

**DESIGN AND MANUFACTURING OF PITCH LINE CHUCK FOR
INTERNAL GRINDING OF HARDENED AND DISTORTED BORE
OF CROWN HYPOID AND BEVEL GEARS**

by

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A project thesis submitted in partial fulfilment of the requirements for the AIT-BUET Post Graduate Diploma in Industrial Engineering.

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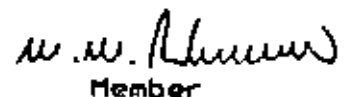
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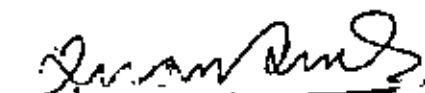
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ABSTRACT

The only Machine Tools Factory in country (BMTF), at present, produces spiral bevel gears by Gleason system to be fitted in 3:2 ratio right angle gear box to drive Deep Well Turbine Pumps. Report on poor performance of gear boxes regularly arrive in BMTF. Study have been made and found that in most of the cases faulty gears are responsible for this poor performance.

These gears, after cutting the teeth, are case carburized and quenched to give desired surface hardness. During quenching the teeth as well as entire gear blank distorts in different pattern. By intelligent engineering the distortion during heat treatment process can be reduced to a minimum but can never be eliminated. This little residual distortion in addition to faulty bore grinding practice causes the pitch cone of the gear to be shifted from the true axis of rotation; which causes the poor gear quality leading to high noise and reduced gear life.

In this project work an attempt have been made to design and make a fixture, the pitch line chuck, to be fitted on internal grinding machine so that the ground bore of gear is true and concentric with the pitch cone.

It is observed that the setting time for bore grinding is greatly reduced as well as the dependence on the efficiency of the worker is also reduced to a minimum. It has been found economic and justified to design and built a Pitch Line Chuck.

LIST OF FIGURES

<u>Fig. No.</u>	<u>Caption</u>	<u>Page No.</u>
1.	Process sheet for Spiral Bevel Gear	3
2.	Pitch circle runout	9
3.	Lateral runout	9
4.	Geometrical definition of backlash	11
5.	Backlash caused by center distance changed	11
6.	Runout position error in terms of pitch circle rotation	14
7.	Various positions of mesh for eccentric gear & a perfect mating pinion with a plot of the position error	14
8.	Tooth thickness variation caused by runout.	16
9.	Geometrical aspects of the mesh of an eccentric gear & perfect pinion	16
10.	Location of a cone by three balls	18
11.	Pitch line chuck	21
12.	Process sheet for fixture plate	28
13.	Process sheet for locking plate	34
14.	Process sheet for hand nut	36
15.	Process sheet for clamping stud	37

LIST OF TABLES

<u>Table No.</u>	<u>Caption</u>	<u>Page No.</u>
1.	Standard composition of raw material to be used for the pitch line chuck	26
2.	Mechanical properties of steel material	26

CONTENTS

	PAGE NO.
CHAPTER 1.00 INTRODUCTION	1
1.01 Existing method for producing Spiral Bevel gears.	2
1.02 Types of manufacturing defects of Spiral Bevel gears	6
1.03 Aims & objectives of the study.	7
CHAPTER 2.00 PROBLEMS CAUSED BY THE EXISTING METHOD OF MANUFACTURING BEVEL GEARS	8
2.01 The effect of existing bore grinding practice on gear performance	9
2.02 General solution of backlash caused by center distance change	10
2.03 Backlash caused by pitch circle runout	13
2.04 Pressure angle variation caused by pitch circle runout	15
CHAPTER 3.00 PROPOSED METHOD FOR BORE GRINDING	16
3.01 Design of a fixture for bore grinding	17
3.02 Advantages of the pitch line chuck	25
3.03 Material to be used for the fixture	25
3.04 Method of manufacturing different parts of the pitch line chuck	27
CHAPTER 4.00 ECONOMICS OF THE PITCH LINE CHUCK	38
4.01 Time saving in the proposed method	38
4.02 Cost saving in the proposed method	41
4.03 Cost estimate of the proposed fixture	42
4.04 Feasibility of the pitch line chuck	46
CHAPTER 5.00 CONCLUSION AND RECOMENDATIONS	49
BIBLIOGRAPHY	51
APPENDIX	52

INTRODUCTION

Bangladesh Machine Tools Factory Ltd. is the largest engineering manufacturing organization of its kind in Bangladesh. This organization is engaged in production of machine tools, pumps, textile machineries, railway equipment, power supply fittings and many other engineering products.

Quality is a major problem for this organization. Some of the products are manufactured in hundreds or thousand pieces but without having a well defined production process. Goods are produced here as in a job shop. The result is non-interchangibility, poor quality and huge machining time. Most of the times customers are dissatisfied with the products.

BMTF has a gear manufacturing section consisting of gear shaper, gear hobbing, shaving, gear grinding, spiral bevel generator and allied machineries. At present BMTF is producing right angle spiral bevel gear box to be fitted with deep well turbine pumps.

Production of quality gears cannot be achieved if all the operations e.g. turning, broaching, gear cutting, heat treatment, grinding lapping etc, for manufacturing the gears are not upto the mark. The present work aims at providing a suggestion to the existing manufacturing process of spiral bevel gears to improve their quality with increased life at a lower cost and less manufacturing time.

1.01 EXISTING METHOD FOR PRODUCING SPIRAL BEVEL GEARS

BMTF, at present, is producing Spiral Bevel gears to be fitted in right angle gear box to drive deep well turbine pumps.

Producing spiral bevel gear is a lengthy task. The existing process of manufacturing spiral bevel gear is schemitically given in fig

The problems of the existing method of manufacturing are discussed in details in chapter 3.00

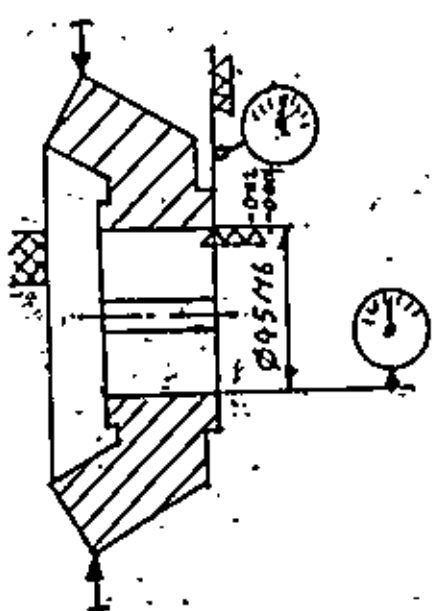
STEP	MACHINE TOOL	OPERATION	SKETCH
1	GRIND HAMMER	Forging	
2	TURRET LATHE	(a) Drilling hole (1) (b) Boring hole to dia. 44.6H7 (c) Chamfering hole (1) 45 deg. x1 (d) Facing surface (2) (e) Facing surface (3) and making step Dia. 45	
3	CENTER LATHE	(a) Facing to length 43.2mm (b) Facing surface (4) to thickness 38mm (c) Making angle 33 deg. x1 in from dia. 92mm	

Fig. 1. contd.

PROCESS SHEET FOR SPIRAL BEVEL GEAR

PART NO. 5185 N/7 (contd.)

STEP	MACHINE TOOL	OPERATION	SKETCH
4	COPYING LATHE	Copy turning as shown in the sketch	
5	COPYING LATHE	Copy turning as shown in the sketch	
6	BRANCHING MACHINE	Prepared by branching as shown in the sketch	

STEP	MACHINE	OPERATION	TOOL	SKETCH
7	INTPOID GENERAT	Gear rough cutting	According to Dimension summary Sheet no. MS220287	
8	INTPOID GENERAT	Gear finish cutting	According to Dimension summary Sheet no. MS220287	
9		Deburring by filing		
10		Case hardening by carburizing Case depth 0.01-0.02 Hardness 18-25 HRC		
11	INTERACTA	Bore grinding GRINDING dia. 45.75 INCHING gear face Clean grinding		
		Inspection		

1.02 TYPES OF MANUFACTURING DEFECTS OF SPIRAL BEVEL GEARS

Following are the common manufacturing defects found in Spiral bevel gears produced in BMTF.

1. Less surface hardness.

This is due to insufficient carbon penetration during carburizing.

2. High distortion of teeth

This is due to improper positioning of gear during quenching.

3. Surface crack during quenching.

This is caused by excessive rapid cooling during quenching.

4. High noise during operation.

This is a combined effect of machining and heat treatment faults.

5. Generation of excessive heat during operation of gears.

This is also a combined effect of machining and heat treatment errors.

6. The teeth are not concentric with reference to the axis.

This fault arises due to improper method of bore grinding.

7. Longitudinal contact is not at the middle of the teeth.

This is due to insufficient development of teeth contact pattern during teeth cutting.

8. Backlash is not constant.

This is caused by improper heat treatment and / or improper method of bore grinding.

1.03 AIMS AND OBJECTIVES OF THE STUDY

The existing process of spiral bevel gear manufacturing was closely observed and found that problems of less surface hardness, high distortion of teeth and surface cracks are generated during heat treatment process.

The rest of the defects i.e. high noise, generation of excessive heat, eccentric teeth, unusual teeth contact pattern and non uniform backlash during operation are directly related to accurate location of the ground bore of gear.

The project work aims at solving the second group of defects. The objective of the study are as follows :-

1. To study the existing process of bore grinding and to observe the problems caused by the existing process.
2. To modify the existing process of bore grinding and develop a more scientific method for the same.
3. To design and develop the required bore grinding fixture.
4. To make an economic analysis showing the advantage of using the new fixture.

CHAPTER 2.00

PROBLEMS CAUSED BY THE EXISTING METHOD OF MANUFACTURING SPIRAL BEVEL GEARS

In the method presently practiced in BHIF, after heat treatment, bore and rear face of the gears are finish ground to final size on internal grinding machine. The work is clamped by a four jaw chuck, the chuck is rotated and checked for trueness of the bore and rear face by dial indicator, the work is adjusted checked for trueness, again readjusted and checked until the operator gets a indicator reading satisfactory to him. Manufacturing problems of the method are:

1. During heat treatment the surface becomes rough and bore becomes distorted, so it is very difficult to get the right position of the gear on the chuck.
2. There is a keyslot made in the bore earlier. This keyslot causes disturbances when the bore is checked for trueness by rotating the work.
3. It takes a long time, even for a skilled operator, to fix one workpiece on the grinding machine.
4. The accuracy of the process entirely depends on the skill of the operator.

As a result of the above manufacturing problems, the gears at final mounting show some degree of inaccuracy of the tooth profile position in relation to the desired ideal circumferential and lateral position.

2.01 THE EFFECT OF EXISTING BORE GRINDING PRACTICE ON GEAR PERFORMANCE

The effect of existing bore grinding practice are :

- i) pitch circle runout &
- ii) lateral runout.

These two effects are described below:

- i) Pitch circle runout.

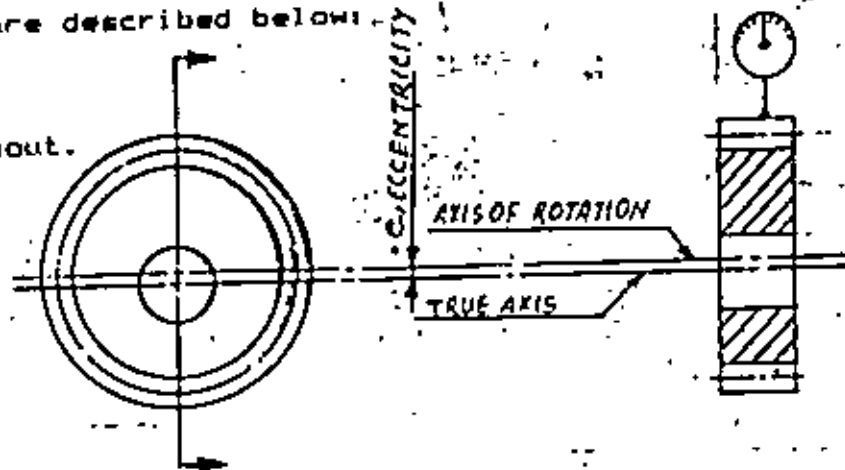


Fig. 2 Pitch circle runout

It is caused by eccentricity between the mounting axis and the center about which the teeth were generated. Pitch circle runout is particularly harmful because of the resultant non-linear output and is a direct measure of gear quality.

- ii) Lateral runout.

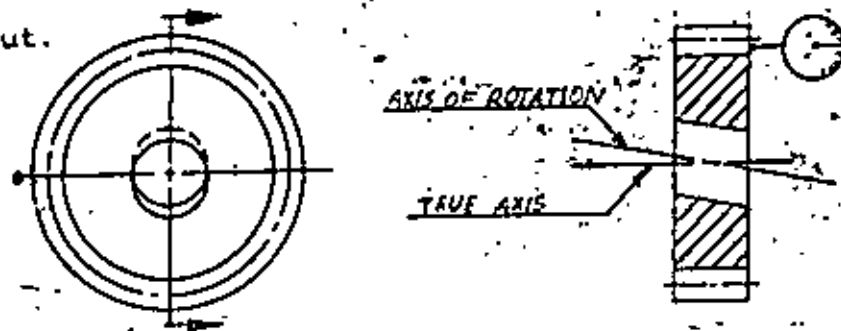


Fig. 3 Lateral runout

This is a lateral movement of gear in relation to the plane of rotation. It can be detected by dial indicator applying on side face of a gear. It has the effect of causing the pitch circle to runout radially with a resulting functional error.

2.02 GENERAL SOLUTION OF BACKLASH CAUSED BY CENTER DISTANCE CHANGE

The relationship between a change in center distance and backlash is of interest both because of small departure from ideal center distance and because of pitch circle runout, which cause the gear center distance to shift position with rotation. A general solution of the backlash effect with change in center distance follows.

