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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CERTIFICATE

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ABSTRACT

The only Machine Tools Factory in co[illegible] (BMTF), at present, produces spiral bevel gears by Gleason system to be fitted in 3:2 ratio right angle gear box to drive Deep Weel Turbie 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.

This 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 distores in different patteren. 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

LIST OF TABLES

CONTENTS

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 handreds or thousand pieces but without having a well defined production process.Good 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

Figure 1. PROCESS SHEET FOR SPIRAL BEVEL GEAR
PART NO. 5185 N/7

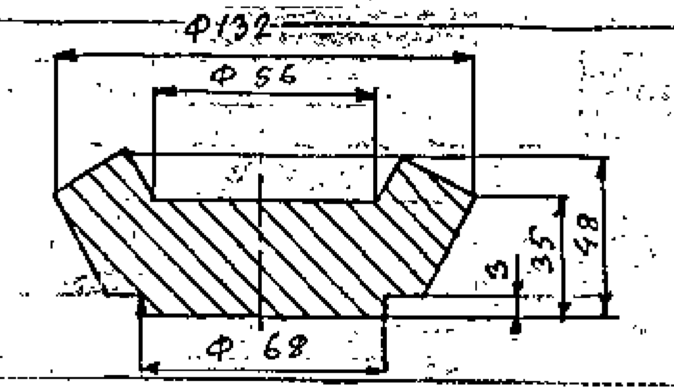
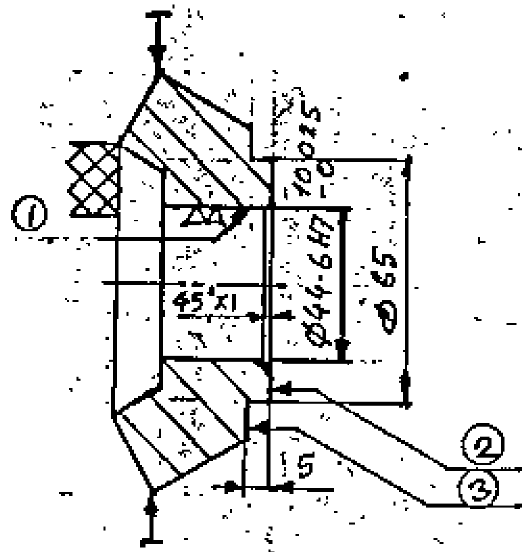
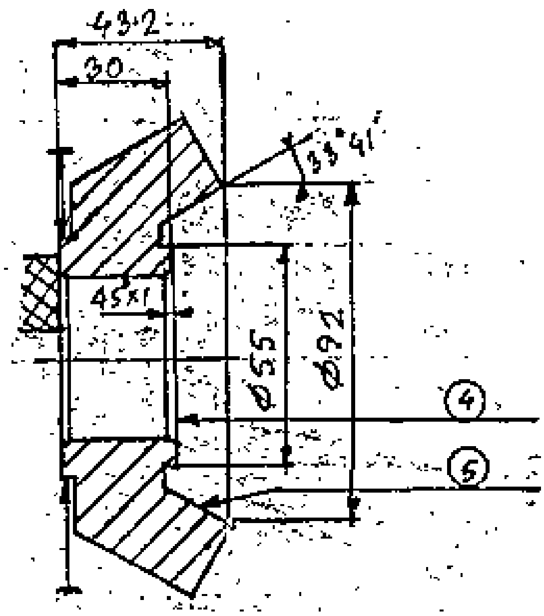
<table>
<tr><th>STEP</th><th>MACHINE TOOL</th><th>OPERATION</th><th>SKETCH</th></tr>
<tr><td>1</td><td>DROP HAMMER</td><td>Forging</td><td>
</td></tr>
<tr><td>2</td><td>TURRET LATHE
3 JAW CHUCK</td><td>(a) Drilling hole (1)
(b) Boring hole to dia.44.6H7
(c) Chamfering hole (1) 45 deg.×1
(d) Facing surface (2)
(e) Facing surface(3)and giving step 5mm & dia.65</td><td>
</td></tr>
<tr><td>3</td><td>CENTER LATHE
SOFT JAW CHUCK</td><td>a) Facing to length 43.2mm
(b) Facing surface(4)to thickness 38mm
(c) Making angle 33deg41min from dia.92mm</td><td>
</td></tr>
</table>

Fig. 1. contd.

PROCESS SHEET FOR SPIRAL BEVEL GEAR

PART NO. 5195 N/7 (contd)

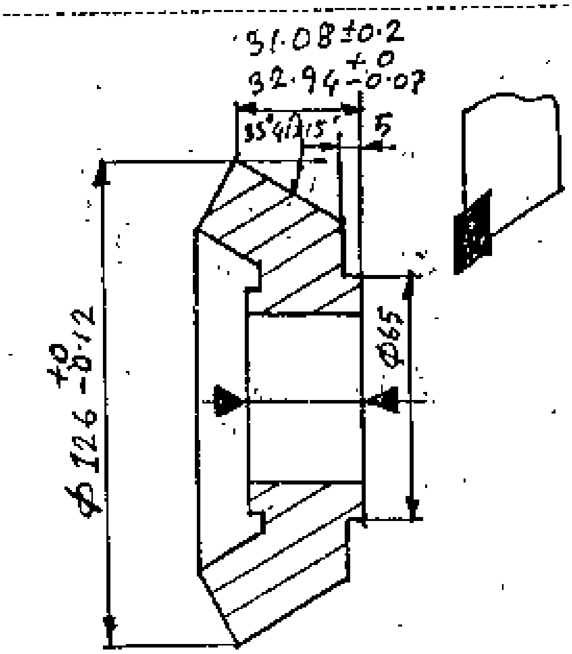
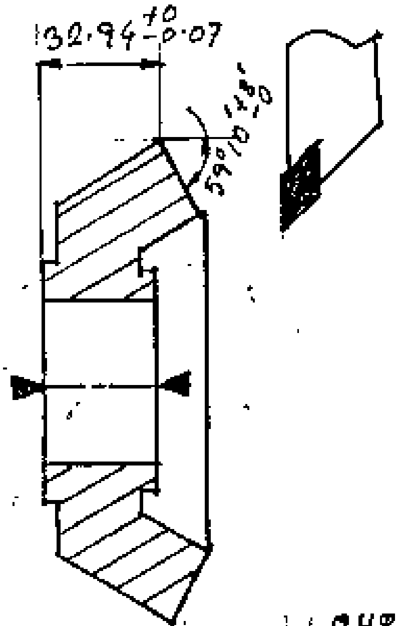
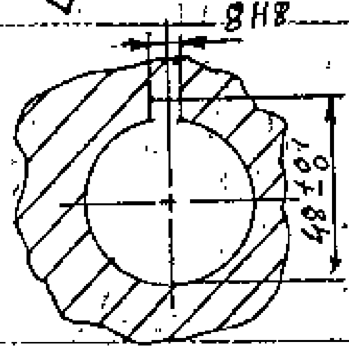
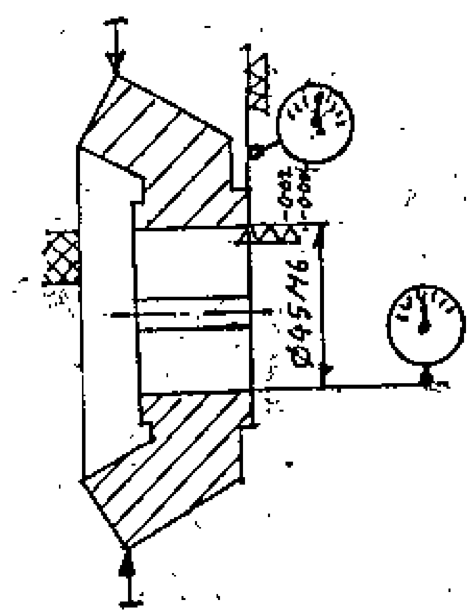
STEP	MACHINE TOOL	OPERATION	SKETCH
4	COPYING LATHE	Copy turning as shown in the sketch	
5	COPYING LATHE	Copy turning as shown in the sketch	
6	BROACHING MACHINE	Keyway broaching as shown in the sketch	

Fig.1. contd.

PROCESS SHEET FOR SPIRAL BEVEL GEAR
PART NO. 5185 N/7 (contd.)

STEP	MACHINE TOOL	OPERATION	SKETCH
7	HYPOID GENERATOR	Gear rough cutting according to Gleason summary sheet no. MS209087	
8	HYPOID GENERATOR	Gear finish cutting according to Gleason summary sheet no. MS009087	
9		Deburring by filing	
10		Case hardening by carburizing Case depth 0.8-1mm Hardness 60-65 HRC	
11	INTERNAL GRINDING MACHINE	a) Bore grinding to dia. 45H6. b) Rear 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,unusuall 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 practised in BMTF, 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 diffcult 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 circumferencial 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.

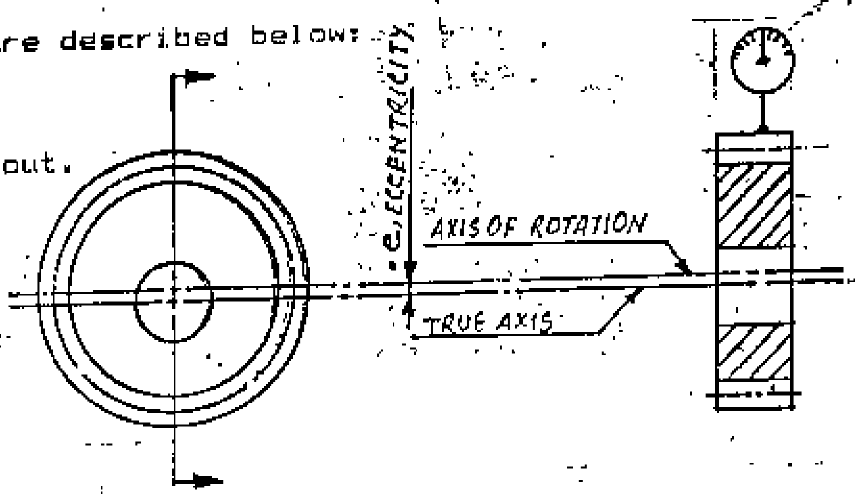


Fig. 2 Pitch circle runout

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.

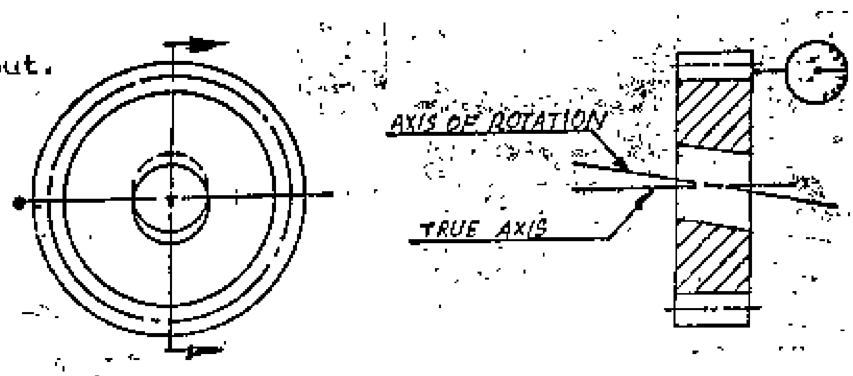


Fig. 3 Lateral runout

This is a lateral movement of gear is 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 distace follows.

Figure 5 shows two mated gear teeth in contact at points Q and Q1 along the line of action II. An increase of center distance C will cause backlash KK1 along the new line of action I'I'. For small change in center distance the line of action II and I'I' are essentially parallel. Furthermore profile lengths KQ and K1Q1 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.

$KK1/QQ1 = \sin\phi$

or, $KK1 = QQ1 \sin\phi$ ------------------------------ (1)

But $QQ1 = \Delta C$

KK1 = normal backlash measured along line of action = Bn/2

Where Bn= Normal Backlash measured alone the line of action (fig.4)

Therefore, $Bn/2 = \Delta C \sin\phi$ ------------------------------ (2)

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

$Bn = B \cos\phi$

Where B= Backlash measured along the pitch circle

or $Bn/B = \cos\phi$ ------------------------------ (2.1)

Now dividing eqn. (2) by eqn. (2.1)

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

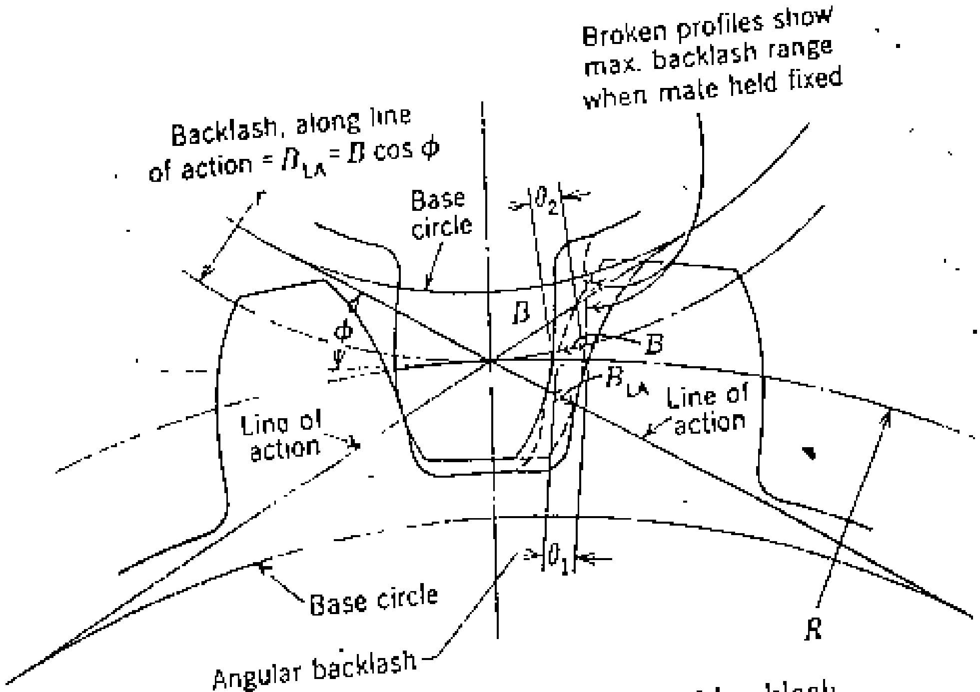


Figure 4. Geometrical definition of backlash.

