DESIGN OF BROACHES USING COMPUTER

A project Thesis

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ABSTRACT

Different types of broaches are used in Bangladesh Machine Tools Factory (BMTF) for machining various types of materials. For this purpose BMTF needs to design different types of broaches. A large number of calculations and table interpolations are needed for designing broaches. It is monotonous and difficult to perform the same calculations repeatedly. For this purpose a software was developed to design broaches with the help of computer.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

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1. INTRODUCTION

1.1 GENERAL INTRODUCTION

Broaching is a machining process used intensively for making internal and external surfaces including intricate profiles in mass production. Basically broach is a multipoint tool in which the cutting edges are distributed along the axis or inclined to axis (helical) or sometimes inclined about the axis of rotation and finishes the operation in one or a number of passes. The broaching machine have straight line ram movement to pull or push the broach, while the component is held against the movement of the tool. Generally broaching is done on premachined component.In Bangladesh Machine Tools Factory, they generally prefer drilling before Broaching. Broaching machine is unique as that it provides only one function that is broaching.

The broach is usually secured in the main slide of the broaching machine and travels with the slide. A round broach travels along the axis of the hole being broached. Since the teeth gradually increase in size from the front to the rear end of the broach, each successive tooth removes a layer of material, there by increasing the size of the hole. If the force is applied to the shank, the body of the broach is in tension. If the force is applied to the rear end of the broach then it is in compression. Bangladesh Machine Tools Factory uses former type of broaching.

Although the cutting speeds used in broaching are relatively low (2 to 15 m per min), the production capacity is very high since total length of the cutting edges that are simultaneously in operation is very long. The output in broaching can be raised still higher if broaching machine with continuous working motion are used, in conjunction with automatic workpiece loading and unloading.

Owing to the high output and machining accuracy (3rd and 5th accuracy grades), as well as the fine surface finish produced (5th and 9th class), broaching is finding wider and wider application in the engineering and metal working industries.

A complete broaches are shown in Figure 1.

The advantages of using broaches in BMTF:

1. The possibility of making external as well as internal intricate profiles in mass production without the need of skilled technician.In BMTF any technician who is available at that time can work on the broaching machine.
2. Roughing and finishing cuts are made in one pass only. Moreover it can also incorporate burnishing surfaces to produces smooth surface finish.
3. The accuracy and the surface finish of the surfaces

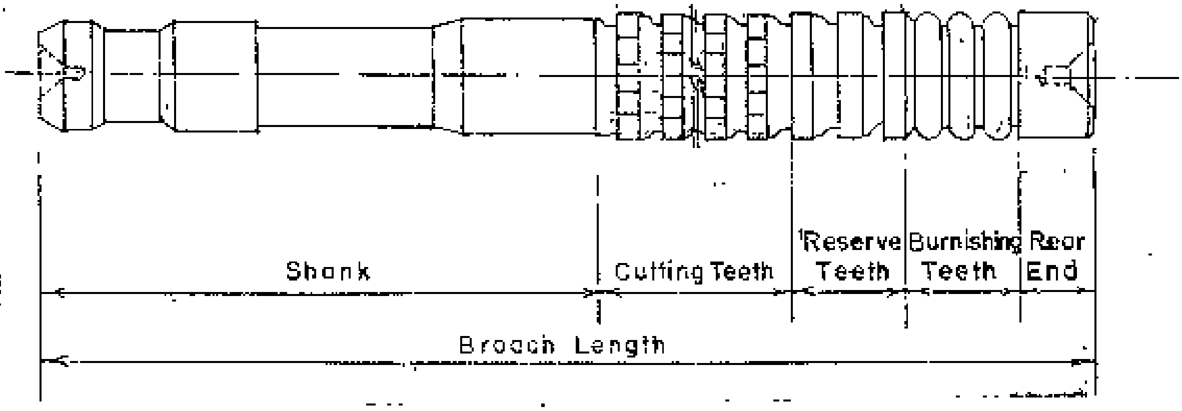


Figure 1.Standard Broach

produced are high.

4. As feed is predetermined it is independent of workers aptitude. Thus it avoids possible human error which leads curtailing of labour costs and rejects
5. Broaches have long life in terms of components produced.
6. Cost of manufacturing is less for mass production. The Table 1 shows the comparative rate of production of holes between different process and Table 2 shows comparative cost of production between milling and broaching. All the studies have been is made in BMTF.
7. The chip flow in broaching is unidirectional which reduces the clogging of chips and scoring of machine surface.
8. In process less inspection is required.
9. The operation can be repeated any time without much loss of setting time and the dimensions are maintained to original component dimensions as they depend purely on tool.

The disadvantages of using Broaches in BMTF:

1. Due to difficulty in manufacturing, even heavy industries cannot make their own tool.
2. The tool cost is high and time required for manufacturing tool is too long.
3. Nonuniform allowance for broaching encounters difficulties.

TABLE 1

COMPARATIVE RATE OF PRODUCTION OF HOLES BETWEEN DIFFERENT PROCESS IN BMTF

Method of Manufacturing	Rate of Production	Cost of Production
Broaching	1	1
Drilling + Boring with single Point Tools	0.6	1.3
Drilling + Fine Boring with Single Point Tools	0.25	2.75
Drilling + Reaming	0.3	1.4
Drilling + Grinding	0.2	3.0

TABLE 2

COMPARATIVE COST AND TIME OF PRODUCTION BETWEEN MILLING AND BROACHING IN BMTF

Thickness of Material Removed, mm	Time of Production for Broaching, Min	Time of Production for Milling Min.
2	0.18	0.918
5	0.356	1.00
10	0.812	1.09

4. Impossibility of broaching a non-through profile.

5. Even small change in profile requires different costlier tools.

6. Difficult to broach thin walled component as the shrinkage is not uniform.

7. It is impossible to broach tapered hole.

8. The disposal of chips, are quite different than in any other process because the chips are trapped in the gullet space and they remain there till the tooth comes out of the work.

9. Resharpening of broach is difficult.

1.2 CLASSIFICATION OF BROACHES USED IN BMTF:

Broaches are classified depending upon

1. **Type of work:**

   A: Internal:- Internal broaches are used to broach internal contours.

   B: Surface:- External surface broaches are used for machining rule surfaces of open contour.

   In BMTF both types of broaches are available.

2. **Method of operation:**

   A: Push:- In the push-type broach the force is applied from the rear end of the broach. The push broach is in compression. To avoid buckling, a push broach should be shorter in length.

B: Pull:- In BMTF the Broaching machine is of this type. In the pull-type broach force is given from the clamping side of the broach. The pull-type broach again may be pulled up or pulled down. The pull-down broaches are more common than pull-up because the pull-down simplifies the chip disposal as the chip falls directly into the base of the machine. The down ward movement also tends to pull the cutting fluid into the hole to provide better lubrication. Work can be positioned easily because the cutting force keeps the component against its support. The advantage of pulled-up type machine is that the component falls at the tail end of the broach so unloading of the component is simplified. Selection of push or pull-type machine depends upon the ratio between diameter of the shank and the diameter of the broach. Long slender broaching tool either pulled or pushed can be used as buckling is no problem because the tool is firmly attached to the machine ram.

3. Construction:

A: Solid:- Solid broach made of single piece of stock material. It is rigid, but material cost is more.

B: Inserted:- In inserted type of broach tooth inserts are clamped mechanically to the main body which is made of medium carbon steel.

C: Segmental:- In segmental broach full length of the broach is divided into a number of segmental parts and are manufactured separately. Finally they are assembled together to from the full length of the broach. This is done to avoid the difficulty in heat treatment of broaches.

BMTF is furnished with all these type of broaches.

4. **Application of broaches in BMTF:**

A: Keyways:- For mass production of keyways, however, regular horizontal or vertical broaching machines are employed. The harden guiding plug known as horn has a ground slot to guide and support the broach.

B: Spline:- For broaching of either straight-slided splines or involute splines, regular spline broaches are available. Straight-sided splines can be broached by the normal keyway broaching procedure when the quantity of production is small. The broach used here will be similar to the keyway broach, except that the top side will be reduced corresponding to that of the outside diameter of the mating shaft.

C: Polygon:- Broaching of polygonal is a common internal broaching operation.

D: Turret:- For work piece where several slotting broaches are to be used consecutively, a horizontal broaching machine with a turret for carrying the broaches will be found. The broaches are carried in a rotary turret and consecutively pulled through the work.

Broaches used in BMTF is mostly for cutting keyways, and spline.

5. Types of teeth:

   A: Helical:- When the teeth are helical.

   B: Straight:- When the teeth are straight.

6. Dual-type broach:

   It will have alternate round and spline teeth at finishing end.

7. Single or set of broach:

   If the length of single broach to complete the operation becomes too long to accommodate in the machine and to heat treat, then the operation is completed by a set of broaches.

1.3 IMPORTANT PARAMETERS:

Few parameters are explained here and it has been shown in Figure 2.

Clearance Angle:- It is made by grinding at the top of the tooth at an angle to the line of cutting. It is generally represented by alpha.

Rake Angle:- The angle between the cutting edge of the tooth and a line perpendicular to the axis of cutting. It is generally represented by gamma.

Pitch:- Pitch is the distance from one point of a tooth to the same point of the next tooth.

1.4 AIMS AND OBJECTIVES

In designing a broach it is necessary to go through a long procedure of calculations. During this process a large number of tables readings, tables interpolations etc. are required. It is very common to make mistakes in doing table interpolation and is monotonous also. But if a program can be developed for designing broaches then the broach design becomes very easier. So the objectives of this work is:

1. To study the design parameters of a broach.
2. To develop a software for broach design so that the design work becomes easier in BMTF in near future.
3. To reduce time required for designing of a broach.
4. To save manpower and thus reduce the cost of production.

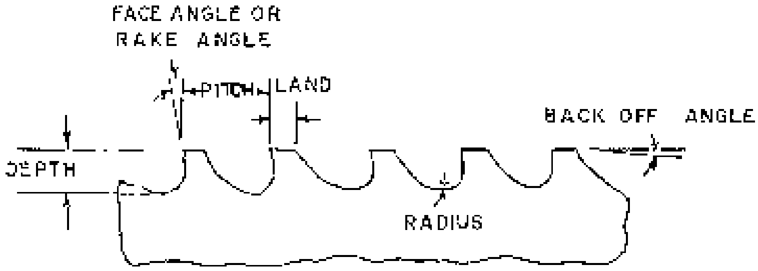


Figure 2.Important Parameter of Broach

CHAPTER 2

DESIGN PRINCIPLES OF BROACHES

2. DESIGN PRINCIPLES OF BROACHES

2.1 TOOTH GEOMETRIC ELEMENT

Broach tooth geometry effects the tool life, cutting efficiency and curling of the chip. The main parameter of the tooth geometry are clearance angles, land, rake angle.