Figure 4 shows two mated gear teeth in contact at points G_1 and G_2 along the line of action TT' . An increase of center distance ΔC will cause backlash KK_1 along the new line of action $T'T''$. For small change in center distance the line of action TT' and $T'T''$ are essentially parallel. Furthermore profile lengths KQ and MQ_1 can be considered straight lines normal to the line of action. There are general conditions which apply for any mesh position along the line of action, and the following relation can be stated.

$$KK_1/QQ_1 = \sin \phi$$

$$\text{or, } KK_1 = QQ_1 \sin \phi \quad \text{--- (1)}$$

$$\text{But } QQ_1 = \Delta C$$

$$KK_1 = \text{normal backlash measured along line of action} = B_n/2$$

$$\text{Where } B_n = \text{Normal Backlash measured along the line of action (fig. 4)}$$

$$\text{Therefore, } B_n/2 = \Delta C \sin \phi \quad \text{--- (2)}$$

It is more convenient to measure backlash B along the pitch circle, which can be derived from the relationship

$$B_n = B \cos \phi$$

$$\text{Where } B = \text{Backlash measured along the pitch circle}$$

$$\text{or } B_n/B = \cos \phi \quad \text{--- (2.1)}$$

$$\text{Now dividing eqn. (2) by eqn. (2.1)}$$

$$\text{We get, } B/2 = \Delta C \tan \phi \quad \text{--- (3)}$$

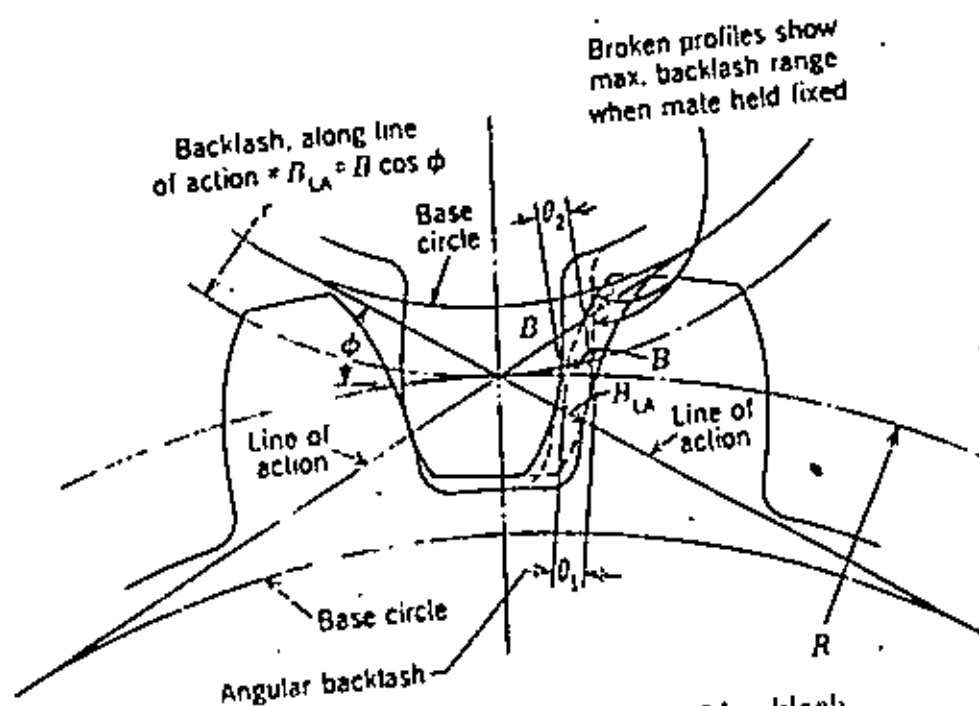


Figure 4. Geometrical definition of backlash.

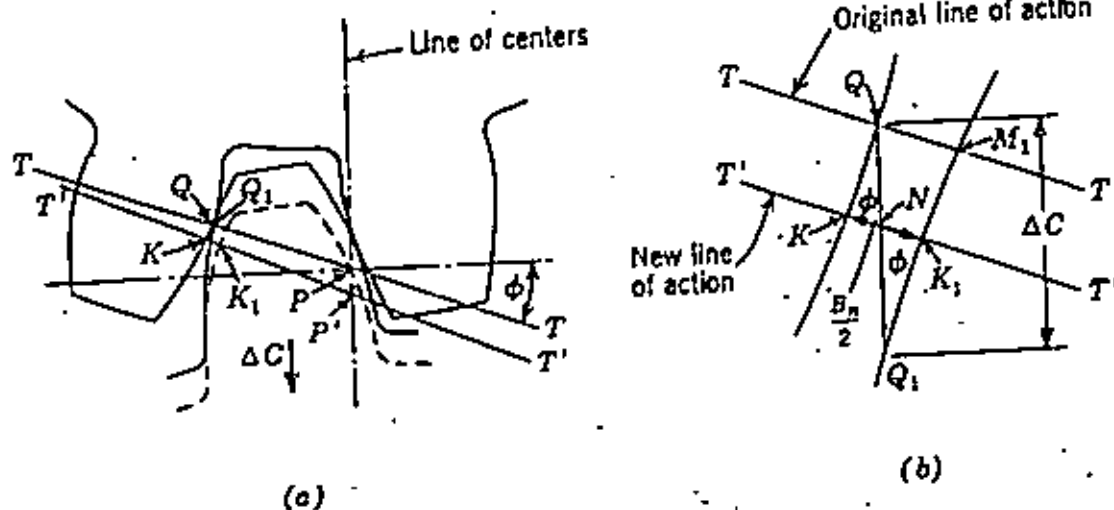


Figure 5. Backlash caused by center distance change: (a) mated teeth before and after increase of center distance, (b) enlarged view of profiles and backlash.

Since there is an equivalent opening of the profiles on the other side of the tooth, the total backlash is.

$$B_n = 2 \Delta C \sin \phi \text{ ----- (4)}$$

= normal backlash measured along line of action.

$$\text{and } B = 2 \Delta C \tan \phi \text{ ----- (5)}$$

= backlash measured along the pitch circle.

The relationship is also true for a closing of centers, and then the value B is negative and a measure of backlash decrease.

Equation 5 is an approximate measure of backlash caused by center distance change. However this is adequate for backlash calculations because the deviation from exact value is very slight particularly if the center distance openings are small, which is the usual case of precision gears.

2.03 BACKLASH CAUSED BY PITCH CIRCLE RUNOUT

As the gear is rotated through mesh, runout causes the teeth to move in and out of engagement. From figure 8 it can be deduced that the gear center moves in and out of mesh with a simple harmonic motion.

$$\Delta C = e \sin \theta \quad \text{--- (A)}$$

Where C = Change in center distance

e = Shifting of true center center of rotation

θ = Angle swept measured in Radians

This change in location of the true center can be equated to resultant backlash by equation (5) and the runout component of backlash caused by eccentricity is,

$$B = 2e \tan \phi \sin \theta$$

where B : runout component of backlash measured along pitch circle

e : shifting of true center from center of rotation

θ : angle swept measured in radians

In relation to the midposition, backlash is increased during half the cycle and decreased during the other half, so that it is, in effect, a plus and minus variable backlash.

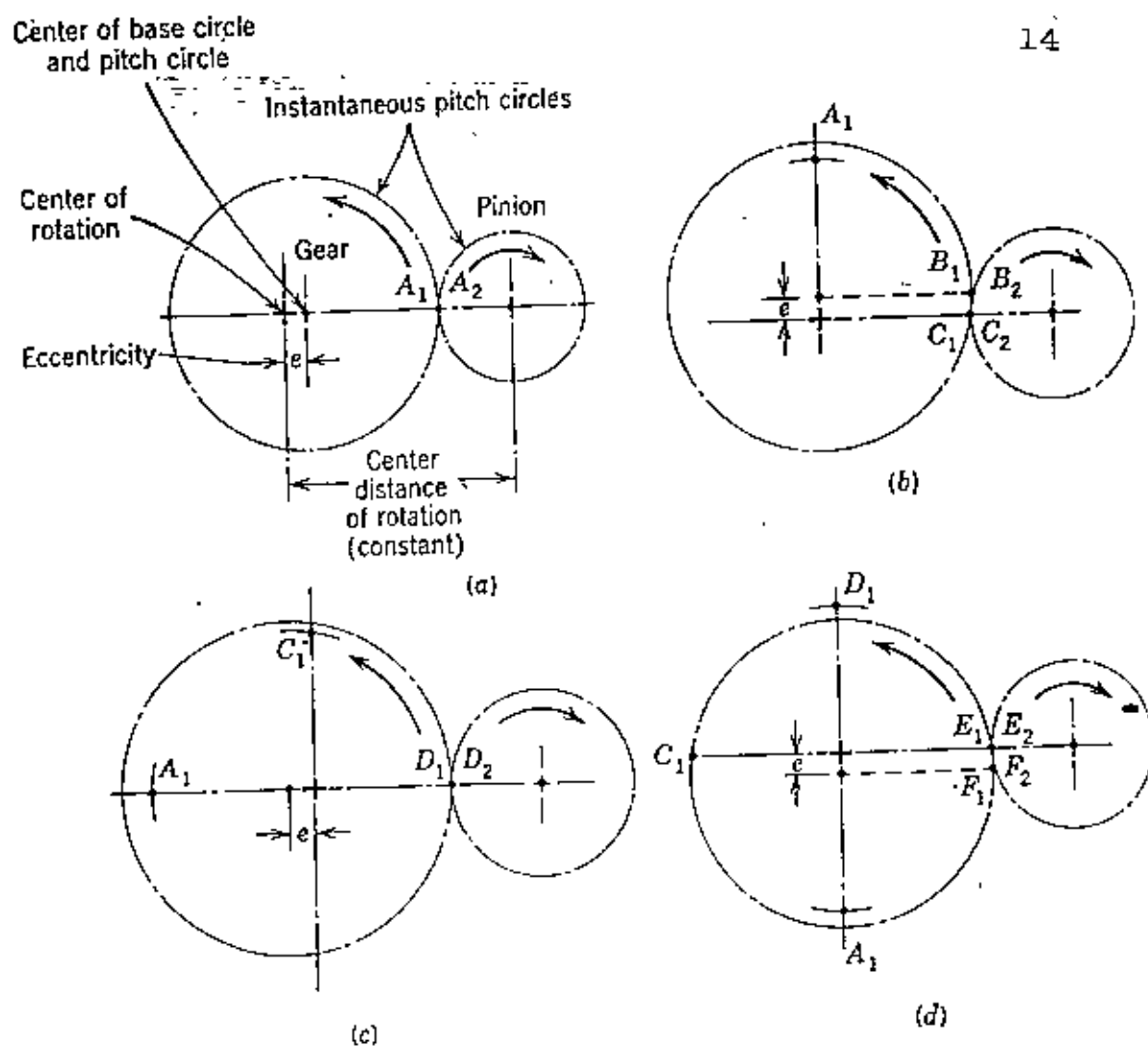


Figure 6. Runout position error in terms of pitch circle rotation.

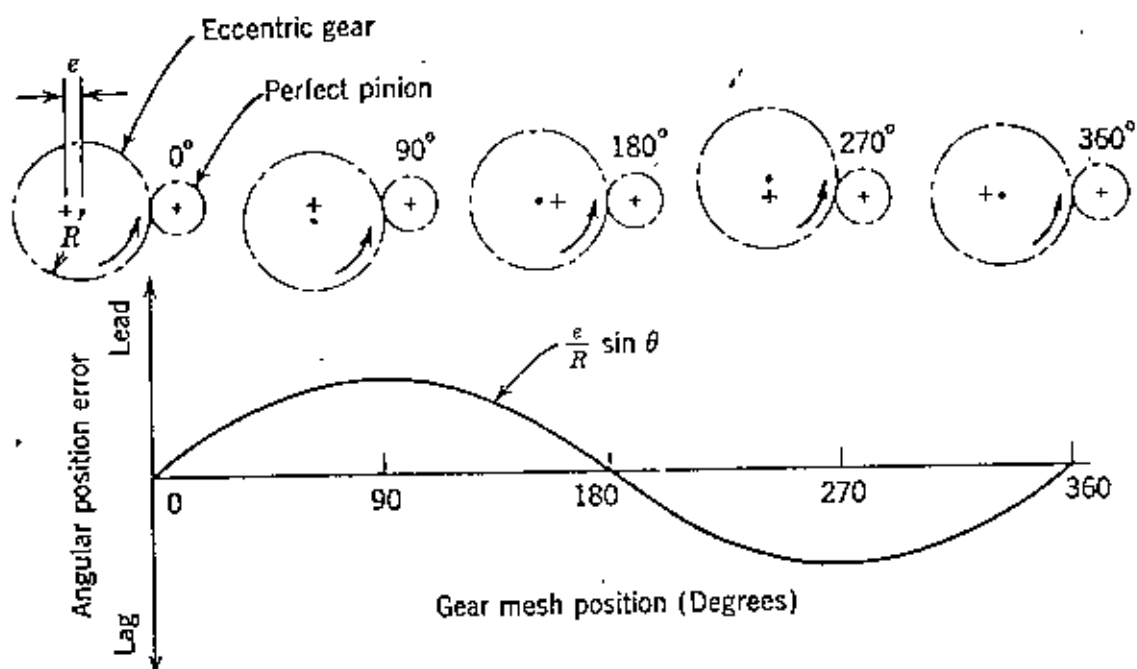


Figure 7. Various positions of mesh for eccentric gear and a perfect mating pinion with a plot of the position error.

2.04 PRESSURE ANGLE VARIATION CAUSED BY PITCH CIRCLE RUNOUT.

Let a perfect pinion is meshed with a gear whose axis of rotation is eccentrically displaced by an amount e . Figure 9 (a-d) show such a defective gear pair in various positions.

In fig. 9(a) the pair is meshed along a line passing through the center of the defective gear's pitch circle. For the gear rotated 90 deg. fig 9(b) the eccentricity increases the center distance of the base circles and there is a new pitch point and large pressure angle. A second rotation of 90 deg. fig 9(c), brings the gears base circle on the line of centers. Then the instantaneous center distance of the base circles and the pressure angle are maximum. A third 90 deg. rotation, fig 9(d), results in an arrangement symmetrical to fig(b), but with the center of base circle below the center of rotation. Another 90 deg. rotation returns the pair to the original condition of fig. 9(a).

It is evident that an eccentric center of rotation will cause:

1. The center of the base circle to follow a circular path about the center of rotation.
2. The instantaneous center distance of the base circles to vary between C_{1e} and C_{2e} .
3. The instantaneous pressure angle to go through parallel fluctuation.
4. The instantaneous pitch point to trace an approximately circular path.

The geometry of the effects is plotted to an enlarged scale in fig. 9(e).

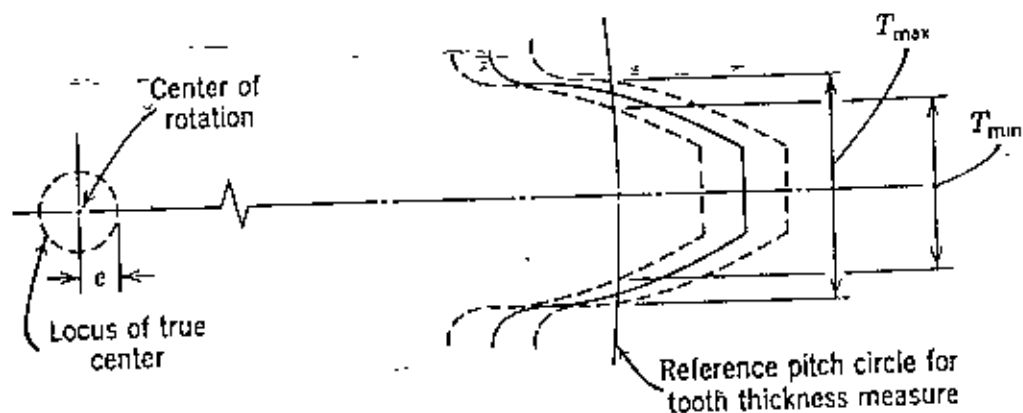


Figure 8. Tooth thickness variation caused by runout.

