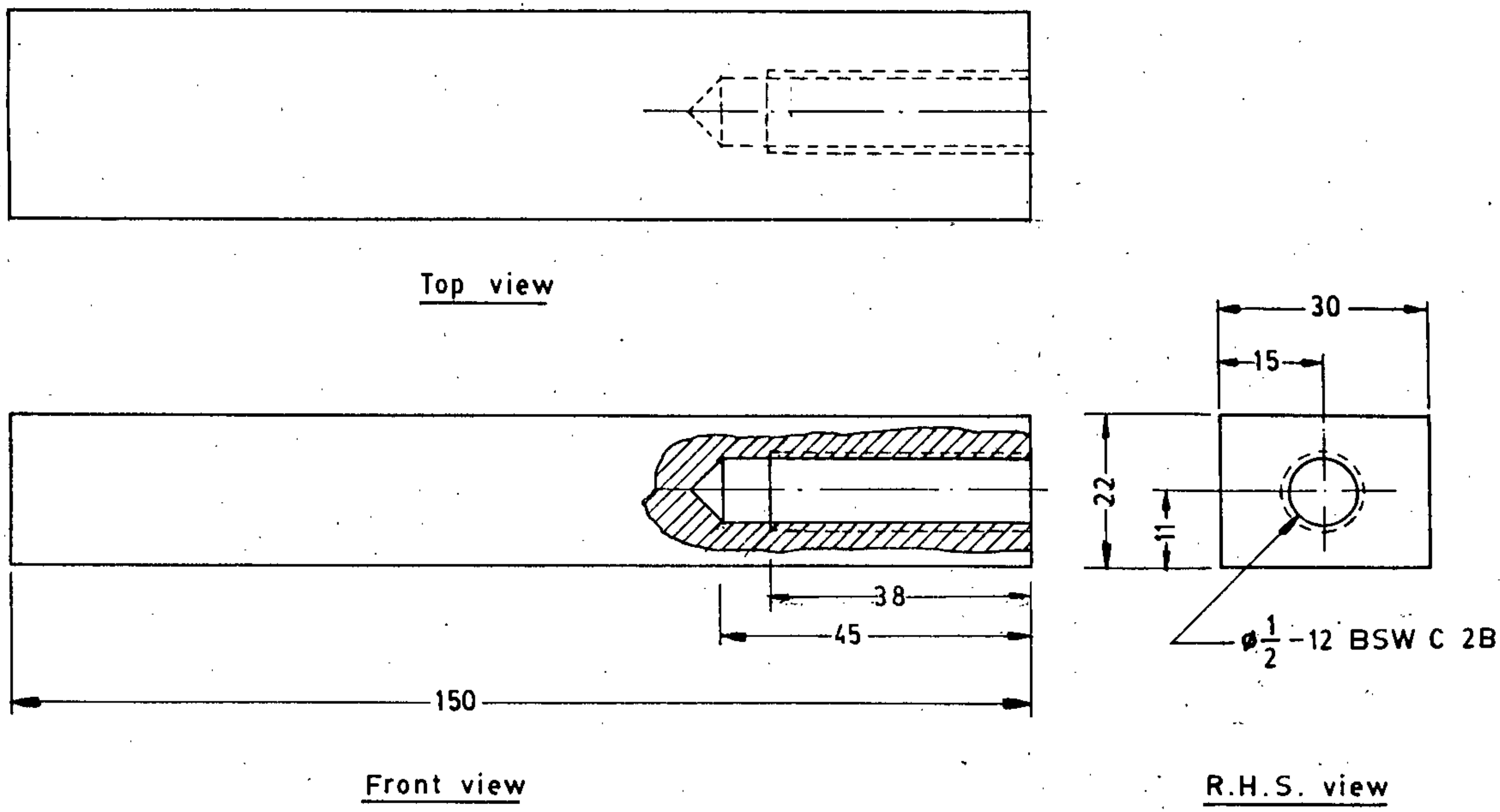
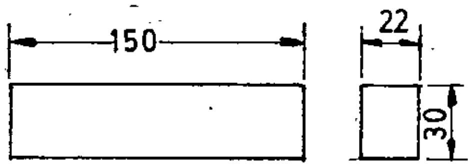
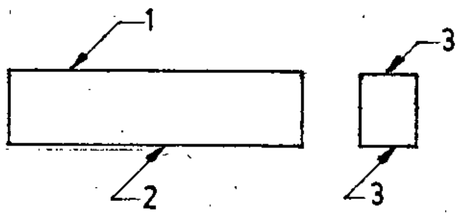
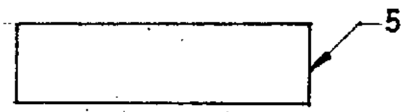
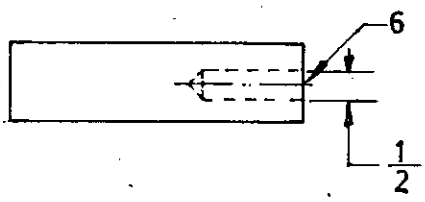


Figure - 10

Detail drawing of Dropper Plate holder

Master Operation Sheet :

Operation No.	Description	Sketches	Machine Fixture Tools and Gauges
1	Cutting off the blank		Power saw Machine vise Scale
2	Machining faces 1 2 3 & 4		Shaper Machine vise.
3	Facing face 5		Lathe Facing tool
4	Drilling hole 6		Drill machine Drill bit Machine vise
5	Cutting of Thread in hole 6		Thread Cutter Vise
6	Cleaning and Chamfering		Brush, [illegible]

4. **Dropper Plate:**

Shape and size of the dropper plate are to be considered by fitting the fixture body, Tool bit holder & Dropper plate holder in their respective places.

Part No.4
Material-Medium Carbon Steel
Scale-Full Size

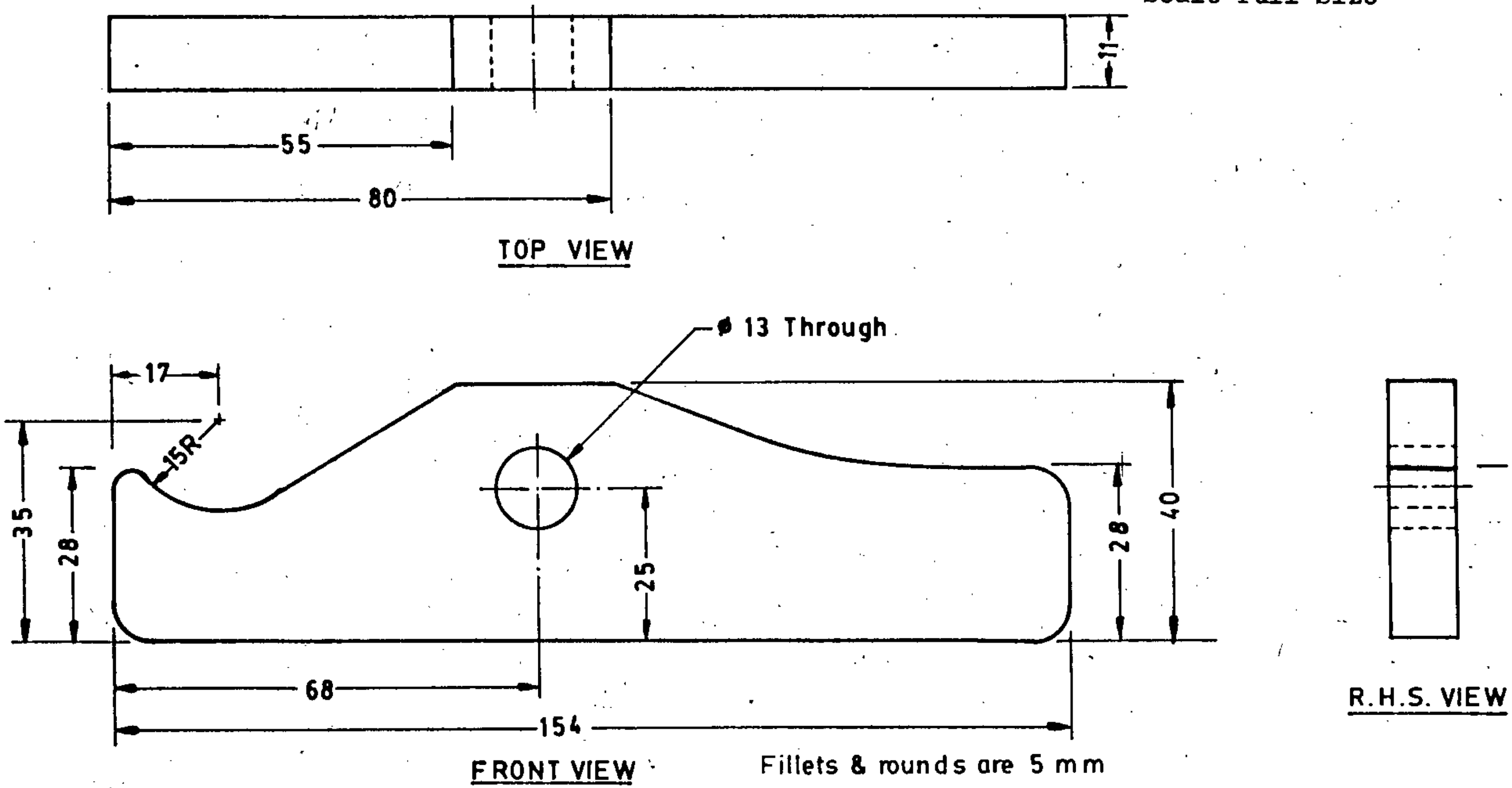
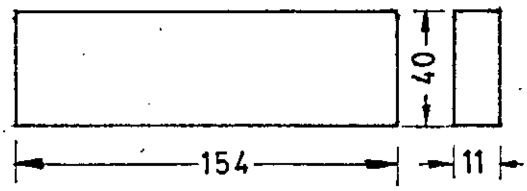
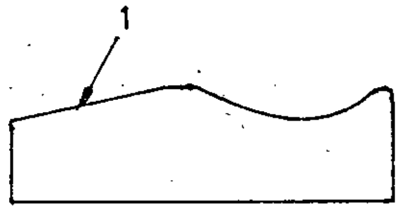
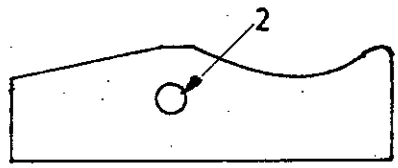


Figure-11
Detail drawing of Dropper plate

Master Operation Sheet:

Operation No.	Description	Sketches	Machine, Fixture, Tools and Gauges
1	Cutting off the blank		Band saw Machine vise scale
2	Machining face 1 to the required shape		Shaper or Milling Machine vise Center punch hammer, scale Grinding machine
3	Drilling hole 2		Drilling machine Drill bit Machine vise Center punch hammer
4	Cleaning and Chamfering		Brush and Files

5 Clamping Plate :

Its shape and size are also to be considered by setting the Tool bit in its proper place on the tool bit holder.

Part No. 5
Material-Medium Carbon Steel
Scale-Full Size

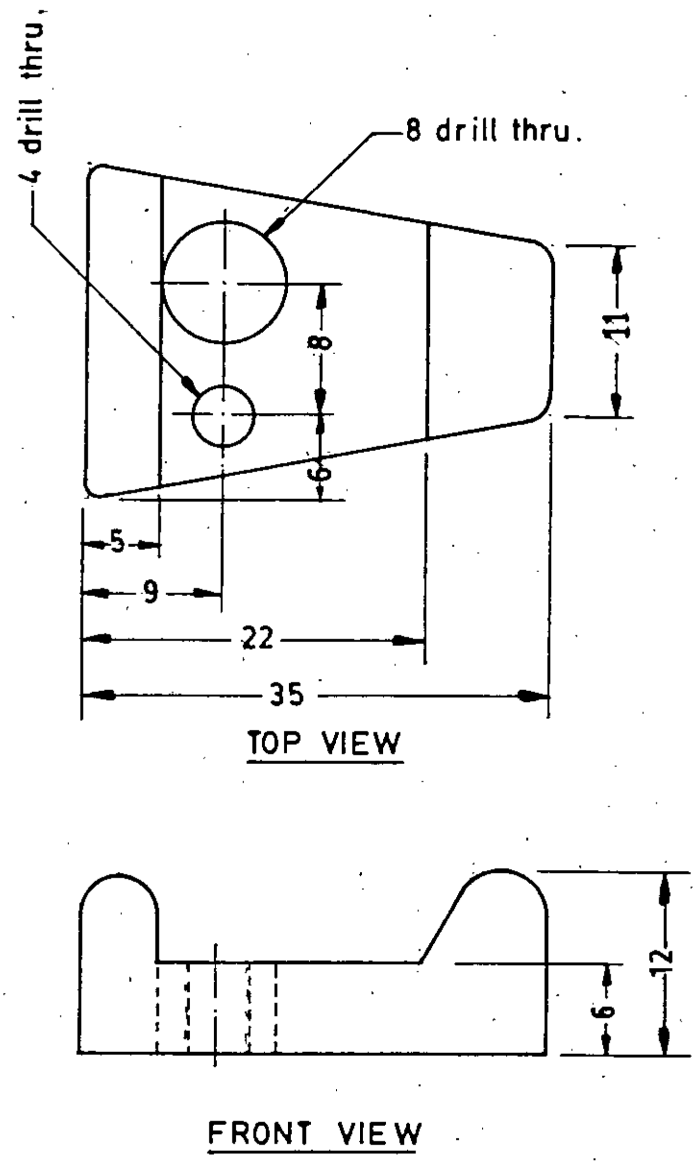
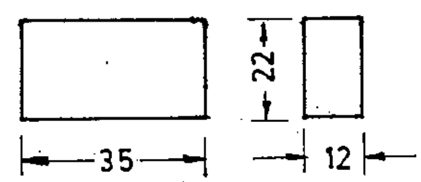
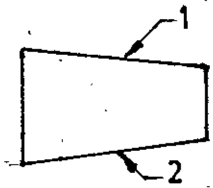
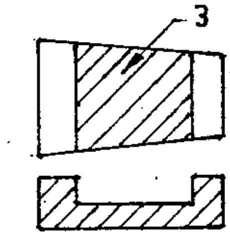
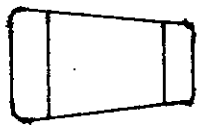
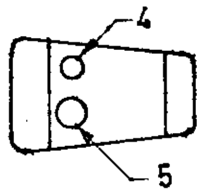


Figure-12

Detail drawing of Clamping Plate

Master Operation Sheet:

Operation No.	Description	Sketches	Machine Fixture Tools and Gauges
1	Cutting off the blank		Band saw Machine vise Scale
2	Machining faces 1 & 2		Shaper, Machine vise scale Center punch hammer
3	Machining surface 3		Do
4	Grinding all the corners		Grinding machine
5	Drilling holes 4 & 5		Drilling machine Drill bits Machine vise Center punch Hammer
6	Cleaning and Chamfering		Brush and Files.