Clearance angle and land in broach tooth effects mainly the tool life. The reduction in the height of the tooth per sharpening is directly proportional to the top clearance angle. The number of times the broach teeth can be sharpened before the last finishing teeth goes below the specified lower limit dimension depends on the amount of land provided in the last finishing teeth.

Rough teeth have 1^0 to 2^0 clearance angle without straight land. The finishing teeth will have 0.2 to 0.4 mm straight land and clearance angle of 1^0 to 20^0 after the straight land portion. Even on straight portion slight clearance angle is provided with oil stone.

Back taper angle is provided along with the broach axis over the full cutting portion of the broach teeth to prevent the rubbing action of the teeth side cutting edges with the machined surface. This back taper should confirm with the tolerance on the component and the functional aspect of the machined surface. The standard shapes and dimensions of gullet are shown in Figure 3.

2.2 CUTTING VARIABLES IN BROACHING

The determination of the cutting variables in broaching consists in assigning the cutting speed, since the feed per tooth,'L' and the width,'b' of the uncut chip are predetermined by constructional elements of the broach.

The feed per tooth L or, as it called in broaching, the cut, or step per tooth is the difference in height between two successive teeth. The cut per tooth L is usually determined from the material to be broached and the diameter to be broached.

The width, b of the uncut or undeformed chip is measured along the cutting edge. In a keyway broach it is the width of the keyway; in a round or spline broach, it is equal to the active length of the cutting edge. This equals the length of the circumference in a round broach and the total width of all the splines in a spline broach.

The cross-sectional area,f of the undeformed chip per tooth is

$$f = Lb \ mm^2$$

for a keyway (single-spline) broach:

$$f = Lbn \ mm^2$$

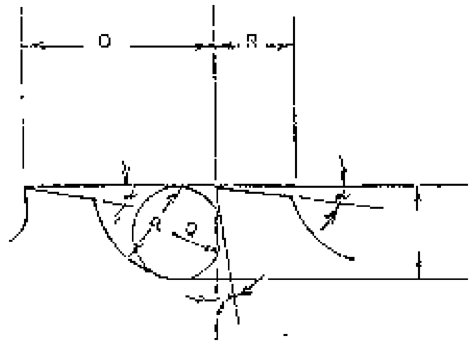


Figure 3. Shapes of Broach Teeth & Chip Spaces

for multiple-spline broach;

$$f = 3.14LA \text{ mm}^2$$

for a round broach;

where L = cut per tooth, mm

b = spline width, mm

n = number of splines

A = diameter of a round broach, mm.

The total cross-sectional area of the undeformed chip is

$$F_t = fU \text{ mm}^2$$

where U is the number of teeth simultaneously in operation.

The machining time required for one pass in broaching is

$$T_m = \frac{L_t}{1000vq} K_c \text{ min}$$

Where L_t = length of the working stroke of the broach, mm

K_c = Coefficient taking into consideration the ratio of the working and return stroke speeds, usually from 1.4 to 1.5.

v = Cutting speed, m per minute

q = Number of workpieces broached simultaneously.

2.3 CHIP FORMATION IN BROACHING

All the phenomena of the cutting process occur during chip formation in broaching are deformation, heat generation, formation of a built-up chip, friction and wear. The cutting process is often accomplished in broaching with very thin chips, especially in internal broaching where L may be as small as 0.015 mm. A heavily deformed continuous chip is obtained in broaching steel, and a fracture chip in broaching cast iron.

It is important to know the shape and size of chip that is to be obtained in broaching. The proper design of the broach may depend upon these data. The chip spaces between the tooth should be of such shape and size so that it can adequately accommodate the formed chip in one pass of the broach. If the curled chip is too large for the chip space it will be compacted into the space, leading to rupture of the broach. Chipbreaker grooves or notches are frequently provided on the cutting teeth to produce narrower chips that fit easier in the chip spaces (Figure 4).

A built-up edge (stagnant zone) is formed in broaching steel. If the chip thickness is greater and the face angle is less then the built-up edge will be larger. The built up edge often breaks off and gets between the works and the back-off surfaces. This may severely impair the finish of the broached surface.

Since broaching is done with a small cut per tooth $\bar{L}$ and at low cutting speeds, the application of a cutting fluid

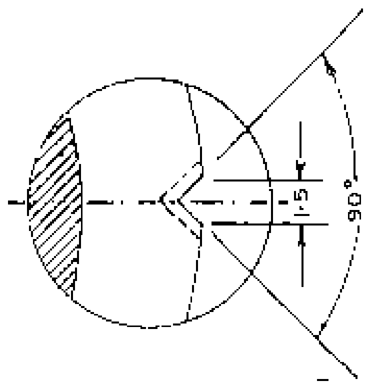


Figure 4.Chip Breaker

acquires prime importance. Sulphurized oil is mainly used in broaching steel (8 to 15 liters per min for internal broaching and 30 to 40 liters per min for surface broaching). A 10 per cent emulsion (soluble oil) is used in broaching stainless steel.

Gray cast iron and malleable iron are commonly broached dry. It is advisable to broach aluminum with a special mixture of oil and kerosene (1:1).

2.4 CUTTING SPEED

Generally, broach teeth are subject to wear on the backoff clearance surface (flank), at the corners, on the cylindrical land (sizing teeth) and the tooth face.

Owing to the use of a broach mainly as a finishing tool (with the exception of external surface broaches), the processing criterion of wear is applied. This means a degree of wear after which the finish off the broach is no longer satisfactory or the geometric features and the dimensions of this surface are not within the specified tolerances.

The maximum permissible wear on the back-off clearance surfaces and at the corners of the chipbreaker grooves is taken in the following limits (in broaching steel or cost iron): up to 0.2 mm for round broaches, and to 0.3 mm for spline and keyway broaches.

The following average life periods are recommended for broaches of high speed steel grades P9 and P18: (a) keyway broaches (keyway width 10mm) - 120 min in broaching steel and 180 min in broaching cast iron; (b) spline broach from 32 to 50 mm in diameter - 420 min in broaching steel and 600 min in broaching cast iron; and (c) round broaches (diameter 30 mm) 180 min in broaching steel and 270 min in broaching cast iron.

The average life of a broach can also be expressed as the total length of surfaces in meters broached between grinds (before resharpening).

The cutting speed is limited in broaching not by the hardness of the tool, but by the conditions that enable a surface finish of high quality to be obtained. An increase in cutting speed dose not have any significant in out put as the handling time in a broaching operation is very long in comparison to the machining time. The following formula can be used to calculate the cutting speed in broaching:

$$V = \frac{C_v}{T^{my}} \text{ m per min}$$

Where C_v = factor characterizing the machining conditions.

T = broach life, min

m & y = exponents of the life and cut per tooth, depending upon the work material, broach material and other conditions.

For example, in broaching a cylindrical hole in a workpiece of steel, grade 35 (BHN 197-269) in order to obtain a fit of 2nd class accuracy the cutting speed is V = 6 m per min for a highspeed steel broach. Data can be found in handbooks for calculating the cutting speed for other conditions.

2.5 SELECTION OF CHIP THICKNESS

The elements of a broach is shown in Figure 2. After studying the component thoroughly, the first is to select the chip thickness which is the height per tooth. The successful working and tool life depend upon the selected chip thickness.

Following should be consider if chip thickness is more:

a. gullet depth, consequently should be more.

b. the rubbing action between face and chip will be more and chip particulars may fate welded to the face.

c. the curling of chip is more difficult.

d. specific cutting resistance will be less.

e. the specific load, the load per unit width will be more, so tool life will be less and sometimes, even the cutting edge may chip off.

f. the surface finish of the component will be poor.

g. less number of tooth will be in contact with the work and vibration may appear due to fluctuation of load.

h. The length of the broach will be comparatively less.

i. Sharpening will be required frequently. So maintenance will be costly.

The following will occur if chip thickness will be less:

a. the specific cutting resistance will be more.

b. surface finish will be better.

c. the length of the broach become too long.

d. if the chip thickness becomes less then the cutting edge radius, tooth may not cut but will rub which reduces the life of the tool considerably.

Keeping in view the advantages and disadvantages of more and less chip thickness, it is better first to make trial on making a shaping tool exactly as one tooth of the broaching tool.

The suggested chip thickness for different materials are given in Table 3.In this work the chip thickness is represented by L.

2.5 TYPES OF GULLET AND THEIR SELECTION

The space between the teeth is called gullet. Gullet is provided for accommodation of the chips formed during the broaching by each of the teeth. This chips can not escape until the teeth passes through the component. Chip space is limited by the pitch of the tooth and in small diameter broaches, by the diameter of the broach.

The volume occupied in the gullet space by the deformed chip is always more than its own volume (BxbxL).

Where B = length of the job

b = width of the teeth

L = thickness of the teeth

The region of the volume occupied by deformed chip to the volume of the chips is called the volume factor K_v. This factor depends upon:

a. Types of chip; because continuous chip occupies more volume than segmental chips.

b. Thicker the chips, curling of chips becomes less.

c. Surface finish of the gullet, hook should be as smooth as possible otherwise excessive heat generation due to friction will cause to occupy more space.

d. Type of production, i.e. if a number of components say two are broached together, the gullet space factor will increase as the curled chip from in the first component will be moved forward by the next component curled chip.