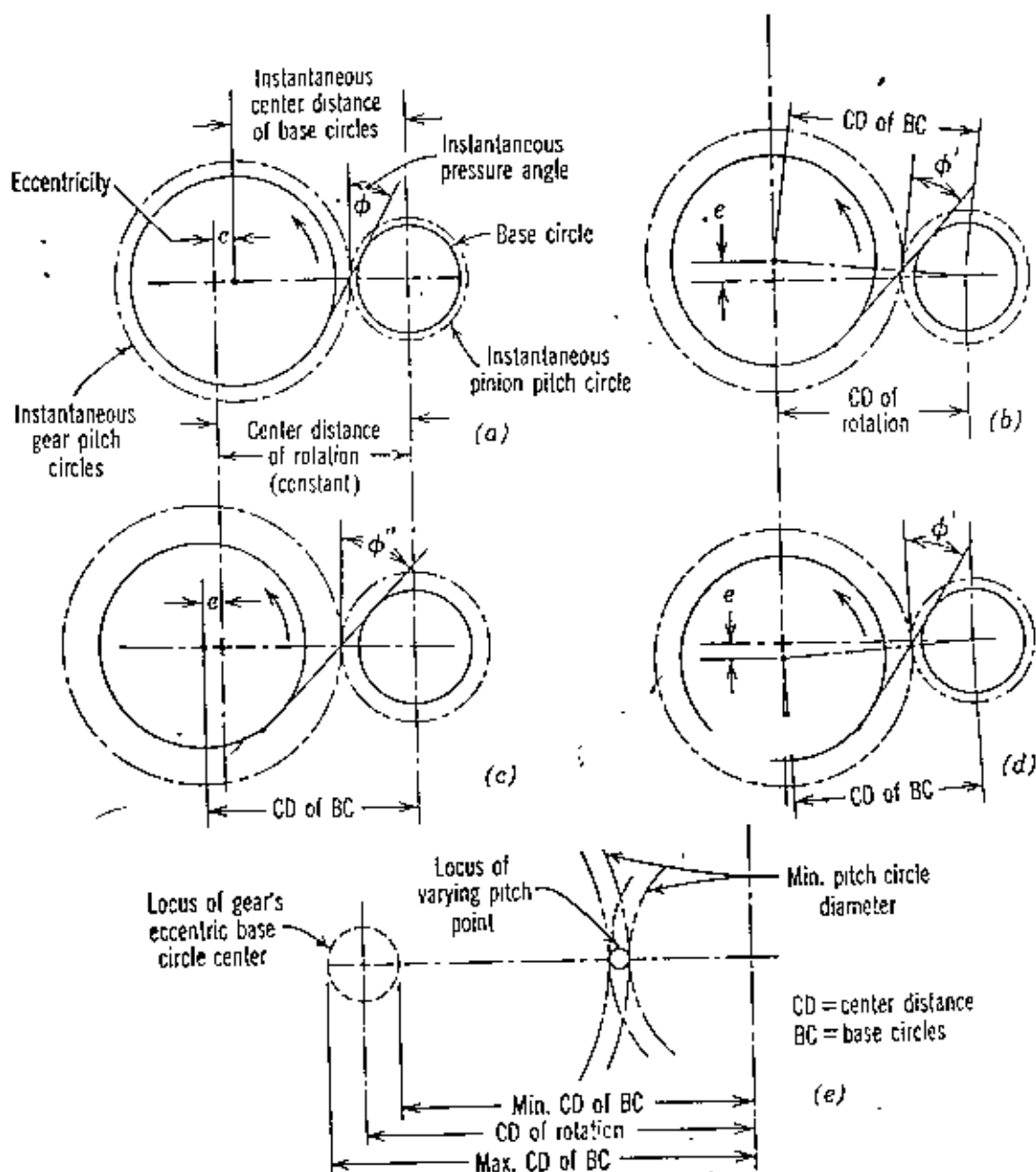


Figure 9. Geometrical aspects of the mesh of an eccentric gear and perfect pinion: (a-d) particular condition positions, (e) summary of variations for one rotation.

For involute gear teeth the relation between center distance and pressure angle is given by.

$$C = (R+r) / \cos \phi$$

where, C = center distance of base circles

R = Base circle radius of gear

r = Base circle radius of pinion

$$\text{or, } \cos \phi = (R+r) / C$$

$$\phi = \cos^{-1}((R+r)/C) \quad \text{---(8)}$$

For a pair of gear and pinion, base circle diameters, R and r are constant. Now if the pair is rotated, the instantaneous center distance goes through parallel fluctuation; pressure angle also will fluctuate as shown in the figure 9.

Let a pinion is transmitting a torque F to the gear, the

tangential component of the torque becomes $F_t = F \cos \phi$ ---(9)

and the radial comp. of the torque becomes, $F_r = F \sin \phi$ ---(10)

Now, if the pressure angle fluctuates in each revolution, the tangential and radial loads on bearing also will fluctuate. If load is transmitted at high rpm, this fluctuation will create hammering effect on bearing which will decrease the life of the bearing.

CHAPTER 3.00

PROPOSED METHOD FOR BORE GRINDING

In the previous chapter it has been observed that most of the operational problems arise from inaccurate location of bore with respect to the pitch circle. To avoid this error a new concept of pitch cone location has been developed.

The idea is to use a fixture so that the pitch circle falls concentric automatically with the axis of the internal grinding machine. There will be three equal size ball headed pins accurately located & equally spaced around the spindle. The flanks of the bevel gear teeth will seat on these balls. As because pitch surface of a bevel gear is a cone and there may be only one plane through three points in space, the gear will seat concentrically and co-axially on the pins. The teeth will be distorted during the heat treatment so the location will not be exact but it will definitely be much more accurate than the existing method.

3.01 DESIGNING OF A FIXTURE FOR BORE GRINDING

It has been mentioned in the previous chapter that a fixture is needed to accurately locate the gear for bore grinding. This fixture is a Pitch Line Chuck, because the objective of the fixture is to locate the pitch circle and pitch cone concentric with the spindle axis of the internal grinding machine. In this chapter the complete design of a pitch line chuck has been given as depicted in fig. 11(a-d). The components of the chuck have been described along with the procedure of manufacture of its various parts.

Item no.1 Hexagonal bolt M12 x 30

It is a 30mm long simple bolt, three in number. They have been used to clamp the Pitch Line Chuck with the internal grinding machine spindle.

Item no.2 Flat washer $\phi 12$

There are three flat washer and have been used with the bolts, item no. 1, to clamp the Pitch Line Chuck.

Item no. 3 Fixture Plate

This is the main part of the Pitch Line Chuck. It is a thick, rigid, round plate. At the left hand side it has been adapted to fit with internal grinding machine spindle. In the right hand side three concentric and accurately located holes have been made to seat the ball reference pins.

Item no.4 Locking Plate

This plate has been designed to hold the workpiece on the ball reference pins.

Item no. 5 Knurled Hand Nut

There are three nuts. After placing the workpiece and the locking plate, these nuts have to be tightened to lock the workpiece and the locking plate.

Item no. 6 Clamping Stud

These studs will remain fixed with the fixture plate. These studs are complementary parts of the work locking system.

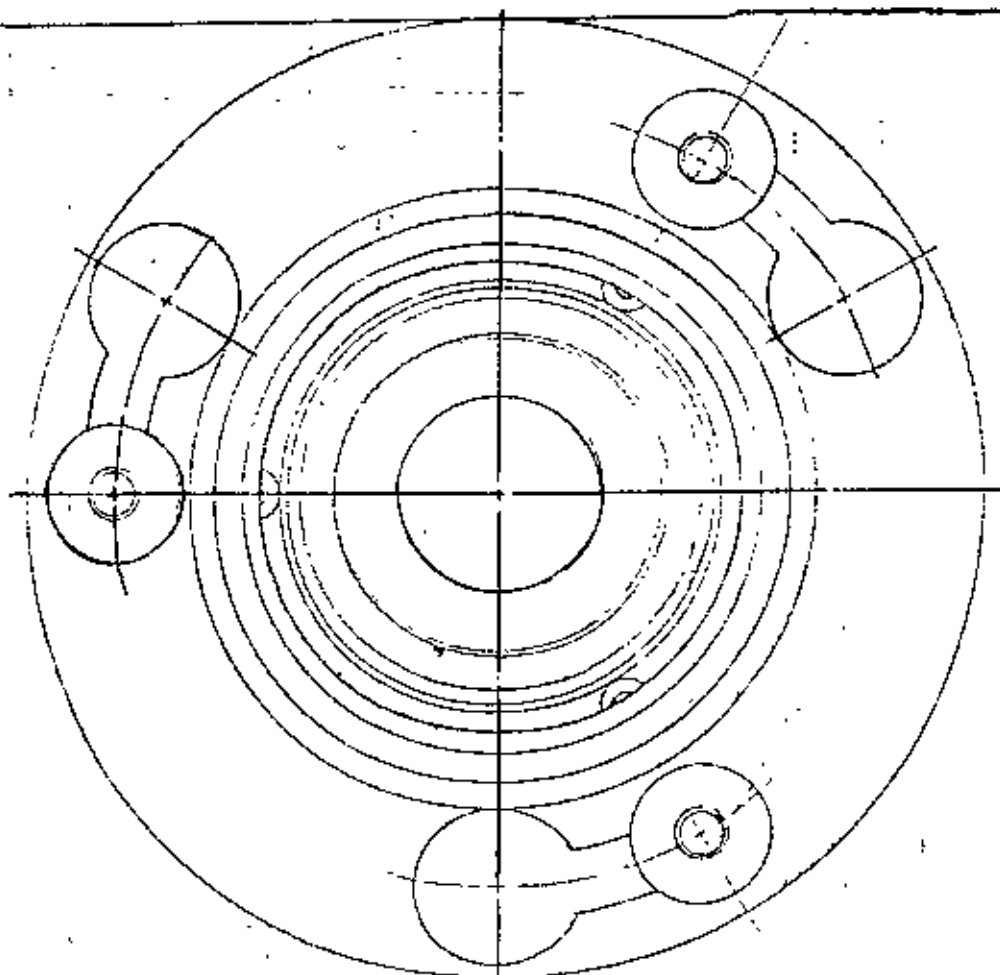
Item no. 7 Ball Reference Pins

These pins are most vital elements of the Pitch Line Chuck. These are hardened and accurately ground parts having ball diameter and length from the centre of the ball to the seating face are within 1 micrometer tolerance. These pins are produced by gauge manufacturers and are to be imported.

Item no. 8 Grub Screw

These screws prevent the chuck from spinning about the grinding machine spindle.

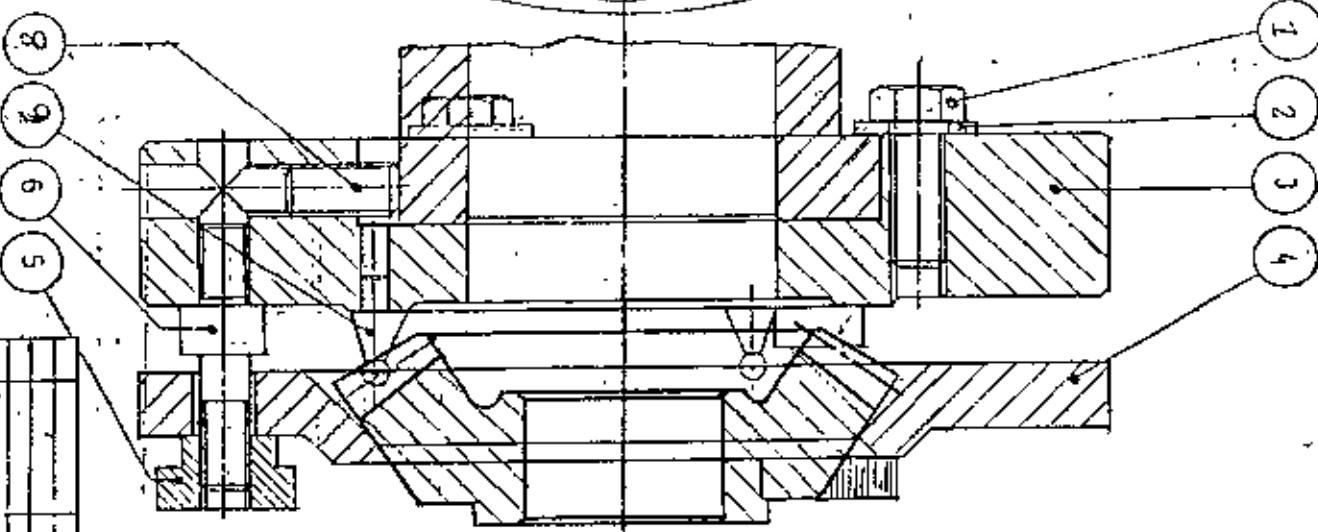
Fig. 11 (a)



NOTE:

THE FIXTURE MUST BE PAINTED BY RED OXIDE COATING FIRST, THEN AFTER DRIVING COATING OF BLACK COLOUR TO BE GIVEN

CAUTION: NO COLOUR ON THE BORE SURFACES, SCREWS, PINS & THREADS.