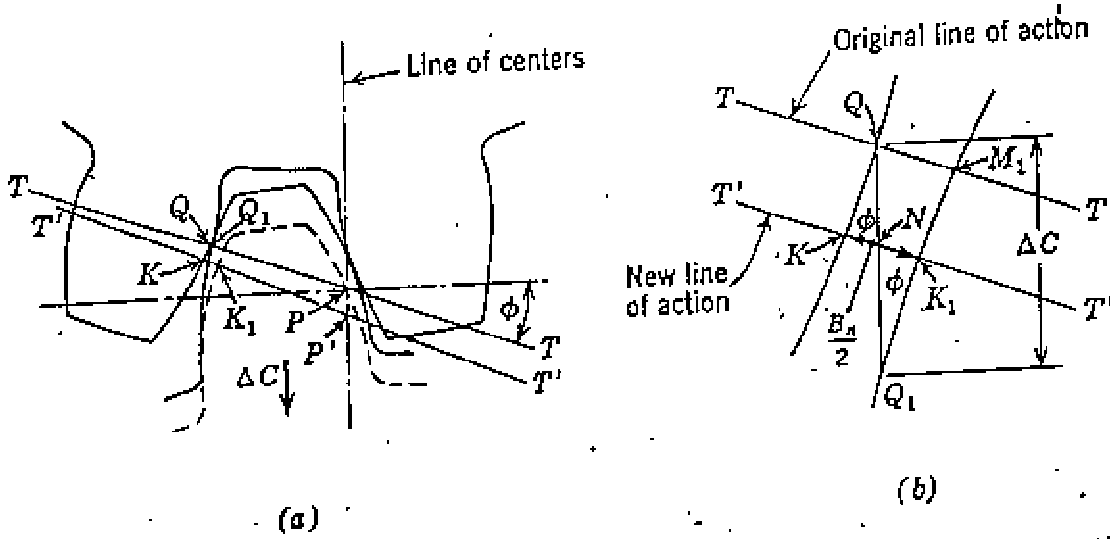


Figure 5. Backlash caused by center distance change: (a) mated teeth before and after increase of center distance, (b) enlarged view of profiles and backlash.

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

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

=normal backlash measured along line of action.

and $B = 2\ \Delta C \tan\phi$ ---------------------------- (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.W3 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.

$$\Delta C = e \sin \theta \quad \text{------------------------------} \quad (6)$$

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 radiens

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.

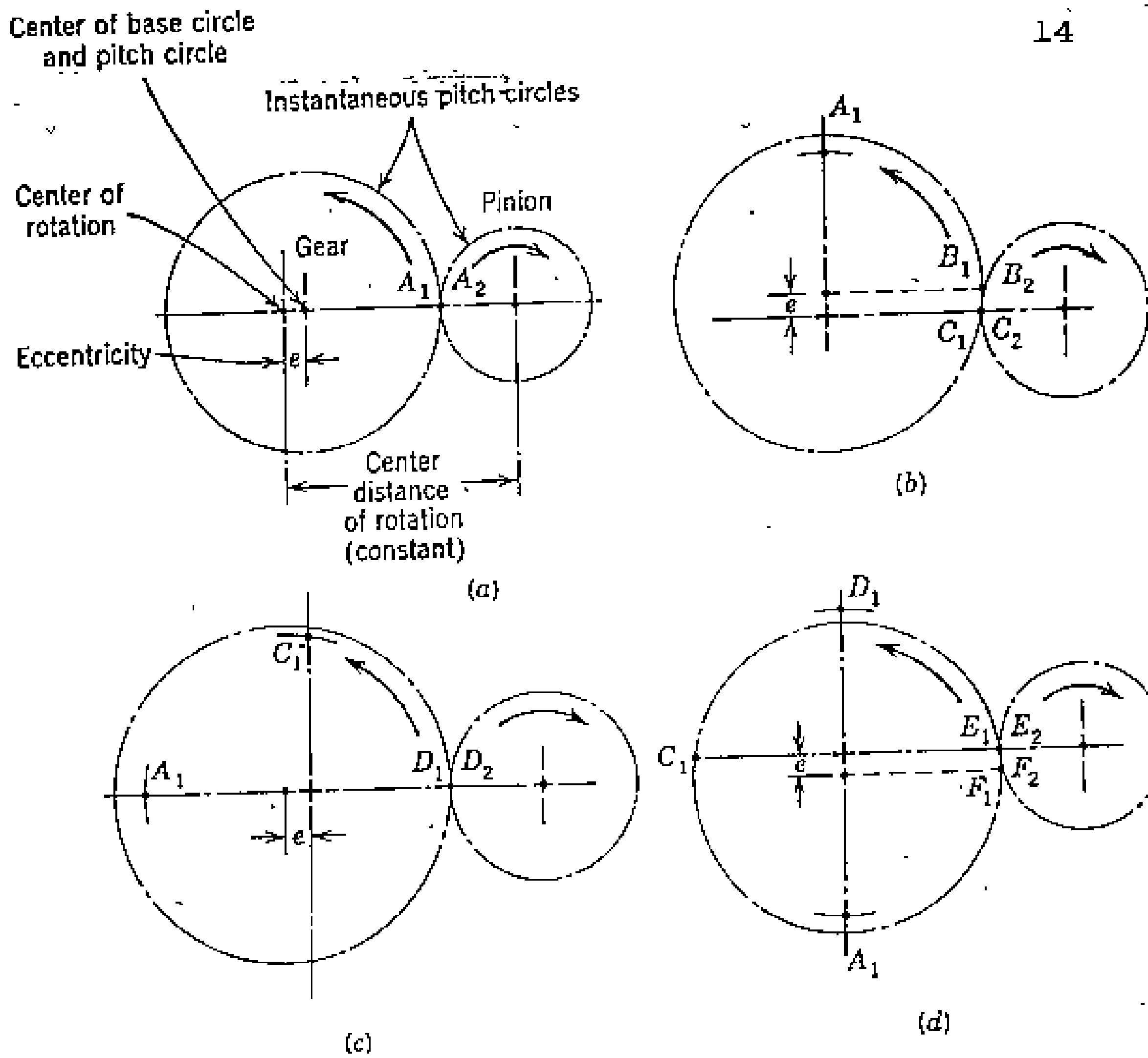


Figure 6. Runout position error in terms of pitch circle rotation.

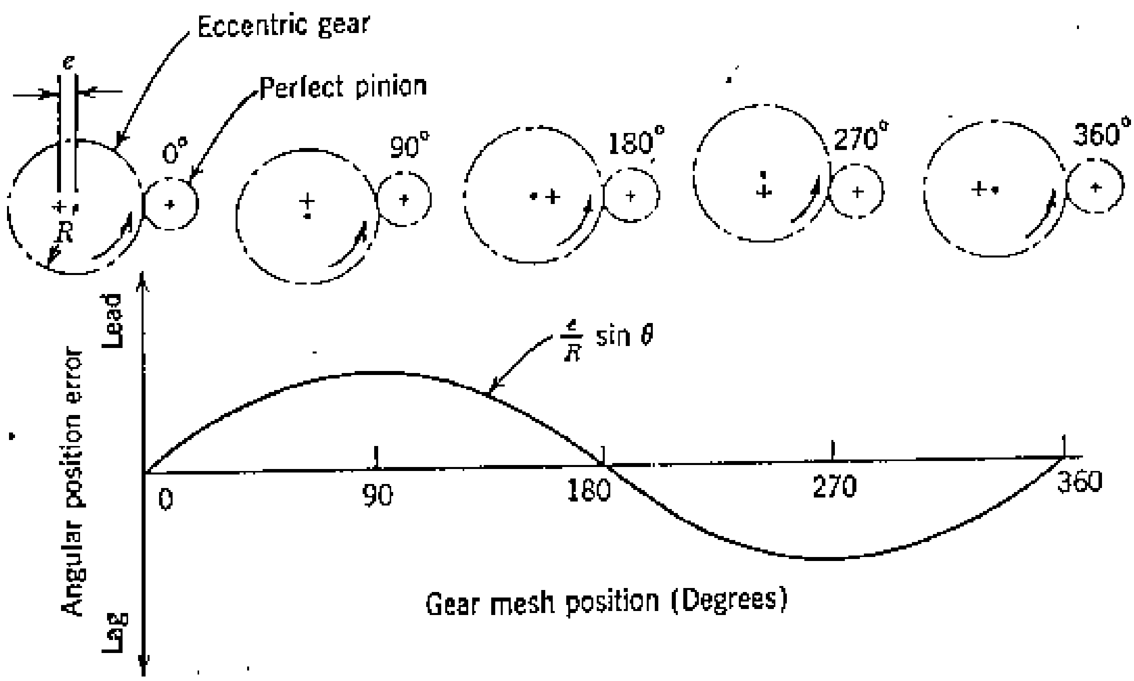


Figure 7. Various positions of mesh for eccentric gear and a perfect mating pinion with a plot of the position error.

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 instantenous 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-e and C+e.

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).

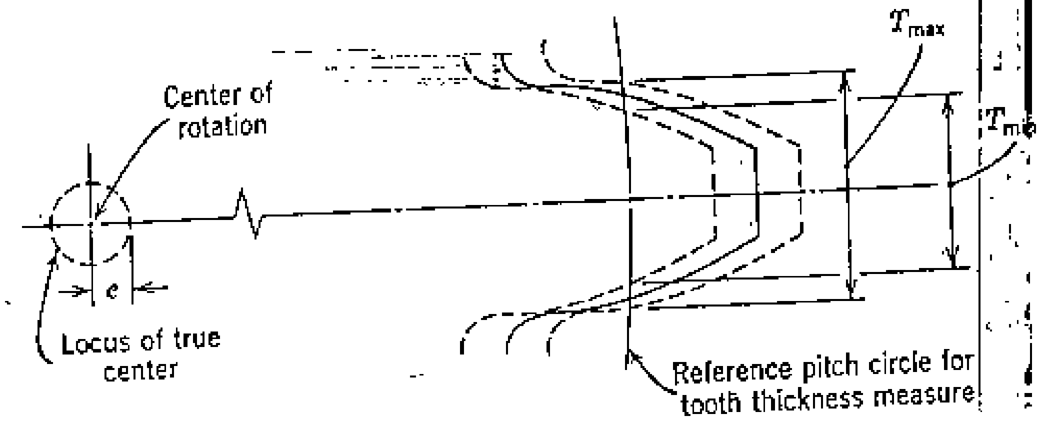


Figure 8. Tooth thickness variation caused by runout.

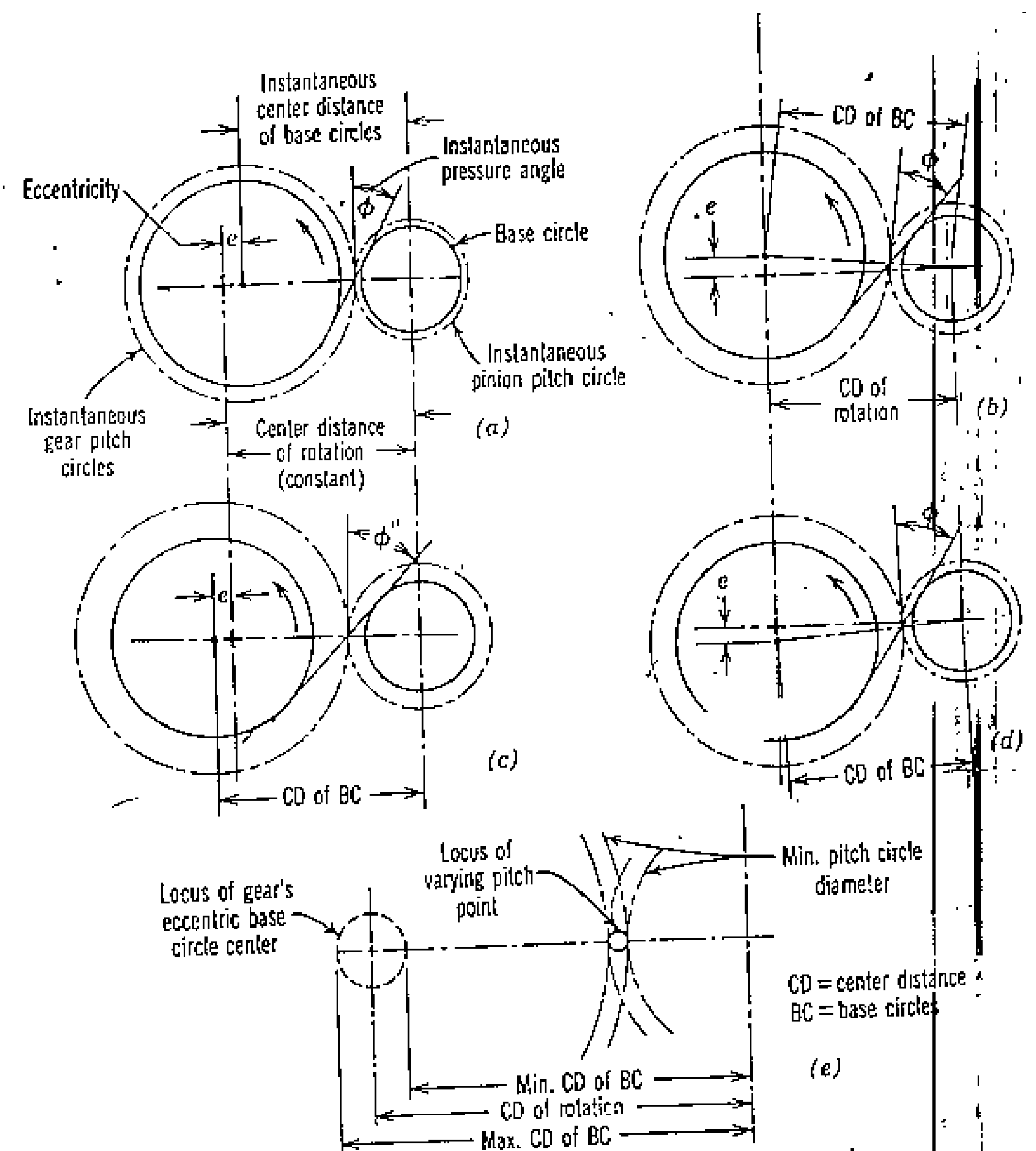


Figure 9 Geometrical aspects of the mesh of an eccentric gear and perfect pinion: (a–d) particular condition positions, (e) summary of variations for one rotation.