TABLE 3

SUGGESTED CHIP THICKNESS FOR DIFFERENT MATERIAL

Chip thickness/rise of tooth in millimeters

Material to be broached	Characteristic of Material: Hardness BHN	Characteristic of Material: Strength in Kg/sq mm	Spline	Round	Keyway
[illegible]rbon Steels	Below 200	Below 70	0.04-0.06	0.02-0.03	0.04-0.07
	200-230	70-80	0.04-0.08	0.02-0.05	0.07-0.12
	Above 230	Above 80	0.03-0.05	0.02-0.03	0.04-0.07
[illegible]lloy Steels	Above 200	Above 70	0.03-0.05	0.02-0.03	0.03-0.06
	200-300	70-80	0.03-0.05	0.02-0.04	0.06-0.12
	Above 230	Above 80	0.03-0.05	0.02-0.03	0.04-0.07
[illegible]st Iron	200	-	0.06-0.10	0.04-0.08	0.08-0.15
	200	-	0.04-0.09	0.03-0.06	0.07-0.12
[illegible]nze and Brass	-	-	0.05-0.12	0.05-0.10	0.06-0.20
[illegible]minum	-	-	0.02-0.10	0.02-0.05	0.05-0.20

Valve of K_v are given in the Table 4.

2.6.1 DIMENSION OF THE GULLET

While broaching, material forming continuous chips gets curled in a circular path. The value of different parameters of the gullet space can be given by the following relations:

$P = 0.5 \times O.$

$Q = 0.3 \times O$

$R = 0.7 \times O$

Where P is the land, Q and R is the tooth geometry and O is the pitch. O,P,Q and R is shown in the Figure-3.

2.7 WIDTH OF THE LAND

The width of the land should be sufficient to take the load even after the allowable sharpening limit of the surface. This depends upon the unit load (Load on unit width of the cutting teeth) on the cutting edge.

Required minimum thickness of the land to withstand the cutting load on the teeth can be found out from the formula.

$$t^2 = \frac{6 * K_s * L * H}{f_s}$$

where t = Minimum thickness of the land to withstand the

TABLE 4

CHIP VOLUME FACTOR

Chip Thickness	Material to be machined: Steel having tensile Strength kg/sq.mm 50	60	70	80	90	Cast Iron	Bronze	Brass
0.100	2.10	2.45	2.25	2.28	2.05	2.00	2.15	2.09
0.095	2.11	2.46	2.26	2.30	2.05	2.02	2.17	2.08
0.090	2.12	2.47	2.27	2.31	2.05	2.05	2.19	2.08
0.085	2.13	2.48	2.29	2.33	2.07	2.09	2.22	2.08
0.080	2.15	2.52	2.31	2.35	2.08	2.12	2.24	2.09
0.075	2.17	2.53	2.33	2.38	2.11	2.15	2.27	2.09
0.070	2.20	2.57	2.36	2.42	2.15	2.20	2.31	2.12
0.065	2.23	2.60	2.38	2.45	2.20	2.24	2.34	2.13
0.060	2.27	2.63	2.43	2.49	2.23	2.30	2.38	2.15
0.055	2.33	2.68	2.47	2.54	2.30	2.37	2.43	2.18
0.050	2.38	2.75	2.52	2.60	2.35	2.45	2.50	2.22
0.045	2.43	2.82	2.58	2.68	2.43	2.55	2.56	2.27
0.040	2.50	2.93	2.63	2.79	2.57	2.68	2.65	2.35
0.035	2.59	3.05	2.72	2.93	2.62	2.83	2.75	2.43
0.030	2.70	3.17	2.82	3.20	2.75	3.13	2.92	2.57
0.025	2.85	3.32	2.92	2.58	2.92	3.47	3.18	2.74
0.020	3.20	3.70	3.10	4.50	3.70	4.50	3.90	3.00

cutting load.

K_s = Specific cutting resistance of the material.

f_s = Allowed bending stress of the tool material.

Total width of the land

= Minimum thickness of land as found out from the above equation + (Sharpening allowance X expected number of sharpening before scrapping the broach).

Sharpening allowance is generally 0.2-0.4 mm per sharpening.

2.8 TEETH

A) CUTTING TEETH

Cutting teeth are those teeth which remove most of the material. Maximum portion of the material is removed by teeth. The number and geometry of cutting teeth depends upon the material and the diameter to be drilled.

B) FINISHING TEETH

Finishing teeth gives the required dimension to the job. The first finishing teeth removes the material about 70 percent left after cutting teeth, the next teeth cut 65 percent and so on. The number of finishing teeth depends on the material left after cutting teeth and the required finishing. The last teeth of the finishing teeth gives the required dimension of the job.

C) RESERVE TEETH

Reserve teeth are not remove any material. When cutting teeth are wornout then the number of cutting teeth worn-out can be replaced by the finishing teeth and the finishing teeth can be replaced by reserve teeth. The worn of the cutting teeth may be due to resharpening also. The number of reserve teeth may be from 4 to 6. The diameter of all reserve teeth are equal to the diameter of last finishing teeth.

D) BURNISHING TEETH

Burnishing teeth are provided not to cut the work surface but (a) to smoothen (b) make the hole accurate, and (c) cold work the same to have better bearing surface if required in the component drawing.

4 to 6 numbers of burnishing teeth are provided in the broach if required, at the end of finishing teeth. Sometimes separate burnishing teeth may be conformed to the reserve teeth functional dimension. Generally the number of burnishing teeth is five. A complete Burnishing teeth is shown in Figure 5.

2.9 CHIP BREAKER

In broaching chip breakers are provided to divide the width of cut. For all internal broaches which cut on complete periphery chip breakers should be provided, as the periphery at the cutting edge is greater than at the bottom of the tooth space which makes chip to be crowded and unable to curl properly into the space. So chip breakers are to be provided to reduce the peripheral cutting surface and also to prevent the formation of chip into complete rings. Chip breakers are not necessary to provide on finishing teeth because depth of cut by this is small and the rings will break by their own accord as to cut cast iron material. In surface broaching chip breakers are used to break up extremely wide chips that might cause jamming or scoring. Chip breakers should be provided on the roughing teeth to facilitate the chip in the space. When tough materials are broached the width of the chip will be more than the width of the cut which may cause the scoring of the machined surfaces and this can be reduced-providing chip breakers. If the width of cut is more than 10 mm, chip breakers must be provided.

This is provided on the width of the cutting edges in the form of nick, of course, the position of them should be staggered. It is seen practically that wear of the cutting edge with chip breakers is more at the transit portion between Chip breaker and cutting edge. Extensive research is going on to find the best shape and size and number for round and keyway broach. We can find out the No of chipbreakers from Table 8. A chip breaker is shown in Figure 4.

2.10 PITCH

Pitch is the distance between the two cutting edges. It depends upon

(1) The chip thickness

(2) Length of cut

(3) Type of work material and

(4) Number of components

The general formula for pitch = 0.35xLength of job.

$$O = 0.35xB$$

This is the basic formula for calculating the other parameter of the broach.

The factors that are to be checked before deciding on the exact pitch are as follows:

1. At least two teeth must act simultaneously to avoid chatter.
2. The total cutting load should not exceed the broach tool capacity and machine capacity.
3. Gullet space should be sufficient to accommodate chip.
4. Land should be adequate for sharpening.

So in calculating pitch it is better to calculate from thickness to be machined from the formula

$$N = \{(SxLxBxM)/3.14\}^{(1/2)}$$

Depending on the value of N the pitch can be read from the Table 5.

Generally the pitch is constant through out the broach.

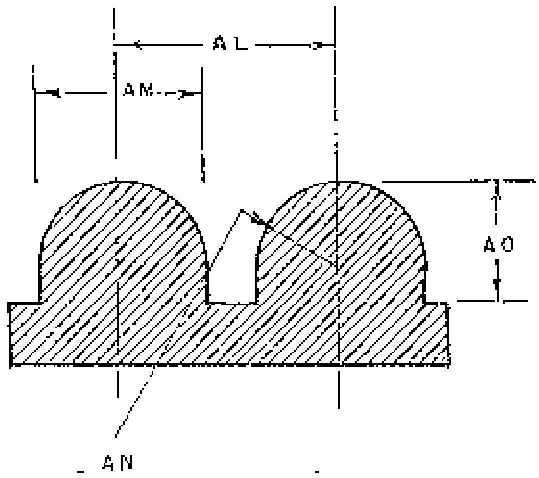


Figure 5.Burnishing Teeth

TABLE 5

DETAILS OF BULLETS SPACE AND PITCH

P	h	b	F	H	F_{oc}	F_{sc}	r	E	r	S	T_{sz}	F_{sz}
mm	mm	mm	mm	kN			mm	mm	mm	mm		
3.00	1.10	1.00	0.35	[illegible]	0.95	1.50	1.00	0.30	0.35	2.09	0.78	1.50
3.50	1.30	1.50	0.55	[illegible]	1.32	2.10	1.20	1.00	0.75	2.30	1.10	2.10
4.00	1.45	1.80	[illegible]	1.10	1.65	2.50	1.30	1.20	0.85	2.70	1.33	2.50
4.50	1.50	2.00	0.80	1.20	2.00	3.20	1.50	1.30	1.00	3.00	1.71	3.40
5.00	1.60	2.20	0.90	1.40	2.30	4.00	1.70	1.50	1.10	3.30	2.00	4.00
5.50	2.20	2.70	1.10	1.50	3.50	6.20	2.00	[illegible]	1.30	4.30	[illegible]	5.30
[illegible]	2.50	3.20	1.70	1.80	4.90	7.30	2.70	2.40	1.70	5.30	2.70	7.30
[illegible]	2.90	3.60	1.40	2.00	6.60	10.50	2.70	[illegible]	1.70	5.50	3.70	[illegible]
[illegible]	3.00	4.10	1.60	2.40	[illegible]	[illegible]	3.00	3.70	1.90	5.00	7.40	[illegible]
[illegible]	3.50	4.50	1.80	2.70	[illegible]	16.20	3.20	[illegible]	2.10	6.70	8.55	[illegible]
[illegible]	4.00	5.00	2.00	3.00	12.30	20.00	3.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4.50	5.50	2.10	3.30	14.50	23.00	[illegible]	3.70	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	5.47	3.50	[illegible]	[illegible]	[illegible]	4.70	[illegible]	3.00	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	7.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.50	10.50	[illegible]	[illegible]
[illegible]	6.30	8.70	[illegible]	[illegible]	[illegible]	[illegible]	6.00	5.40	[illegible]	12.00	[illegible]	[illegible]
[illegible]	7.20	9.10	3.80	[illegible]	[illegible]	[illegible]	6.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	10.00	4.00	[illegible]	[illegible]	[illegible]	7.20	6.50	4.80	[illegible]	[illegible]	[illegible]
[illegible]	8.00	11.00	4.70	[illegible]	63.60	[illegible]	8.30	7.50	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10.00	12.70	[illegible]	7.60	78.50	120.00	9.00	8.40	5.00	18.50	67.50	129.00
32.00	11.50	14.00	5.50	8.00	[illegible]	150.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

when a tooth leaves the work, the resistance will be less than the broach begins to cut. So next tooth starts to cut at high speed and produces a shocks. If pitch is constant, the shocks occur at regular intervals. Pitch has been shown in Figure 2.