Detail drawing
and
Master Operation Sheet :

Part No.6
Scale- Full Size

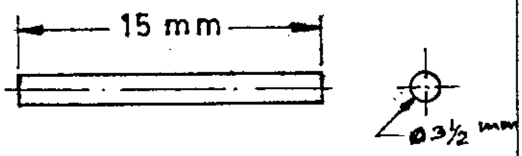
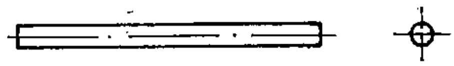
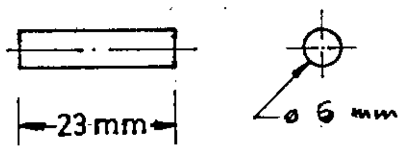
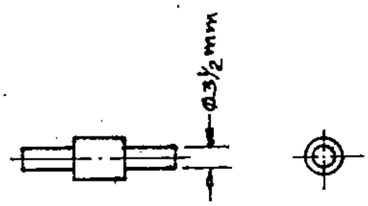
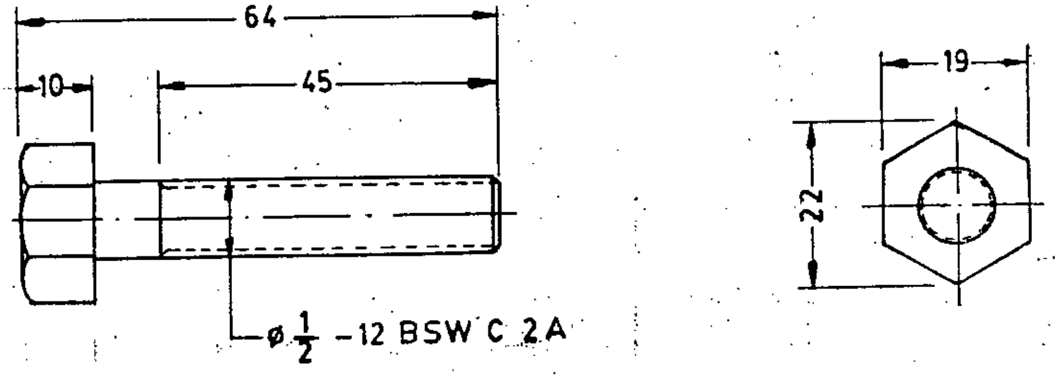
Operation No.	Description	Sketches	Machine Fixture Tools & Gauges
a) Cast Iron Pin			
1	Parting of the rod		Engine Lathe, Lathe tool
2	Turning to the desired diameter		Engine Lathe Tool Calliperse
b) Steel Pin			
1	Parting off the rod		Engine lathe Lathe tool
2	Turning to the desired shape and size		Engine Lathe Lathe Tool Calliperse

Figure-13

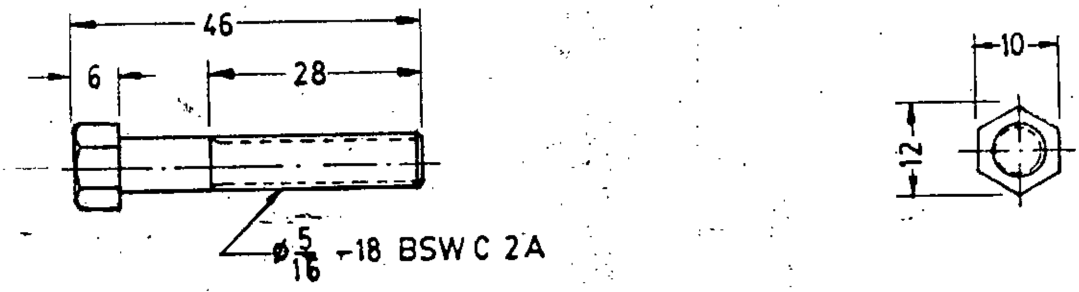
Part No.7

Material-Medium Carbon Steel

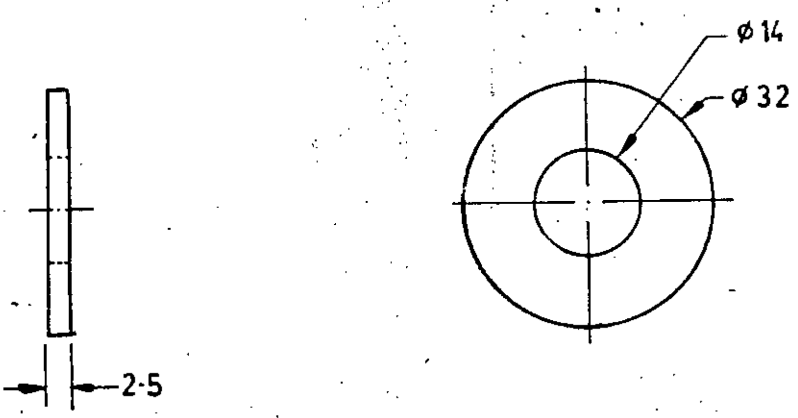
Scale- Full Size



(a)



(b)



(c)

Figure- 14

Detail drawing of Standard Fasteners

Part No.8

Material- Single Carbide BK 8 (USSR)
(92% WC,8% Co)

Scale- Full Size

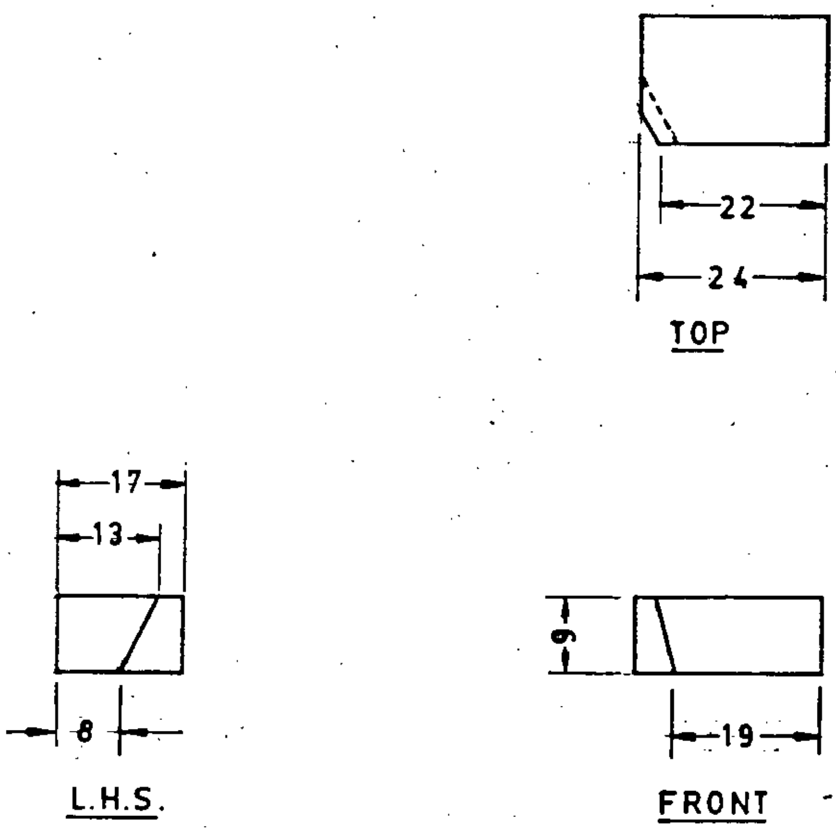


Figure-15

Detail drawing of Tool bit

Figure - 16 Shows the Dropping Tool Apparatus fitted in the turret of the lathe during cutting operation.

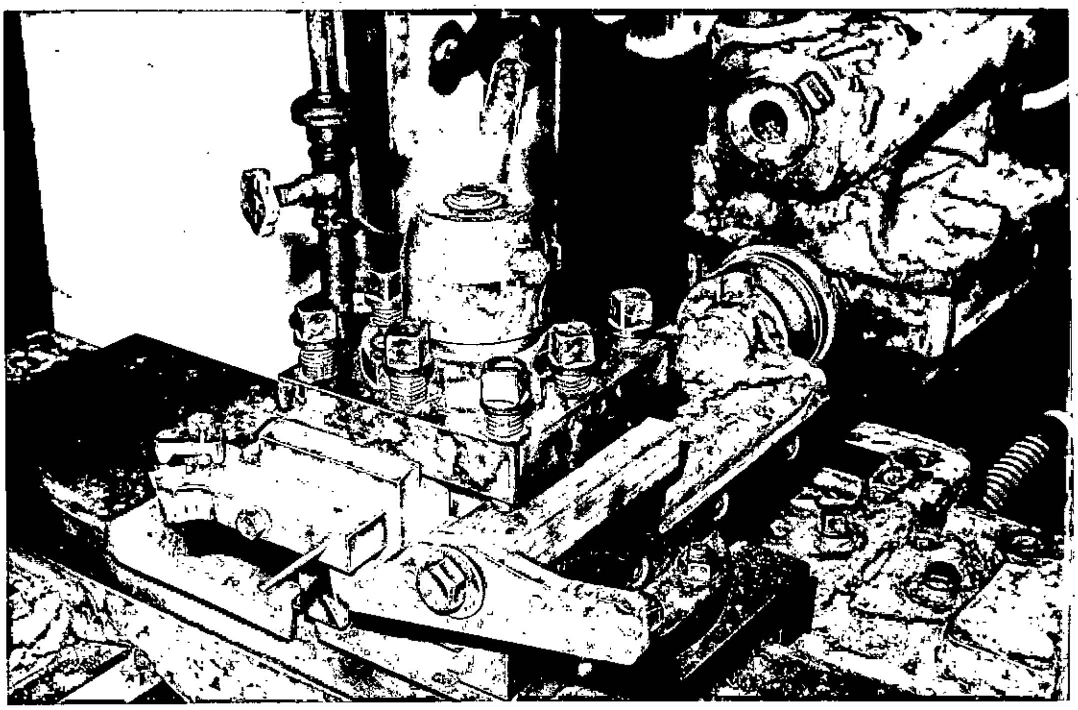


Figure - 16

Dropping Tool Apparatus fitted in the turret of the lathe during cutting operation.

Tool bit is mechanically clamped in its position of Tool bit holder by the clamping plate fixed with the steel pin and standard 5/16" BSW bolt. Then the tool bit holder is fixed to the Fixture body with the help of standard 5/16" BSW bolt and cast iron pin. Dropper plate is attached to the Dropper plate holder by standard ½" BSW bolt.

2.3 Working Principle of the Apparatus :

During the course of cutting operation, a hammer is was used to break down the cast iron pin instantaneously which causes rotation of the tool-bit holder around the fixed bolt, as shown in Figure - 16(a)

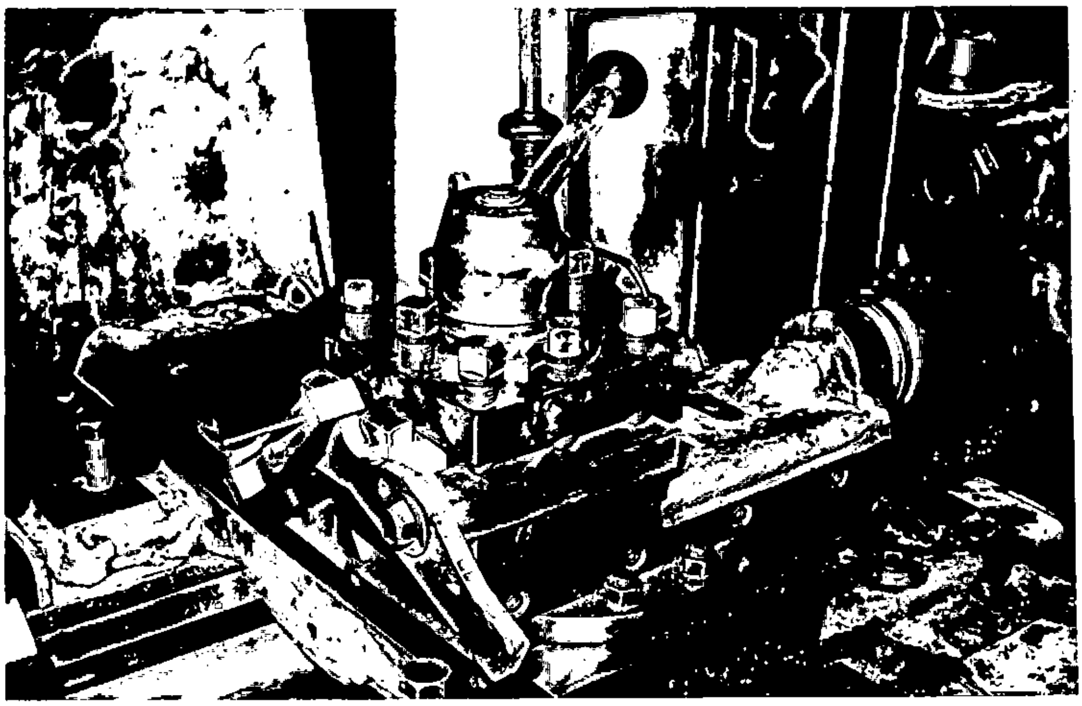


Figure - 16(a)

Position of the apparatus during partition of Chip-Tool contact region.