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

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

$\phi = \cos^{-1}((R+r)/C)$ ---------------------------- (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 distanc 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 $Ft = F\cos\phi$ --(9)

and the radial comp. of the torque becomes, $Fr = F\sin\phi$ --(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 arround 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 internel grinding machine spindle.

Item no.2 Flat washer ϕ12

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.

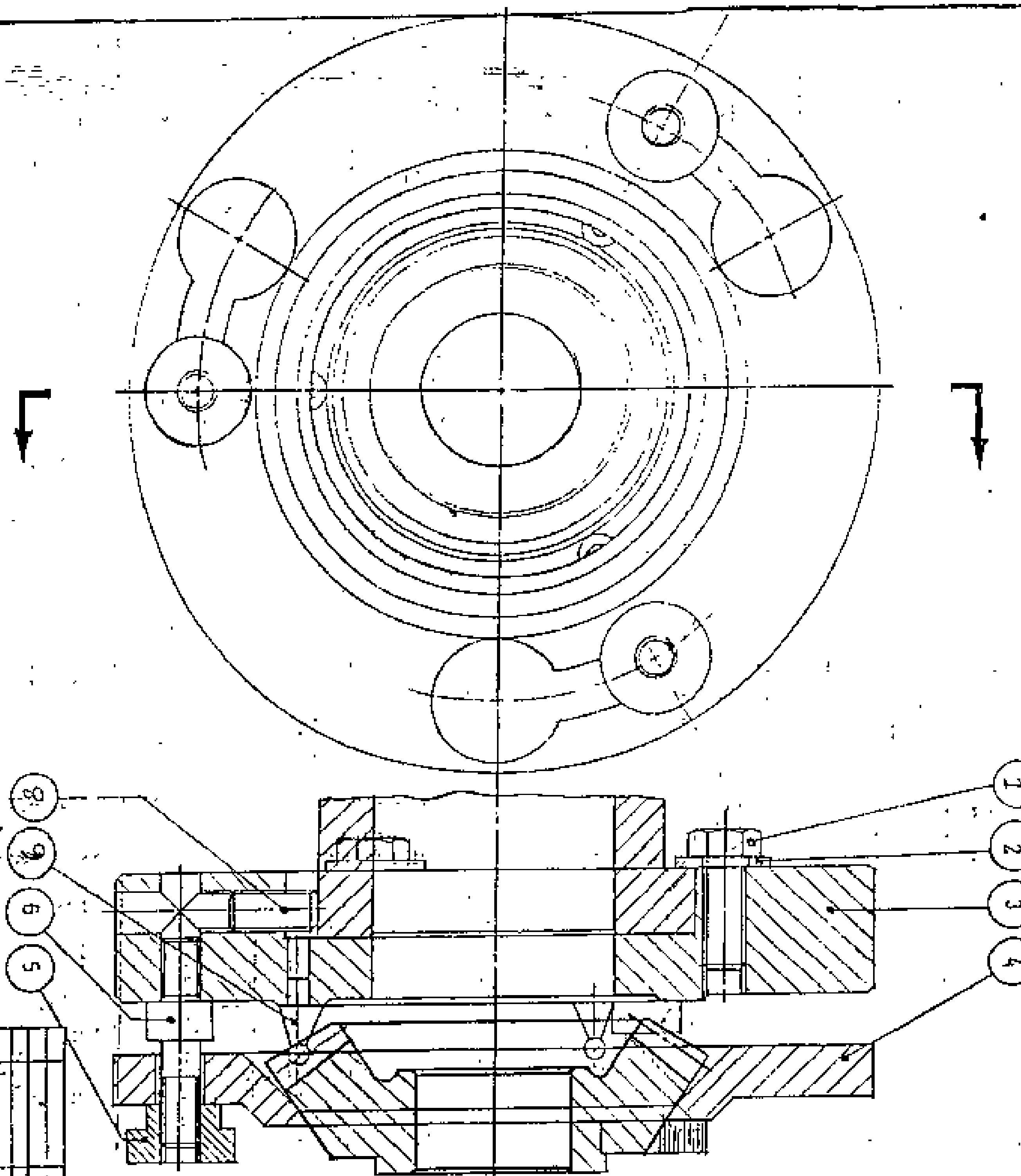
Item no. 7 Ball Reference Pins

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 spining about the grinding machine spindle.

Fig. 11 (a)



NOTE:
THE FIXTURE MUST BE PAINTED BY RED OXIDE COATING FIRST, THEN AFTER DRYING COATING OF GREY COLOUR TO BE GIVEN.

CAUTION:
NO COLOUR ON THE GROUND SURFACES, SCREWS, AND THREADS.

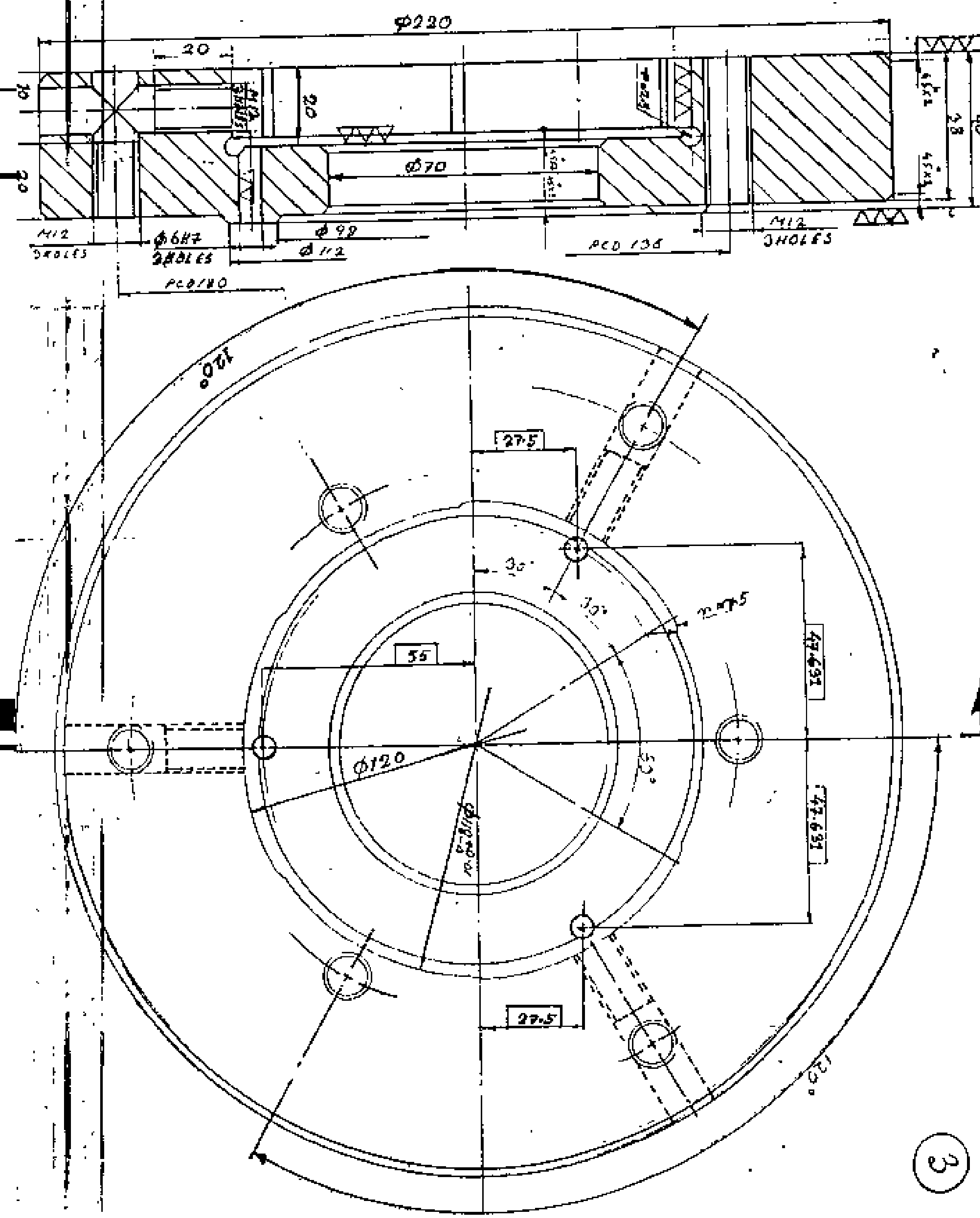
10					
9					
8	3	GRUB SCREW M12X25	BMTF 3125	AMS-5	HARDENED 30-35 HRC
7	3	BALL REFERENCE PIN	-	AMS-7	HARDENED 40-45 HRC
6	3	CLAMPING STUD	-	AMS-5	HARDENED 30-35 HRC
5	3	KNURLED HAND NUT	-	AMS-5	HARDENED 30-35 HRC
4	1	LOCKING PLATE	—	AMS-5	HARDENED 30-35 HRC
3	1	FIXTURE PLATE	—	AMS-5	—
2	3	FLAT WASHER Ø12	BMTF 3172	AMS-5	HARDENED 30-35 HRC
1	3	HEX BOLT M10X30	BMTF 3105	AMS-5	HARDENED 30-35 HRC
[illegible]		PART NAME	STANDARD	MATERIAL	HEAT TREATMENT

SPIRAL BEVEL GEAR, APPLICATION 33TEETH

MATERIAL

PITCH LINE CHUCK

BANGLADESH MACHINE TOOLS FACTORY LTD



Φ220
20
Φ70
Φ98
Φ112
M12
3HOLES
Φ6H7
2HOLES
PCD180
PCD 136
M12
3HOLES
Φ120
55
27.5
27.5
30°
30°
47.631
47.631
120°
120°
3

Fig. 11 (b)

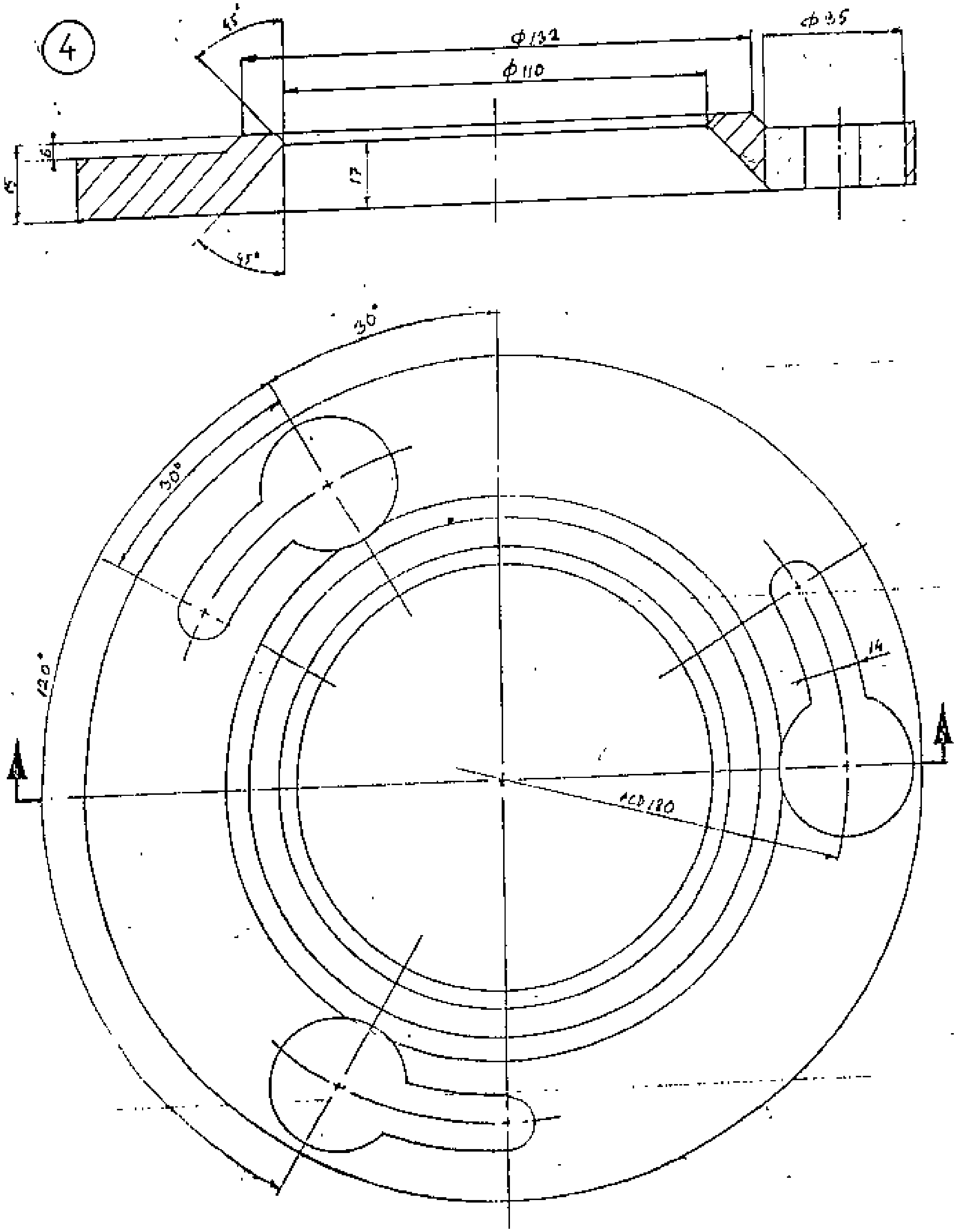


Fig. 11 (c)