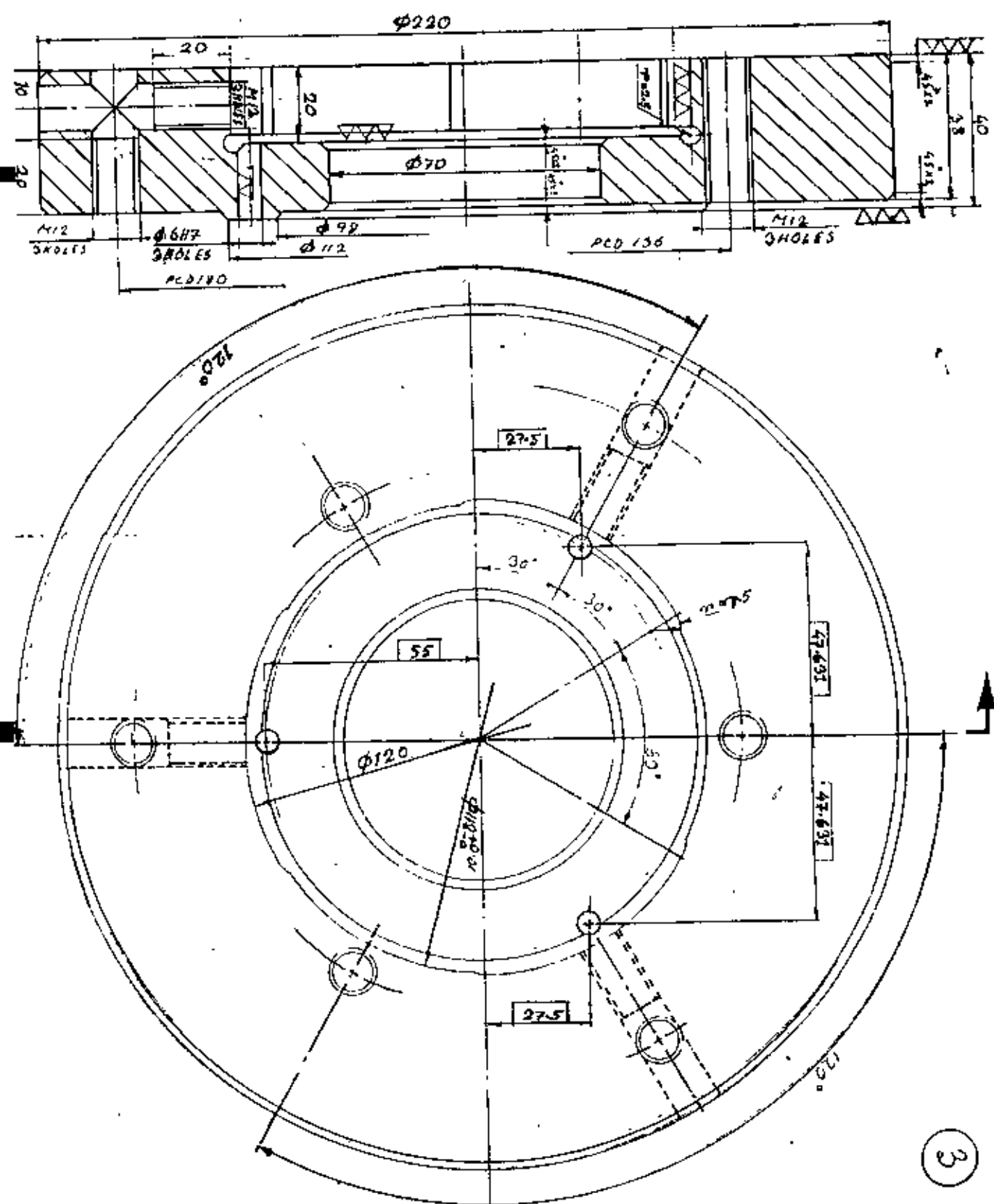


ITEM NO.	QTY	PART NAME	STANDARD	MATERIAL	HEAT TREATMENT
10					
9					
8	3	GRUB SCREW M12X25	BSMT 3125	A41-S	HARDENED 30-35 HRC
7	3	BALL REFERENCE PIN	-	A41-S	HARDENED 30-35 HRC
6	3	CLAMPING STUD	-	A41-S	HARDENED 30-35 HRC
5	3	KNURLED HAND KUT	-	A41-S	HARDENED 30-35 HRC
4	1	LOCKING PLATE	-	A41-S	HARDENED 30-35 HRC
3	1	FIXTURE PLATE	-	A41-S	-
2	3	FLAT WASHER 12X	BSMT 3122	A41-S	HARDENED 30-35 HRC
1	3	HEX BOLT M10X30	BSMT 3105	A41-S	HARDENED 30-35 HRC

ITEM NO.	QTY	PART NAME	STANDARD	MATERIAL	HEAT TREATMENT
10					
9					
8					
7					
6					
5					
4					
3					
2					
1					

CANESESH MACHINE TOOLS FACTORY LTD.

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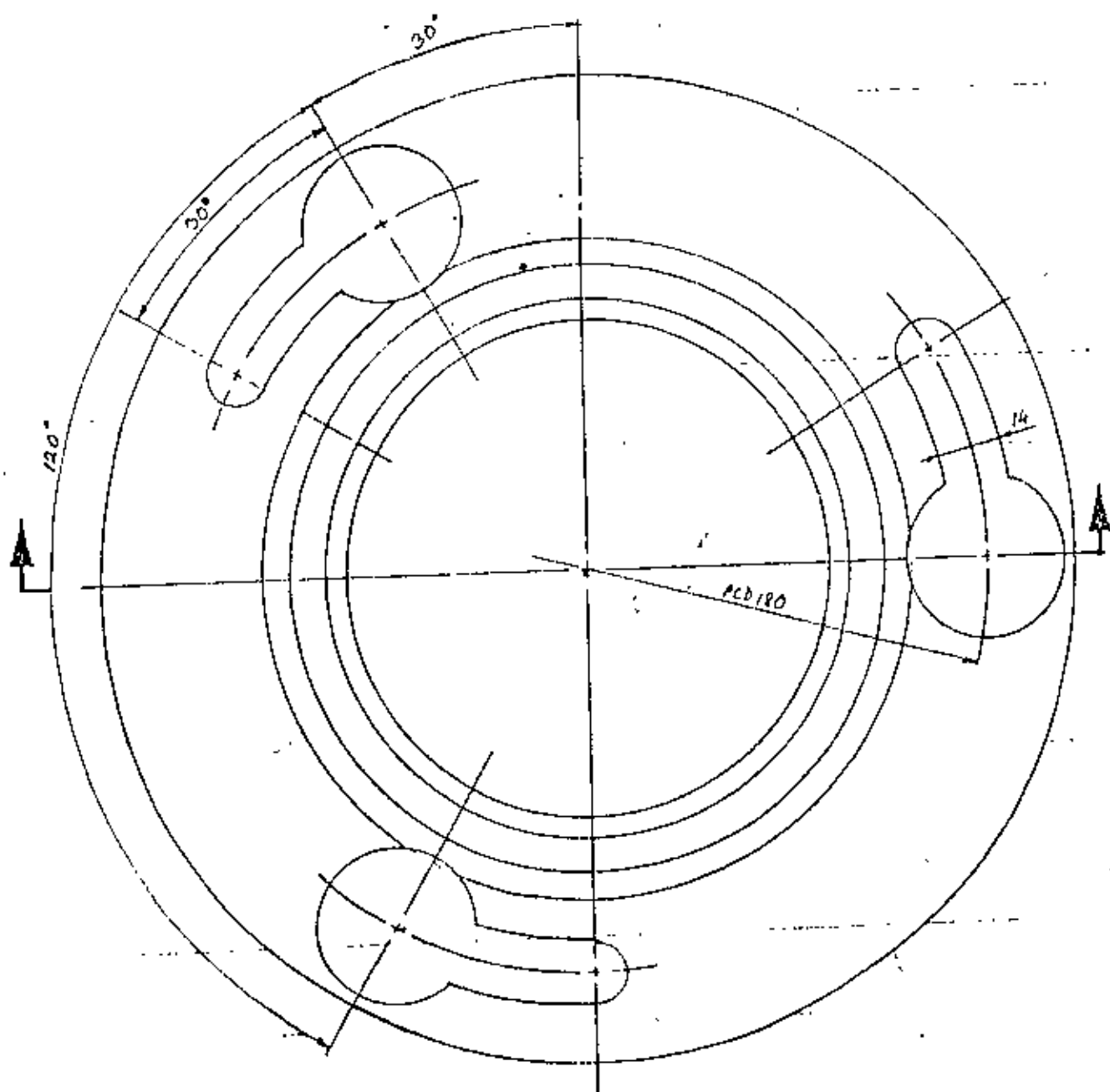
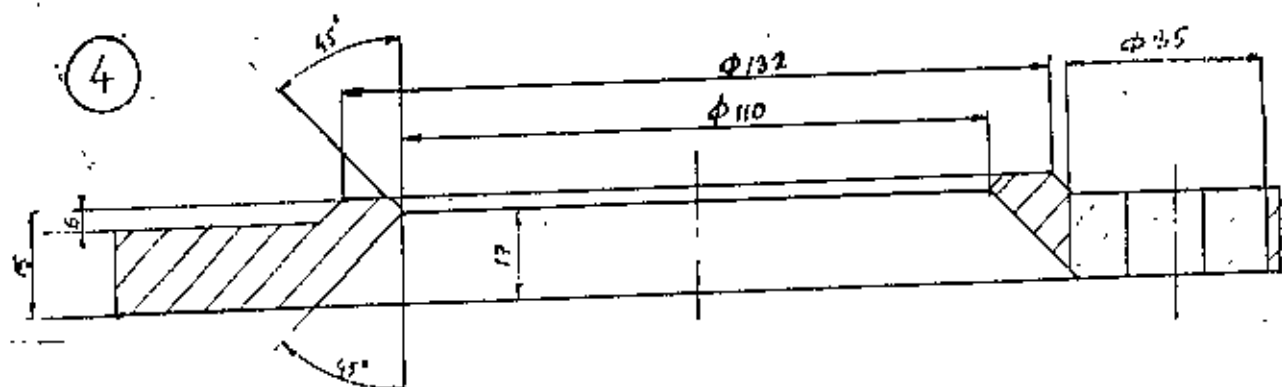
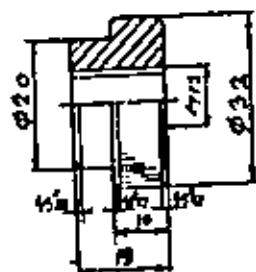


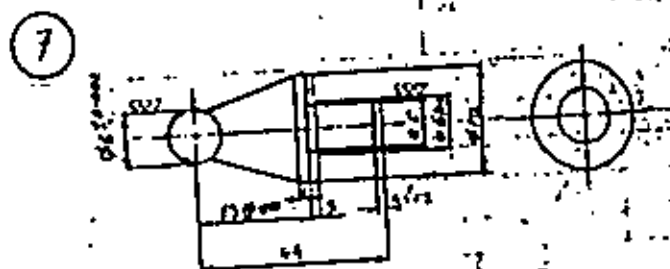
Fig. 11 (c)



5



6



7

Fig. 11(a)

3.02 ADVANTAGES OF USING THE PITCH LINE CHUCK

The advantages of using pitch line chuck over the existing method are given as follows :-

1. The bevel gear can be easily clamped in the chuck.
2. Proper location of the gear can easily be achieved.
3. No need of dial indicators.
4. Clamping & setting time is greatly reduced.
5. Reduce fatigue of the operator.

3.03 MATERIAL TO BE USED FOR THE FIXTURE

All the material except the ball reference pins are available in BMTF. BMTF has round bar or plates of different composition. All these materials are imported from abroad. Every country has his own national standard and for the same material every country has his own code. To get rid of this problem BMTF has developed it's own standard codes as BMTF standard. All the steels are specified in this standard. Table 1 shows the composition of steel used for different parts of Pitch Line Chuck and in Table 2 mechanical properties of steel materials are given.

TABLE 1 STANDARD COMPOSITION OF RAW MATERIAL

MATERIAL	BMTF CODE NO	CHEMICAL COMPOSITION				
		C	Mn	Si	Ph	Si
MILD STEEL	BMS-1	0.06	0.30	0.05	0.04	0.04
		0.14	0.50	0.30		
	BMS-2	0.09	0.60	0.05	0.05	0.05
		0.16	0.90	0.30		
MEDIUM STEEL	BMS-3	0.15	0.40	0.10	0.04	0.04
		0.25	0.70	0.40		
MEDIUM STEEL	BMS-4	0.32	0.50	0.10	0.04	0.035
		0.38	0.80	0.40		
CARBON STEEL	BMS-5	0.42	0.50	0.10	0.04	0.035
		0.48	0.80	0.40		
HIGH CARBON STEEL	BMS-6	0.50	0.50	0.10	0.04	0.035
		0.60	0.80	0.40		
HIGH CARBON STEEL	BMS-7	0.50	0.50	0.10	0.04	0.035
		0.80	0.80	0.40		

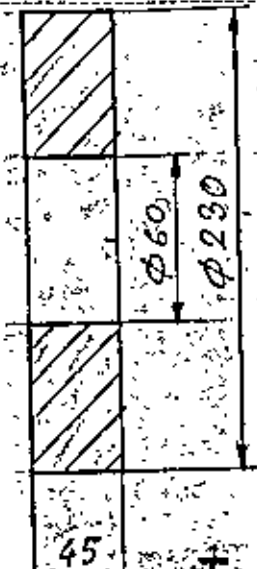
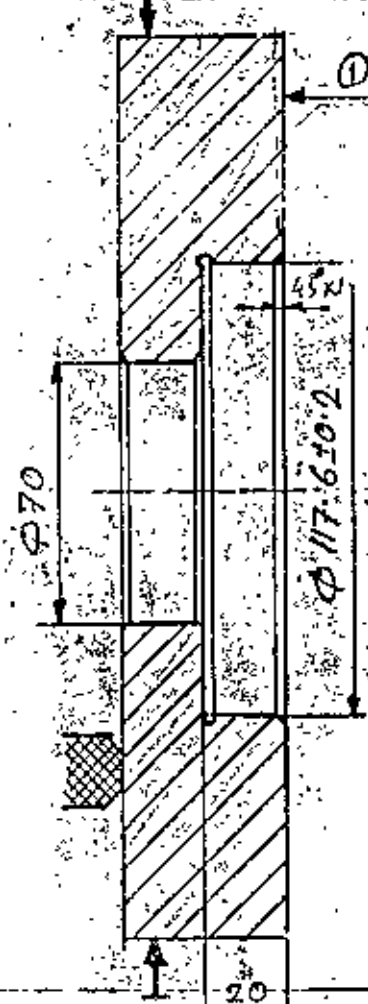
TABLE 2 MECHANICAL PROPERTIES OF STEEL MATERIAL

MATERIAL	BMTF CODE NO	YEILD POINT	TENSILE STRENGTH	ELONGATION % =5d	HARDNESS HB SOFT ANNEALED
		N/MM ²	N/MM ²	%	
MILD MEDIUM CARBON STEEL	BMS-1	275	470	16	131
			640		
	BMS-2	333	590	14	146
			780		
MEDIUM CARBON STEEL	BMS-3	410	660	15	203
			880		
HIGH CARBON STEEL	BMS-6	1050	1200	7	210
			1450		
HIGH CARBON STEEL	BMS-7				217

3.04 METHOD OF MANUFACTURING DIFFERENT PARTS OF THE PITCH LINE CHUCK

The chuck has 8 different parts. Among these two parts are standard items. These are nuts and ball reference pins, hence these two parts not needed to be manufactured. The nonstandard parts are to be manufactured. After manufacturing, all the parts are to be assembled to build up the complete fixture. For the making of the nonstandard parts different machines are needed such as centre lathe, drilling machine, grinding machine and jig boring machine. The detailed operation procedure for these nonstandard parts are schemetically given in fig. 12 to fig. 15. The assembly drawing and its various parts are shown in fig 11.