Such devise makes a sudden Withdrawl of the Tool-bit during cutting operation, leaving a partially formed chip attached to the workpiece. The section of the metal in the vicinity of the partially formed chip is so-called Chip-Tool contact region which is parted from the workpiece very carefully.

CHAPTER -3

EXPERIMENTAL DETERMINATION OF THE EFFECT OF CUTTING SPEED ON CHIP-TOOL PROCESS AND TOOL WEAR.

3.1. Experimental Conditions and Data Generation

The experiment was performed on a lathe machine as specified in Chapter 2, p.12. The cutting conditions of the experiment were as follows:

Cutting Tool- Single Carbide BK 8 (USSR)

92% WC, 8% Co

Feed, S = 0.20 mm/rev.

Depth of cut, t = 1.0 mm

Cutting Speeds, V = 2, 2.5, 5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 45, 50,75, 100, m/min.

A computer program was developed on a microcomputer IBM PCXT to select the machine RPM and Diameter of the Work-piece material with a view to maintain the desired speeds. The flow chart of the program is given in figure-17. Selected values of the RPM and Workpiece Diameter from the program are shown in Table-1. All the experiments were performed at toom temperature and without the application of cutting fluid. In the experiment Dropping Tool Apparatus was used to collect the chip tool contact region by "freezing" the cutting process instantaneously in the same way as described in section 2.3.

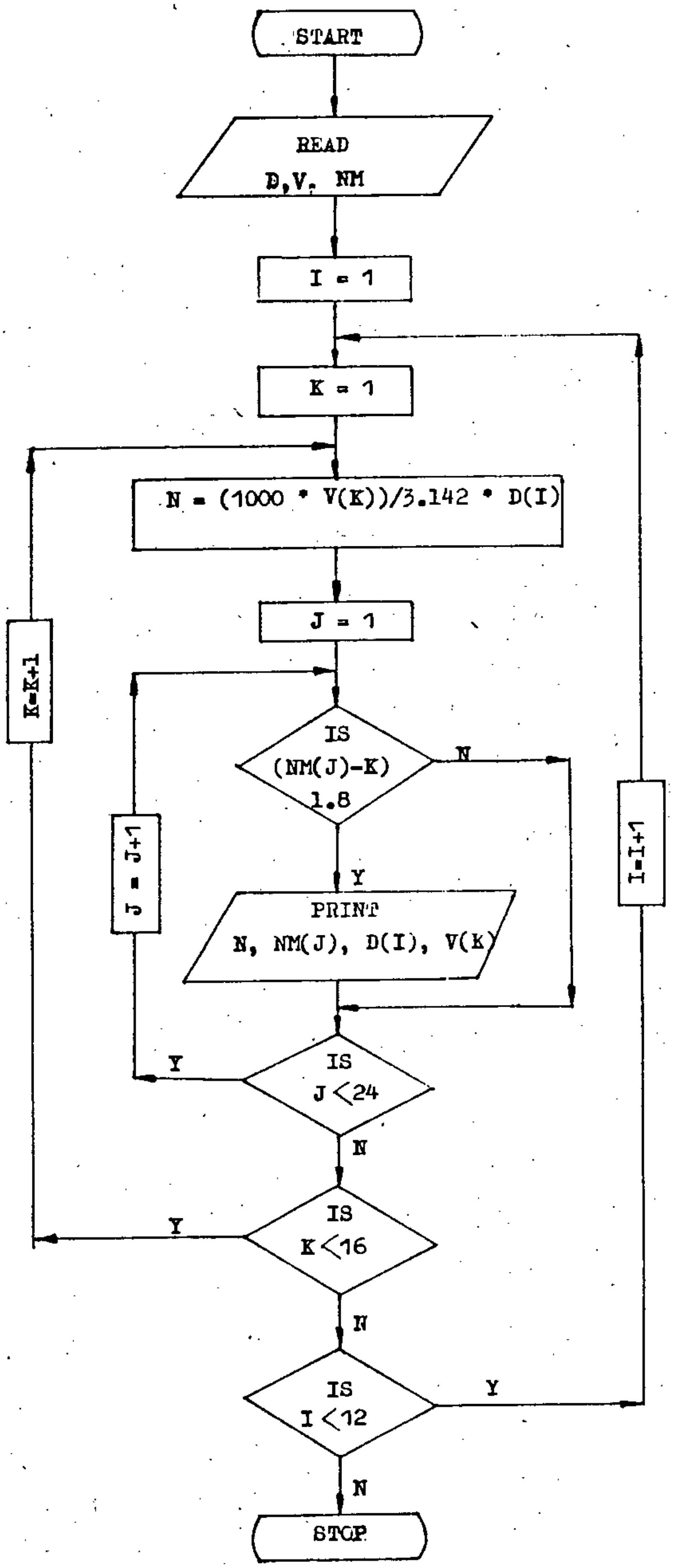


Figure-17
Flow Chart of the Computer Program

```
10  REM"SELECTION OF MACHINE RPM"
20  DIM D(12),V(16),NM(24)
30 FOR I= 1 TO 12
40 READ D(I)
50 NEXT I
60 FOR K= 1 TO 16
70 READ V(K)
80 NEXT K
90 LPRINT "   N"," NM"," D"," V"
100 LPRINT
110 FOR J= 1 TO 24
120 READ NM(J)
130 NEXT J
140 FOR I=1 TO 12
150     FOR K= 1 TO 16
160       LET N= (1000*V(K))/(3.142*D(I))
170           FOR J= 1 TO 24
180             IF ABS (NM(J)-N) <1.8  THEN  LPRINT N,NM(J),D(I),
                V(K) ELSE GOTO 190
190           NEXT J
200     NEXT K
210 NEXT I
220 DATA 86,84,82,80,78,75,70,68,66,60,56,53,2,2.5,5,7.5,10,12.5,
    15,20,25,30,35,40,45,50,75,100,12,15,19,24,30,38,46,58,76,
    96,120,150,185,230,305,380,460,480,600,610,765,955,1200,1500
230 BEEP
240 END
```

N	NM	D	V
18.50399	19	86	5
37.00798	38	86	10
46.25997	46	86	12.5
185.0399	185	86	50
18.94456	19	84	5
28.41684	30	84	7.5
37.88912	38	84	10
47.36141	46	84	12.5
56.83369	58	84	15
75.77825	76	84	20
94.72281	96	84	25
151.5565	150	84	40
378.8912	380	84	100
19.40662	19	82	5
29.10994	30	82	7.5
38.81325	38	82	10
58.21987	58	82	15
77.6265	76	82	20
97.03312	96	82	25
19.89179	19	80	5
29.83768	30	80	7.5
39.78358	38	80	10
59.67537	58	80	15
119.3507	120	80	30
10.20092	12	78	2.5
20.40184	19	78	5
30.60275	30	78	7.5
183.6165	185	78	45
306.0275	305	78	75
10.60896	12	75	2.5
148.5254	150	75	35
11.36674	12	70	2.5
22.73347	24	70	5
45.46695	46	70	10
56.83368	58	70	12.5
11.70105	12	68	2.5
23.40211	24	68	5
46.80421	46	68	10
58.50527	58	68	12.5
12.05563	12	66	2.5
24.11126	24	66	5
96.44504	96	66	20
120.5563	120	66	25
10.60896	12	60	2
13.26119	12	60	2.5
13.26119	15	60	2.5
39.78358	38	60	7.5
185.6567	185	60	35
11.36674	12	56	2
14.20842	15	56	2.5
28.41684	30	56	5
56.83369	58	56	10
12.01014	12	53	2
15.01267	15	53	2.5
30.02534	30	53	5
45.03801	46	53	7.5
75.06336	76	53	12.5
120.1014	120	53	20
150.1267	150	53	25
600.5068	600	53	100

3.2. Specimen Preparation

The specimen showing the chip-tool contact region was collected at each of the aforesaid speeds. For convenience in handling the specimens were frozen in a definite orientation into a cylindrical shape with the help of special plastic material Redont.* Each of the specimen and flat surface. Next the polished surface was etched with a reagent of 2% Nitric acid and 98% Ethyl alcohol. The etched surface of the specimen was photographed through a Micro-Hardness Tester, at a magnification of 400 times. Total magnification of this photo-prints - 1400 times. Each of these photographs are shown below sequentially.

---

*Redont- Plastic Powder and a liquid. On gradual addition of the liquid plastic powder gets dissolved into its forming a thick fluid. After standing for a shot period of time it gets hardened.

Table-1

No. of obs.	Designed Speeds m/min	Selected RPM NM	Selected Dia. mm	Actual RPM	Actual Speeds m/min
1	2.0	12	53	12.00	2.00
2	2.5	12	66	12.00	2.50
3	5	19	86	19.58	5.2
4	7.5	30	84	31.03	8.1
5	10	38	86	38.79	10.4
6	12.5	46	86	50.70	13.6
7	15	58	84	60.22	15.9
8	20	76	84	78.30	20.6
9	25	96	84	99.76	26.3
10	30	120	80	124.14	31.1
11	35	150	75	155.75	36.7
12	40	150	84	153.71	40.5
13	45	185	78	189.75	46.5
14	50	185	86	189.50	51.1
15	75	305	78	313.20	76.7
16	100	380	84	393.80	103.9

Selected Machine RPM and Workpiece Diameter.

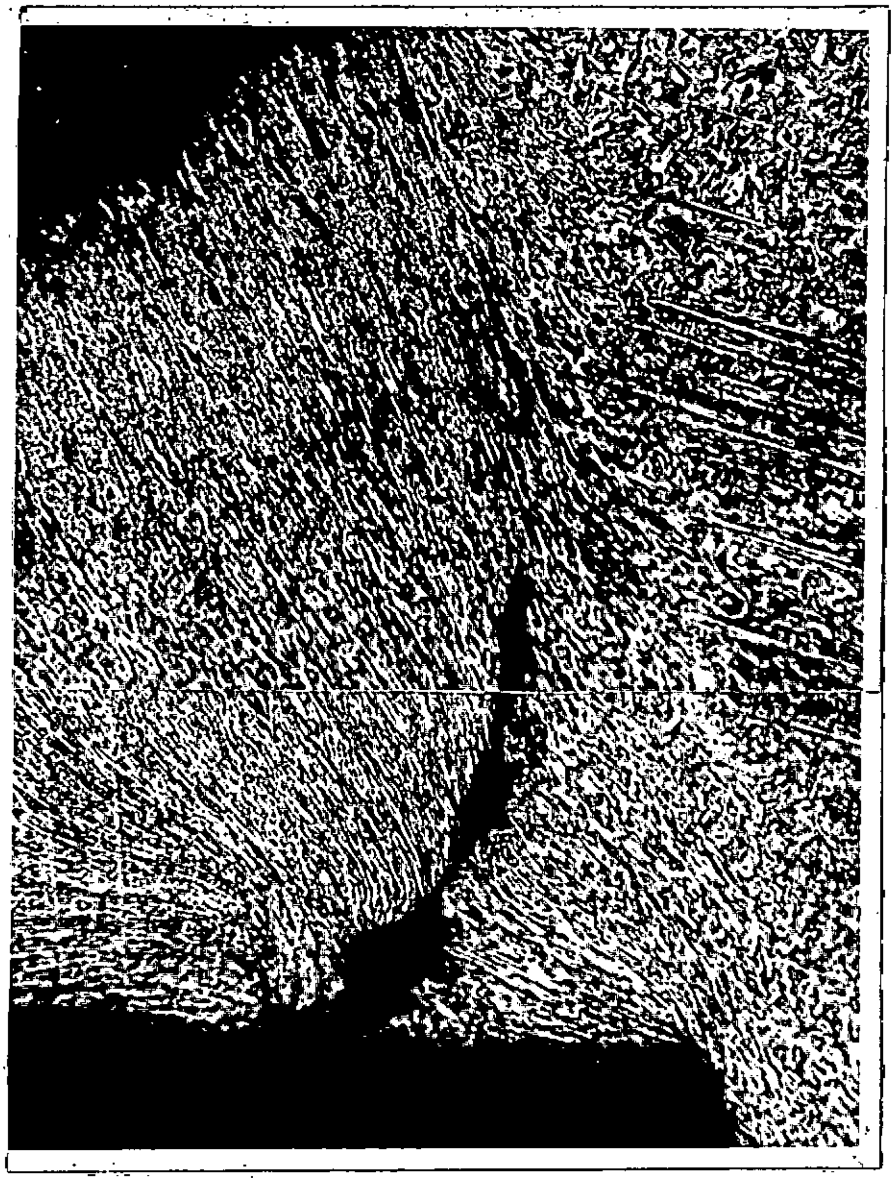


Figure-18. V = 2.0 m/min, t = 1 mm, S = 0.20 mm/rev.