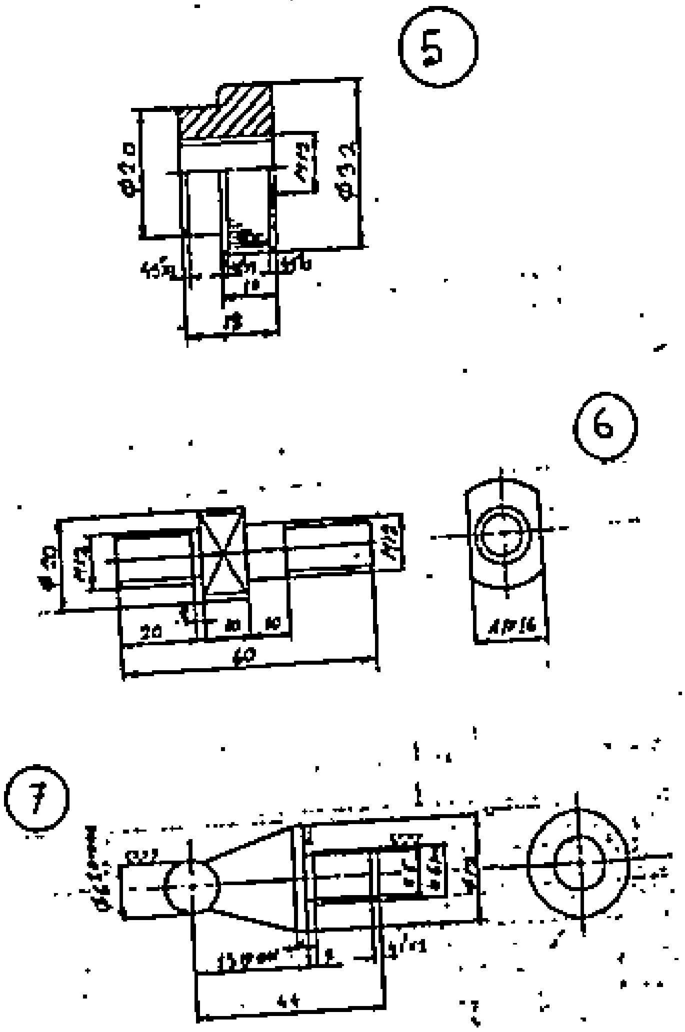


Fig. 11(d)

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 clapmed 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 COMPOSITIN OF RAW MATERIAL

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

TABLE 2 MECHANICAL PROPERTIES OF STEEL MATERIAL

MATERIAL	BMTF CODE NO	YEILD POINT N/MM^2	TENSILE STRENGTH N/MM^2	ELONGATION L=5d%	HARDNESS HB SOFT ANNEALED
	BMS-1	295	490 640	16	131
MILD MEDIUM CARBON STEEL	BMS-2	335	590 780	14	146
	BMS-5	410	660 800	16	208
HIGH CARBON STEEL	BMS-6	1050	1200 1450	7	210
	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 nonstandrad 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 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

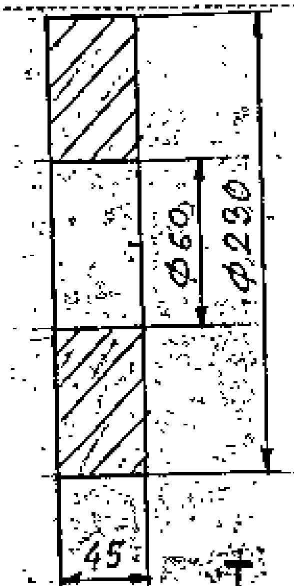
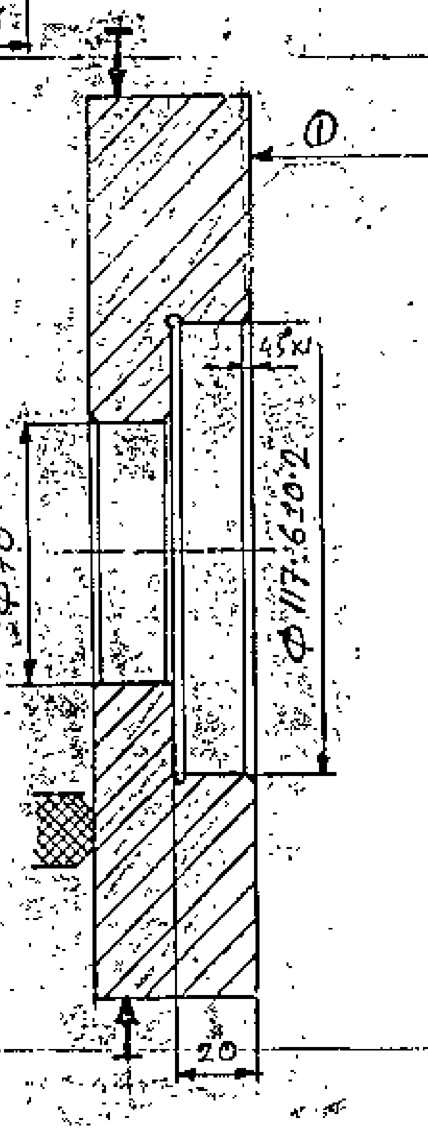
STEP	MACHINE TOOL	OPERATION	SKETCH
1	FLAME CUTTING EQUIPMENT	Flame cutting the plate as shown in the sketch	
2	CENTER LATHE 105	(a)Facing surface (1) (b)Boring dia.70 through (c)Boring dia. 117.6+.2 to 20mm depth (d)Grooving as shown in the sketch (e)Chamfering (45deg*1) as shown.	

Fig-12.contd.

PROCESS SHEET FOR FIXTURE PLATE
ITEM NO.3

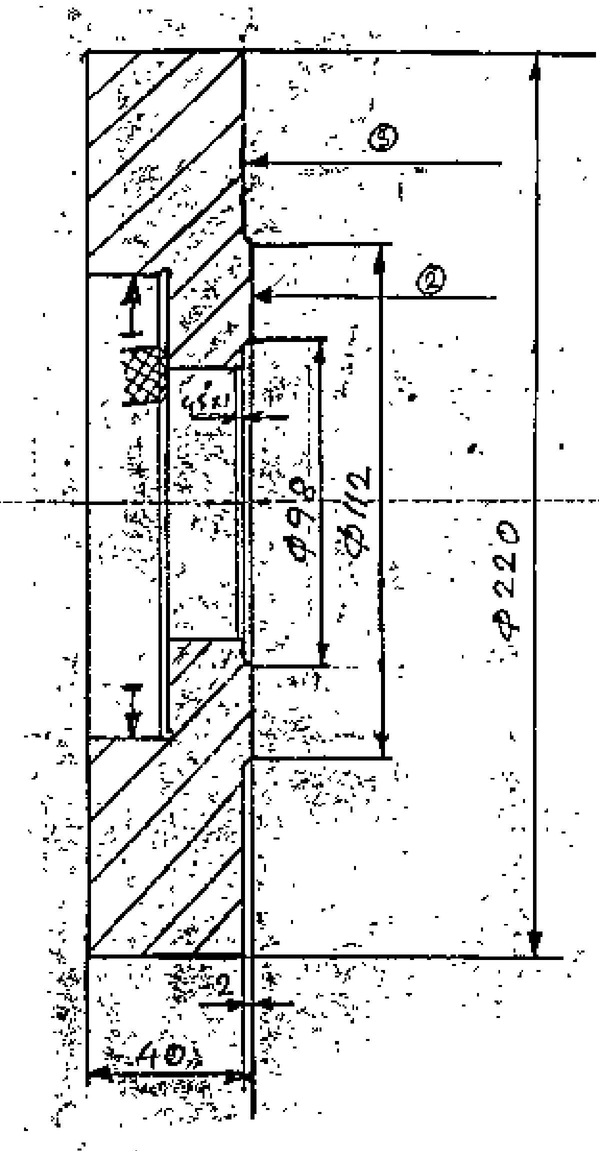
STEP	MACHINE TOOL	OPERATION	SKETCH
3	CENTER LATHE	(a)Facing surface (2) (b)Facing surface (3) (c)Chamfering 45deg*1 as shown.	
4	MARKING TOOLS	Marking all hole positions	

Fig. 12. contd.

PROCESS SHEET FOR FIXTURE PLATE

ITEM NO.3

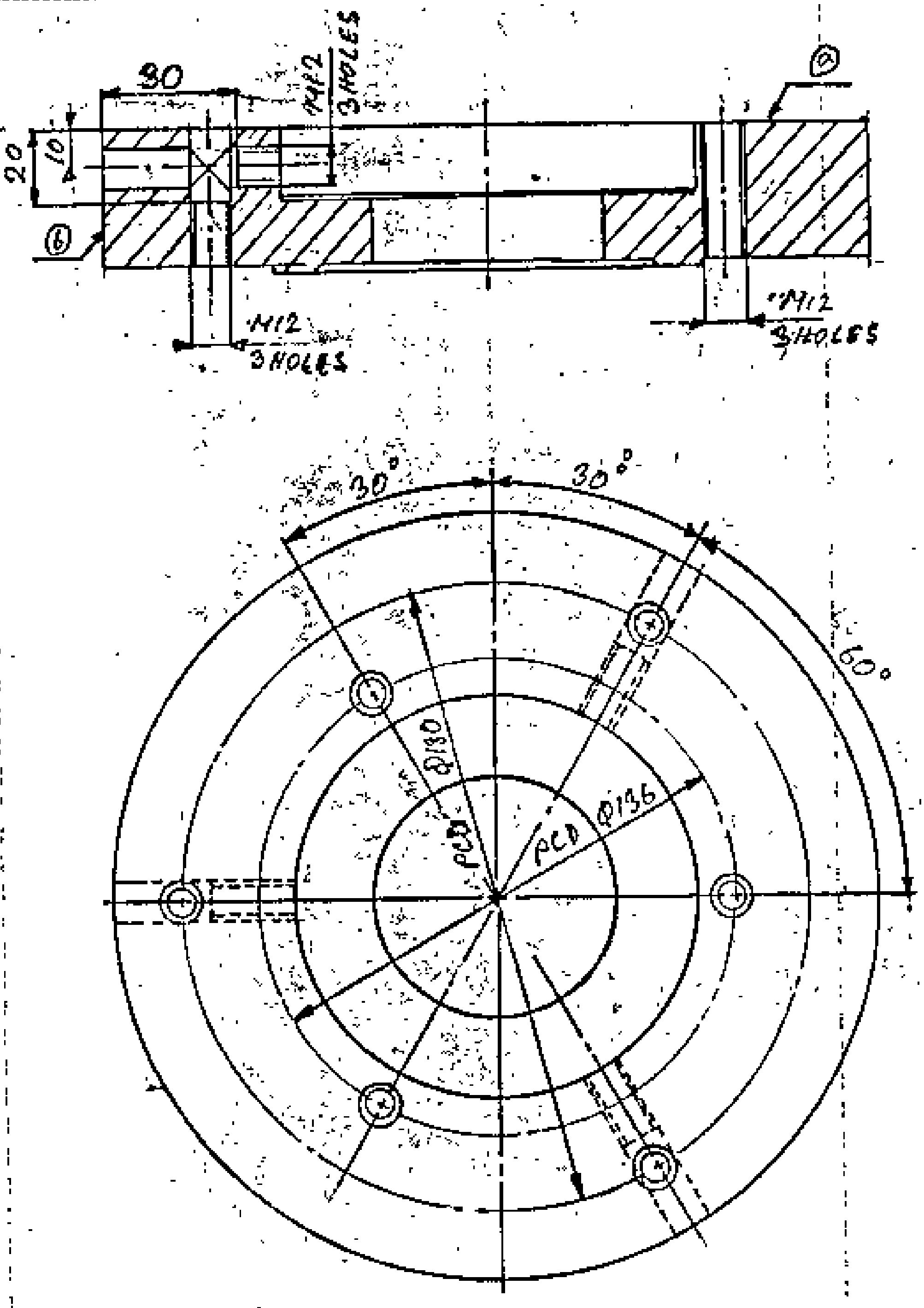
STEP	MACHINE TOOL	OPERATION	SKETCH
5	RADIAL DRILLING MACHINE	1) Drilling & tapping 6, M12 holes on surface (a) 2) Drilling 3 holes dia 10.5 mm on surface (b) 3) Drilling 3 holes, 30mm depth on previous holes as shown 4) Tapping 3, M12 holes	

Fig. 12 contd.

PROCESS SHEET FOR FIXTURE PLATE
ITEM NO.3

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

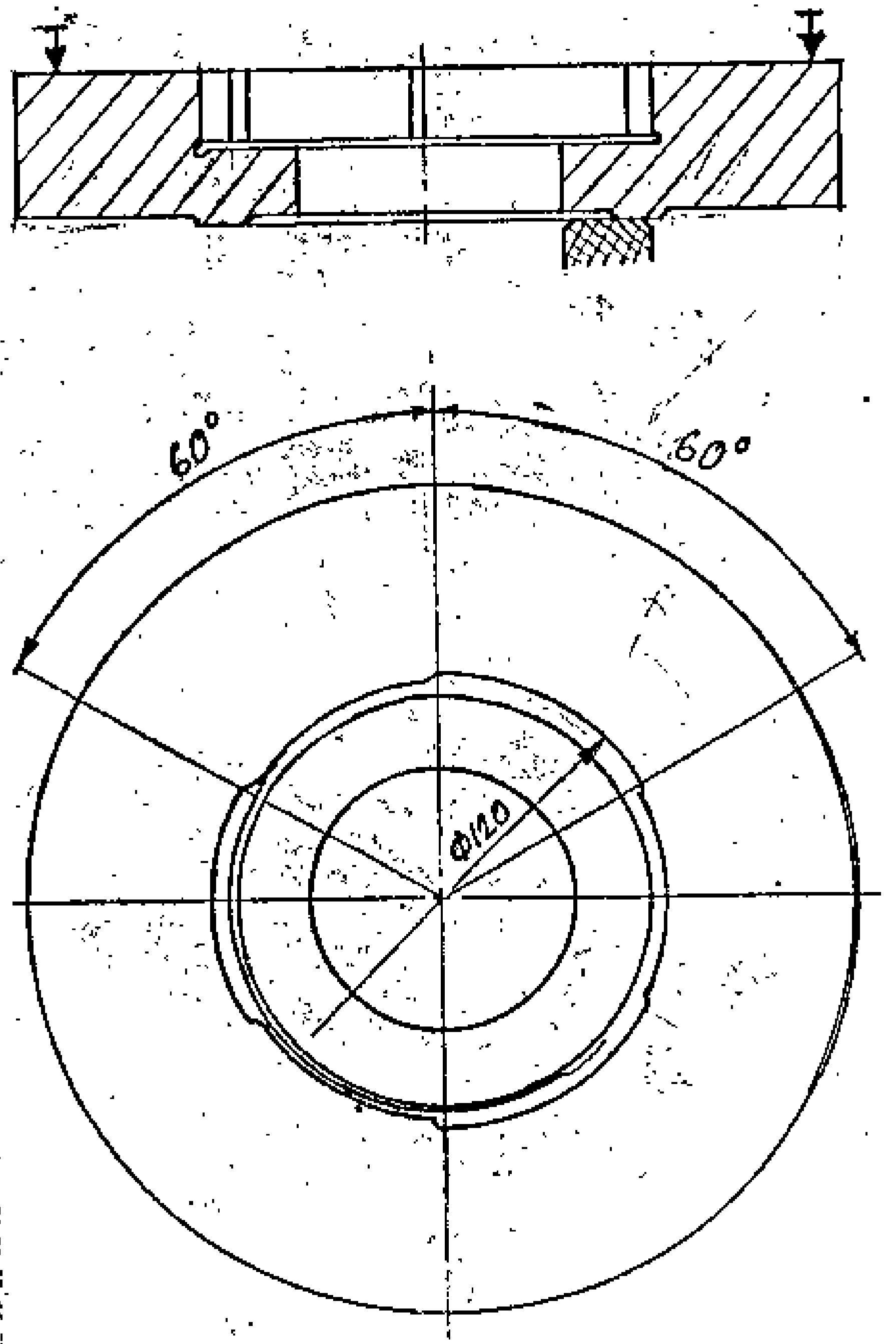


Fig. 12. contd.