2.11 PULL END

The pull end of a broach serves to engage the broach with the pulling head of the machine. The design and dimensions of pull end have been standardized. One of the most common type is the key-type pull end (Figure 6). The slot on the broach has a corresponding slot in the puller head and the two are locked by dropping a key through the slot.

In the case where a slot for a key seriously weakens the shank, the pin type pull-end can be used. Here the broach end is engaged with a pin through an off-set hole. Pin type pullers may also be made automatic in operation.Pull end of keyway broach may be threaded and engaged with the tapped hole in the puller, as keyway broaches need not be disconnected between strokes. Since there is a possibility of injury to the operation while screwing the broach into the holder. The puller is often provided with a quick-set up type of threaded holder. This has threaded jaws which grip over the threaded on the broach. The broach is initially inserted by pulling an outer sleeve which releases the jaws.

The follower-end dimensions depend on the design of the follower-rest with which the machine is equipped. The dimension also deepens on whether the follower end is used.

2.12 FRONT PILOT

The front pilot of internal broaches, which aligns the broach and work, is made to have a slide fit with the previously machined hole. A front lead taper is provided for are easy entry. As the pilot also serves as a check against improper allowance in the hole, pilots should never be ground undersize.

2.13 REAR END

At the rear end of the cut, the rear pilot engages with a bush provided in the fixture and protects the broach from sagging. This also helps in maintaining the alignment of the broach for the return travel. Otherwise a possibility of a damage to the broach teeth by buckling may exist. The rear pilot is made slightly smaller in size than the finishing teeth.

2.14 SURFACE BROACH CONSTRUCTION

Even though a part of the foregoing discussion on the design of cutting elements is common to both internal and surface broaches. Surface broaches differ in construction from internal broaches. Surface broaches are generally heavy and

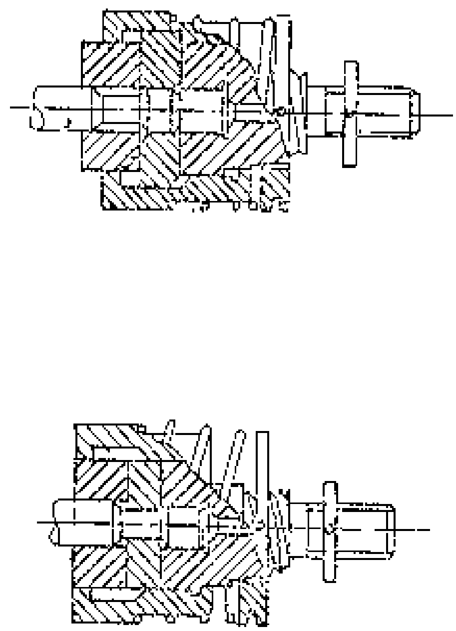


Figure 6.Automatic Round Shank Pull End
(Refference: Manual Of The Machine)

invariably of built up construction. The broach inserts are made conveniently short and held mechanically in the broach holder. Broach inserts can be held either with screws or wedges. The use of the holder saves tapping innumerable holes on the machine slide. The holder can be standardized for size and can be replaced completely with another broach holder without disturbing the alignment of broach inserts. The broach holder is normally located with vertical and horizontal tenon slots and clamped with dovetail sides or T-slots. The splitting up of the entire length of a broach into small length inserts makes manufacturing, heat treatment and regrinding simple. They can be aligned easily on the ground slots of the holder and the height can be easily adjusted after regrinding either with shims or tapered height elements. Complicated profiles can be split into simple, easy-to-manufacture signant and assembled to provide a complete broach profile. Similar is the case with straddle and wraparound broach construction. Carbide inserts, either the brazed or throwaway tapes, can be held conveniently with age.

2.15 ALLOWANCE FOR BROACHING

Because broaching is an economical method of obtaining high finish and close accuracy, sufficient material must be allowed. Thus the broaching operation will remove any irregularities due to previous operation in the stock material.Again it should be as small as possible to reduce the length of the broach.

The tolerances on the roughing teeth is not so much important as in the finishing teeth. It is always better to make the broach to the maximum size of the component and after taking trial if necessary can be reground to correct size. Tolerance on the broach depends upon the following:

(1) The material of component

(2) Wall thickness of the component

(3) Reduction in size of the resharpening

(4) Improper setting of tool and the component

Generally the tolerance on roughing teeth height is about 0.01-0.02 and the tolerance on the finishing teeth for steel component are shown in Table 6.

2.16 EFFECT OF TOOTH DESIGN ON CHATTER

Chatter in broaching operation causes poor surfaces finish, excessive wear of teeth, loss of accuracy, and sometimes causes breakage of the broach. Inherent interrupted cutting in broaching operation increases this chatter. Circular broaches are susceptible to chatter because of severe interrupted cutting. To reduce chatter the points to be considered in design are:

1. Teeth can be staggered longitudinally to provide more

uniform cutting for flat surface and spline broaches,

2. For the round hole broaches helical teeth instead of round teeth can be provided,

3. The pitch can be made small as far as possible so that the change in cutting load will be less,

4. Pitch can be varied (i.e. can be made less than in roughing teeth) for finishing teeth if required.

2.17 PARAMETERS TO BE CHECKED IN BROACH DESIGN

The tool parameters to be checked is the strength of the broach core cross-section, this should withstand the cutting load for the specific component at the minimum cross-section. Cutting load depends on the following:

(a) Chip thickness,

(b) Width of chip,

(c) Material to be cut,

(d) Maximum number of teeth in contact with the component in operation.

It is found out from the equation:

$P_{max} = P_z$ and $P_z = L \times B \times U \times V \times K$

Where P_z = Cutting load acting on each tooth

U = Number of teeth in action in operation

L = Thickness of the chip

b = Width of the chip

V is the specific cutting resistance depends on the material and chip thickness. Table-7 shows the various values of Ks.

K = Constant to safeguard for the wear of the tool and for hard spots which can taken 1.4 to 2.

For a round broach the strength of the broach is found out from the equation

$$P_b = 3.14x\ D_c^2 x f_t$$

Where D_c = Core diameter at the weakest point of broach.

f_t = Tensile strength of the broach material after hardening.

P_b = Maximum load at the core.

Safe tensile strength for the H.S.S. in calculations can be taken as 20 kg/mm^2.

$P_b > P_{max}$ for safe working of broach.

The suitability of the broaching machine for a particular operation depends on

a: Maximum load capacity of the machine

b: Stroke of the machine

Pmax should be less than the capacity in the machine, and the stroke length in machine also should be higher than the required length of pass for the particular broaching tool in operation.

Length of the broach should be checked from the manufacturing feasibility points. These are as follows:

TABLE 6

TOLERANCE ON BROACH

Tolerance on the finishing teeth T	Size of the Broach
0 to 0.015	Minimum size of hole + (0.85 to 1.1) T-0.003
0.015 to 0.03	Minimum size of hole + (0.8 to 1)T-0.005
0.03 to 0.04	Minimum size of hole + (0.075 to 0.9)T-0.007
0.04 to 0.07	Minimum size of hole + (0.75)T-0.01
Above 0.07	Minimum size of hole + 0.075 T-0.015

TABLE 7

SPECIFIC CUTTING FORCE, K_s kg/mm^2

Material	Riso por tooth,mm					
	0.03	0.04	0.05	0.06	0.08	0.1
Mild steel	425	365	335	310	280	260
Alloy steel	580	490	450	425	385	360
Grey cast iron	380	330	300	270	250	235
Malleable CI	340	290	270	250	225	210

A. Heat treatmont:- If the broach length is large it is suspectable to distortion during heat treatment and furnace may not able to accommodate.

B. Availability of grinding machine for grinding large broaches.

2.18 RECOMMENDED SEQUENCE FOR DESIGN OF BROACH

1. STUDY

   a) Shape of the component and functional dimensions specified in the component drawing.

   b) Machine details i.e. capacity and stroke suitability for the component to be broached.

   c) Determining the mode of cutting depending upon the functional surface to be broached.

2. SPACE OF THE TOOTH

   a) Chip thickness or rise per tooth.

   b) Space factor K_ψ.

   c) Height of gullet.

   d) Expected life of the broach, i.e., number of recharpening can be made before scraping the broach

   e) Pitch and land

   f) Maximum and minimum number of teeth working at a time

   g) Preparation of sketch for tooth.

3. LENGTH OF BROACH

a) Type of holder to suit machine tool and its standard lengths available.

b) Front and rear pilot length.

c) Number of roughing and semifinishing teeth required, this depends on the allowance in component to be broached.

d) Number of finishing teeth depending on the expected life of broach and burnishing teeth number if required.

e) Determining whether single broach or set of broaches are required for the component.

4. LOAD CALCULATION

a) Calculation of load per tooth and finding out the load of cutting for the component depending upon the maximum number of teeth in action during operation.

b) Checking the capacity available in the machine tool.

c) Checking for the working stress in the weakest point in the broach.

d) Tolerance to be applied on finishing teeth.

2.19 RESHARPENING OF BROACH

Broaches are resharpened mainly by grinding the tooth faces.

Infrequently, the back off clearance is ground. The grinding is done by the tapered side of the disk wheel. The face surface of round and spline broaches is conical. To obtain the specified rake angle on the broach (i) the axes of the grinding wheel and the broach must be in one plane and (ii) the radius of grinding wheel in a plane section perpendicular to the wheel axis must be less than the radius of curvature of the tooth face in the same section.

2.20 DETAILS OF CALCULATION

1) First to calculate the diameter to be drilled. It can be calculated by the equation.

$$J = A - 0.005 \times A - 0.15 \times (B)^2 \ldots\ldots\ldots\ldots (1)$$

Where J = Diameter to be drilled

A = Diameter to be broached

B = Length of the job

2) The diameter of the drill must be standardized from the standard drill table.

3) The chip thickness L should be selected from Table 3 depending on the material to be drilled and the type of broach.

4) The chip volume factor M should be selected from Table 4 depending on the material and chip thickness.