Photograph of chip tool contact region.

Magnification = 1400

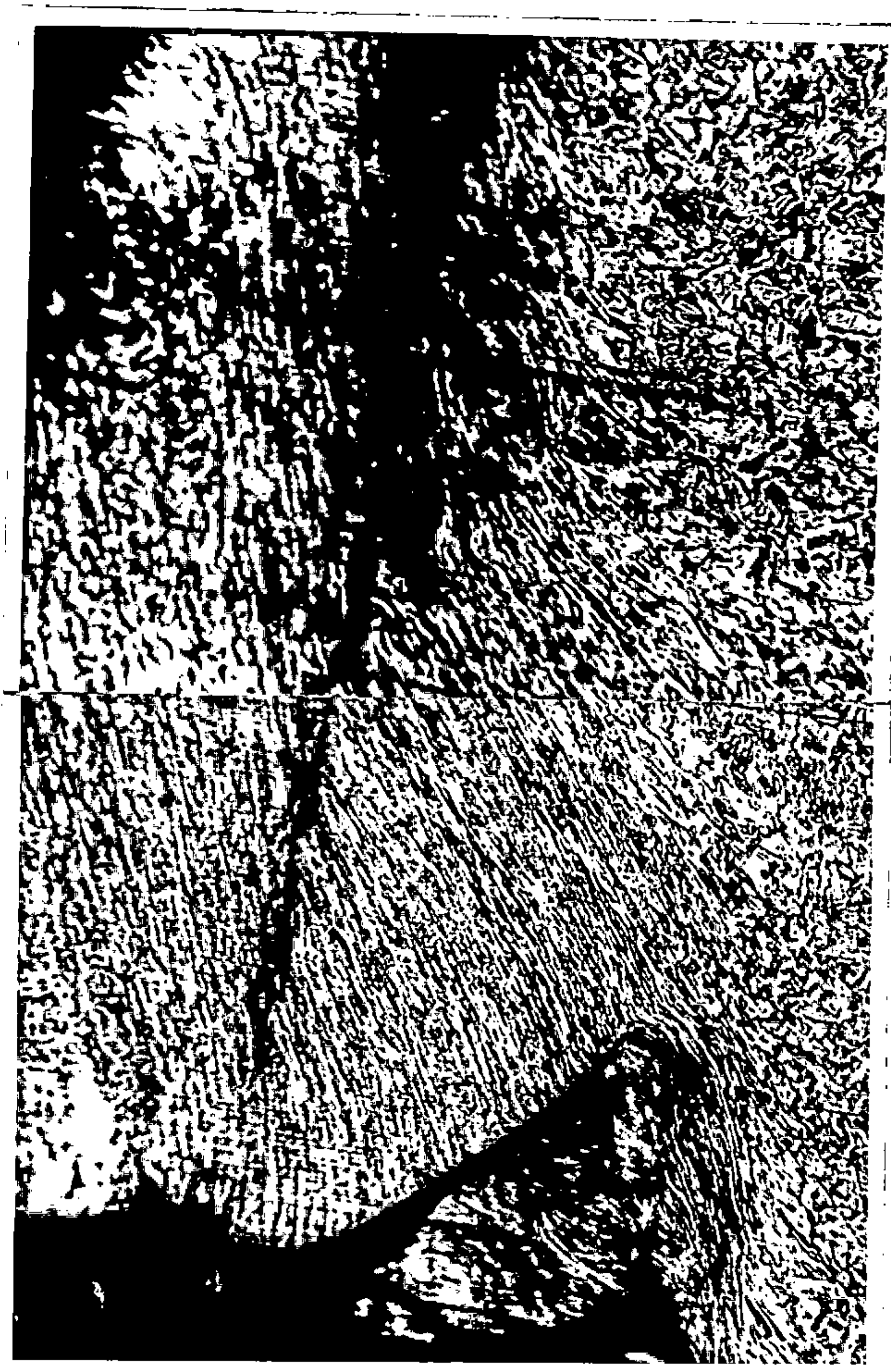


Figure-19. Photograph of chip-tool contact process at V = 2.5 m/min , t = 1 mm, S = 0.20 mm/rev.

Magnification = 1400.

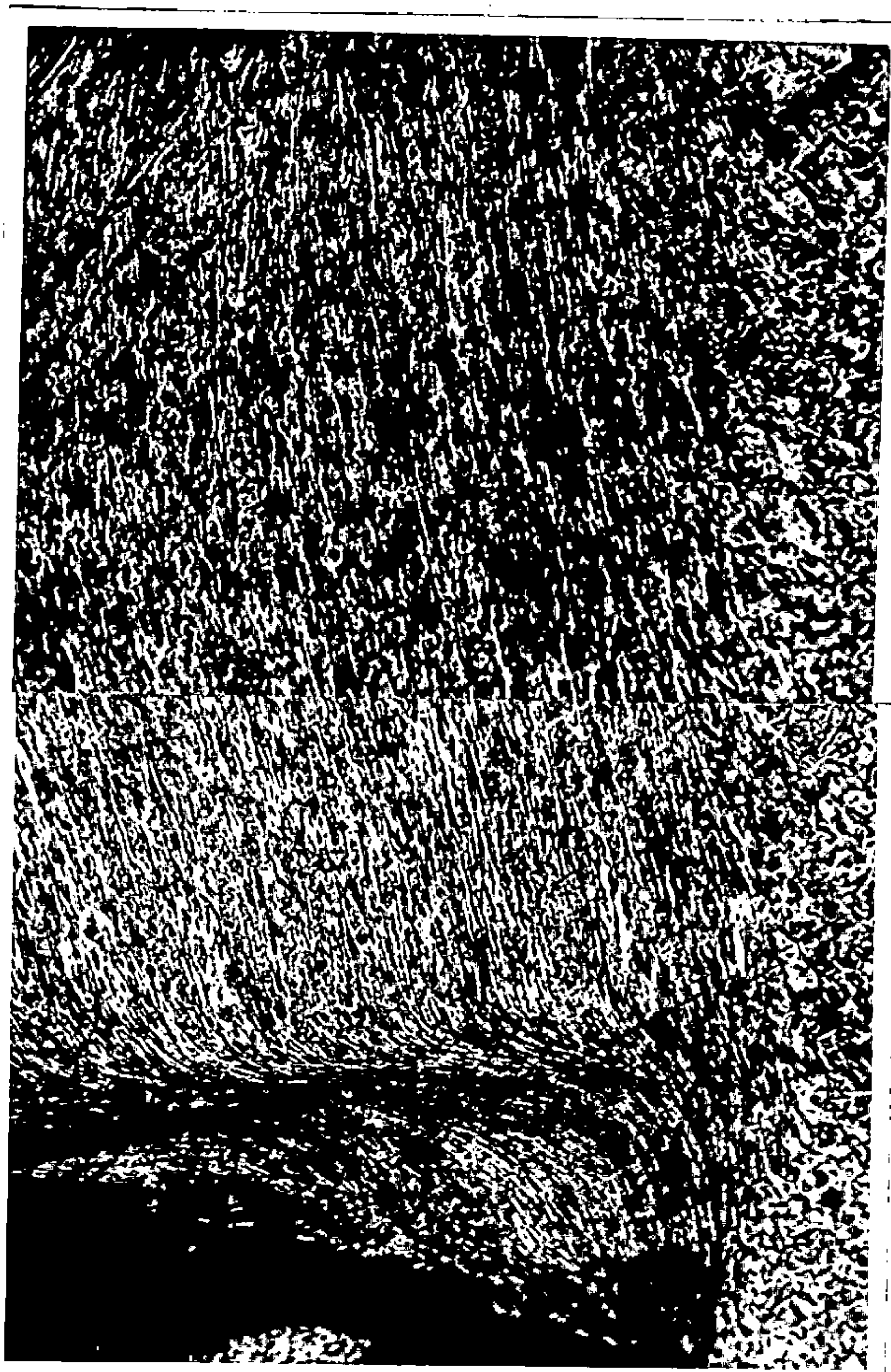


Figure-20. Photograph of chip-tool contact region at V = 5.2 m/min, t=1 mm, S =0.20 mm/rev Magnification = 1400.

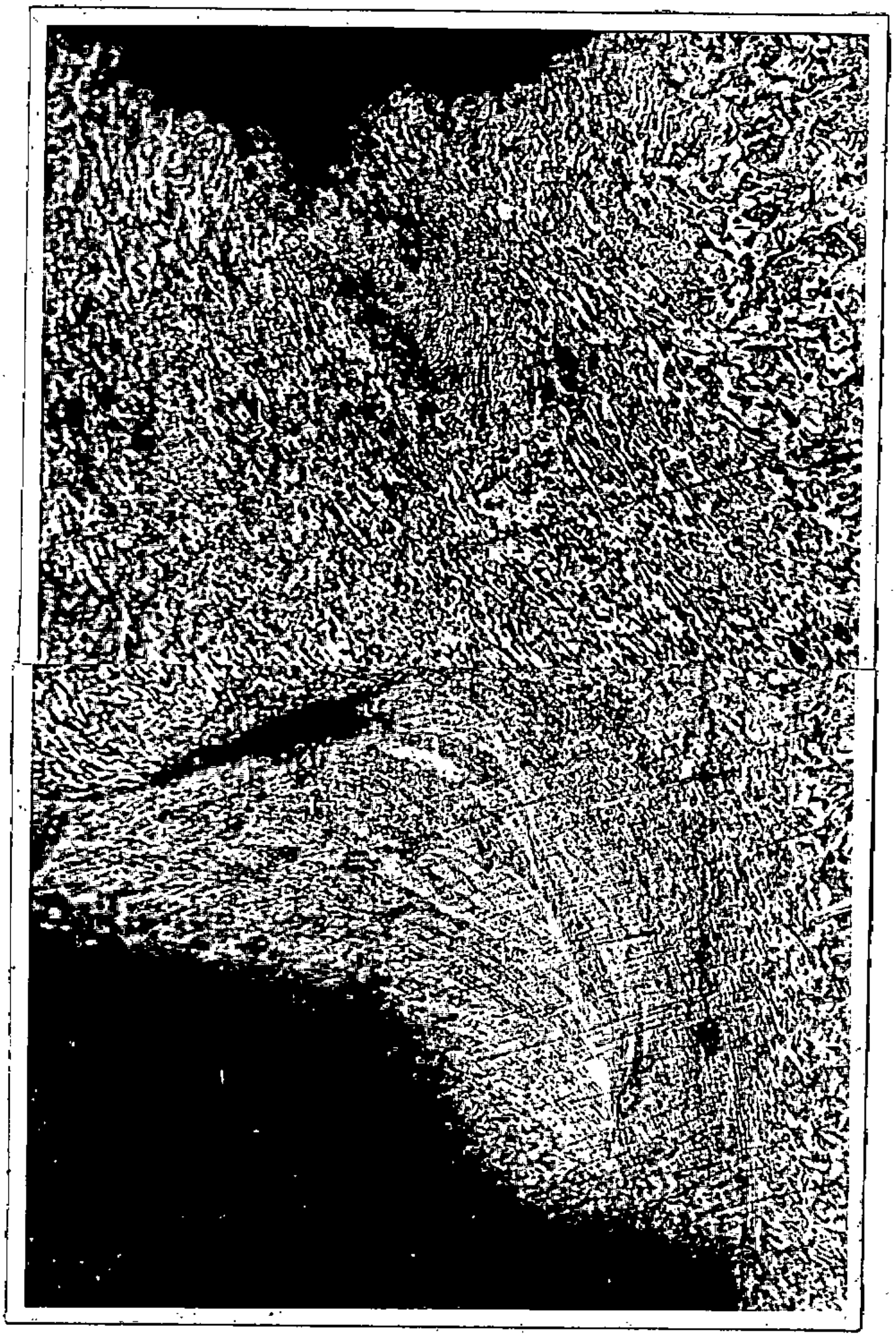


Figure -21. Photograph of chip-tool contact region at V = 8.1 m/min, t = 1 mm, S = 0.20 mm/rev. Magnification = 1400.