PROCESS SHEET FOR FIXTURE PLATE
ITEM NO.3

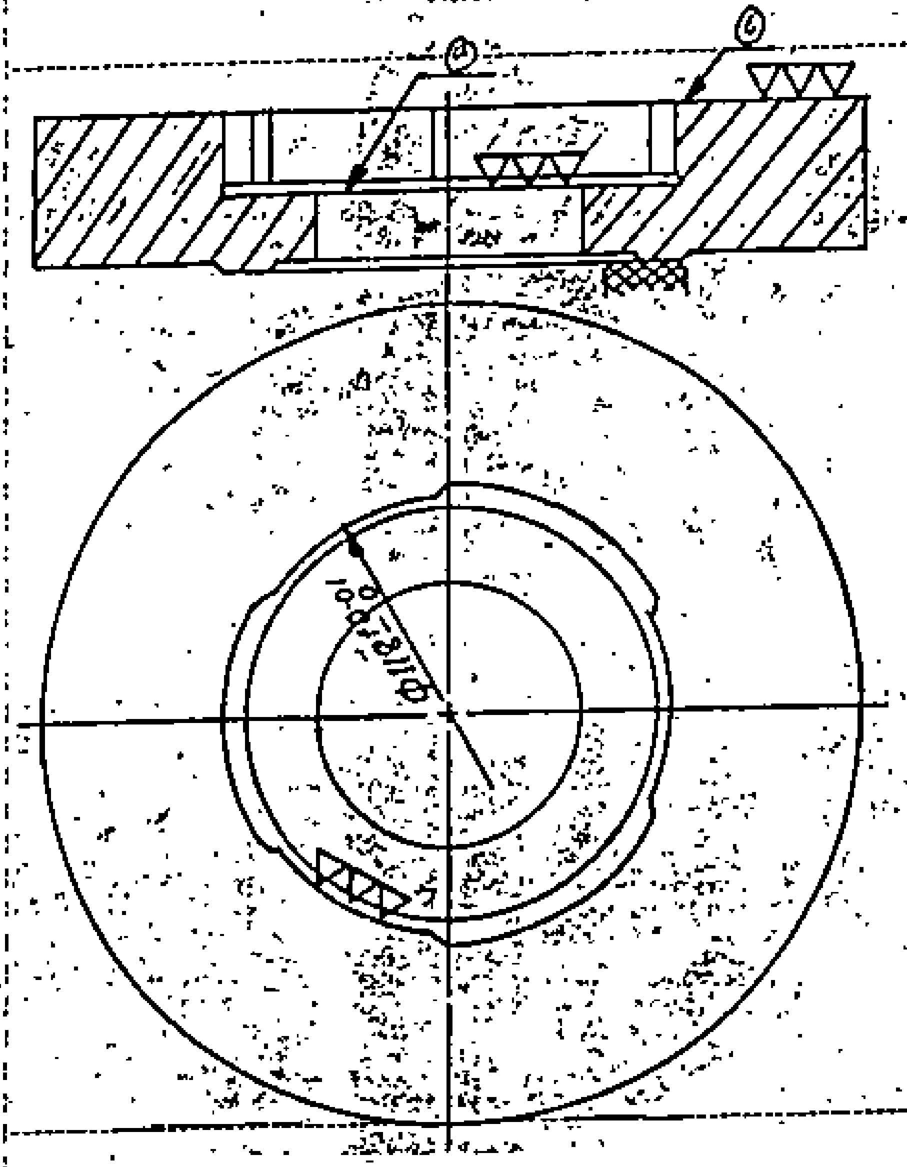
STEP	MACHINE TOOL	OPERATION	SKETCH
7	INTERNAL GRINDING MACHINE	1)Grinding the bore to dia.118 +.201 as shown 2)Grinding surface (a) 3)Grinding surface (b)	
8	SURFACE GRINDING MACHINE	Clean grinding the top surface as shown in the sketch.	

Fig 12. contd.

PROCESS SHEET FOR FIXTURE PLATE
ITEM NO.3

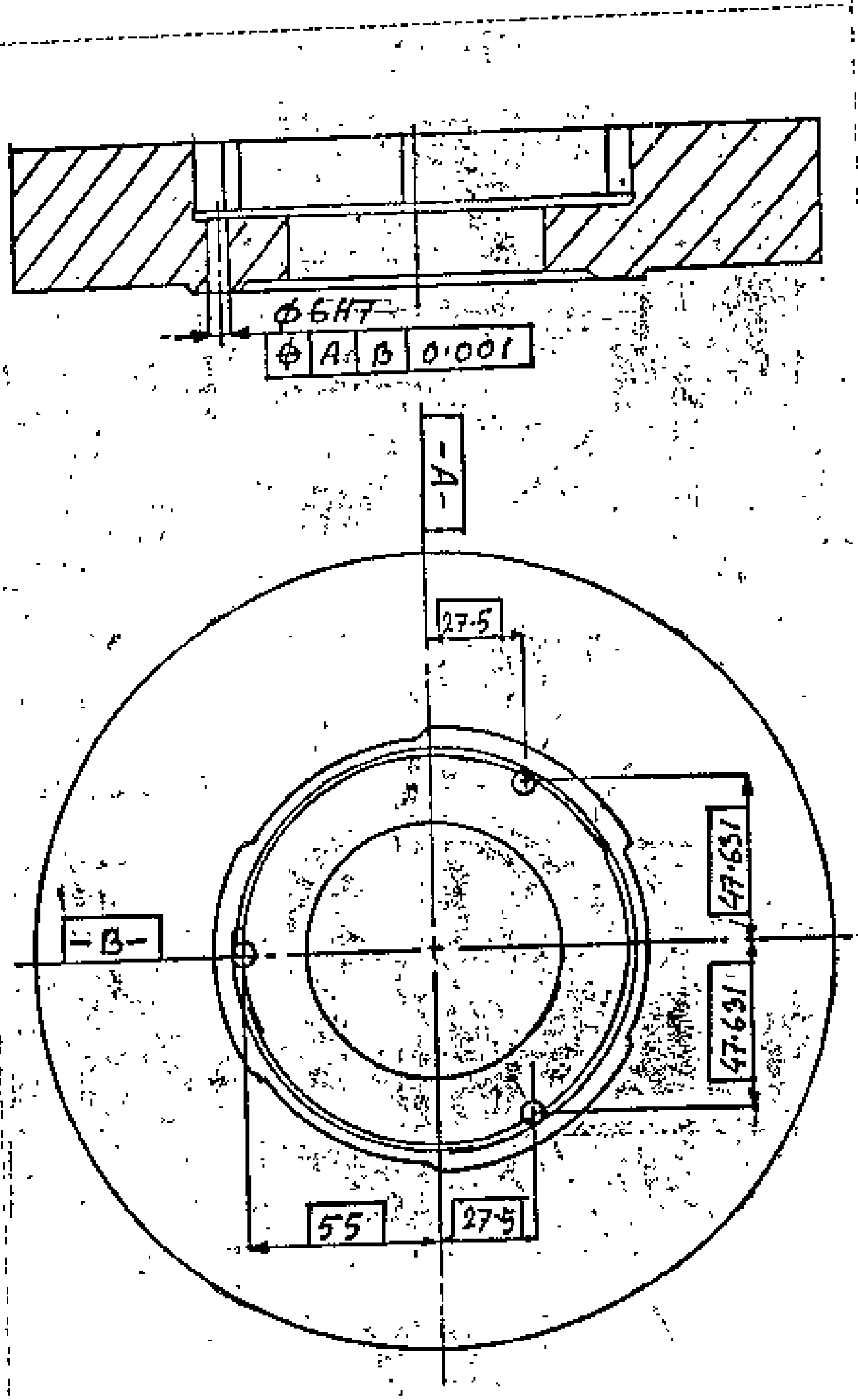
STEP	MACHINE TOOL	OPERATION	SKETCH
9	JIG BORING MACHINE	Boring 3 holes dia.6H7 at location shown in the sketch	

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

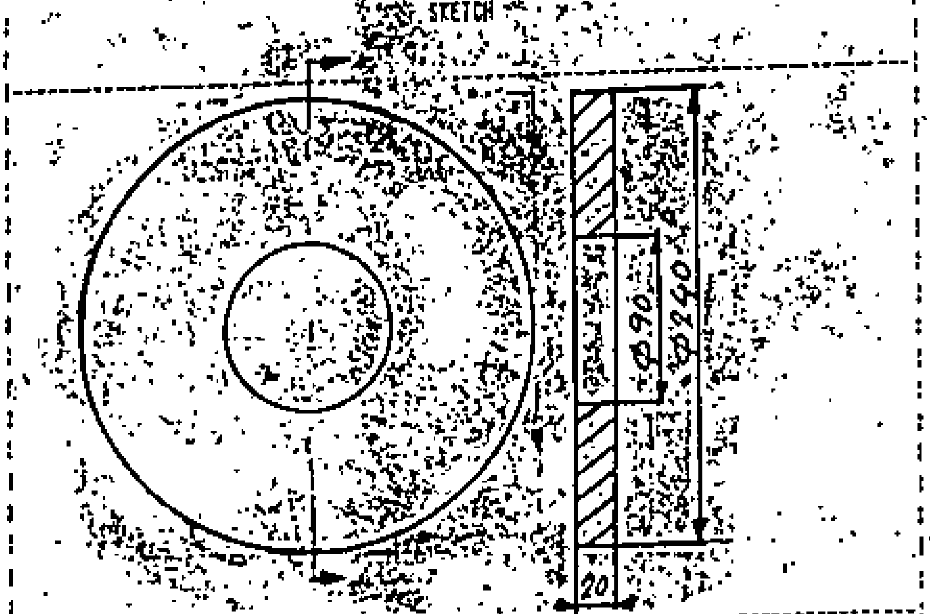
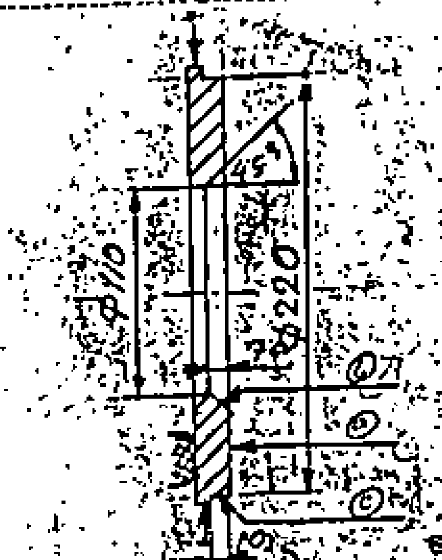
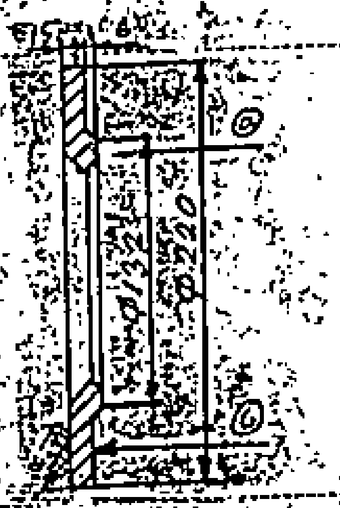
STEP	MACHINE TOOL	OPERATION	SKETCH
1	FLAME CUTTING EQUIPMENT	Flame cutting 20mm thick plate as shown in the sketch	
2	CENTER LATHE	1) Facing surface (a) 2) Boring hole dia.110 3) Turning 45 deg. angle upto depth 7mm 4) Outside dia. turning upto depth 10mm to dia.220	
3	CENTER LATHE	1) Facing surface (a) to rate thickness 15mm 2) Facing surface (b) & chamfer to dia. 132 3) Chamfering the hole 45deg.	

Fig. 13. contd.