Figure 12. PROCESS SHEET FOR FIXTURE PLATE
ITEM NO. 3

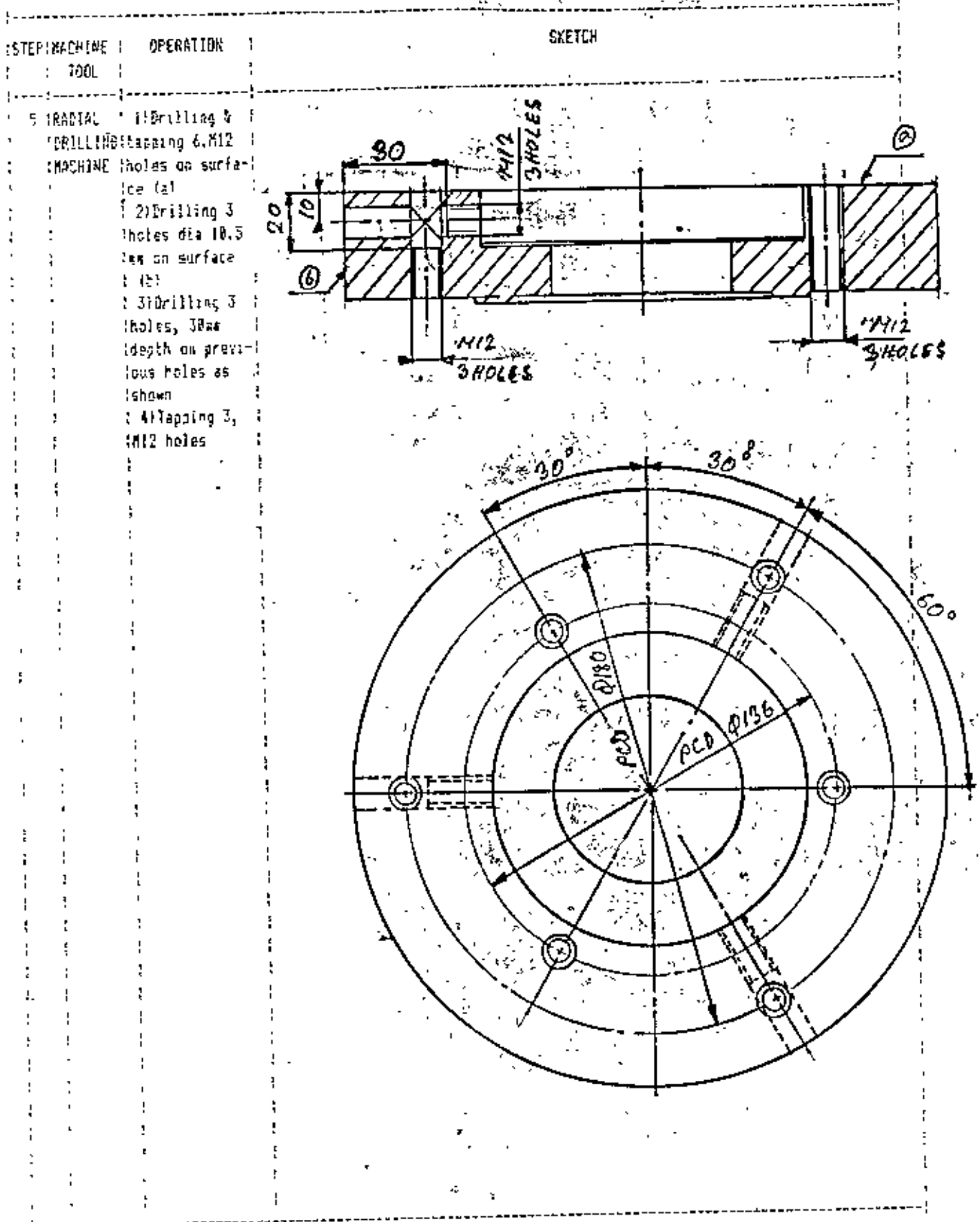
STEP	MACHINE	OPERATION	SKETCH
1	FLAME CUTTING EQUIPMENT	Flame cutting the plate as shown in the sketch	
2	CENTER LATHE	(a) Facing surface (1) (b) Boring dia. 70 through (c) Boring dia. 117.6 ± 0.2 to 20 in depth (d) Bore as shown in the sketch (e) Chasing 45 as shown.	

PROCESS SHEET FOR FIXTURE PLATE
ITEM NO. 3

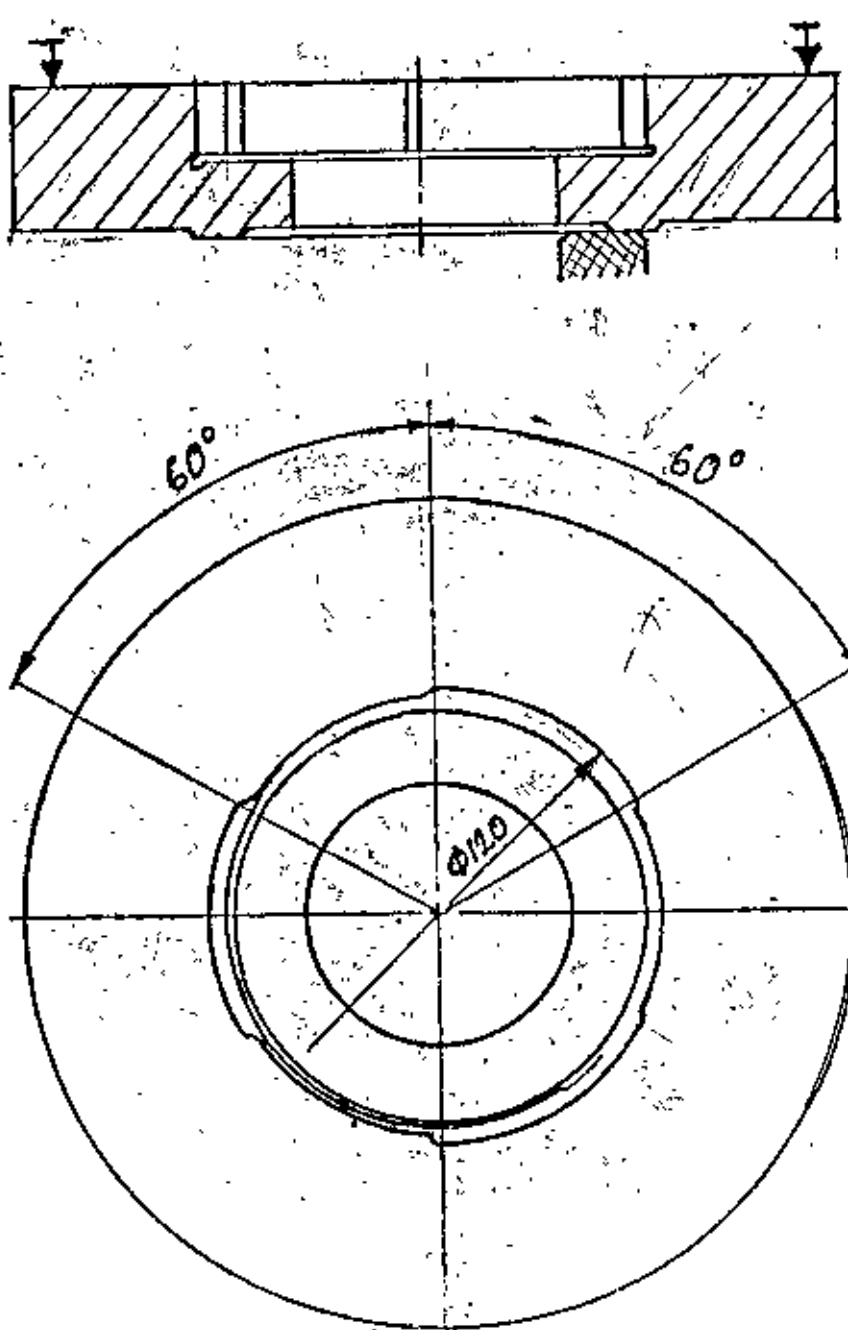
STEP	MACHINE	OPERATION	SKETCH
3	CENTER LATHE	(a) Facing surface (2) (b) Facing surface (3) (c) Chamfering 45 deg 1 as shown.	
4	MARKING	Marking all hole positions	

Fig. 12. contd.

PROCESS SHEET FOR FIXTURE PLATE
ITEM NO. 3



PROCESS SHEET FOR FIXTURE PLATE
ITEM NO. 3

STEP	MACHINE	TOOL	OPERATION	SKETCH
1	VERTICAL MILLING MACHINE		(a) Fixing on rotary table (b) Milling grooves as shown in the sketch	

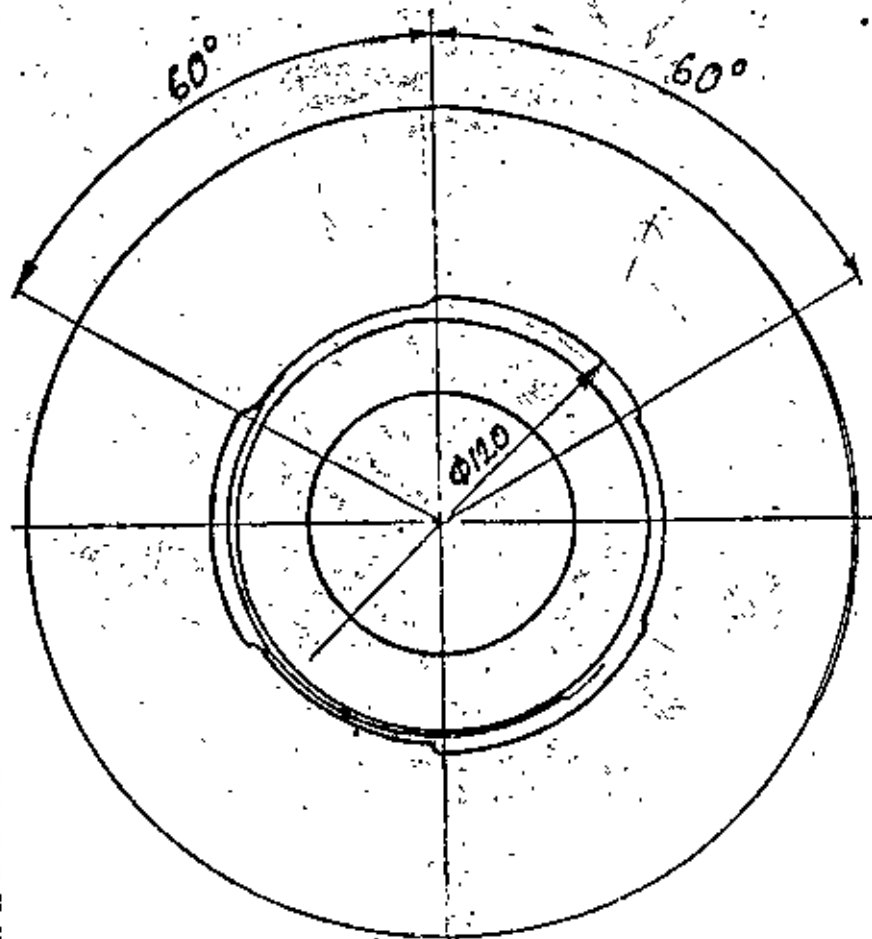
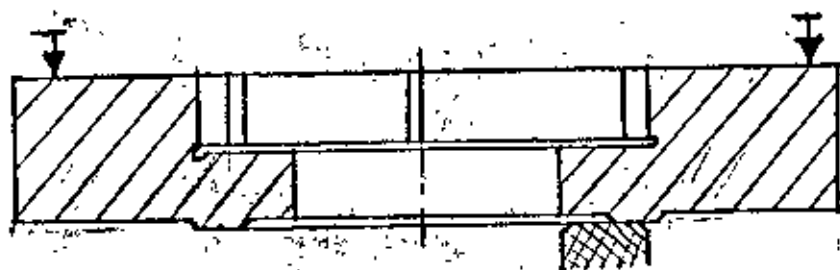


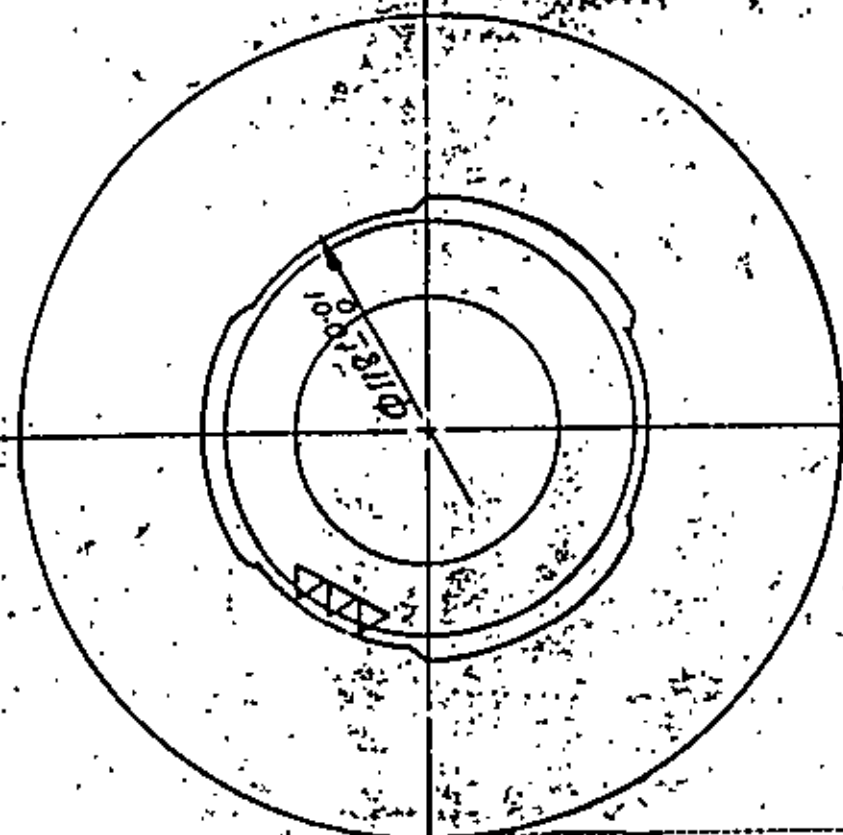
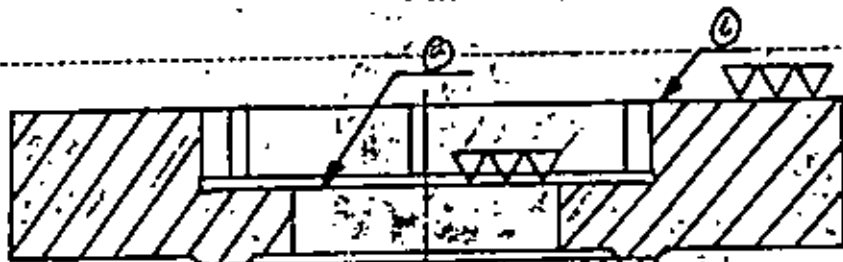
Fig. 12. Contd.

PROCESS SHEET FOR FITTURE PLATE
ITEM NO. 3

STEP MACHINE OPERATION
7 157A

7 INTERNAL GRINDING the
GRINDING: bore to dia. 1.180
MACHINE: $\pm .001$ as shown
2) Grinding
surface (a)
3) Grinding
surface (b)

SKETCH



8 SURFACE Clean grinding
GRINDING: the top surface
MACHINE: as shown in the
sketch



Fig 12. Contd.