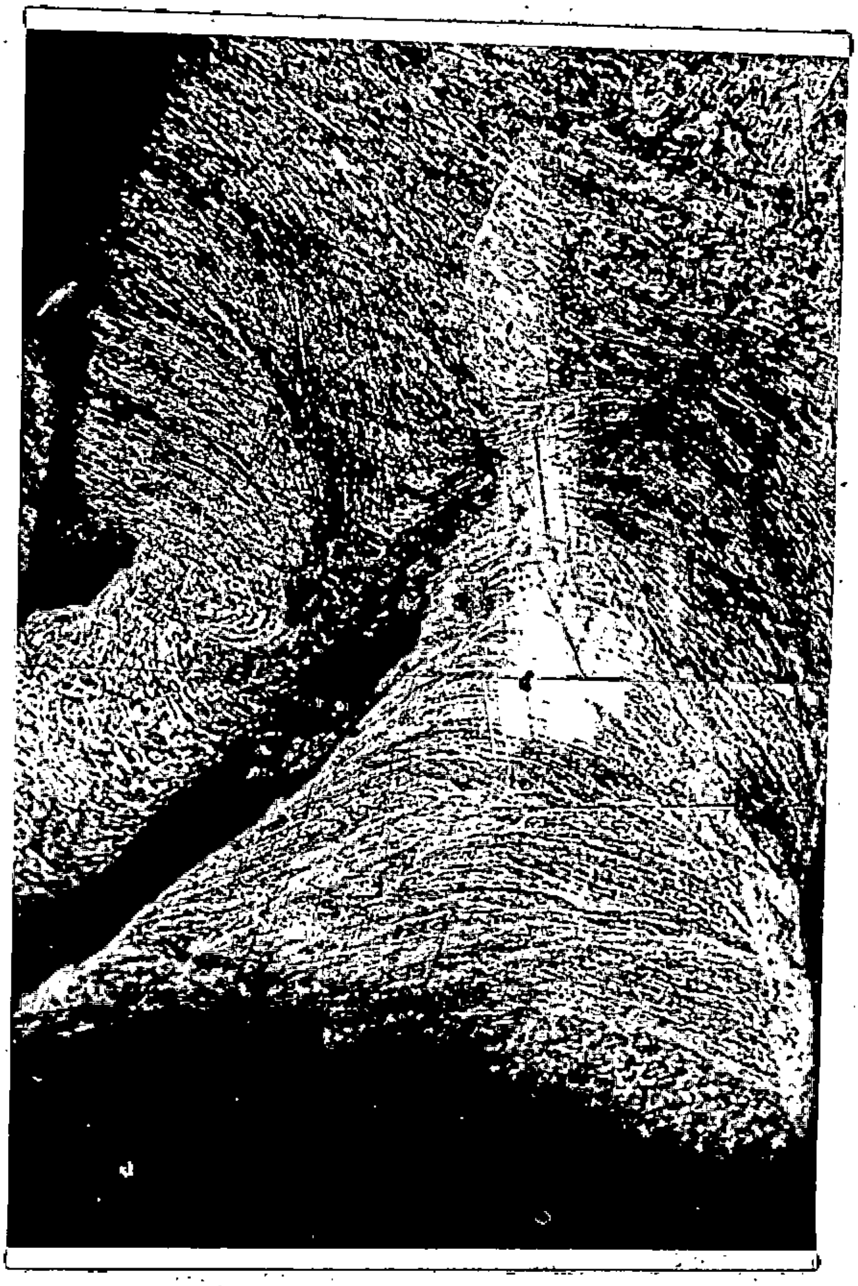


Figure-22. Photograph of chip-tool contact region at V = 10.4 m/min, t=1 mm, S = 0.20 mm/rev. Magnification = 1400.

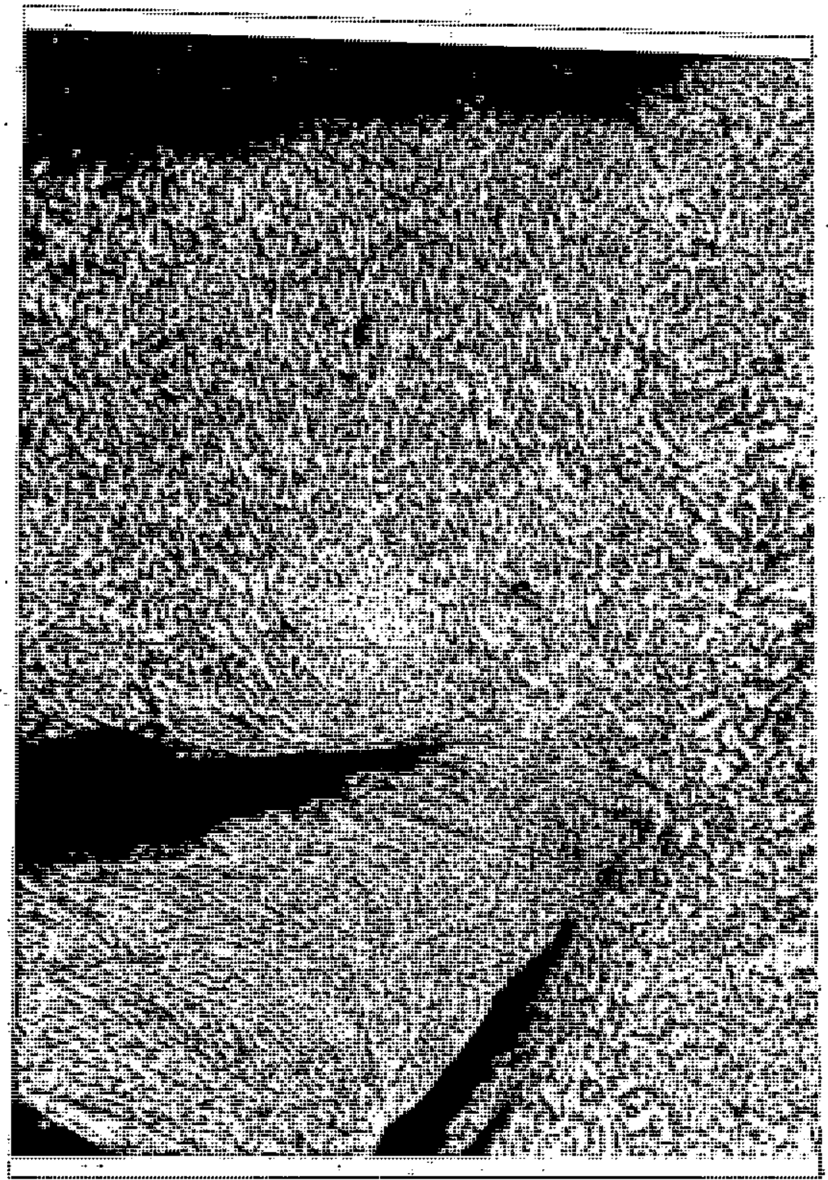


Figure-23. Photograph of chip tool contact region

$V = 13.6$ m/min, $t=1$ mm, $S = 0.20$ mm/rev.

Magnification = 1400.

Figure-24. Photograph of chip-tool contact region.

V=15.9 m/min, t = 1 mm , S = 0.20 mm/rev.

Magnification = 1400

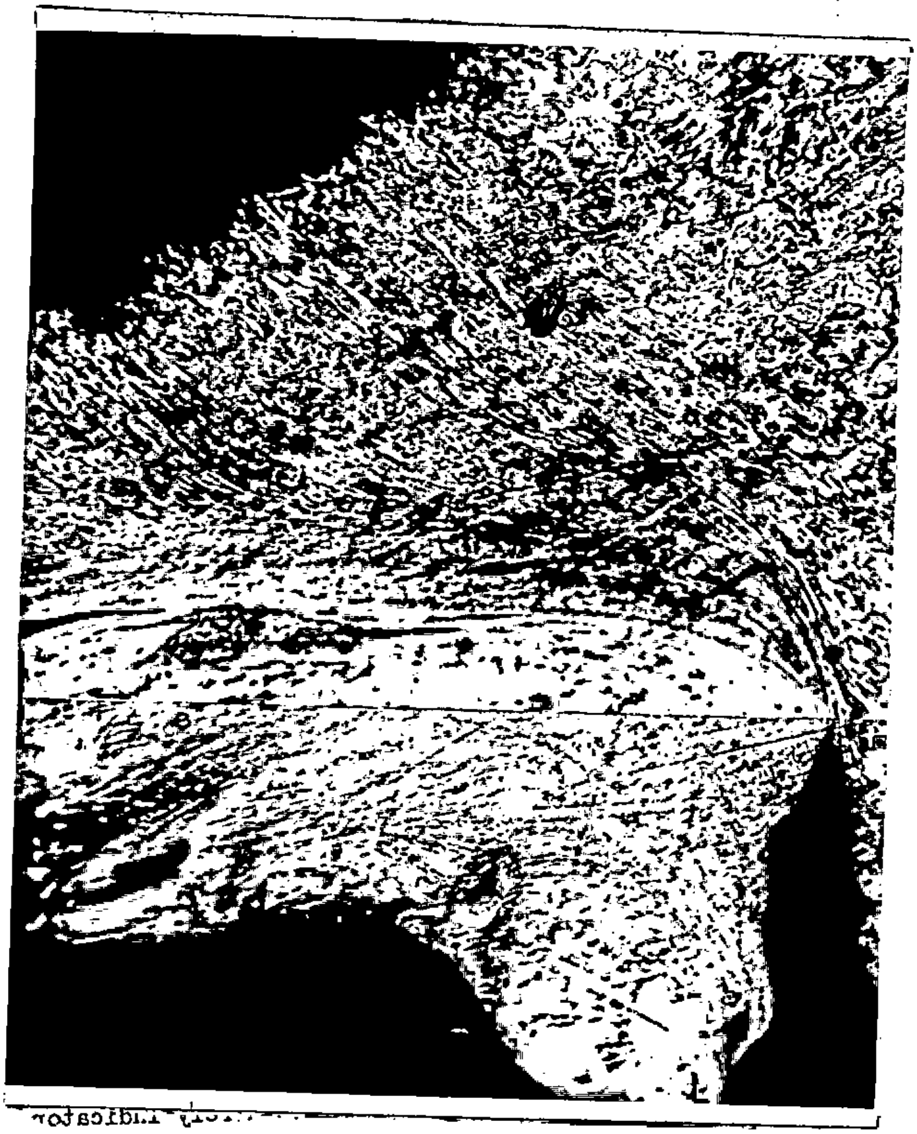


Figure-25. Photograph of chip-tool contact region at V = 20.6 m/min , t = 1 mm, S = 0.20 mm/rev.
Magnification = 1400

Figure-26. Photograph of chip-tool contact region
at V= 26.3 m/min, t= 1mm, S = 0.20 mm/rev.
Magnification = 1400

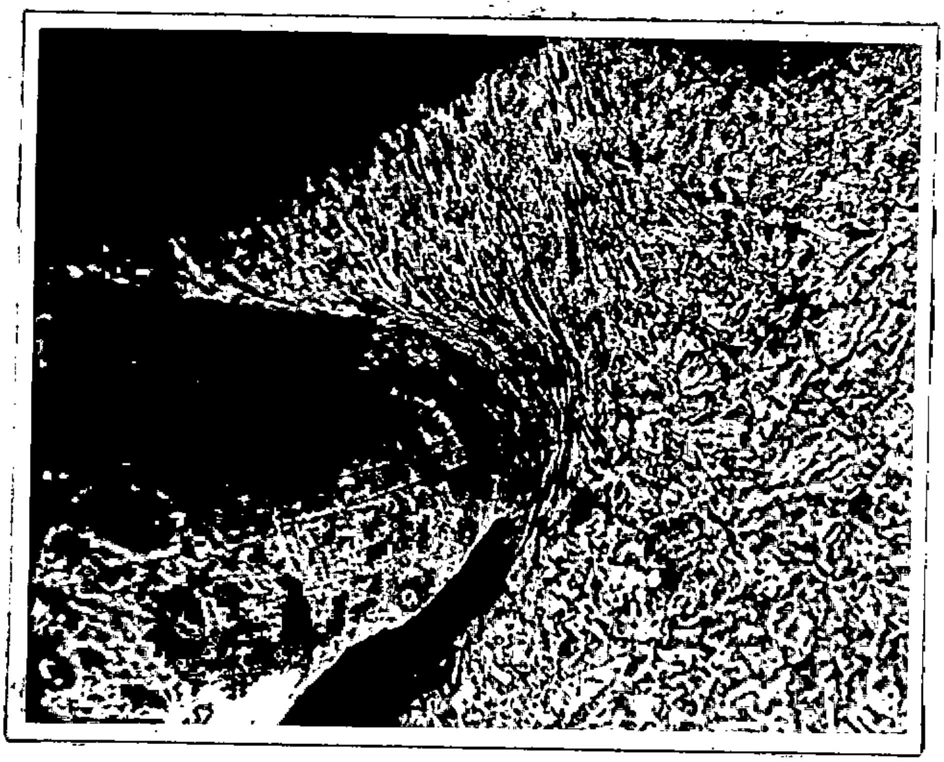


Figure-27. Photograph of chip-tool contact region
at V = 31.1 m/min, t = 1 mm, S = 0.20 mm/rev.
Magnification = 1400

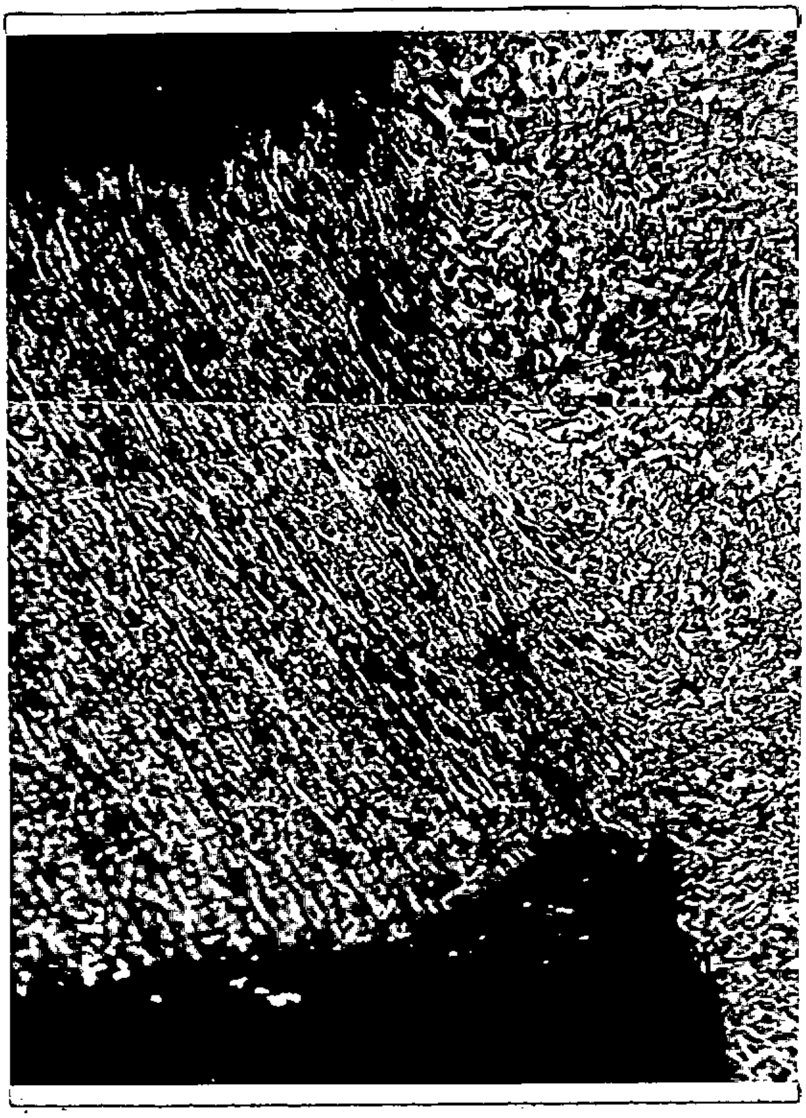


Figure 28 . Photograph of Chip-tool contact region

V= 36.7 m/min , t= 1 mm, S = 0.20 mm/rev.