PROCESS SHEET FOR LOCKING PLATE

ITEM NO.4

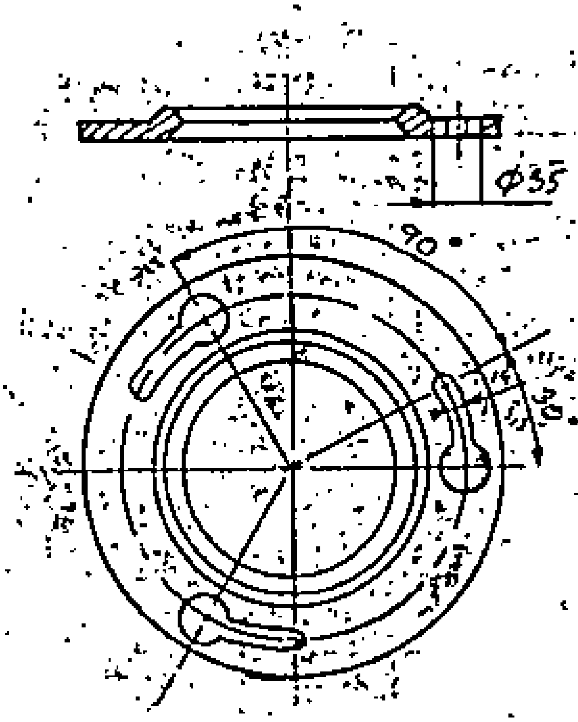
STEP	MACHINE TOOL	OPERATION	SKETCH
4	VERTICAL MILLING MACHINE	a)Fixing the part on rotary table b)Making 3holes dia.35 on PCD 180mm,120deg. apart c)Making 3slots 24mm wide as shown in the sketch	

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

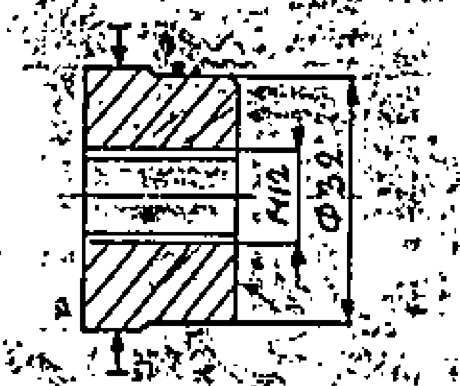
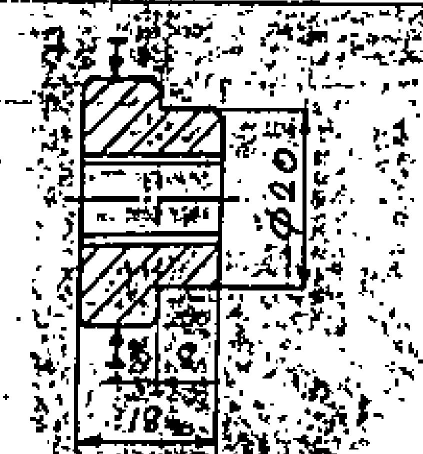
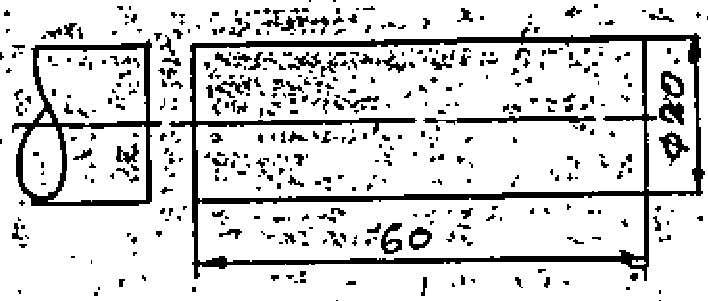
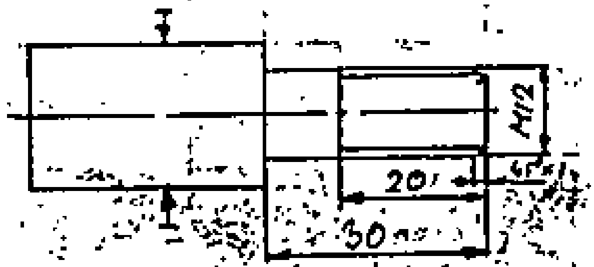
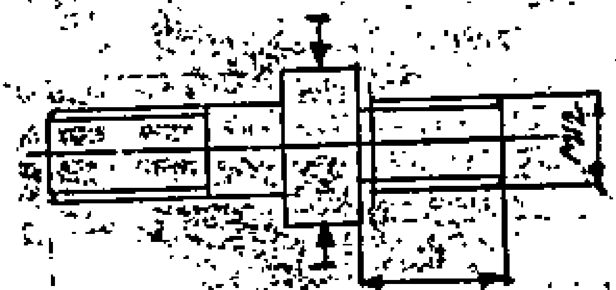
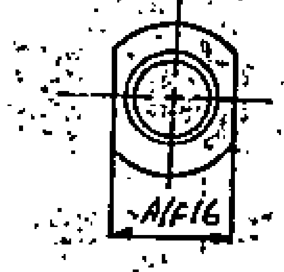
STEP	MACHINE TOOL	OPERATION	SKETCH
1	POWER HACKSAW	Parting off dia.34 round bar to length 20mm	
2	CENTER LATHE	1)Facing front face 2)Drilling dia 10.5 through 3)Threading M12 through 4)Turning outside dia.32 upto length 12mm 5)Knurling on dia.32 pitch 1mm	
3	CENTER LATHE	1)Facing to length 18mm 2)Making step 8mm at dia.20 3)Chamfering all corners 45degx1	

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

STEP	MACHINE TOOL	OPERATION	SKETCH
1	POWER HACKSAW	Parting off dia.20 round bar to length 60mm	
2	CENTER LATHE	1)Holding in 3J soft jaw chuck 2)Turning dia. 12 upto length 30mm 3)Chamfer the end 45degX1 4)Threading M12,upto length 20mm from end	
3	CENTER LATHE	1)Holding the piece in a 3 soft jaw chuck 2) Making 2mm wide groove at length 20 3)Chamfering at the end 45deg.X1 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 consitutes 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 fatique allowance referes 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 obsereved 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 fatique 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 x 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 & fatique allowance will remain the same.Handling time for the various, identical or similiar 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, Cs= Time saving in the propdsed 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) Fixture plate: M1 $= \pi D^2 L*7800/(4*1000^3)$,

where D is the dia in mm

L is the length in mm

7800 is the specific wt. of steel in Kg/m^3.

$=\pi*230^2*45*7800/(4*1000^3) = 14.73$ kg.

ii) Locating plate M2 $= L*l*b*7800/(1000^3)$

where L is the length in mm

l is the breadth in mm

b is the thickness in mm

$=240*240*20*7800/1000^3 = 09.08$ Kg.

iii) Knurled hand nut M3 $= \pi*D^2*L*7800*3/(4*1000^3)$

where D is the dia in mm

L is the length in mm

$=\pi*34^2*20*7800*3/(4*1000^3) = 0.43$ kg.

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

where D is the dia in mm

L is the length in mm

$=\pi*22^2*65*7880*3/(4*1000^3)$ =0.50 Kg.

Total steel material required=M1+M2+M3+M4

=14.73+9.08+0.43+0.50= 24.82 kg.

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

Cost of steel material=24.82Kg*Tk.25.00/kg= Tk620.50.

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 referance pin)

=90.00*33 = Tk. 2970.00.

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

=Tk. 620.50 + Tk. 2970.00

=Tk. 3590.50 ~ 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 BMTF 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 * 40 = Tk. 3314.40

= Tk. 3315.00 (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 recomending 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

Cs = 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) $Q * Cs < D$, the chuck should not be adopted

ii) $Q * Cs = D$, the adoption of the chuck depends upon the policy of the manager

iii) $Q * Cs > D$, the chuck can be adopted

Let,

Cm = manufacturing cost of the picth 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 ,

Cm = production cost of the pitch line chuck

= Tk. 7915.00

so, straight line depreciation, D = Cm/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,

$$Q * Cs > D$$

$$\Rightarrow \quad Q > D/Cs$$

from the previous data D/Cs = Tk. 791.50/Tk. 25.10

= 31.53 = 32 (approx)

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 avarage demand of spiral bevel gears is about 1200 numbers per year.

Therefore,

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

= Tk. 25.10 * 1200

= 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 fatique and ultimatev 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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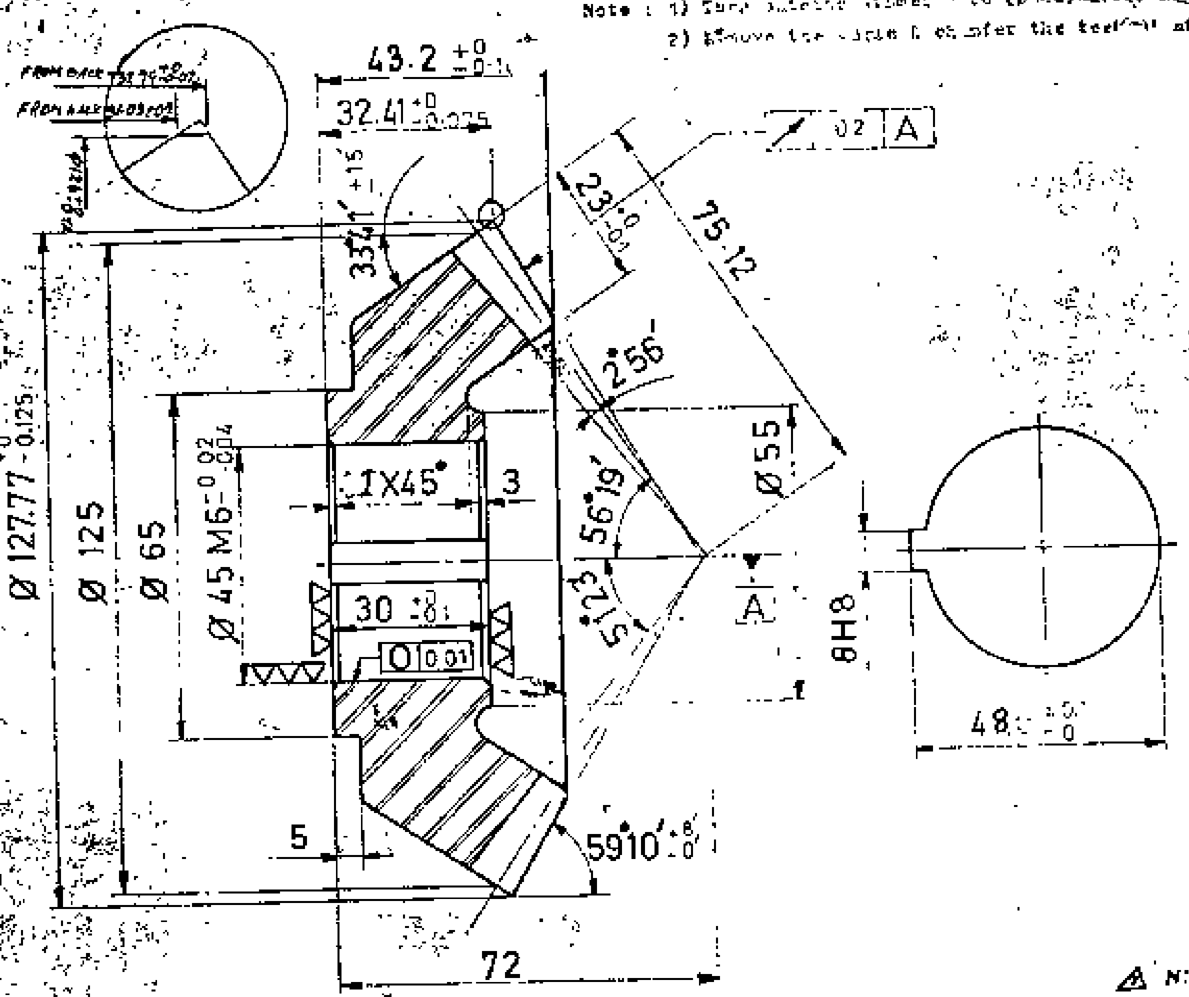
APPENDIX

Note : 1) Turn [illegible] to (Ø126) after milling the teeth.
2) [illegible] the [illegible] after the teeth after milling.

GLEASON SPIRAL TOOTHING

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



Spiral Bevel Gear

409-0001-6

△ N.B:- Depth of case hardening is 0.4 m.m.

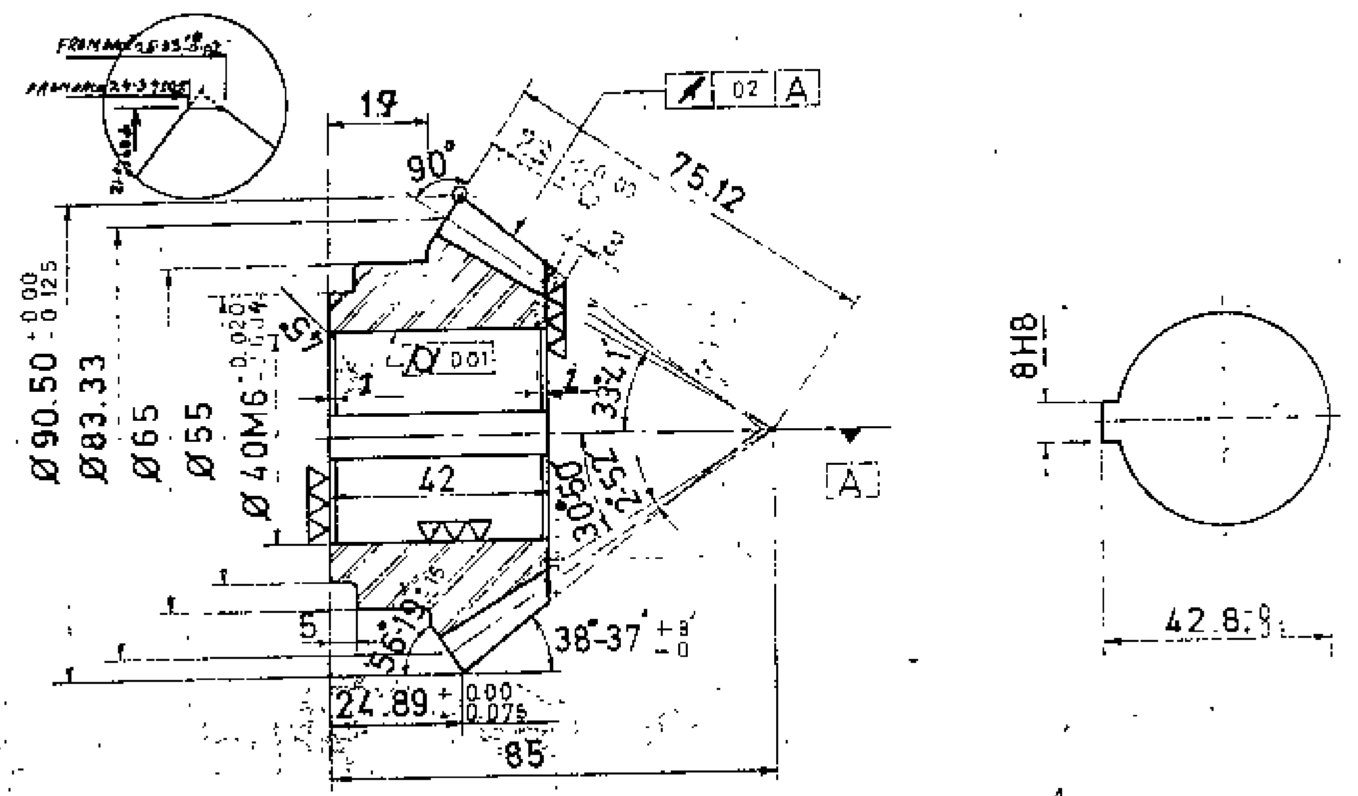
▽▽ (▽▽▽)

This drawing is made as per Gleason dimension sheet No.5009087 dated 28.6.84 for 3:2 transmission for further clarification the said sheet may be consulted.