PROCESS SHEET FOR FIXTURE PLATE
ITEM NO.3

STEP	MACHINE TOOL	OPERATION	SKETCH
9	216 BORING MACHINE	Boring 3 holes dia. 647 at location shown in the sketch	$\phi 647$ $\phi A, B \ 0.001$ 27.5 47.631 47.631 55 27.5

Figure 13. PROCESS SHEET FOR LOCKING PLATE
ITEM NO. 4

STEP	MACHINE TOOL	OPERATION	SKETCH
1	FLAME CUTTING EQUIP- MENT	1) Flame cutting 2) 28mm thick 3) plate as shown in the sketch	
2	CENTER LATHE	1) Facing sur- face (a) 2) Boring hole dia. 118 3) Turning 45 deg. angle motor depth 7mm 4) Outside dia. turning upto depth 15mm to dia. 220	
3	CENTER LATHE	1) Facing sur- face (a) to plate thickness 15mm 2) Facing sur- face (b) to chamfer to dia. 132 3) Chamfering the hole 45deg.	

Fig. 13. Contd.
PROCESS SHEET FOR LOCKING PLATE
ITEM NO. 4

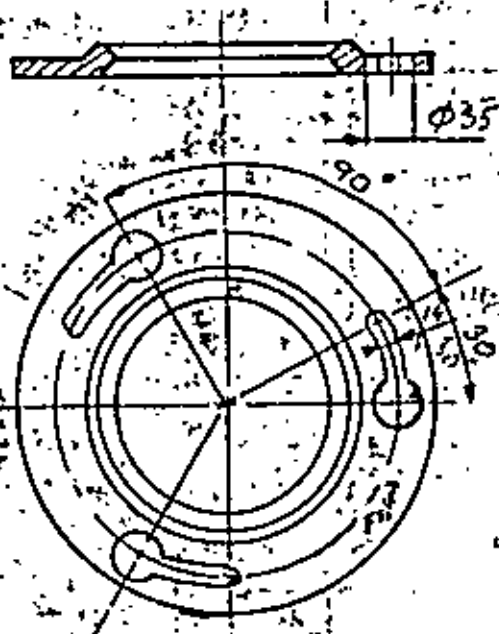
STEP	MACHINE	OPERATION	SKETCH
	TOOL		
4	VERTICAL MILLING MACHINE	Flange the part on rotary table Making Sholes: dia. 35 on FCD 180 deg. 12 deg. part Making Slots: 14mm wide as shown in the sketch	

Figure 14. PROCESS SHEET FOR HAND NUT
ITEM NO. 5

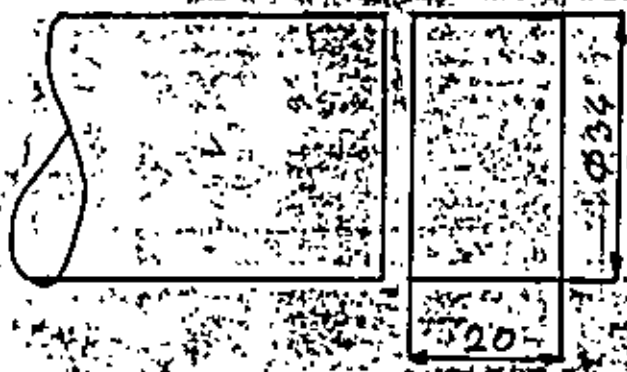
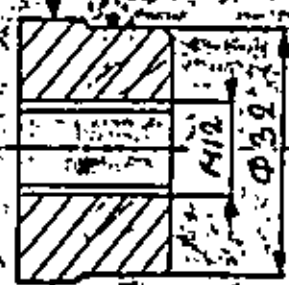
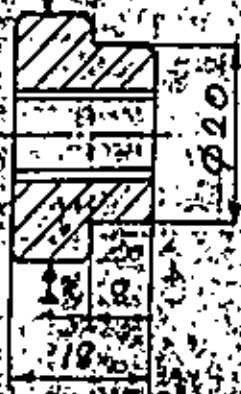
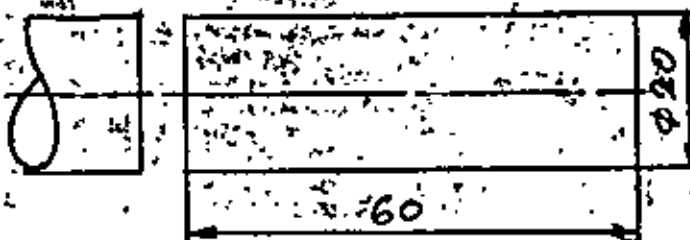
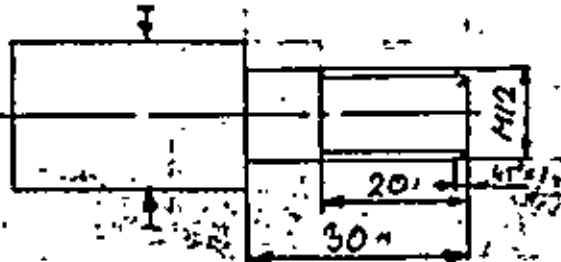
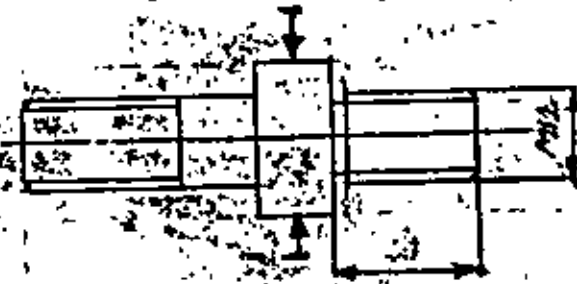
STEP	MACHINE	OPERATION	TOOL	SKETCH
1	POKER HACKSAW	1 Parting off 2 dia. 34 round 3 bar to length 4 20		
2	CENTER LATHE	1 Facing front 2 face 3 Drilling dia. 18.5 through 4 Threading M12 through 5 Turning out- side dia. 32 6 Up to length 7 12 8 Finishing on dia. 32 pitch 9		
3	CENTER LATHE	1 Facing to length 18 2 Making step 8 at dia. 20 3 Chamfering all corners 4 5		

Figure 15. PROCESS SHEET FOR CLAMPING STUD
ITEM NO. 6

STEP: MACHINE TOOL	OPERATION	SKETCH
1 POWER MACHINE	1 Parting off dia. 28 round bar to length 54mm	
2 CENTER LATHE	1 Holding in 3 soft jaw check 2 Turning dia. 12 upto length 23mm 3 Chamfer the end 45deg. 1 4 Threading M12, upto length 28mm from end	
3 CENTER LATHE	1 Holding the piece in a 3 soft jaw check 2 Making 2mm wide groove at length 28 3 Chamfering at the end 45deg. 1 4 Threading M12 as shown	
4 MILLING MACHINE	1 Fixing in a vice 2 Making flat surfaces as shown to make across flat 16	

CHAPTER 4.00

ECONOMICS OF THE PITCH LINE CHUCK

This chapter presents some light on the economic justification for the use of the pitch line chuck. For this purpose the following two aspects have been discussed :

1. Time saving in the proposed method by the use of the pitch line chuck.
2. Break-even quantity of the job to be produced to meet the cost of the newly designed pitch line chuck.

4.01 TIME SAVING IN THE PROPOSED METHOD

The standard production time can be calculated by using the following expression:

$$T = T_m + T_h + T_s + T_f$$

where, T = standered operation time in minute

T_m = machining time in minute

T_h = handling time in minute

T_s = time required for servicing the work
piece in minute

T_f = time required for rest & personal needs,
i.e. fatigue allowance in minute

The machining time is the time during which the chip is being cut from the work piece without the direct participation of the worker.

Handling time constitutes the following :

- i) Time required for setting & clamping the blank
- ii) Removing the finished work piece
- iii) Starting & stoping the machine
- iv) Changing the spindle speed & rate of feed
- v) Setting the cutting tool & advancing it to the work, etc.

In general the handling time is about 200% of machining time for lot production.

Servicing time is the time required for the maintenance of the work piece in performing the given job. It includes the following time elements :

- i) Time needed for making necessary adjustments in the machine tools in the course of operation.
- ii) Time for changing dulled tools.
- iii) Time for cleaning & lubricating the machine etc.

Usually the servicing time is taken as 20% of the total machining & handling time.

The fatigue allowance refers to time allowed for personal needs of the operator. Usually it is 10 % of the total machining & handling time.

According to existing process time required for bore grinding has been observed. The observed time is as follows :

Average machining time , $T_m = 6.0$ minutes per piece

Average handling time , $T_h = 15.0$ minutes per piece

Average servicing time , $T_s = 1.0$ minute per piece

Average fatigue allowance, $T_f = 0.5$ minute per piece

Standard operation time , $T = 22.5$ minutes per piece

It is found from daily production report that an average worker produces 20 pieces per shift. Standard shift time is taken as 7 hrs. So $7 \times 60 / 22.5 = 18.66$ pieces is the calculated shift production target, which fits closely with 20 pcs per shift.

In the proposed method only the handling time will be reduced. Machining, servicing & fatigue allowance will remain the same. Handling time for the various, identical or similar works using fixtures have been observed and found that 4 minutes is a good approximation in this case.

So, in the proposed method time required for bore grinding will be :

Average machining time, $T_m = 6.0$ minutes per piece

Average handling time, $T_h = 4.0$ minutes per piece

Average servicing time, $T_s = 1.0$ minute per piece

Average fatigue allowance, $T_f = 0.5$ minute per piece

Standard operation time, $T = 11.5$ minutes per piece.
It is seen from above estimation that, grinding time will be reduced by $(22.5 - 11.5 =) 11$ minutes per piece.

4.02 COST SAVING IN THE PROPOSED METHOD

Operation cost includes machining cost, labour cost and overhead. For the machine shop of BMTF the following hourly rate were obtained from accounts deptt. (base year 1989)

Operation cost = Tk. 46.75 per hour

Labour cost = Tk. 20.00 per hour

Overhead cost = Tk. 70.18 per hour

Manufacturing cost = Tk. 136.98 per hour

Now, Cost saving in the proposed method, $C_s = \text{Time saving}$
 in the proposed method * Manufacturing cost

= Tk.11/60*136.93 per piece.

= Tk.25.10 per piece.

4.03 COST ESTIMATE OF THE PROPOSED FIXTURE

To calculate the production cost, the following factors have been considered:

- a) Design cost
- b) Material cost
- c) Manufacturing cost

The approximate breakup of different costs are given below:

- a) Design cost
-

The design took about 5 working days to be completed. Hence the design cost is taken as about one fourth of an engineers monthly salary, i.e:

Design cost = Tk.1000.00

b) Material cost

Material estimate

$$i) \text{ Fixture plate: } M1 = \pi D^2 L * 7880 / (4 * 1000^3),$$

where D is the dia in mm

L is the length in mm

7880 is the specific wt. of steel in Kg/m³

$$= \pi * 230^2 * 45 * 7880 / (4 * 1000^3) = 14.73 \text{ Kg.}$$

$$ii) \text{ Locating plate } M2 = L * l * b * 7880 / (1000^3)$$

where L is the length in mm

l is the breadth in mm

b is the thickness in mm

$$= 240 * 240 * 20 * 7880 / 1000^3 = 09.08 \text{ Kg.}$$

$$iii) \text{ Knurled hand nut } M3 = \pi * D^2 * L * 7880 * 3 / (4 * 1000^3)$$

where D is the dia in mm

L is the length in mm

$$= \pi * 34^2 * 20 * 7880 * 3 / (4 * 1000^3) = 0.43 \text{ kg.}$$

$$\text{iv) Clamping stud, } M4 = \pi D^2 L \cdot 7880 \cdot 3 / (4 \cdot 1000^3)$$

where D is the dia in mm

L is the length in mm

$$= \pi \cdot 22^2 \cdot 65 \cdot 7880 \cdot 3 / (4 \cdot 1000^3) = 0.58 \text{ Kg.}$$

$$\text{Total steel material required} = M1 + M2 + M3 + M4$$

$$= 14.73 + 9.08 + 0.43 + 0.58 = 24.82 \text{ Kg.}$$

Cost of medium and high carbon steel is about Tk. 25.00 per Kg. (cost obtained from accounts deptt).

$$\text{Cost of steel material} = 24.82 \text{ Kg} \cdot \text{Tk. } 25.00 / \text{Kg} = \text{Tk. } 620.50.$$

Ball reference pins are not available in the local market. The cost of a set of 3 pins is about US\$ 90.00. The exchange rate of US\$ is about Tk. 33.00 per US\$ in 1989.

The cost of standard commercial part (ball reference pin)

$$= 90.00 \cdot 33 = \text{Tk. } 2970.00.$$

Total material cost = Steel mat. cost + Standard Commercial parts cost ;

$$= \text{Tk. } 620.50 + \text{Tk. } 2970.00$$

$$= \text{Tk. } 3590.50 \sim \text{Tk. } 3600.00$$

c) Manufacturing cost

The time estimation has been made with consultation with the incharge of Central Tooling Department (CTD) and comparing similar components which has previously been made in the CTD shop. The following machining time has been estimated for different component of the pitch line chuck.

1. Fixture plate	-	30 hrs
2. Locking plate	-	4 hrs
3. Knurled hand nut (3 nos)	-	3 hrs
4. Clamping stud (3 nos)	-	3 hrs

Total machining time reqd. = 40 hrs

The following information have been obtained from accounts department of GMF on different costs of CTD.

Operation cost = Tk. 33.57 per hr

Labour cost = Tk. 22.00 per hr

Over head cost = Tk. 27.29 per hr

Manufacturing cost = Tk. 82.86 per hr

So, the construction cost of the pitch line chuck is

$$= 82.86 \times 40 = \text{Tk. } 3314.40$$

$$= \text{Tk. } 3315.00 (\text{approx})$$

The production cost of the pitch line chuck is,

a) Design cost = Tk. 1000.00

b) Material cost = Tk. 3600.00

c) Manufacturing cost = Tk. 3315.00

 Production cost of the
 pitch line chuck = Tk. 7915.00

4.04 FEASIBILITY OF THE PITCH LINE CHUCK

Before finally recommending for the use of the chuck in the proposed method it is required to know the breakeven quantity of the gears to be produced to meet the cost of the fixture.

Let,

Q = Annual production qty. of gears

C_s = Cost saving of bore grinding per piece in the
 proposed method

D = Straight line depreciation of the chuck

The following criteria may be followed for the economic consideration of the chuck.