5) Calculate N, where N is the height of the teeth. This N should be standardized from Table 5.

$$N = \{(8xLxB)/3.14\}^{(1/2)} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

6) Depending on the value of N the pitch O can be read from Table 5

7) The tool geometry P,Q,R can be calculated from the equation

$$P = 0.5xO \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$Q = 0.3xO \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$R = 0.7xO \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

8) Read the value of number of chip breakers, S from Table 8 depending on the diameter to be broached.

9) Read the value of rake angle, T from Table 9.

10) Calculate the number of teeth in contact by the formula

$$U = B/O + 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

11) Read the value of specific cutting force, V from Table 7 from the value of L and material.

12) Calculate the cutting load, W from the formula

$$W = UxLxAxVx1.2x3.14/1000 \ldots\ldots\ldots\ldots\ldots (7)$$

13) Check whether the value of cutting load is greater then the capacity of the machine,E. If W>E then reduce the number of teeth, calculate the cutting force and check the load again.

14) Calculate where the stress is maximum. It may be occur at the clamping portion of the tool or at the tool diameter. This stress must be less than the ultimate strength of the tool material.

15) Calculate Tolerance. It should be depended on the fit required.

16) Calculate the number of cutting teeth. It should be calculated by subtracting from the value of maximum diameter to be broached and the diameter to be drilled. Then divide this by chip thickness L. Only integer number should be taken as the number of cutting teeth.

17) The number of finishing teeth should be calculated based on, the material left by the cutting teeth. The maximum amount of material to be removed by each of the cutting teeth should be less than 0.05 mm.

18) The number of burnishing teeth should be read from Table-10. It depends on the length of the job and pitch. Different parameters of the burnishing should be calculated from Table 9.

If AL is the pitch of the burnishing teeth then

$$AM = 0.7 \times AL \qquad (8)$$

$$AN = 0.5 \times AL \qquad (9)$$

$$AO = 0.15 \times AL \qquad (10)$$

Where AM, AN and AO are shown in the Figure 5

19) The number of burnishing teeth should be read from Table 10. It depends on the type of fit required, shape of the broach etc.

20) The total length of the broach could be obtained by adding up the followings: Clamping length of the tool,

Length of the job, Total length of the cutting teeth, Total length of the finishing teeth, Total length of the reserve teeth, Total length of the burnishing teeth and the clearance for the rear end. Thus, Ap becomes as follows:

$$AP = G+B+(AR+AJ+6)xO+4xAL+8+I\ldots\ldots(11)$$

Where AP is the total length of the broach

G is the length of the clamping portion of the tool

B is the length of the job

AR is the number of cutting teeth

AJ is the number of finishing teeth

I is the length of rear end

O is the pitch of the cutting, finishing and reserve teeth

And AL is the pitch of the burnishing teeth.

Beside this 8 mm is taken a clearance.

TABLE 8

NUMBER OF CHIP BREAKERS	
Dia D in mm	No. of chip breakers n
10-13	5
13-16	8
16-20	10
20-25	12
25-30	14
30-35	16
35-40	18
40-45	20
45-50	22
50-55	24
55-60	28
60-65	30
65-70	32
70-75	34
75-80	36
80-85	38
85-90	40
90-95	42
95-100	44

TABLE 9

VALUE OF RAKE ANGLE (   )

	Material to be broached	in degrees
Steel	Less than 60 kg/2mm2	15 to 18
	60 to 100 kg/mm2	12 to 15
	More than 100 kg/mm2	8 to 10
Cast iron	Less than 150 BHN	1 to 10
	More than 150 BHN	4 to 8
Aluminum		12 to 15
Bronze		0 to 5
Babit		10 to 15
Copper		15
Brass (Hard)		2
Brass (Soft)		8

TABLE 10

BURNISHING TEETH

Length of Job	10-13	13-22	22-36	36-52	52-76	76-112	112-150
Pitch AL mm	5	6	8	10	12	15	18

Amount of material removed by burnishing teeth = 0.002-0.005 mm

Lower values for aluminum and higher values for steel.

For symmetrical shape AM = ALx0.7

AN = AMx0.5

AO = ALx0.15

CHAPTER 3

DEVELOPMENT OF SOFTWARE

3. DEVELOPMENT OF A COMPUTER SOFTWARE FOR DESIGN OF BROACH

3.1 INTRODUCTION

A software has been developed so that it can be used for designing different types of broaches. The software program has the three section such as, (i) input data section, (ii) Computational work section and three output section. In the input data section, the program will require the basic input data of the broach in particular. Thus for any change in the input data will change all the parameters of the broach.
The input data section contains two types of data. These are the basic input data as mentioned above and the design parameter in tabular form. Thus numerous tables are builtin the program. In computational section the required empirical formula and basic equations are given. The output is obtained in the line printer in usual form. The numerical values of output design specificationing could be used to draw the prototype broach. In the following paragraphs the INPUT and COMPUTATIONAL sections are described.

INPUT

In designing a broach the following data are necessary:

Diameter to be broached, A (mm)

Length of the job to be broached, B (mm)

Material to be broached, (CI/CS/AS/BR/AL) C$

Hardness of the material, D(BHN)

Capacity of the machine, E (Ton)

Stroke length of the machine, F (mm)

Clamping length of the tool, G (mm)

Diameter of the clamping portion, H (mm)

Length of the rear end, I (mm)

COMPUTATION:

After receiving the data the programme will compute those in the following way:

a) Size of the hole,J to be drilled, $J = A-.005xAx0.15x(B)^2$

b) This diameter should be standardized from the standard drill table.

c) Chip thickness, L should be selected from the table depending on C$ and D.

d) Chip volume factor, M and specific cutting force, V should be read from the table.

e) Metal to be removed is to be calculated by the formula $N = \{(8xLxBxM)/3.14\}^{(1/2)}$

f) This N should be standardized from the table.

g) The value of pitch O should be read from the table. This will depend on the value of N.

h) Depending on the value of O the tool geometry P,Q,R is are be calculated.

i) No. of chip breakers, S is to be read from the table depending on the value of A.

j) The value of Gamma and Alpha is to be read from the table depending on the material C$ and the diameter B.

k) The No of the teeth in contact U is to be calculated by the formula U = B/O+1

l) The cutting load, W is to be calculated by the formula W = (UxLxAxVx1.2x3.14)/1000

m) Check weather W>E or not. If it does than U should be U-1 and so on until W<E.

n) Find out the root diameter of the broach by the formula X = J-2xN.

o) Find out the stress on the root diameter Y and also on the diameter of the clamping portion AA of the tool by the formula $Y = (Wx4x1000)/(3.14xH^2)$ and $AA=(Wx4x1000)/(3.14xX^2)$

p) Check which one of Y and AA is greater. The ultimate stress of the tool material must be higher than that.

q) Calculate tolerance depending on the fit required.

r) Calculate the No. of cutting teeth, AR.

s) Calculate the diameter of all cutting teeth, AS. It should be different from one to another.

t) Calculate the No. of finishing teeth, AJ.

u) Calculate the diameter of all finishing teeth.

v) Read the pitch for burnishing teeth, AL depending on the length of the job, B.

w) Calculate the tool geometry of the burnishing teeth, AM, AN, AO.

x) Calculate the total length of the broach AP.

y) Check whether the result is to be printed or not.

z) Check whether more set of calculation is required or not.

3.2 DETAILED DESCRIPTION OF THE PROGRAM

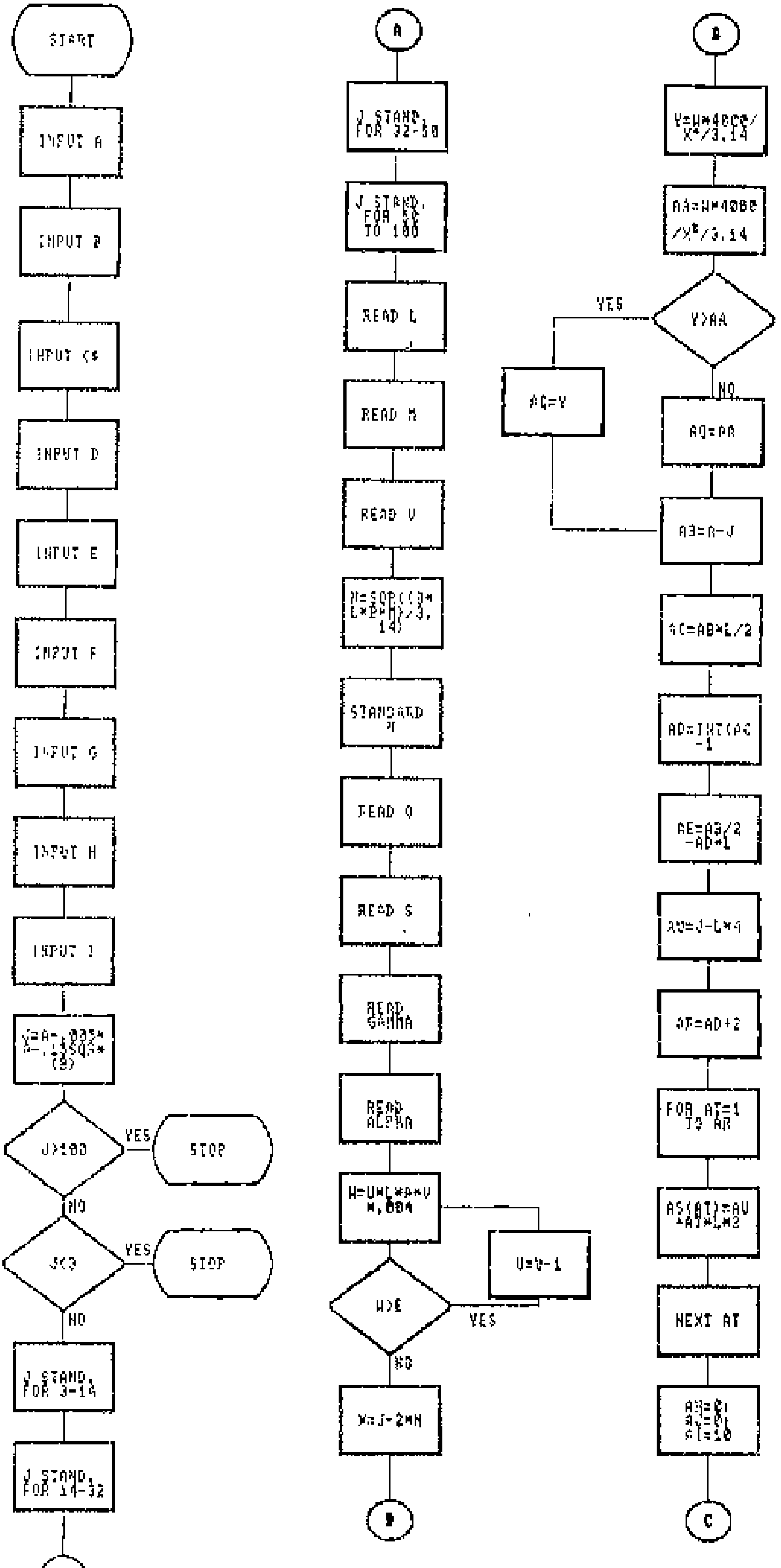
The first line of the program gives the name of the program. When the program is called then through a batch file the program will be loaded and run automatically. Next CLEAR command is given to set numeric variables to zero and all string variable to null. KEY OFF erases the soft key display from the 25th line, making that the line available for program use. It does not disable the function key. CLS to clear the screen.