			Application R.I. 100 3:2	Drg index	Qty 1	Non Tol Dimension
K-1-89	△		Material BMS-27	Stock Size	Stock wt.	Finish wt
16-7-87	△					
27.7.76						
Date	Modification	Sign				
Store Code(Raw mat)			Drawn	Checked / Approved	Date 30-7-85	Heat treatment 65HRC / Surf. Treatment
Store Code(Finish)			Part Name Vertical Bevel Gear		Part No. MODIFIED 5185 N/8 bis	
BANGLADESH MACHINE TOOLS FACTORY Ltd					Scale 1:1	Folio

38070074

GLEASON SPIRAL TOOTHING	
No. OF TEETH	Z = 22
MODULE	3.780
PRESSURE ANGLE	20°
SPIRAL TOWARDS LEFT	32°
TRANSMISSION RATIO	3:2



Spiral Bevel Pinion

5000-604

This drawing is made as per Gleason dimension sheets No.K 3009087 dated ~~[illegible]~~84 for 3 : 2 transmission. For further clarification the said sheet may be consulted.

N.B.) 2 Depth of case hardening is 0·4 mm.

▽▽ (▽▽▽)

16-4-87	3	
16-3-87	2	
29-7-86		
Date	Modification No.	Sign

Application	R.I. 100 3:2	Drg index	Qty	Non Tol Dimension
Material	BMS-27	Stock Size	Stock wt	Finish wt
Drawn	Checked	Approved	Date 29-7-85	Heat Treatment 65 HRC	Surf Treatment

Store Code (Raw Mat)

Store Code (Finish)

Part Name: Horizontal Bevel Gear

Part No: 5185 N/7bis

BANGLADESH MACHINE TOOLS FACTORY Ltd.

Scale 1:1

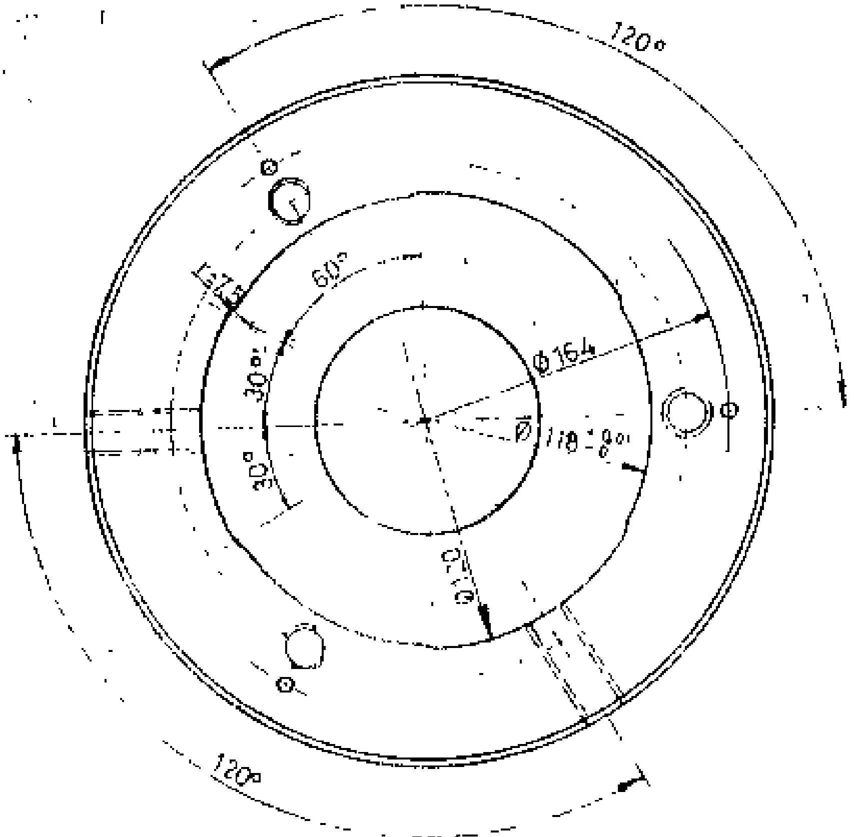
Folio

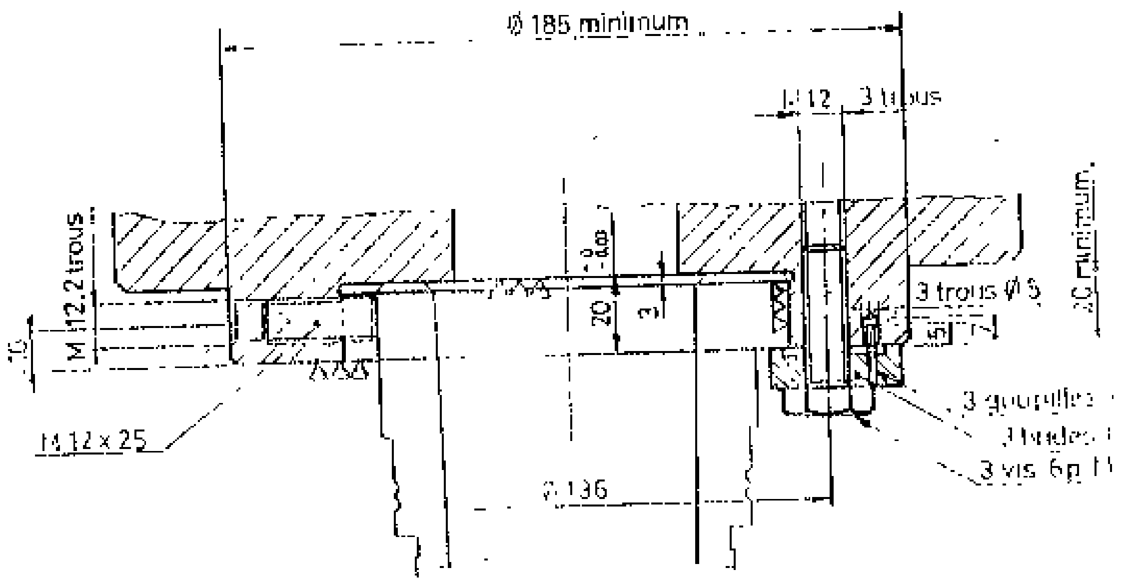
Flasques pour machines 5-52-400

Instructions techniques

Distrib. 1/5 3/6

Internal Grinding Machine Spindle





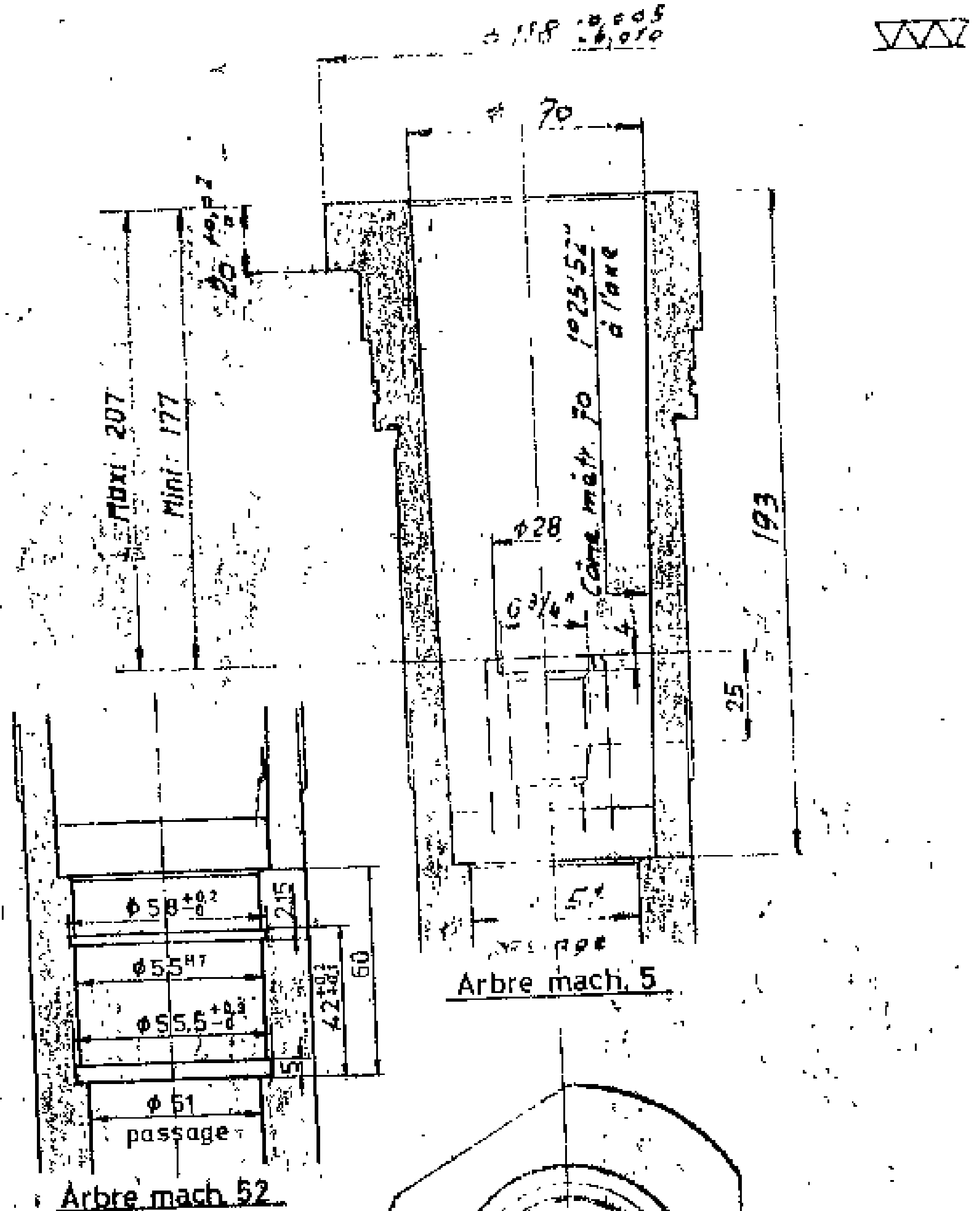
Date	Dess.	Visa	Mod.: Annule et remplace même N° du 15.5.74.			Nb. files
			13.9.77	JG	MG	
6.75	Mo.					

VOUMARD

Nez PPP machine 5 et 52

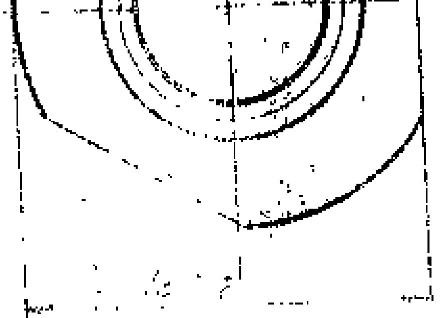
Machine 52 Instructions diverses

Internal Grinding Machine (Continued)



Arbre mach. 5

Arbre mach 52



Gleason
MACHINE DIVISION

ROCHESTER, NEW YORK 14692 U.S.A.

SPIRAL BEVEL GEAR DIMENSIONS NO. * 5009087 FORM M DATE 6/28/84 TIME 10:14

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

	PINION	GEAR
NUMBER OF TEETH	22	33
PART NUMBER		
MODULE		3.788
FACE WIDTH	23.00	23.00
PRESSURE ANGLE	20D 0M	
SHAFT ANGLE	90D 0M	
TRANSVERSE CONTACT RATIO . .		1.275
FACE CONTACT RATIO		1.447
MODIFIED CONTACT RATIO . . .		1.929
OUTER CONE DISTANCE		75.12
MEAN CONE DISTANCE		63.62
PITCH DIAMETER	83.33	125.00
CIRCULAR PITCH	11.90	
WORKING DEPTH	6.80	
WHOLE DEPTH	7.51	7.51
CLEARANCE	0.71	0.71
ADDENDUM	4.30	2.50
DEDENDUM	3.21	5.02
OUTSIDE DIAMETER	90.50	127.77
FACE ANGLE JUNCTION DIAMETER		

	PINION	GEAR
THEORETICAL CUTTER RADIUS .	2.828"	
CUTTER RADIUS	3.000"	
CALC. GEAR FINISH. PT. WIDTH		0.079"
GEAR FINISHING POINT WIDTH .		0.080"
ROUGHING POINT WIDTH	0.050"	0.060"
OUTER SLOT WIDTH	0.068"	0.080"
MEAN SLOT WIDTH	0.070"	0.050"
INNER SLOT WIDTH	0.063"	0.080"
FINISHING CUTTER BLADE POINT	0.040"	0.050"
STOCK ALLOWANCE	0.013"	0.020"
MAX. RADIUS-CUTTER BLADES .	0.041"	0.060"
MAX. RADIUS-MUTILATION . . .	0.055"	0.068"
MAX. RADIUS-INTERFERENCE . .	0.034"	0.050"
CUTTER EDGE RADIUS	0.030"	0.040"
CALC. CUTTER NUMBER	9	15
MAX. NO. BLADES IN CUTTER .		
CUTTER BLADES REQUIRED . . .	STD DEPTH	STD DEPTH

CUTTERS - REF SUMMARY 179 010

GEAR ANGULAR FACE - CONCAVE
GEAR ANGULAR FACE - CONVEX .
GEAR ANGULAR FACE - TOTAL .