- i) $Q * C_s < D$, the chuck should not be adopted
- ii) $Q * C_s = D$, the adoption of the chuck depends upon the policy of the manager
- iii) $Q * C_s > D$, the chuck can be adopted

Let,

C_m = manufacturing cost of the pitch line chuck (Tk)

n = life of the chuck (years)

Since the chuck has been designed for long term production the life of the chuck is considered as 10 years.

i.e $n=10$ years

From previous section 4.03 ,

C_m = production cost of the pitch line chuck

= Tk. 7915.00

so, straight line depreciation, $D = C_m/n$

= Tk. 7915.00/10

= Tk. 791.50 per year

~~Now, if the chuck~~ is to be used in the bore grinding operation then the third criteria of this article must have to be satisfied.

From the third criteria it is shown that,

$$Q * Cs > D$$

$$\Rightarrow Q > D/Cs$$

from the previous data $D/Cs = \text{Tk. } 791.50/\text{Tk. } 25.10$

$$= 31.53 = 32 \text{ (approx)}$$

$$\text{i.e. } Q > 32$$

From the above discussion it can be concluded that, if the number of gears to be produced per year is more than 32, then the use of the chuck is justified.

It may be mentioned here that the average demand of spiral bevel gears is about 1200 numbers per year.

Therefore,

Cost saving per year = cost saving per piece * qty. produced per year

$$= \text{Tk. } 25.10 * 1200$$

$$= \text{Tk. } 30120.00$$

It is seen from the above that the investment for the pitch line chuck will save about Tk. 30120.00 per year and significant in productivity by reducing production times. This will help BMTF to maintain delivery schedule at lower production cost.

CHAPTER 5.00

CONCLUSION AND RECOMENDATIONS

The existing process for bore grinding of gears was studied throughly and the problems arise were identified. It was found that most of the operational problems arise from faulty location of bore with respect to the pitch cone of gear. To eliminate the operational as well as manufacturing problem a fixture called the pitch line chuck was developed. Though the fixture was not built, yet the following conclusions could be drawn from the project work.

- i) Many operational problems of gears can be eliminated by using pitch line chuck such as excessive heat generation, non uniform backlash, improper contact pattern etc.
- ii) Manufacturing problems, such as disturbances by key slot and clamping the workpiece in right position is easily achieved.
- iii) A pitch line chuck can save a considerable amount of efforts, labour hour, machinig time, operators fatigue and ultimatley reduce the production cost significantly.
- iv) Use of pitch line chuck will improve the quality of bevel gears. This will help BMTF to satisfy its customers and effectively compete in the market.
- v) Introduction of pitch line chuck in manufacturing process will save an amount of taka 30120.00 per year for only one type of gear.

It was not possible to manufacture the pitch line chuck within the short period of time. The ball reference pins, whice are standard commercial items are not available in the local market. But step have already taken to procure ball reference pins for pith line chuck.

The pitch line chuck designed for the project work is useful not only for bore grinding of Spiral Bevel gears but also for Straight Bevel and Hypoid gears. This type of chuck is also useful for any other conical machine element whose bore is to be ground concentric with the cone.

The fixture plate, on which the pins will seat, is also a very precision component. The holes on which the pins will seat are to be accurately located. This accuracy is possible only by jig boring or jig grinding machines. In Bangladesh BMTF and BITAC can perform this job.

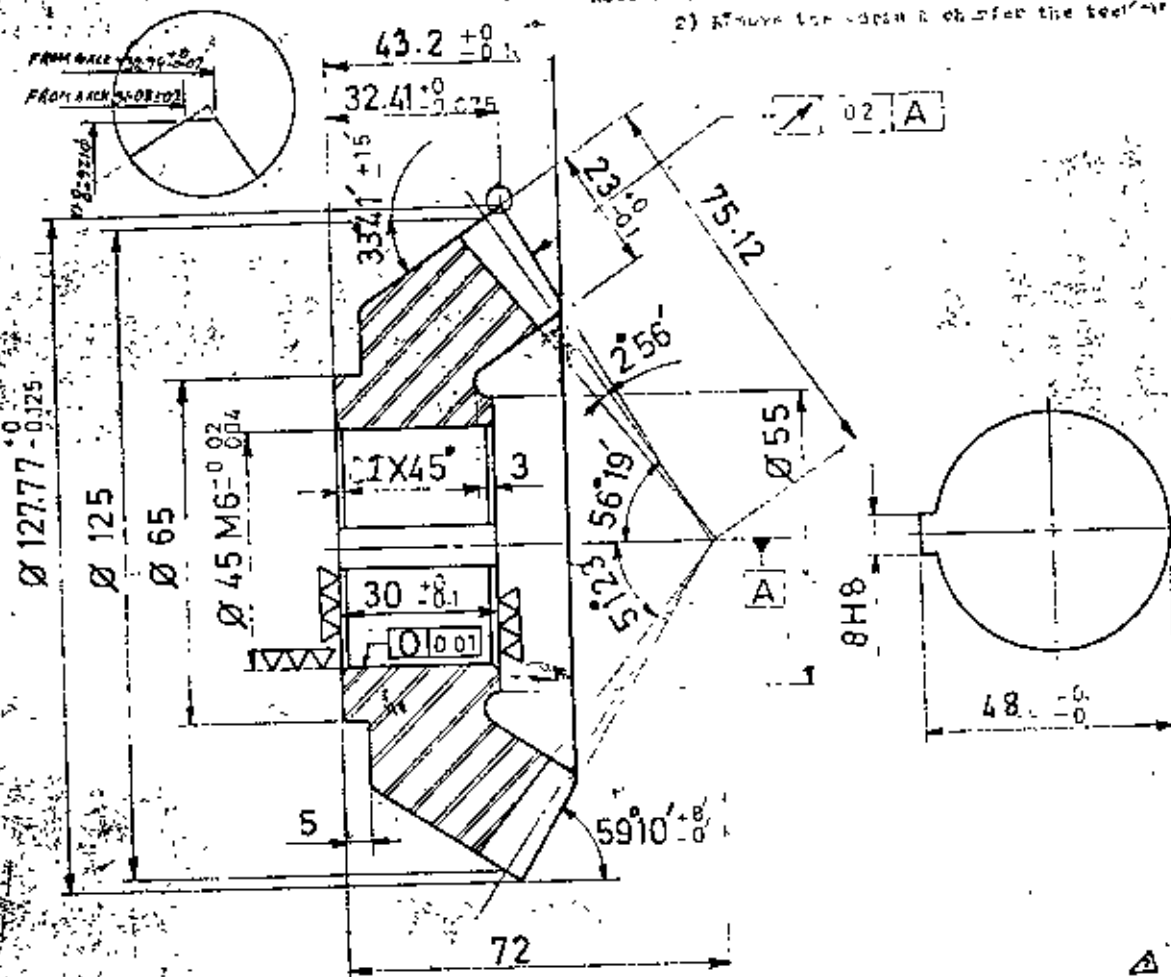
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APPENDIX

Note : 1) Turn surface A on to (p126) after milling the teeth
2) Remove the chamfer & transfer the teeth after milling.

NO. OF TEETH	35
MODULE	3.788
PRESSURE ANGLE	20°
SPINAL TOWARDS RIGHT	32°
TRANSMISSION RATIO	3:2



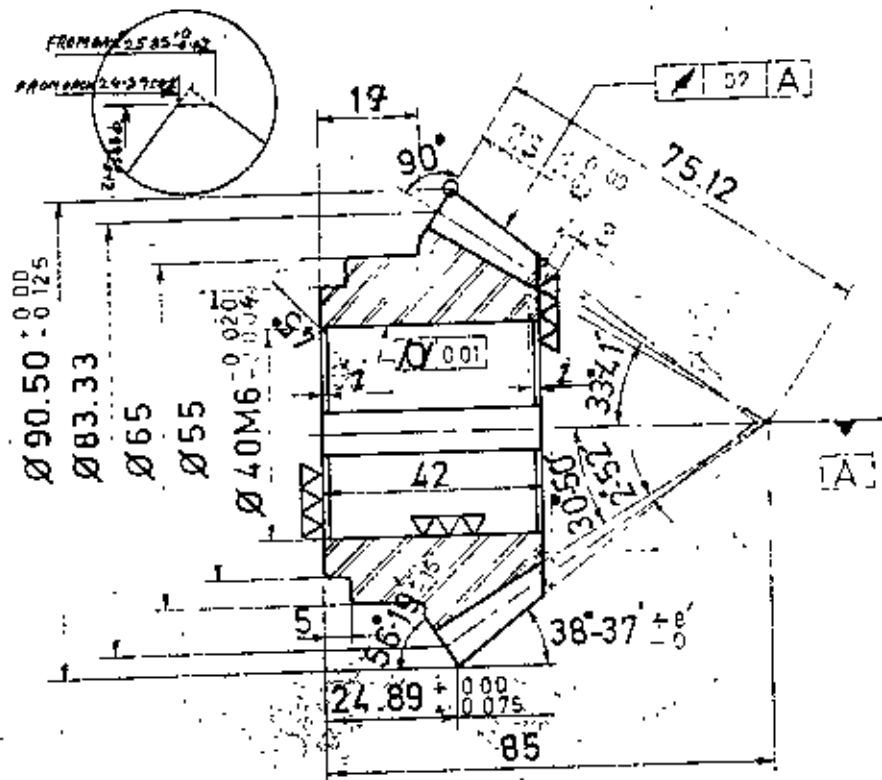
This drawing is made as per Gleason dimension sheet No. 6009087 dated 23.6.84 for 3:2 transmission for further clarification the said sheet may be consulted.

Δ N:B- Depth of case hardening is 0.4 mm.

Spiral Bevel Gear

409-000016

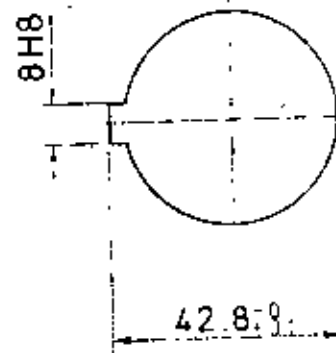
Application		R.I. 100 3:2	Org. Index	Qty.	Non Tol. Dimension
Material		BMS-27	Stock Size	Stock Wt.	Finish Wt.
Date	Modification	Sign	30-7-85	55 HRC	Heat Treatment
Store Code (Raw mat.)	Drawn	Checked	Approved	Part No.	5105N/8 bis
Store Code (Finish)	Part Name		Vertical Bevel Gear		
BANGLADESH MACHINE TOOLS FACTORY Ltd					Scale 1:1
38070074					Folio



This drawing is made as per Gleason dimension sheets No. M 5009087 dated 10/15/84 for 3:2 transmission. For further clarification the said sheet may be consulted.

GLEASON SPIRAL TOOTHING

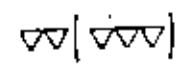
No. OF TEETH	Z = 22
MODULE	3.288
PRESSURE ANGLE	20°
SPIRAL TOWARDS LEFT	32°
TRANSMISSION RATIO	3:2



Spiral Bevel Pinion

409-00015

H.G. 2 Depth of case hardening is 0.4 mm.



Application		R.T. 100	3:2	Org index	61y	Non Tol Dimension
Material		BMS-27		Stock Size	Stock wt	Finish wt
Date Modification	29-7-85	65 HRA		Stock	Stock	Stock
Store Code (Part Name)	Horizontal Bevel Gear	5185N/7bis		Part No	5185N/7bis	
BANGLADESH MACHINE TOOLS FACTORY Ltd						



Flasques pour machines 5-52-400

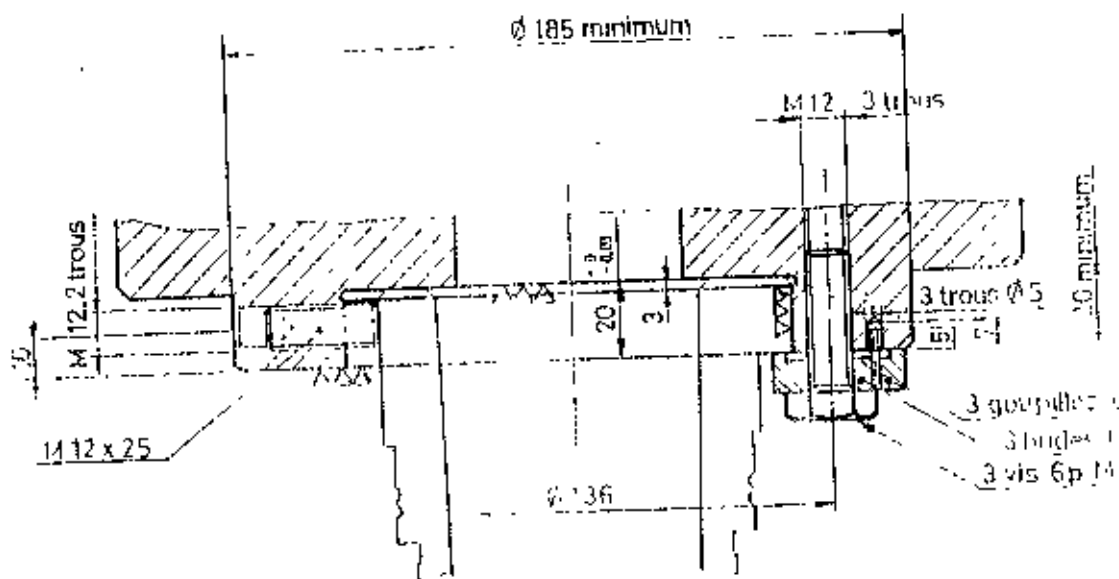
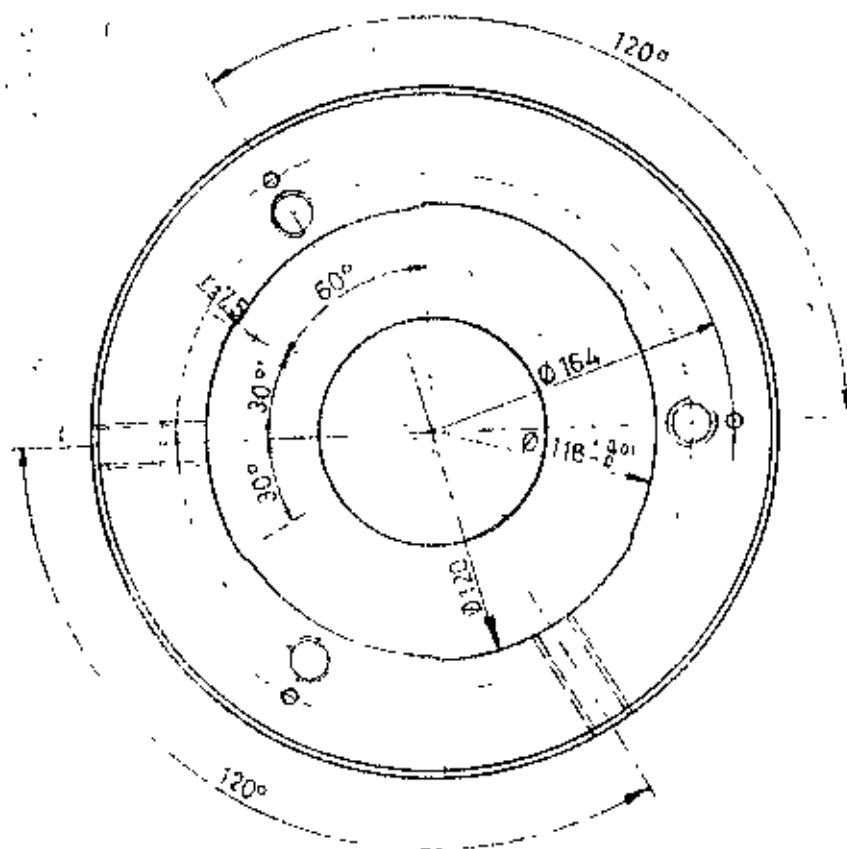
Instructions techniques