After this two line will be print on the screen showing the restriction of the program. This two lines are THIS PROGRAM HAS BEEN DEVELOPED FOR DESIGN ROUND BROACH ONLY. The information PRESS ENTER TO CONTINUE is given to clear the screen and to take the next command. The program will give a BEEP in every cases to take DATA.

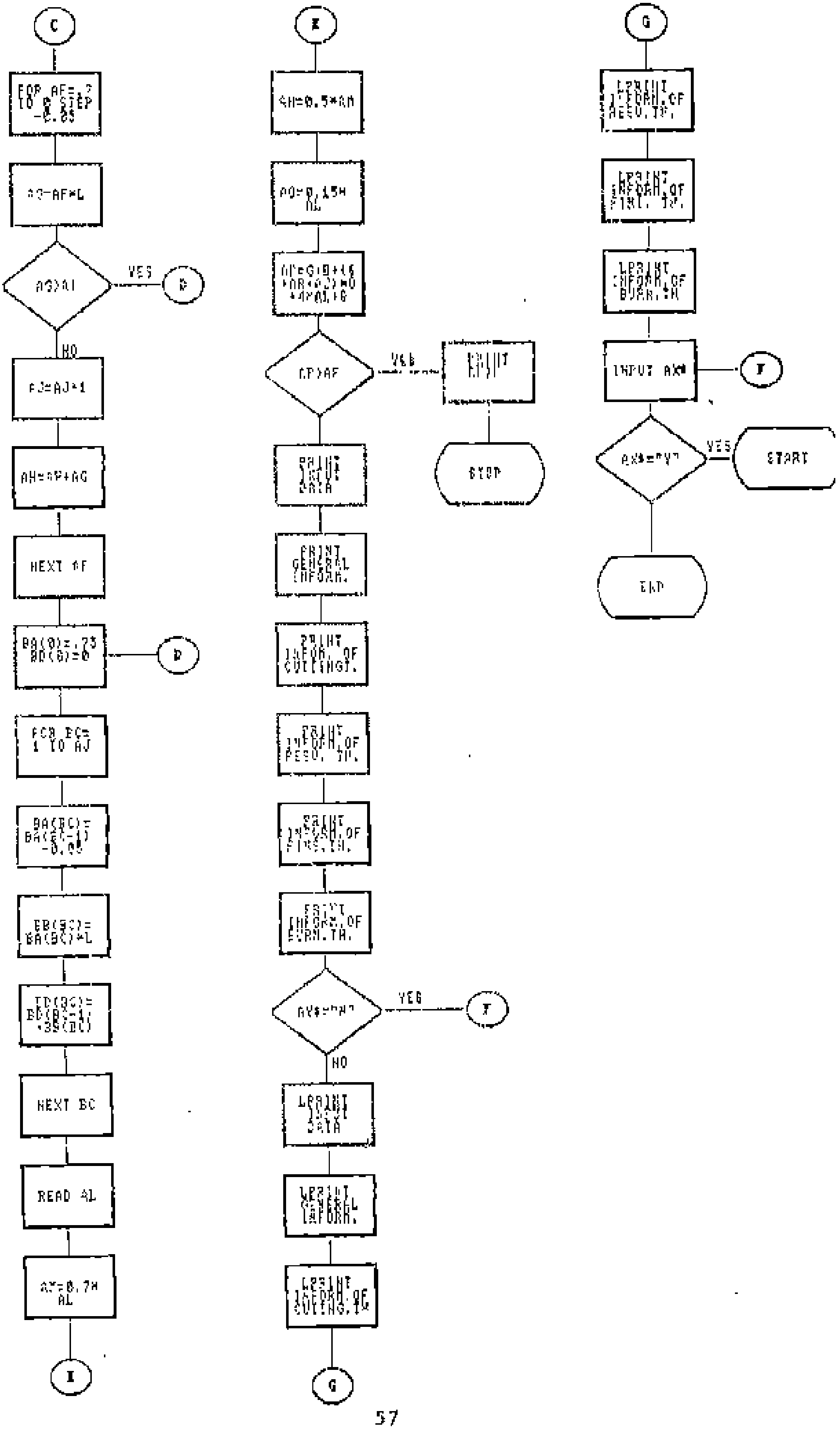
The input system of the program will then open. The program will ask all the input data required for broach design. First "MATERIAL TO BE BROACHED" is to be input. During this it is necessary to follow the material specification given in the program. If material input is mis-match with the above stated symbol then the program will give long BEEP and again ask the MATERIAL TO BE BROACHED. The line 220 is to check whether the input character is in match with the character or not. The program then ask HARDNESS OF THE MATERIAL to be broached. This should be in BHN. The next input is CAPACITY OF THE MACHINE. This should be in TON. STROKE LENGTH OF THE MACHINE, CLAMPING LENGTH OF THE TOOL, DIAMETER OF THE CLAMPING PORTION AND DIAMETER OF THE HOLD TO BE BROACHED should be in mm. The program then also check whether the diameter of the hole to be broached is less then the diameter of the clamping portion of the tool or not. If the diameter of the clamping portion of tool is less than the diameter of the hole to be broached then this broach can not be used.

Now the program requires TOLERANCE for its input. In most of the broaching the tolerance is either H6,H7 or H8. Here the program will also check whether the input is H6,H7, or H8. The last input is the LENGTH OF THE REAR END in mm.

The program will not start unless the diameter of the job to be drilled has been calculated. The formula is given in line



START
INPUT A
INPUT B
INPUT C$
INPUT D
INPUT E
INPUT F
INPUT G
INPUT H
INPUT I
J>100
YES
STOP
NO
J<3
YES
STOP
NO
J STAND. FOR 3-14
J STAND. FOR 14-32
A
A
J STAND. FOR 32-50
J STAND. FOR 50 TO 100
READ L
READ M
READ V
STANDARD
READ Q
READ S
READ GAMMA
READ ALPHA
V=V-1
YES
NO
B
B
Y>AA
YES
NO
AQ=Y
AQ=AA
AB=A-J
AC=AB*L/2
AE=AB/2 -AD*1
FOR AT=1 TO AR
NEXT AT
C