		PINION		GEAR
PITCH APEX TO CROWN		60.11		39.59
FACE ANG JUNCT TO PITCH APEX				
MEAN CIRCULAR THICKNESS . .		5.65		4.23
OUTER NORMAL TOP LAND . . .		1.90		2.00
MEAN NORMAL TOP LAND . . .		2.06		2.14
INNER NORMAL TOP LAND . . .		2.24		1.96
PITCH ANGLE		33D 41M		56D 19M
FACE ANGLE OF BLANK		38D 37M		59D 10M
INNER FACE ANGLE OF BLANK .				
ROOT ANGLE		30D 50M		51D 23M
DEDENDUM ANGLE		2D 52M		4D 56M
OUTER SPIRAL ANGLE				36D 2M
MEAN SPIRAL ANGLE				32D 0M
INNER SPIRAL ANGLE				28D 38M
HAND OF SPIRAL	LH		RH	
DRIVING MEMBER	PIN			
DIRECTION OF ROTATION-DRIVER	REV			
OUTER NORMAL BACKLASH . . .	MIN	0.13	MAX	0.18
DEPTHWISE TOOTH TAPER . . .	TRL			
GEAR TYPE				GENERATED
FACE IN PERCENT OF CONE DIST				30.619
DEPTH FACTOR - K				
ADDENDUM FACTOR - C1				

		PINION		GEAR
GEOMETRY FACTOR-STRENGTH-J .		0.2550		0.2546
STRENGTH FACTOR-Q		11.000		7.34644
EDGE RADIUS USED IN STRENGTH		0.030"		0.040"
CUTTER RADIUS FACTOR - KX .		1.000		
FACTOR	KI	1.0370		
STRENGTH BALANCE DESIRED . .	STRS			
STRENGTH BALANCE OBTAINED .	STRS			0.004
GEOMETRY FACTOR-DURABILITY-I		0.0848		
DURABILITY FACTOR-Z		4399.77		3592.39
GEOMETRY FACTOR-SCORING-G .		0.002820		
SCORING FACTOR - X		0.2620		
ROOT LINE FACE WIDTH		23.00		23.00
PROFILE SLIDING FACTOR . . .		0.00297		0.00287
RATIO OF INVOLUTE/MEAN CONE		1.612 (HIGH)		
AXIAL FACTOR-DRIVER CW . . .	OUT	0.546	OUT	0.005
AXIAL FACTOR-DRIVER CCW . .	IN	0.703	OUT	0.338
SEPARATING FACTOR-DRIVER CW	SEP	0.008	SEP	0.364
SEPARATING FACTOR-DRIVER CCW	SEP	0.507	ATT	0.135
DUPLEX SUM OF DEDENDUM ANG .		8D 12M		
ROUGHING RADIAL		2.704"		

Spiral Bevel Gear Dimensions

Generated Spiral Bevel Summary

GENERATED SPIRAL BEVEL SUMMARY   NO. M S009087   SHEET 1 OF 4   DATE 6/28/84   TIME 10:30

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

	PINION	GEAR
NUMBER OF TEETH	22	33
MODULE		3.788
FACE WIDTH	23.00	23.00
PRESSURE ANGLE - PIN CONCAVE	20D 0M	
- PIN CONVEX	20D 0M	
SHAFT ANGLE	90D 0M	
OUTER CONE DISTANCE		75.12
ADDENDUM	4.30	2.50
DEDENDUM	3.21	5.02
WORKING DEPTH		6.80
WHOLE DEPTH - THEORETICAL .	7.51	7.51
OUTSIDE DIAMETER	90.50	127.77
PART NUMBER		

REF. SUMMARY 179.010 CUTTERS

	PINION	GEAR
PITCH APEX TO CROWN	60.11	39.59
PITCH ANGLE	33D 41M	56D 19M
FACE ANGLE OF BLANK	38D 37M	59D 10M
ROOT ANGLE	30D 50M	51D 23M
DEDENDUM ANGLE	2D 52M	4D 56M
SPIRAL ANGLE	32D 0M	32D 0M
HAND OF SPIRAL	LH	RH
CUTTING METHOD	FIXED SETTING	SPREAD BLADE
BACKLASH	MIN 0.13	MAX 0.18
DRIVING MEMBER	PIN	
DIRECTION OF ROTATION	REV	
INPUT DATA . . . . KTT	M	
DEPTH FACTOR - K		0.000
ADDENDUM FACTOR - C1		0.000
MOUNTING DISTANCE	MD	

GEAR TOOTH SIZES AT MIDDLE OF FACE

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

PINION TOOTH SIZES AT MIDDLE OF FACE

	FINISHED
NORMAL CHORDAL ADDENDUM . .	3.36
NORMAL CHORDAL THICKNESS . .	4.82
MEAN WHOLE DEPTH	5.95

DEPTH CHECKING DATA - NO. 15 BLANK CHECKER - FINISHING

	PINION	GEAR
CHECKING DIAMETER	73.02	101.40
BACKING	MD - 60.11	MD - 38.64

ALL LINEAR DIMENSIONS EXCEPT CUTTER SPECIFICATIONS ARE IN METRIC UNITS

CUSTOMERS ORDER NO   SALES ORDER NO   NO OF SETS   DATE

RELEASED BY - KBF   KBF

MACHINE DIVISION

GENERATED SPIRAL BEVEL SUMMARY NO. M 5009087 SHEET 2 OF 4 DATE 6/28/84 TIME 10:30

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

CUTTER SPECIFICATIONS - GEAR ROUGHING

DIAMETER		6.000"
OUTSIDE BLADE ANGLE		18D 0M
INSIDE BLADE ANGLE		22D 0M
POINT WIDTH		0.060"
BLADE LETTER		
BLADE EDGE RADIUS		0.025"
BLADE DEPTH	STD	
TYPE OF CUTTER		
CUTTER GAGING POSITION		0.000"

GEAR ROUGHING SETTINGS - NO 116 GENERATOR

MACHINE ROOT ANGLE		51D 23M
MACHINE CENTER TO BACK	MD +	0.00
SLIDING BASE	WITH	1.46
BLANK OFFSET		0.00
ECCENTRIC ANGLE		36D 0M
CRADLE ANGLE		1D 47M
SWIVEL ANGLE		0D 0M
CUTTER SPINDLE ROTATION ANG		0D 0M
CRADLE TEST ROLL		30D 0M
WORK TEST ROLL		35D 55M
DECIMAL RATIO		0.7903
NC/50 RATIO GEARS		52/47 X 50/70

GEAR TOOTH SIZES AT MIDDLE OF FACE

	ROUGHED	FINISHED
NORMAL CHORDAL ADDENDUM	1.94	1.94
NORMAL CHORDAL THICKNESS	4.13	3.62
MEAN WHOLE DEPTH	5.95	5.95
BACKLASH IN RADIANS - GEAR MIN	0.00265 MAX	0.00375

DEPTH CHECKING DATA - NO 15 BLANK CHECKER

CHECKING DIAMETER		101.40
BACKING	MD -	38.64

ALL LINEAR DIMENSIONS EXCEPT CUTTER SPECIFICATIONS ARE IN METRIC UNITS

RELEASED BY - KBF

CUTTER SPECIFICATIONS - GEAR FINISHING

DIAMETER		6.000"
OUTSIDE BLADE ANGLE		18D 0M
INSIDE BLADE ANGLE		22D 0M
POINT WIDTH		0.080"
BLADE LETTER		
BLADE EDGE RADIUS		0.035"
BLADE DEPTH	STD	
TYPE OF CUTTER		
NO. BLADES IN FINISH. CUTTER		
CUTTER GAGING POSITION		0.000

GEAR FINISHING SETTINGS - NO 116 GENERATOR

MACHINE ROOT ANGLE		51D 23M
MACHINE CENTER TO BACK	MD +	0.00
SLIDING BASE	WITH	1.46
BLANK OFFSET		0.00
ECCENTRIC ANGLE		36D 0M
CRADLE ANGLE		1D 47M
SWIVEL ANGLE		0D 0M
CUTTER SPINDLE ROTATION ANG		0D 0M
CRADLE TEST ROLL		30D 0M
WORK TEST ROLL		35D 55M
DECIMAL RATIO		0.7903
NC/50 RATIO GEARS		52/47 X 50/70

Generated Spiral Bevel Summary (Continued)

MACHINE DIVISION

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

CUTTER SPECIFICATIONS - PINION ROUGHING	
DIAMETER	6.000"
OUTSIDE BLADE ANGLE	12D 0M
INSIDE BLADE ANGLE	28D 0M
POINT WIDTH	0.050"
BLADE EDGE RADIUS	0.020"
BLADE DEPTH . . . . STD	
CUTTER GAGING POSITION . . .	0.000"

PINION ROUGHING	NO 116 GENERATOR
MACHINE ROOT ANGLE . . . . . PLUS	30D 50M
MACHINE CENTER TO BACK . . . MD +	0.00
SLIDING BASE . . . . WITH	8.30
BLANK OFFSET	0.00
ECCENTRIC ANGLE	35D 53M
CRADLE ANGLE	142D 6M
SWIVEL ANGLE	23D 13M
CUTTER SPINDLE ROTATION ANG.	22D 17M
CRADLE TEST ROLL	20D 0M
WORK TEST ROLL	35D 53M
DECIMAL RATIO	0.7893
NC/50 RATIO GEARS	.52/41 X 56/90

ALL LINEAR DIMENSIONS EXCEPT CUTTER SPECIFICATIONS ARE IN METRIC UNITS

RELEASED BY -   KBF

GENERATED SPIRAL BEVEL SUMMARY   NO. M S009087   SHEET 4 OF 4   DATE 6/28/84   TIME 10:30

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

CUTTER SPECIFICATIONS - PINION FINISHING

SIDE OF TOOTH	CONCAVE - OB	CONVEX - IB
POINT DIAMETER	5.970"	5.800"
BLADE ANGLE	14D 0M	31D 0M
BLADE LETTER		
BLADE EDGE RADIUS	0.030"	0.030"
BLADE DEPTH	STD	STD
TOPREM LETTER		
CUTTER GAGING POSITION . . .	0.000"	0.000"

PINION FINISHING SETTINGS - NO 116 GENERATOR

SIDE OF TOOTH	CONCAVE - OB		CONVEX - IB	
MACHINE ROOT ANGLE		34D 44M		37D 16M
MACHINE CENTER TO BACK . . .	MD -	3.33	MD +	4.99
SLIDING BASE	WITH	6.13	WITH	5.37
BLANK OFFSET	UP	1.00	DOWN	2.89
ECCENTRIC ANGLE		34D 46M		37D 52M
CRADLE ANGLE		147D 57M		132D 28M
SWIVEL ANGLE		46D 47M		39D 9M
CUTTER SPINDLE ROTATION ANG.		26D 26M		52D 55M
CRADLE TEST ROLL		20D 0M		20D 0M
WORK TEST ROLL		34D 8M		39D 10M
DECIMAL RATIO		0.7508		0.8616
NC/SO 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				5.95
BACKLASH IN RADIANS - GEAR	MIN	0.00265	MAX	0.00375

DEPTH CHECKING DATA - NO 15 BLANK CHECKER

CHECKING DIAMETER		73.02
BACKING	MD -	60.11

V/H CHECK	SOFT GEAR	SOFT PINION
	CONCAVE TOE HEEL TOTAL	CONVEX TOE HEEL TOTAL
	V	V
	H	H

ALL DIMENSIONS ARE METRIC UNLESS OTHERWISE SPECIFIED

RELEASED BY -   KBF

TOPREM IS A GLEASON WORKS TRADE MARK

PROPORTIONAL CUTTING CHANGES - NO 116 GENERATOR

SIDE OF TOOTH	CONCAVE - OB		CONVEX - IB	
BIAS CHANGE - 60 MIN. BIAS OUT				
MACHINE CENTER TO BACK . . .	ADV	2.15	WITH	2.23
SLIDING BASE	WITH	1.23	ADV	1.35
ECCENTRIC ANGLE	DEC	0D 15M	INC	0D 28M
SWIVEL ANGLE	DEC	1D 22M	INC	1D 0M
WORK TEST ROLL	DEC	1D 0M	INC	1D 0M
DECIMAL RATIO	DEC	0.0220	INC	0.0220
PROFILE CURVATURE CHANGE - 2.54MM PROFILE OUT				
BLANK OFFSET	UP	2.54	DOWN	2.54
ECCENTRIC ANGLE	DEC	1D 20M	INC	1D 13M
SWIVEL ANGLE	INC	1D 13M	DEC	1D 34M
WORK TEST ROLL	DEC	0D 56M	INC	0D 53M
DECIMAL RATIO	DEC	0.0207	INC	0.0195
LENGTHWISE CURVATURE CHANGE - .100"INC IN LENGTH				
SLIDING BASE	ADV	0.13	WITH	0.26
ECCENTRIC ANGLE	DEC	0D 27M	INC	0D 22M
SWIVEL ANGLE	INC	1D 3M	DEC	1D 0M
CUTTER DIAMETER	DEC	0.100"	INC	0.100"
SPIRAL ANGLE CHANGE - 2.54MM OFF THE TOE				
ECCENTRIC ANGLE	DEC	1D 20M	INC	1D 13M
SWIVEL ANGLE	INC	1D 13M	DEC	1D 34M

PINION CONTROL DATA

SIDE OF TOOTH	CONCAVE - OB		CONVEX - IB	
PATTERN LENGTH FACTOR . . .		0.350		0.350
DELTA AX - 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

BANGLADESH

BANGDALESH MACHINE TOOL/A.D.R.- JOYDEPUR

SUMMARY NO. S009087
RATIO 22 X 33 DATE 6/20/84

GEN. GEAR	CONVEX	CONCAVE
PIN BLADE ANG.	14.00	31.00
GEAR BLADE ANG	22.00	18.00
POINT DIAMETER	5.970	5.800
CONT LGTH FACT	0.35	0.35
DELTA AX	0.000	0.000
DELTA E.	0.000	0.000
DELTA GAMMA M.	6.000	9.000
DELTA GAMMA X.	-2.800	-2.500
DELTA D DELTA.	0.000	0.000

GEAR	CONVEX	CONCAVE
TOE POSITION	0.25	0.25
HEEL POSITION	0.25	0.25

RM*100		MEAN	TOE	HEEL	TOTAL
CX	E(V)	-5	21	-36	57
	P(H)	1	-27	31	57
CV	E(V)	-7	-45	36	81
	P(H)	3	40	-38	78

INCREMENT: MOTION 40, CONTACT 0.17
NOTE: A001 SPEC ANALYSIS

RERUN? TYPE NO, DP, UH, XX, OR END

TOOTH CONTACT ANALYSIS - FINISHING