Internal Grinding Machine Spindle

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Date

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GENERATED SPIRAL BEVEL SUMMARY NO. M 5009087

BANGLADESH MACHINE TOOL/A.B.R.- JOYDEPUR
BANGLADESH MACHINE TOOL/A.B.R.- JOYDEPUR

SHEET 1 OF 4 DATE 6/28/84 TIME 10:30

NUMBER OF TEETH	PINION 22	GEAR 33
MODULE	23.00	3.788
FACE WIDTH	200 DM	23.00
PRESSURE ANGLE	- PIN CONCAVE	
	- PIN CONVEX	
SHAFT ANGLE		75.12
OUTER CONE DISTANCE		2.50
ADDENDUM	4.30	5.02
DEDENDUM	3.21	6.80
WORKING DEPTH	7.51	7.51
WHOLE DEPTH - THEORETICAL	90.50	127.77
OUTSIDE DIAMETER		
PART NUMBER		

REF. SUMMARY 179.010 CUTTERS

PITCH APEX TO CROWN	PINION 60.11	GEAR 39.59
PITCH ANGLE	330 41M	560 19M
FACE ANGLE OF BLANK	380 37M	590 10M
ROOT ANGLE	300 50M	510 23M
DEDENDUM ANGLE	20 52M	40 56M
SPIRAL ANGLE	320 0M	320 0M
HAND OF SPIRAL	LH	RH
CUTTING METHOD	FIXED SETTING	SPREAD BLADE
BACKLASH	0.13	MAX 0.18
DRIVING MEMBER	PIN	
DIRECTION OF ROTATION	REV	
INPUT DATA	KTY M	
DEPTH FACTOR - X		0.000
ADDENDUM FACTOR - C1		0.000
MOUNTING DISTANCE		

GEAR TOOTH SIZES AT MIDDLE OF FACE

NORMAL CHORDAL ADDENDUM	ROUGHED 1.94	FINISHED 1.94
NORMAL CHORDAL THICKNESS	4.13	3.62
MEAN WHOLE DEPTH	5.95	5.95

PINION TOOTH SIZES AT MIDDLE OF FACE

NORMAL CHORDAL ADDENDUM	3.36	FINISHED 3.36
NORMAL CHORDAL THICKNESS	4.82	4.82
MEAN WHOLE DEPTH	5.95	5.95
DEPTH CHECKING DATA - NO. 15 BLANK CHECKER - FINISHING		
CHECKING DIAMETER	PINION 73.02	GEAR 101.40
BACKING	MD - 60.11	MD - 38.64

ALL LINEAR DIMENSIONS EXCEPT CUTTER SPECIFICATIONS ARE
IN METRIC UNITS

RELEASED BY - KBF

CUSTOMERS ORDER NO SALES ORDER NO NO OF SETS DATE

Generated Spiral Bevel Summary (Continued)

SHEET 2 OF 4 DATE 6/28/84 TIME 10:30

GENERATED SPIRAL BEVEL SUMMARY NO. M 5009087

BANGLADESH
BANGLADESH MACHINE TOOL/A.S.R. JOYDEPUR

CUTTER SPECIFICATIONS - GEAR ROUGHING		CUTTER SPECIFICATIONS - GEAR FINISHING	
DIAMETER	6.000"	DIAMETER	6.000"
OUTSIDE BLADE ANGLE	18° 0M	OUTSIDE BLADE ANGLE	18° 0M
INSIDE BLADE ANGLE	22° 0M	INSIDE BLADE ANGLE	22° 0M
POINT WIDTH	0.060"	POINT WIDTH	0.080"
BLADE LETTER		BLADE LETTER	0.035"
BLADE EDGE RADIUS	0.025"	BLADE EDGE RADIUS	STD
BLADE DEPTH	STD	BLADE DEPTH	STD
TYPE OF CUTTER		TYPE OF CUTTER	
NO. BLADES IN FINISH CUTTER		NO. BLADES IN FINISH CUTTER	
CUTTER GAGING POSITION	0.000"	CUTTER GAGING POSITION	0.000
GEAR ROUGHING SETTINGS - NO 116 GENERATOR		GEAR FINISHING SETTINGS - NO 116 GENERATOR	
MACHINE ROOT ANGLE	51° 23M	MACHINE ROOT ANGLE	51° 23M
MACHINE CENTER TO BACK	MD +	MACHINE CENTER TO BACK	MD +
SLIDING BASE	WITH	SLIDING BASE	WITH
BLANK OFFSET	0.00	BLANK OFFSET	0.00
ECCENTRIC ANGLE	36° 0M	ECCENTRIC ANGLE	36° 0M
CRADLE ANGLE	1° 47M	CRADLE ANGLE	1° 47M
SWIVEL ANGLE	0° 0M	SWIVEL ANGLE	0° 0M
CUTTER SPINDLE ROTATION ANG	0° 0M	CUTTER SPINDLE ROTATION ANG	0° 0M
CRADLE TEST ROLL	100 0M	CRADLE TEST ROLL	300 0M
WORK TEST ROLL	350 55M	WORK TEST ROLL	350 55M
DECIMAL RATIO	0.7903	DECIMAL RATIO	0.7903
NC/50 RATIO GEARS	-52/47 X 50/70	NC/50 RATIO GEARS	-52/47 X 50/70

GEAR TOOTH SIZES AT MIDDLE OF FACE		FINISHED
NORMAL CHORDAL ADDENDUM	ROUGHED	1.94
NORMAL CHORDAL THICKNESS		3.62
MEAN WHOLE DEPTH		5.95
BACKLASH IN RADIANS - GEAR MIN	0.00265 MAX	0.00375

DEPTH CHECKING DATA - NO 15 BLANK CHECKER		FINISHED
CHECKING DIAMETER	MD -	101.40
BACKING		38.64

ALL LINEAR DIMENSIONS EXCEPT CUTTER SPECIFICATIONS ARE IN METRIC UNITS

RELEASED BY -

KBF

Generated Spiral Bevel Summary (Continued)

MACHINE DIVISION

TIME 10:30

DATE 7/28/84

SHEET 3 OF 4

NO. M 5009087

GENERATED SPIRAL BEVEL SUMMARY

BANGLADESH
BANGDALESH MACHINE TOOL/A-B-R.- JOYDEPUR

CUTTER SPECIFICATIONS - PINION ROUGHING		NO 116 GENERATOR	
DIAMETER	6.000"	MACHINE ROOT ANGLE	30D 50M
OUTSIDE BLADE ANGLE	12D 0M	MACHINE CENTER TO BACK	0.00
INSIDE BLADE ANGLE	28D 0M	SLIDING BASE	0.30
POINT WIDTH	0.050"	BLANK OFFSET	0.00
BLADE EDGE RADIUS	0.020"	ECCENTRIC ANGLE	35D 53M
BLADE DEPTH	STD	CRADLE ANGLE	142D 6M
CUTTER GAGING POSITION	0.000"	SWIVEL ANGLE	23D 13M
		CUTTER SPINDLE ROTATION ANG.	22D 17M
		CRADLE TEST ROLL	20D 10M
		WORK TEST ROLL	35D 153M
		DECIMAL RATIO	0.7893
		NC/50 RATIO GEARS	52/41 X 56/90

ALL LINEAR DIMENSIONS EXCEPT CUTTER SPECIFICATIONS ARE
IN METRIC UNITS.

KBF

RELEASED BY -

GENERATED SPIRAL BEVEL SUMMARY - NO. N 8009037

BANGLADESH
BANGLADESH MACHINE TOOL/A.O.R.- JOTDEPUR

CUTTER SPECIFICATIONS - PINION FINISHING
CONCAVE - 0B CONVEX - 1B
SIDE OF TOOTH
POINT DIAMETER 5.970" 3.800"
BLADE ANGLE 140 0M 310 0M
BLADE LETTER
BLADE EDGE RADIUS 0.030" 0.030"
BLADE DEPTH STD STD
TOPREY LETTER
CUTTER GAGING POSITION 0.000"
PINION FINISHING SETTINGS - NO 116 GENERATOR
CONCAVE - 0B CONVEX - 1B
SIDE OF TOOTH
MACHINE ROOT ANGLE 340 64M 370 10M
MACHINE CENTER TO BACK - NO 6.99
SLIDING BASE 3.33 MD 6.99
BLANK OFFSET 6.13 WITH 3.37
ECCENTRIC ANGLE 1.00 2.89
CABLE ANGLE 340 64M 370 52M
CABLE ANGLE 1670 57M 1320 28M
SWIVEL ANGLE 400 47M 390 9M
CUTTER SPINDLE ROTATION ANG. 260 26M 520 55M
CABLE TEST ROLL 200 0M 200 0M
WORK TEST ROLL 340 0M 390 10M
DECIMAL RATIO 0.7508 0.8610
MC/SD RATIO GEARS 52/44 X 47/74 55/42 X 50/76

PINION FINISHING TOOTH SIZES AT MIDDLE OF FACE
NORMAL CHORDAL ADDENDUM 3.36
NORMAL CHORDAL THICKNESS 4.82
MEAN WHOLE DEPTH 5.93
BACKLASH IN RADIAN - GEAR 91M 0.00265 MAX 0.00375

DEPTH CHECKING DATA - NO 15 BLANK CHECKER 73.02
CHECKING DIAMETER MD - 60.11
BACKING

V/M CHECK SOFT GEAR SOFT PINION
CONCAVE TOE HEEL TOTAL Y
V M
CONCAVE TOE HEEL TOTAL

ALL DIMENSIONS ARE METRIC UNLESS OTHERWISE SPECIFIED

RELEASED BY - RBF

TOPREY IS A GLEASON WORKS TRADE MARK

SHEET 4 OF 4 DATE 6/28/84 TIME 10:50

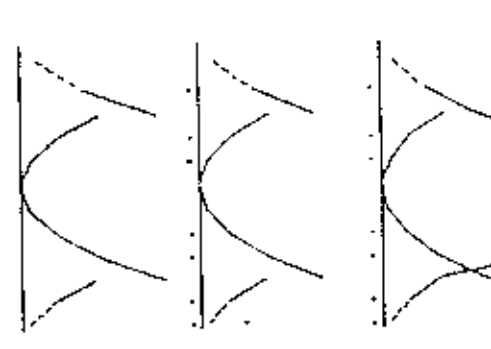
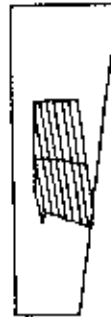
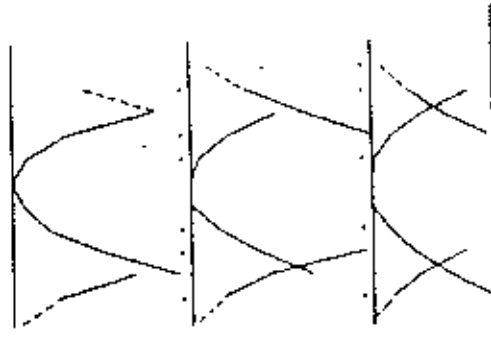
PROPORTIONAL CUTTING CHANGES - NO 116 GENERATOR
CONCAVE - 0B CONVEX - 1B
SIDE OF TOOTH
BIAS CHANGE - 60 MIN. BIAS OUT
MACHINE CENTER TO BACK 2.15 WITH 2.23
SLIDING BASE 1.23 ADV 1.33
ECCENTRIC ANGLE 0B 15M INC 0B 28M
SWIVEL ANGLE 10 22M INC 10 0M
WORK TEST ROLL 10 0M INC 10 0M
DECIMAL RATIO 0.0220 0.0220
PROFILE CURVATURE CHANGE - 2.54MM PROFILE OUT
BLANK OFFSET 2.34 30MM 2.54
ECCENTRIC ANGLE 10 20M INC 10 13M
SWIVEL ANGLE 10 13M DEC 10 34M
WORK TEST ROLL 0B 50M INC 0B 53M
DECIMAL RATIO 0.0207 INC 0.0195
LENGTHWISE CURVATURE CHANGE - 100-INC IN LENGTH
SLIDING BASE 0.13 WITH 0.24
ECCENTRIC ANGLE 0B 27M INC 0B 22M
SWIVEL ANGLE 10 3M DEC 10 0M
CUTTER DIAMETER 0.100" INC 0.100"
SPIRAL ANGLE CHANGE - 2.54MM OFF THE TOE
ECCENTRIC ANGLE 10 20M INC 10 13M
SWIVEL ANGLE 10 13M DEC 10 34M

PINION CONTROL DATA
CONCAVE - 0B CONVEX - 1B
SIDE OF TOOTH
PATTERN LENGTH FACTOR 0.350 0.350
DELTA AK - BIAS CHANGE 0.000 0.000
DELTA EP - PROFILE CHANGE 0.000 0.000
DELTA GAMMA X 2.000 2.500
DELTA D DELTA 0.000 0.000
DELTA GAMMA M 6.000 9.000

UNDEVELOPED SETTINGS - UNCONFIRMED FOR PRODUCTION

Tooth Contact Analysis

TOOTH CONTACT ANALYSIS - FINISHING GEAR - CONCAVE



TOE

MEAN

HEEL

BANGLADESH

BANGLADESH MACHINE TOOL/A.B.R.- JOYDEPUR

SUMMARY NO. 500987
RATIO 22 X 33 DATE 6/28/84

GEN. GEAR CONVEX CONCAVE
PIN BLADE ANG. 14.00 31.00
GEAR BLADE ANG. 22.00 18.00
POINT DIAMETER 5.978 5.800
CONT LGTH FACT 0.35 0.35
DELTA AX . . . 0.000 0.000
DELTA E . . . 0.000 0.000
DELTA GAMMA N. 6.000 9.000
DELTA GAMMA X. -2.000 -2.500
DELTA D DELTA. 0.000 0.000

GEAR CONVEX CONCAVE
TOE POSITION 0.25 0.25
HEEL POSITION 0.25 0.25

MEASUR MEAN TOE HEEL TOTAL
CX E(U) -5 21 -36 57
PX(U) 1 -27 31 57
CV E(U) -7 -45 36 81
PX(U) 3 40 -38 78

INCREMENT: MOTION 40, CONTACT 0.17
NOTE: AG01 SPEC ANALYSIS

RETURN? TYPE NO, DP, UN, XX, OR END