C
YES
D
NO
AJ=AJ+1
NEXT AF
D
BA(BC)*L
NEXT BC
READ AL
AL
E
AH=0.5*AH
AL
YES
STOP
YES
NO
LPRINT
DATA
LPRINT
LPRINT
G
G
LPRINT
INFORM.OF
LPRINT
INFORM.OF
LPRINT
INFORM.OF
F
YES
START
END

```
10 COLOR 7,9,11
20 '***NAME OF THIS PROGRAM IS BROACH***
30 CLEAR
40 KEY OFF
50 CLS
60 PRINT "THIS PROGRAM HAS BEEN DEVELOPED FOR"
70 PRINT "THE DESIGN OF ROUND BROACH ONLY"
80 PRINT
90 PRINT "PRESS ENTER TO CONTINUE";:INPUT AY$:BEEP
100 CLS
110 '***INPUT DATA***
120 PRINT "LENGTH OF THE JOB(mm)";:INPUT B:BEEP
130 CLS
140 PRINT "PLEASE FOLLOW THE FOLLOWING NOTATION"
150 PRINT
160 PRINT
170 PRINT "CI for Cast Iron"
180 PRINT "CS for Cast Steel"
190 PRINT "AS for Alloy Steel"
200 PRINT "BR for Bronge and Brass"
210 PRINT "AL for Aluminium"
220 PRINT "MATERIAL TO BE BROACHED";: INPUT C$:BEEP
230 IF C$="CS" OR C$="CI" OR C$="AS" OR C$="BR" OR C$="AL" THEN GOTO 250
240 BEEP:BEEP:BEEP:GOTO 140
250 CLS
260 PRINT "HARDNESS OF THE MATERIAL(BHN)";: INPUT D:BEEP
270 CLS
280 PRINT "CAPACITY OF THE MACHINE(Ton)";: INPUT E:BEEP
290 CLS
300 PRINT "STROKE LENGTH OF THE MACHINE(mm)";: INPUT F.BEEP
310 CLS
320 PRINT "CLAMPING LENGTH OF THE TOOL(mm)";: INPUT G:BEEP
330 CLS
340 PRINT "DIAMETER OF THE CLAMPING PORTION(mm)";: INPUT H:BEEP
350 CLS
360 PRINT "DIAMETER OF HOLE TO BE BROACHED(mm)";: INPUT A:BEEP
370 CLS
380 IF A<H THEN :BEEP:BEEP:BEEP: PRINT "DIAMETER OF THE CLAMPING PORTION IS BIGE
 R" : GOTO 370
390 PRINT "TOLARENCE (H6/H7/H8)";: INPUT DA$:BEEP
400 CLS
410 IF DA$="H6" OR DA$="H7" OR DA$="H8" THEN GOTO 430
420 GOTO 390
430 PRINT "LENGTH OF THE REAR END(mm)";: INPUT I:BEEP
440 '***CALCULATION FOR DIAMETER TO BE DRILLED***
450 J=A-.005*A-.15*SQR(B)
460 IF J>100 THEN GOTO 4190
470 IF J<3 THEN GOTO 4200
480 '***TABLE FOR STANDRED DRILL(DIA 3-14)***
490 DIM K(45)
500 FOR Z=1 TO 45
```

```
510 READ K(Z)
520 IF K(Z)>J THEN J=K(Z-1):GOTO 680
530 NEXT Z
540 DATA 3,3.2,3.5,3.8,4,4.2,4.5,4.8,5,5.2,5.5,5.8,6,6.2,6.5,6.8,7,7.2,7.5,7.8,8
,8.2,8.5,8.8,9,9.2,9.5,9.8,10,10.2,10.5,10.8,11,11.2,11.5,11.8,12,12.2,12.5,12.8
,13,13.2,13.5,13.8,14
550 '***TABLE FOR STANDRED DRILL(DIA 14-32)***
560 FOR K= 14 TO 32 STEP .25
570 IF K>J THEN J=K.25 : GOTO 680
580 NEXT K
590 '***TABLE FOR STANDRED DRILL(DIA 32-51)***
600 FOR K=32 TO 51 STEP .5
610 IF K>J THEN J=K-.5 . GOTO 680
620 NEXT K
630 '***TABLE FOR STANDRED DRILL(DIA 51-100)***
640 FOR K=51 TO 100 STEP 1
650 IF K>J THEN J=K-1 : GOTO 680
660 NEXT K
670 '***READ VALUE OF CHIP THICKNESS L***
680 IF C$="CS"AND D<=200 THEN L=.025
690 IF C$="CS" AND 220<D AND D<230 THEN L=.035
700 IF C$="CS" AND D>=230 THEN L+.025
710 IF C$="AS" AND D<=200 THEN L=.025
720 IF C$="AS" AND 200<D AND D<230 THEN L*.003
730 IF C$="AS" AND D>=230 THEN L.025
740 IF C$="CI" AND D<=200 THEN L=.06
750 IF C$="CI" AND D>200 THEN L=.045
760 IF C$="BR" THEN L=.075
770 IF C$="AL" THEN L=.035
780 '***READ CHIP VOLUME FACTOR M AND SPECIFIC CUTTING RESISTANCE V***
790 IF C$="CS" AND L=.025 THEN M=3.08:V=430
800 IF C$="CS" AND L=.035 THEN M=2.815:V=305
810 IF C$="AS" AND L=.025 THEN M=3.25:V=600
820 IF C$="AS" AND L=.03 THEN M=3.925:V=800
830 IF C$="CI" AND L=.06 THEN M=2.3:V=200
840 IF C$="CI" AND L=.045 THEN M=2.55;V=205
850 IF C$='BR" THEN M=2.18:V=190
860 IF C$="AL" THEN M=1.98.V=220
870 '***CALCULATE AVERAGE HEIGHT OF GULLET N***
880 N=SQR((4*L*B*M*2)/3.14)
890 '***READ THE VALUE OF STANDRED AVERAGE HEIGHT OF GULLET N AND PITCH O***
900 IF N<=1.1 THEN N=1.1:O=3 : GOTO 1110
910 IF 1.1<N AND N<=1.3 THEN N=1.3:O=3.5:GOTO 1110
920 IF 1.3<N=1.45 THEN N=1.45:O=4:GOTO 1110
930 IF 1.45<N AND N<=1.6 THEN N=1.6:O=4.5:GOTO 1110
940 IF 1.6<N AND N<=1.8 THEN N=1.8:O=5 : GOTO 1110
950 IF 1.8<N AND N<=2.2 THEN N=2.2:O=6 : GOTO 1110
960 IF 2.2<N AND N<=2.5 THEN N=2.5:O=7 : GOTO 1110
970 IF 2.5<N AND N<=2.9 THEN N=2.9:O=8 : GOTO 1110
980 IF 2.9<N AND N<=3.3 THEN N=3.3:O=9 : GOTO 1110
990 IF 3.3<N AND N<=3.6 THEN N=3.6:O=20 , GOTO 1110
1000 IF 3.6<N AND N<=4! THEN N=4!:O=11 : GOTO 1110
```

```
1010 IF 4!<N AND N<=4.3 THEN N=4.3:O=12 : GOTO 1110
1020 IF 4.3<N AND N<=5.1 THEN N=5.1:O=14 : GOTO 1110
1030 IF 5.1<N AND N<=5.8 THEN N=5.8:O=16 : GOTO 1110
1040 IF 5.8<N AND N<=6.5 THEN N=6.5:O=18 : GOTO 1110
1050 IF 6.5<N AND N<=7.2 THEN N=7.2:O=20 : GOTO 1110
1060 IF 7.2<N AND N<=8! THEN N=8!:O=22 : GOTO 1110
1070 IF 8!<N AND N<=9! THEN N=9!:O=25 : GOTO 1110
1080 IF 9!<N AND N<=10! THEN N=10!:O=28 : GOTO 1110
1090 IF 10!<N AND N<=11.5 THEN N=11.5:O=32 : GOTO 1110
1100 '***CALCULATE DIFFERENT PARAMETER OF THE TEETH***
1110 P=.7*O
1120 Q=.5*O
1130 R=.3*O
1140 '***READ THE VALUE OF NO. OF CHIP BREAKERS S***
1150 IF A<10 THEN S=0 : GOTO 1360
1160 IF A>=10 AND A<13 THEN S=6:GOTO 1360
1170 IF A>=13 AND A<16 THEN S=8:GOTO 1360
1180 IF A>=16 AND A<20 THEN S=10:GOTO 1360
1190 IF A>=20 AND A<25 THEN S=12:GOTO 1360
1200 IF A>=25 AND A<30 THEN S=14:GOTO 1360
1210 IF A>=30 AND A<35 THEN S=16:GOTO 1360
1220 IF A>=35 AND A<40 THEN S=18:GOTO 1360
1230 IF A>=40 AND A<45 THEN S=20:GOTO 1360
1240 IF A>=45 AND A<50 THEN S=22:GOTO 1360
1250 IF A>=50 AND A<55 THEN S=24:GOTO 1360
1260 IF A>=55 AND A<60 THEN S=26:GOTO 1360
1270 IF A>=60 AND A<65 THEN S=28:GOTO 1360
1280 IF A>=65 AND A<65 THEN S=28:GOTO 1360
1290 IF A>=65 AND A<70 THEN S=30:GOTO 1360
1300 IF A>=70 AND A<75 THEN S=32:GOTO 1360
1310 IF A>=75 AND A<80 THEN S=34:GOTO 1360
1320 IF A>=80 AND A<85 THEN S=36:GOTO 1360
1330 IF A>=85 AND A<90 THEN S=38:GOTO 1360
1340 IF A>=90 AND A<100 THEN S=40:GOTO 1360
1350 '***READ THE VALUE OF GAMMA T***
1360 IF C$="CS" AND D<=200 THEN T=10
1370 IF C$="AS" AND D<=200 THEN T=16
1380 IF C$="CS" AND 200<D AND D<=230 THEN T=13
1390 IF C$="AS" AND 200<D AND D<=230 THEN T=14
1400 IF C$="CS" AND D>=200 THEN T=13
1410 IF C$="AS" AND D>=200 THEN T=10
1420 IF C$="CI" AND D<150 THEN T=7
1430 IF C$="CI" AND D>150 THEN T=4
1440 IF C$="BR" THEN T=4
1450 IF C$="AL" THEN T=12
1460 '***CALCULATE NO. OF TEETH IN CONTACT***
1470 U=B/O+1
1480 '***CALCULATE THE CUTTING LOAD***
1490 N=U*A*V*[illegible]/1000
1500 '***CALCULATE WHEATHER THE CUTTING LOAD IS GREATER THEN M/S CAPACITY OR NOT
 ***
```

```
1510 IF W>E THEN U=U-1: GOTO 1490
1520 IF W=O THEN GOTO 4210
1530 '***FIND OUT WHERE THE STRESS IS HIGHER***
1540 X=J-2*N
1550 Y=W*4/3.14/(X)^2*1000
1560 AA=W*4/3.14/(H)^2*1000
1570 IF Y>AA THEN AQ=Y:GOTO 1590
1580 AQ=AA
1590 '***CALCULATE TOLARENCE********
1600 IF A>=3 AND A<6 THEN DB=SQR(3*6)
1610 IF A>=6 AND A<10 THEN DB=SQR(6*10)
1620 IF A>=10 AND A<18 THEN DB=SQR(10*18)
1630 IF A>=18 AND A<30 THEN DB=SQR(30*18)
1640 IF A>=30 AND A<50 THEN DB=SQR (30*50)
1650 IF A>=50 AND A<80 THEN DB=SQR(80*50)
1660 IF A>=80 AND A<100 THEN DB=SQR(80*100)
1670 DC=.45*(DB)^(1/3)+.001*DB
1680 IF DA$="H6" THEN DD=10*DC
1690 IF DA$="H8" THEN DD=25*DC
1700 DE=DD/1000+A
1710 '***CALCULATE NO. AND DIMENSION OF CUTTING TEETH***
1720 AB=DE-J
1730 AC=(AB)/(2*L)
1740 AD=INT(AC)-1
1750 AE=(AB/2-AD*L)
1760 AU=J-L*4
1770 AR=AD+2
1780 DIM AS (AR)
1790 FOR AT=1 TO AR
1800 AS(AT)=AU+AT*L*2
1810 NEXT AT
1820 '***CALCULATE NO. OF FINISHING TEETH**
1830 AH=0:AJ=0:AI=10
1840 FOR AF=.7 TO 0 STEP-.05
1850 AG=AF*L
1860 IF AG>AI THEN GOTO 1920