Magnification = 1400

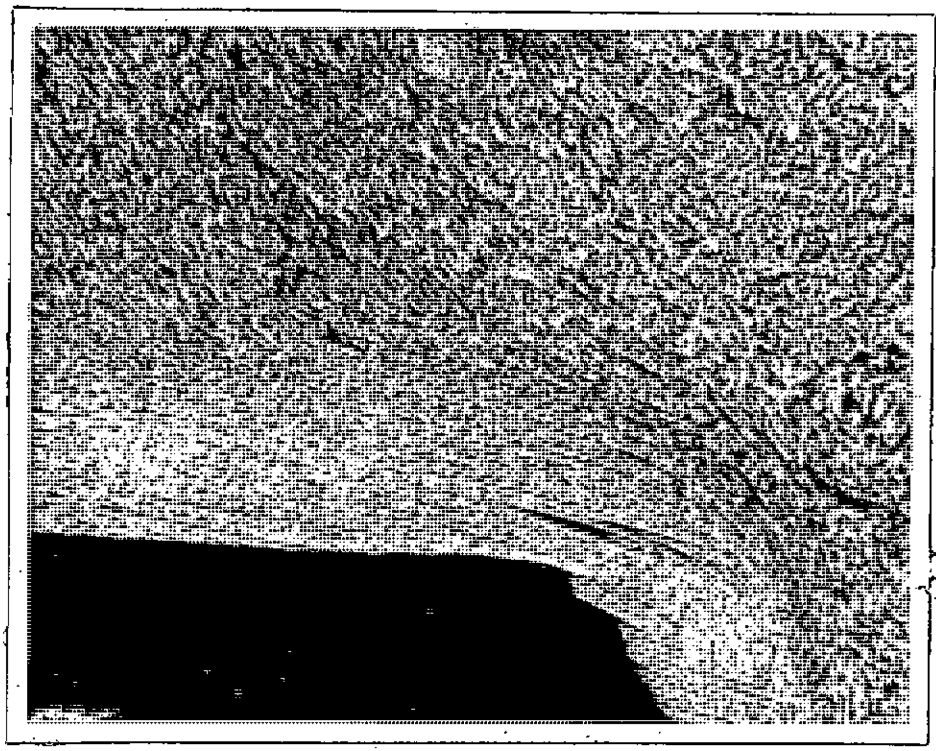


Figure 29 . Photograph of Chip-tool contact region

V = 40.5 m/min, t = 1 mm, S = 0.20 mm/rev.

Magnification = 1400

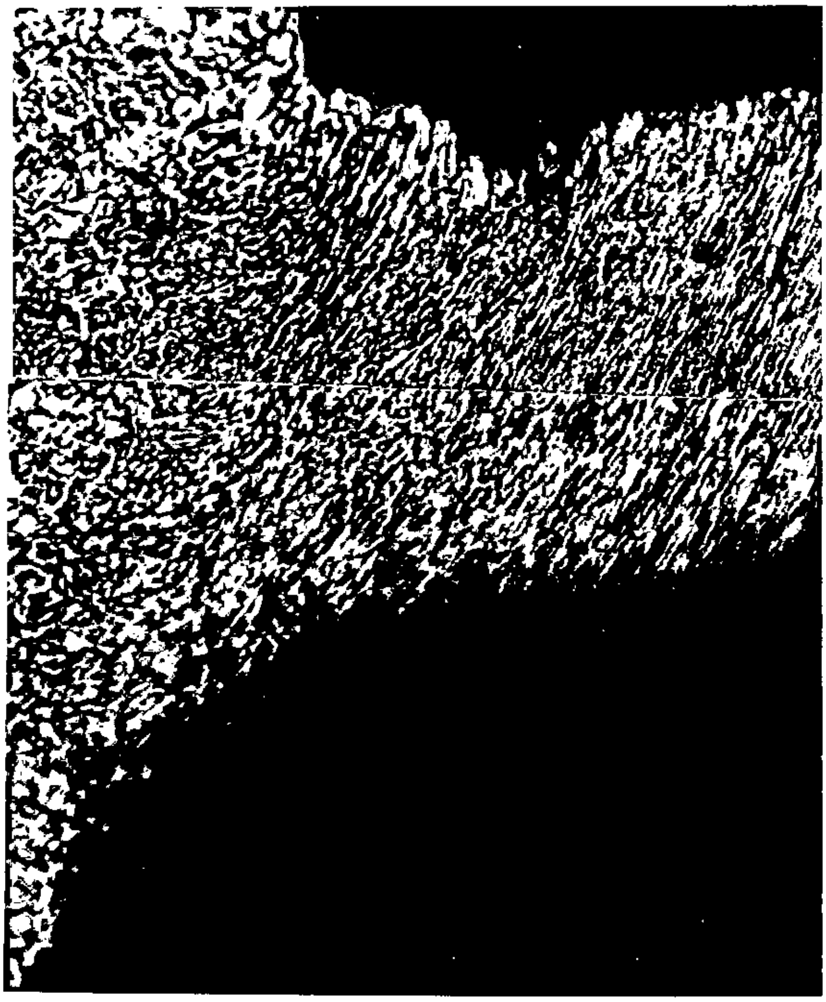


Figure 30. Photograph of Chip-tool contact region

$V = 46.5$ m/min , $t = 1$ mm, $S = 0.20$ mm/rev.

Magnification = 1400

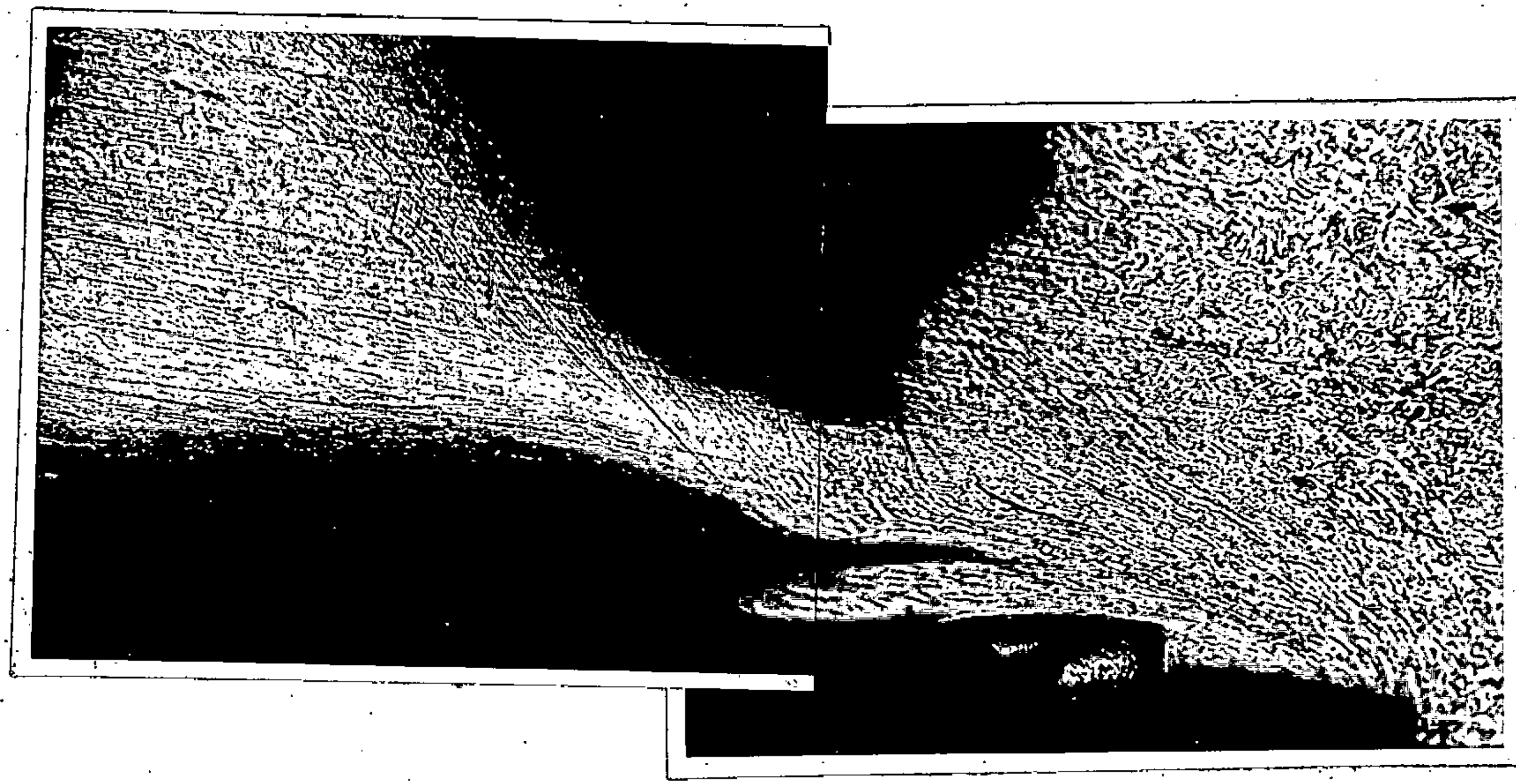


Figure 31. Photograph of Chip-tool contact region

V = 51.1 m/min, t = 1 mm, S= 0.20 mm/rev.

Magnification = 1400

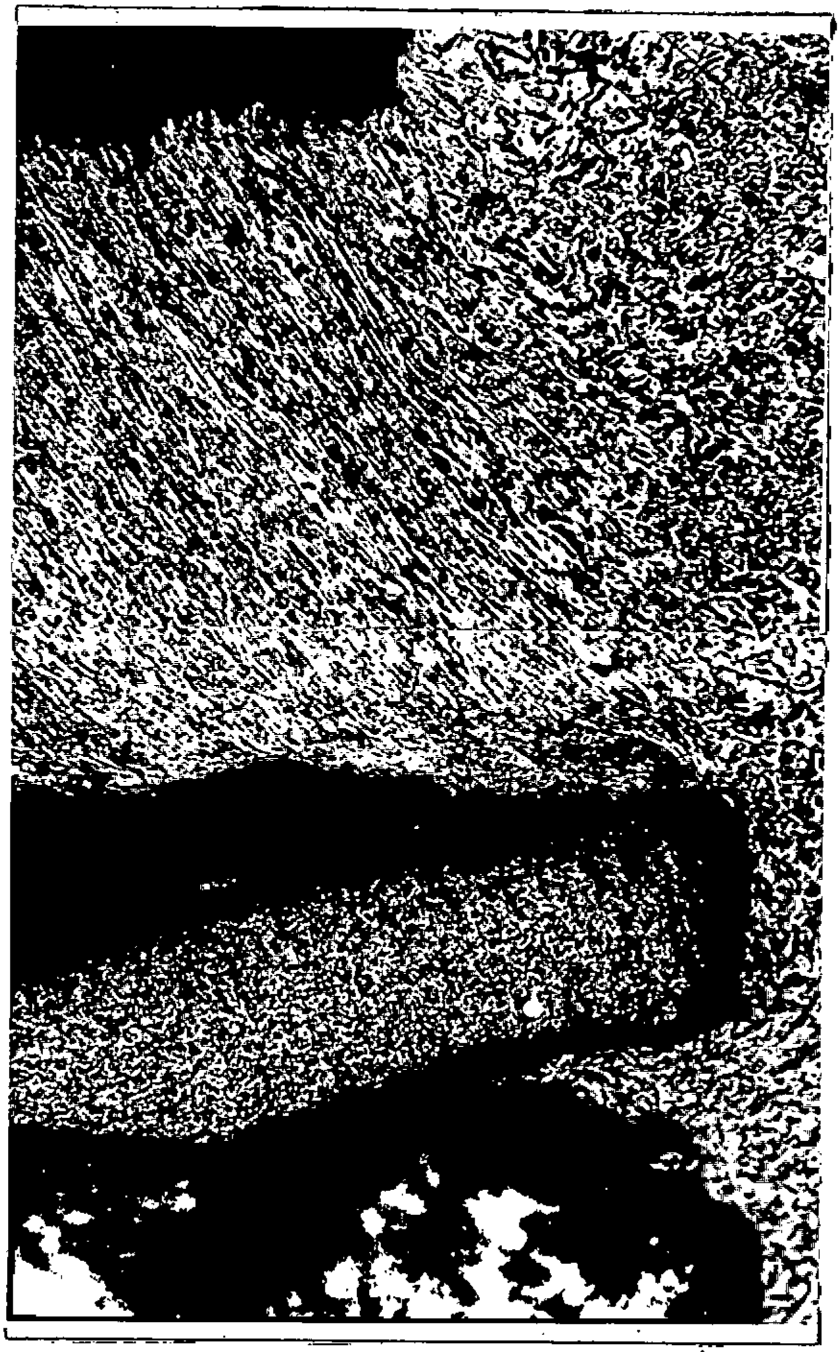


Figure 32. Photograph of Chip-tool contact region

$V = 76.7$ m/min, $t = 1$ mm, $S = 0.20$ mm/rev.

Magnification = 1400

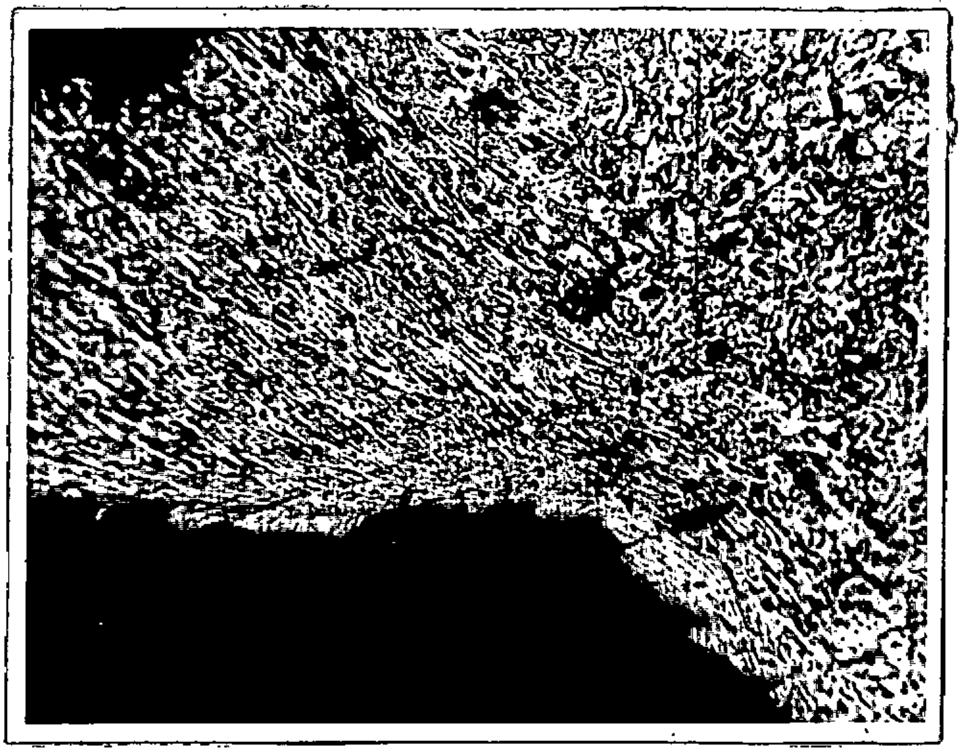


Figure 33. Photograph of Chip-tool contact region

$V = 103.9$ m/min, $t = 1$ mm, $S = 0.20$ mm/rev.

Magnification = 1400

3.3. Effect of Cutting Speed on Chip-tool Contact Process

After a careful study of these photographs (Figure 18-33) it becomes evident that BUE started at a cutting speed, V = 2.5 m/min (Figure-19) and disappeared at Speed, V = 46.5 m/min (Figure-30). Height of BUE at different cutting speed was measured and shown in Table-2. Figure-34 shows the variation of the height of BUE with cutting speed-which is of the same pattern as obtained by Isaev(3) (Fig.34a). Different speed range at which different types of BUE formed are also shown in the same figure. The cutting speed at which BUE disappeared is evidently, V = 46.5 m/min (Figure -30). So this is the desired critical speed at which transition from contact process with BUE to contact process without BUE observed. It is very important to note that during this experiment stepless variation of cutting speed was not possible. Therefore such transition may occur at any speed from V = 41 to 46 m/min as the speed was varied stepwise.

Table -2

No. of obs.	Actual speed in m/min.	Height of BUE measured from Photograph in Cm.	Actual Height of BUE in Micron
1	2.0	0.00	0.00
2	2.5	4.50	32.14
3	5.2	5.00	35.71
4	8.1	8.50	60.71
5	10.4	10.00	71.00
6	13.6	9.00	64.28
7	15.9	8.00	57.14
8	20.6	6.50	46.40
9	26.3	8.50	60.71
10	31.1	6.00	42.85
11	36.7	3.00	21.42
12	40.5	1.00	07.14
13	46.5	0.00	0.00
14	51.1	0.00	0.00
15	76.7	0.00	0.00
16	103.9	0.00	0.00

Height of BUE at different cutting speed.

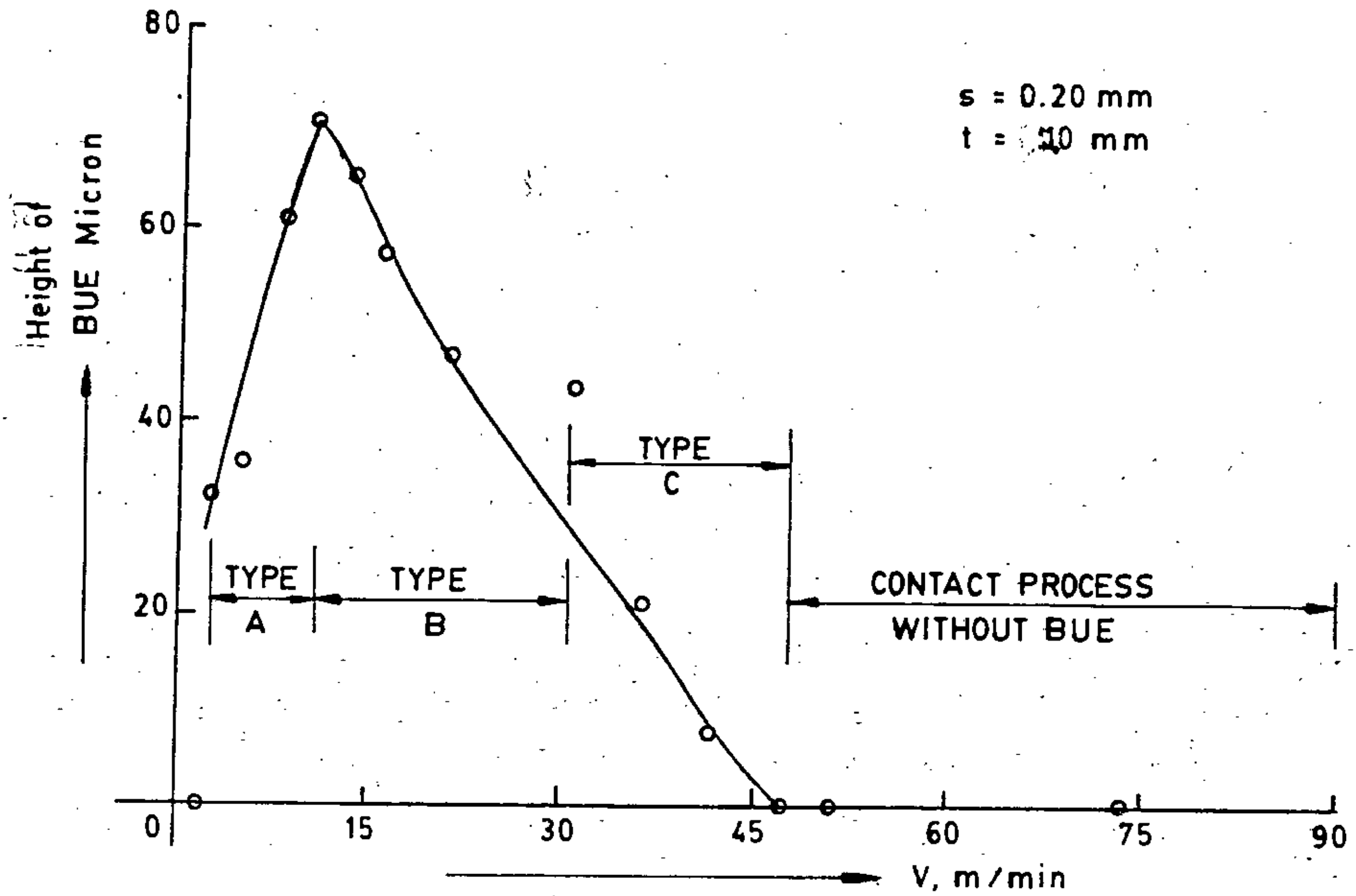


Figure-34 Height of BUE Vs. Cutting Speed

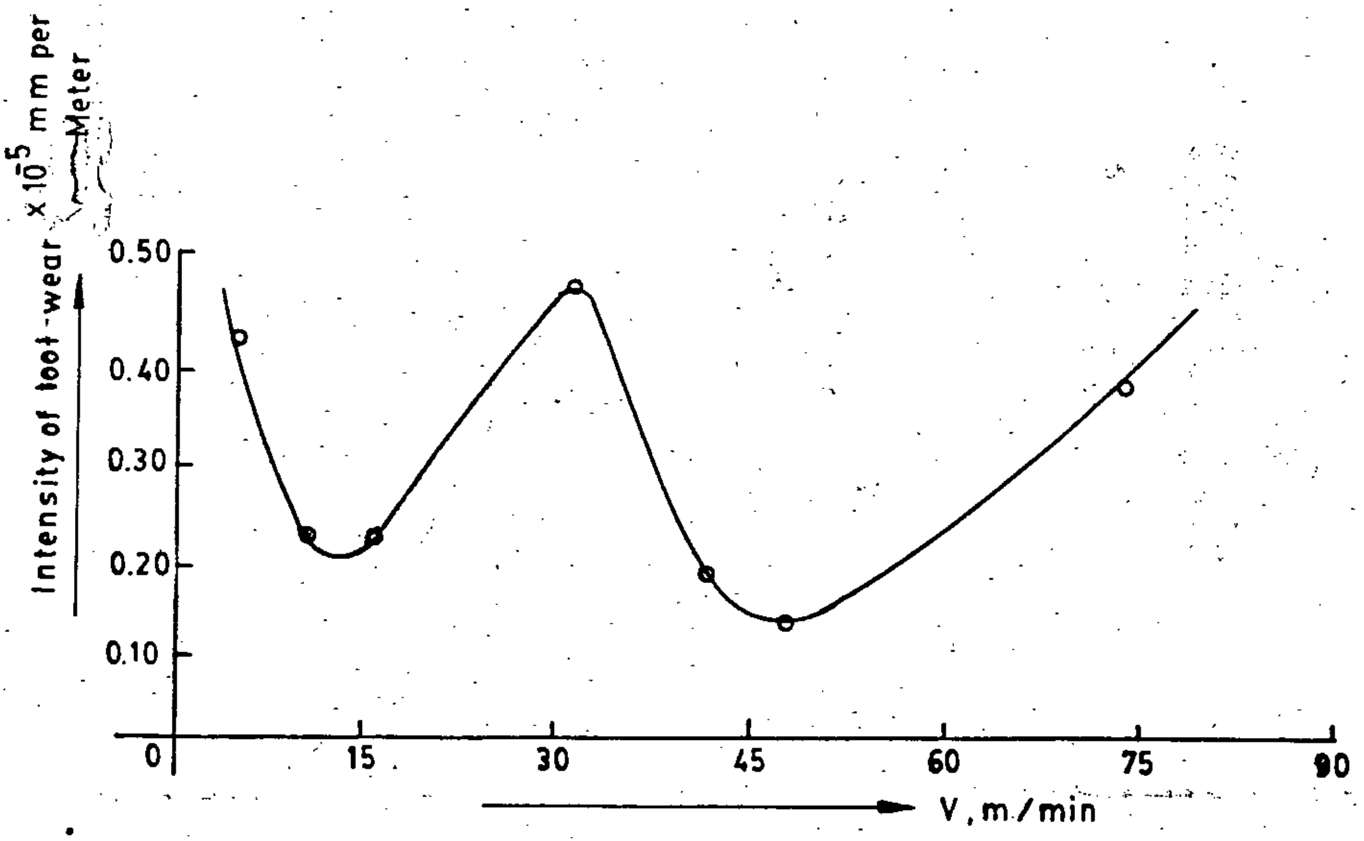


Figure-36 Intensity of tool wear Vs. Cutting Speed

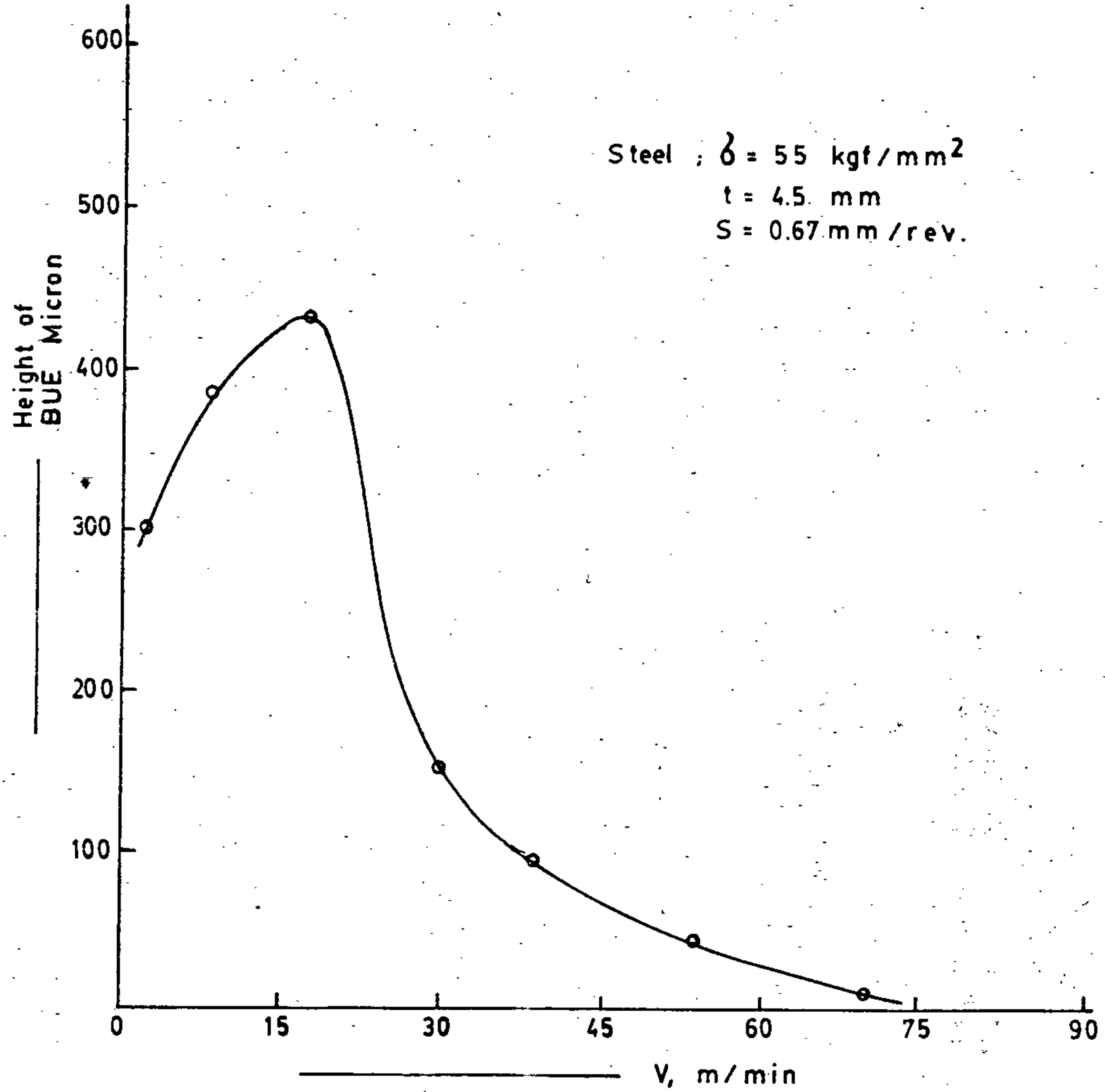


Figure - 34(a) Height of BUE Vs. Cutting Speed. (After A. Iseav)

3.4 Effect of Cutting Speed on Tool-Wear

Cutting speed is one of the most important factor upon which tool wear depends. It is only the flank wear (h_f) which determines the useful life of a Tool. Variation of 'h_f' with respect to cutting speed is shown in Figure-2. It has been established that variation of the intensity of tool wear with respect to Cutting Speed also follows a definite pattern[21]. However, in order to show the relationship between "Tool Wear and other factors-it is very necessary to devise methods by which Tool Wear can be measured properly and correctly. Different methods can be adopted for this purpose[12]. In this experiment a conventional method was used which needed a Metallurgical Microscope (Model-ZEISS 35196, CARL, GERMANY) and a Chemical reagent aqua-regia (HCl: HNO_3=1:3). The reagent was used for cleaning the BUE and other micro-elements which most frequently adhere on the Tool face in welded condition. The cutting length of the workpiece was limited and it was divided only in four almost equal divisions for four different observations of tool wear at every speed. The cutting operation was interrupted at the end of each division on the workpiece for every observation. Consequently four values of 'h_f' were obtained to every cutting speed which are shown in Table - 3 . During the experiment all the conditions remained same as described in section 3.1. Different curves of 'h_f' as function of cutting length were plotted as shown in Figure - 35. Intensity of Tool wear which is defined as the Tool wear per unit cutting length of the workpiece was also calculated at these speeds.

TABLE -3

Machine RPM NM	Actual RPM N	Actual speed V m/min	Length of cut L mm	Time of cut T min	Initial Flank wear h_{f_0} mm	Final Flank wear h_{f_1} mm	Flank Wear $h_f = h_{f_1} - h_{f_0}$ mm	Cumulative cut length mm
			45.8	11.69	0.00	0.027	0.02	45.8
			47.19	12.05	0.027	0.06	0.04	92.99
19	19.58	5.2	45.03	11.50	0.06	0.08	0.02	138.02
			47.48	12.12	0.08	0.098	0.018	185.50
			46.00	5.93	0.00	0.025	0.025	46.00
38	38.79	10.4	44.91	5.79	0.025	0.030	0.005	90.91
			46.62	6.01	0.030	0.039	0.009	137.53
			49.41	6.37	0.039	0.050	0.011	186.94
			48.1	3.993	0.00	0.022	0.022	48.1
			46.9	3.89	0.022	0.040	0.018	97.00
58	60.22	16.0	47.8	3.97	0.040	0.050	0.010	144.80
			42.2	3.50	0.050	0.059	0.009	187.00
			49.35	1.60	0.00	0.030	0.030	49.35
			46.55	1.51	0.030	0.055	0.025	95.90
120	124.14	31.1	44.60	1.45	0.055	0.078	0.023	140.50
			47.90	1.55	0.078	0.100	0.022	188.40
			47.50	1.26	0.00	0.025	0.025	47.50
			47.20	1.24	0.025	0.041	0.016	94.70
150	153.71	40.5	44.80	1.18	0.041	0.048	0.007	139.50
			45.50	1.198	0.048	0.056	0.007	185.00
			44.40	1.169	0.00	0.010	0.010	44.40
			47.50	1.251	0.010	0.015	0.005	91.90
185	189.75	46.5	43.55	1.147	0.015	0.020	0.001	135.45
			48.55	1.279	0.020	0.025	0.005	184.00
			47.7	0.761	0.00	0.01	0.01	47.7
			45.6	0.727	0.010	0.028	0.018	93.3
380	393.2	76.7	45.7	0.727	0.028	0.046	0.018	139.0
			46.1	0.735	0.046	0.063	0.017	185.1

Tool Wear at different cutting length

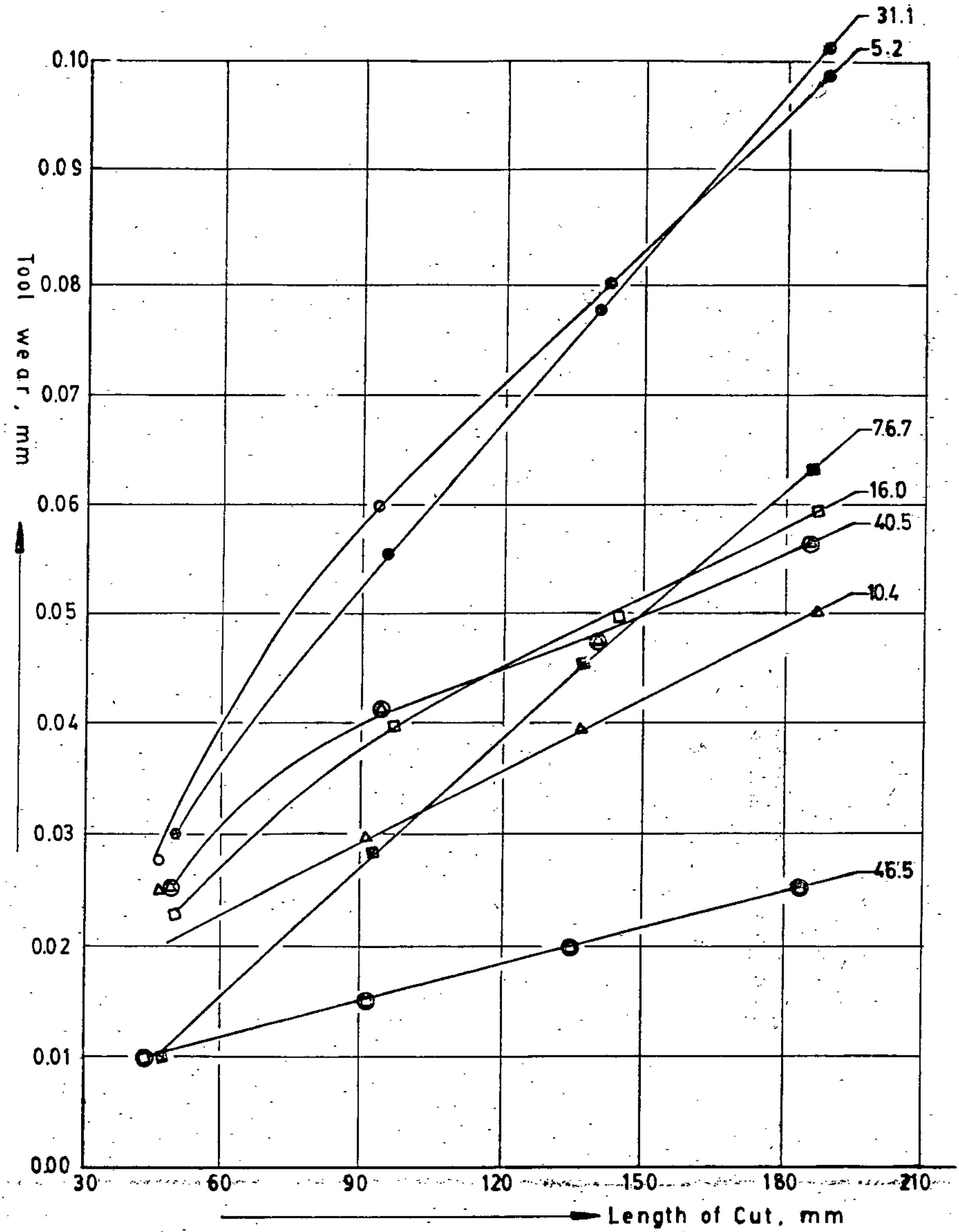


Figure. 35. Tool wear Vs. Length of Cut at Different Cutting Speed

Finally a curve, showing the intensity of Tool Wear Vs. Cutting Speed was plotted as shown in Fig.36. Fig.34 and 36 were plotted up and down respectively on the same page where cutting speed for both the figures was taken in the same scale. It was done for better observation of the relationship between Chip-tool Contact Process and wear rate.

CHAPTER - 4

DISCUSSION AND CONCLUSION

4.1 Discussion

Experimental results show that initially Wear is higher than normal Wear at almost all the Cutting Speeds (Figure-35). This is due to the fact that the tools were not given initial wear by grinding - thus it is obvious that rate of wear is always higher for a sharp edge. However initial wear was avoided in calculating the intensity of Tool Wear. It can be observed from Fig.36 that at low cutting speeds intensity of tool wear is high. This is because of the absence of BUE (Figure-18) in this speed range and due to the formation of discontinuous chip which causes chipping action on the tool-face. BUE Type-A started appearing at cutting speed, V = 2.5 m/min (Figure-19). Because of this Tool wear started decreasing from this speed onward. This decrease may be explained by the fact that with the increase in cutting speed, BUE became stable in nature and it was hardened and welded on the Tool face, saving the tool from intensive wear. This process continued upto the speed, V=10.4 m/min (Figure-22). Then starting from the speed, V = 13.6 m/min (Figure-23) BUE type B was formed, which extended beyond the rake surface. Starting from this speed Tool Wear started increasing. This process was observed upto the speed, V = 31.1 m/min. (Figure-27). This may be explained by the fact that BUE,

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type-B is unstable and it has the tendency of brittle breakage and being dragged along the flank surface of the tool. Further increase in cutting speed caused decrease of Tool Wear. This is because of the change in chip-tool contact process. In this speed range BUE, type-C was formed (Figure-28 to 29). This type of BUE is soft enough due to high temperature. It has the tendency to move along the rake surface of the tool in case of its breakage. Height of such a BUE is also small unlike type A and B. All these factors contribute extremely low wear rate of the tool in this cutting speed range. Starting from the speed V = 51.1 m/min (Figure-30), BUE disappeared completely and a continuous contact of chip and Tool was observed. Therefore Tool Wear started rising abruptly from this speed. A good indication to identify this speed is that the tool touching face of the chip has mirror-like surface finish.

4.2. Conclusions:

1. It has been reaffirmed that for any pair of steel and cemented carbide tool of definite geometry and a particular condition of cut the type of chip and chip-tool contact process has a definite law of formation. At low cutting speed element type chip with no BUE is formed which is followed respectively by partially continuous and continuous chip with BUE types A,B, C and continuous chip without BUE.

2. There is a particular cutting speed at which chip-tool contact process changes abruptly from contact process with BUE to that without BUE. Tool touching surface of chip after this speed has a mirror-like surface finish but has traces of BUE before this speed. This particular speed is termed as critical cutting speed, V_c.

3. It has been established that for a carbon steel of any composition tool wear is a function of chip-tool contact process. Tool wear is high in the cutting speed range of element chip formation without BUE, low for contact process with BUE types A and C and high for BUE type B and continuous chip without BUE above V_c.

4. Cutting speed corresponding to minimum intensity of tool wear, for single carbide tool is in the range

of BUE type C and just below critical speed, V_c. This speed is termed as optimum cutting speed, V_{op}.

5. Dropping tool apparatus may be successfully used for finding the optimum cutting speed, V_{op} of any pair of steel and tool material for any condition of cut and as such it may be used for determining machinability of steel and testing the quality of cemented carbide tools.

4.3 Recommendation for future work

A Single Workpiece was used in the experiment due to the limitation of time. For the same reason it was not possible to change the feed, depth of cut, tool material and tool geometry. Although the test results confirms the theoretical ideas, yet there remains a scope of further study by changing the above conditions. It will be wise to use several work-piece materials for a better confirmation of the test results.

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