1870 AJ=AJ+1
1880 AH=AH+AG
1890 AI=AE-AH
1900 NEXT AF
1910 '***READ THE VALUE OF ALL BURNISHING TEETH***
1920 DIM BA(AJ),BB(AJ),DB(AJ)
1930 BA(0)=.75:BD(0)=0
1940 FOR BC=1 TO AJ
1950 BA(BC)=BA(BC-1)-.05
1960 BB(BC)= BA(BC)*I
1970 BD(BC)=BD(BC-1)+BB(BC)
1980 NEXT BC
1990 '***CALCULATE DIFFERENT PARAMETER OF BURNISHING TEETH***
2000 IF B>13 THEN AL=5: GOTO 2060
```

```
2010 IF 13<=B AND B<22 THEN AL=6: GOTO 2060
2020 IF 22<=B AND B<36 THEN AL=8: GOTO 2060
2030 IF 36<=B AND B<52 THEN AL=10: GOTO 2060
2040 IF 52<=B AND B<76 THEN AL=12: GOTO 2060
2050 IF 76<=B AND B<100 THEN AL=15: GOTO 2060
2060 AM=.7*AL
2070 AN=.5*AM
2080 AO=.15*AL
2090 '***CALCULATE TOTAL LENGTH OF BROACH***
2100 AP=G+B+I+(AR+AJ+6)*O+4*AL+8
2110 IF AP>F THEN GOTO 4220
2120 CLS
2130 PRINT "*************INPUT DATA**************"
2140 PRINT
2150 PRINT "DIAMETER OF HOLE TO BE BROACHED(mm)";A
2160 PRINT
2170 PRINT  "LENGTH OF THE JOB(mm)";B
2180 PRINT
2190 PRINT  "MATERIAL TO BE BROACHED  ";C$
2200 PRINT
2210 PRINT  "TOLARENCE  ";DA$
2220 PRINT
2230 PRINT  "HARDNESS OF THE MATERIAL (BHN)";D
2240 PRINT
2250 PRINT  "CAPACITY OF THE MACHINE (Ton)";E
2260 PRINT
2270 PRINT  "STROKE LENGTH OF THE MACHINE(mm)";F
2280 PRINT
2290 PRINT "CLAMPING LENGTH OF THE TOOL(mm)";G
2300 PRINT
2310 PRINT "DIAMETER OF THE CLAMPING PROTION(mm)";H
2320 PRINT
2330 PRINT "LENGTH OF THE REAR END(mm)";I
2340 PRINT
2350 PRINT "PRESS ENTER TO CONTINUE",:INPUT AV$ : BEEP
2360 CLS
2370 PRINT "********** GENERAL INFORMATION **********"
2380 PRINT
2390 PRINT "THE YIELD STRESS OF THE TOOL MATERIAL MUST BE>";AQ;"kg/Sq-mm"
2400 PRINT
2410 PRINT "THE TOTAL LENGTH OF THE BROACH=";AP;"mm"
2420 PRINT
2430 PRINT "DIAMETER TO BE DRILLED BEFORE BROACHING=";J;"mm"
2440 PRINT
2450 PRINT "PRESS ENTER TO CONTINUE";:INPUT AV$: BEEP
2460 CLS
2470 PRINT "**********INFORMATIOIN FOR THE CUTTING TEETH**********"
2480 PRINT
2490 PRINT "NO. OF CUTTING TEETH=";AH
2500 PRINT "PITCH 'O'(mm)        =" USING "##.##";O
```

```
2510 PRINT "R(mm)                    =" USING "##.##";R
2520 PRINT "P(mm)                    =" USING "##.##";P
2530 PRINT "Q(mm)                    =" USING "##.##";Q
2540 FOR AT=1 TO AR
2550 PRINT "DIAMETER OF";AT;"NO. CUTTING TEETH (mm)="USING "##.##";AS(AT)
2560 NEXT AT
2570 PRINT
2580 PRINT "LENGTH OF ALL CUTTING TEETH (mm)=";AR*O
2590 PRINT
2600 PRINT "NO. OF CHIP BREAKERS=";S
2610 PRINT
2620 PRINT "DETAILS OF CHIP BREAKER:"
2630 PRINT
2640 PRINT "CHIP BREAKERS ARE NORMALLY MADE AROUND 1.5 mm"
2650 PRINT "DEEP AND 0.5-2.0 mm WIDE"
2660 PRINT
2670 PRINT "GAMMA=";T;"deg"
2680 PRINT
2690 PRINT "ALPHA = 3 deg"
2700 PRINT
2710 PRINT "PRESS ENTER TO CONTINUE";:INPUT AV$:BEEP
2720 CLS
2730 PRINT "**********INFORMATION OF FINISHING TEETH**********"
2740 PRINT
2750 PRINT "NO. OF FINISHING TEETH=";(AJ+1)
2760 PRINT "PITCH 'O'(mm)   =" USING "##.##";O
2770 PRINT "R(mm)           =" USING "##.##";R
2780 PRINT "P(mm)           =" USING "##.##";P
2790 PRINT "Q(mm)           =" USING "##.##";Q
2800 FOR AW=1 TO AJ
2810 PRINT "DIAMETER OF";AW;"NO. FINISHING TEETH (mm)  =" USING "##.##";AS(AR)+2
*BD(AW)
2820 NEXT AW
2830 PRINT "DIAMETER OF";(AJ+1);"NO. FINISHING TEETH(mm)="USING"##.##";DE
2840 PRINT "LENGTH OF ALL FINISHING TEETH (mm) ="USING "##.##";(AJ+1)*O
2850 PRINT "GAMMA               =";T;"deg"
2860 PRINT "ALPHA               =1/2 deg"
2870 PRINT "PRESS ENTER TO CONTINUE";:INPUT AV$:BEEP
2880 CLS
2890 PRINT "********** INFORMATION FOR RESERVE TEETH **********"
2900 PRINT
2910 PRINT "NO. OF RESERVE TEETH                = 5"
2920 PRINT "PITCH 'O'(mm)                       =" USING "##.##";O
2930 PRINT "R(mm)                               =" USING "##.##";R
2940 PRINT "P(mm)                               =" USING "##.##";P
2950 PRINT "Q(mm)                               =" USING "##.##";Q
2960 PRINT "DIAMETER OF ALL RESERVE TEETH (mm)="USING "##.##";DE
2970 PRINT "LENGTH OF ALL RESERVE TEETH (mm)  ="USING "##.##";5*O
2980 PRINT "GAMMA                                =";T;"deg"
2990 PRINT "ALPHA                                =3 deg"
3000 PRINT
```

```
3010 PRINT "PRESS ENTER TO CONTINUE";:INPUT AV$:BEEP
3020 CLS
3030 PRINT "********** INFORMATION BURNISHING TEETH **********"
3040 PRINT
3050 PRINT "NO. OF BURNISHING TEETH              = 4"
3060 PRINT "PITCH 'AL'(mm)                        =" USING "##.##";AT
3070 PRINT "AM(mm)                               =" USING "##.##";AM
3080 PRINT "AN(mm)                               =" USING "##.##";AN
3090 PRINT "AO(mm)                               =" USING "##.##";AO
3100 PRINT "f(mm)                                =0.8"
3110 PRINT
3120 PRINT "DIAMETER OF ALL BURNISHING TEETH (mm)=" USING "##.##";DE
3130 PRINT "LENGTH OF ALL BURNISHING TEETH(mm)="USING "##.##":4*AL
3140 PRINT
3150 PRINT "PRESS ENTER TO CONTINUE";:INPUT AV$:BEEP
3160 CLS
3170 PRINT "DO YOU WANT TO PRINT THE RESULT ON PRINTER(Y/N)";:INPUT AY$:BEEP
3180 IF AY$="Y" OR AY$="y" OR AY$="N" OR AY$="n" THEN GOTO 3200
3190 BEEP:BEEP:BEEP: GOTO 3170
3200 IF AY$="n" OR AY$="N" THEN GOTO 4130
3210 LPRINT "***************INPUT DATA***************"
3220 LPRINT
3230 LPRINT "DIAMETER OF HOLE TO BE BROACHED(mm)";A
3240 LPRINT
3250 LPRINT  "TOLARENCE  ";DA$
3260 LPRINT
3270 LPRINT  "LENGTH OF THE JOB(mm)";B
3280 LPRINT
3290 LPRINT  "MATERIAL TO BE BROACHED  ";C$
3300 LPRINT
3310 LPRINT  "HARDNESS OF THE MATERIAL (BHN)";D
3320 LPRINT
3330 LPRINT  "CAPACITY OF THE MACHINE (Ton)";E
3340 LPRINT
3350 LPRINT  "STROKE LENGTH OF THE MACHINE(mm)";F
3360 LPRINT
3370 LPRINT "CLAMPING LENGTH OF THE TOOL(mm)";G
3380 LPRINT
3390 LPRINT "DIAMETER OF THE CLAMPING PROTION(mm)";H
3400 LPRINT
3410 LPRINT "LENGTH OF THE REAR END(mm)";I
3420 LPRINT
3430 LPRINT "********** GENERAL INFORMATION **********"
3440 LPRINT
3450 LPRINT "THE YIELD STRESS OF THE TOOL MATERIAL MUST BE>";AQ;"kg/Sq-mm"
3460 LPRINT
3470 LPRINT "THE TOTAL LENGTH OF THE BROACH=";AP;"mm"
3480 LPRINT
3490 LPRINT "DIAMETER TO BE DRILLED BEFORE BROACHING=";J;"mm"
3500 LPRINT
```

```
3510 LPRINT "**********INFORMATIOIN FOR THE CUTTING TEETH**********"
3520 LPRINT
3530 LPRINT "NO. OF CUTTING TEETH=";AH
3540 LPRINT "PITCH 'O'(mm)          =" USING "##.##";O
3550 LPRINT "R(mm)                  =" USING "##.##";R
3560 LPRINT "P(mm)                  =" USING "##.##";P
3570 LPRINT "Q(mm)                  =" USING "##.##";Q
3580 FOR AT=1 TO AH
3590 LPRINT "DIAMETER OF";AT;"NO. CUTTING TEETH (mm)="USING "##.##";AS(AT)
3600 NEXT AT
3610 LPRINT "LENGTH OF ALL CUTTING TEETH (mm)=";AH*O
3620 LPRINT "NO. OF CHIP BREAKERS=";B
3630 LPRINT "DETAILS OF CHIP BREAKER:"
3640 LPRINT "CHIP BREAKERS ARE NORMALLY MADE AROUND 1.5 mm"
3650 LPRINT "DEEP AND 0.5-2.0 mm WIDE"
3660 LPRINT "GAMMA=";T;"deg"
3670 LPRINT "ALPHA = 3 deg"
3680 LPRINT
3690 LPRINT
3700 LPRINT
3710 LPRINT
3720 LPRINT
3730 LPRINT "**********INFORMATION OF FINISHING TEETH**********"
3740 LPRINT
3750 LPRINT "NO. OF FINISHING TEETH=";(AJ+1)
3760 LPRINT "LENGTH OF ALL FINISHING TEETH (mm) ="USING "##.##";(AJ+1)*O
3770 LPRINT "GAMMA               =";T;"deg"
3780 LPRINT "ALPHA               =1/2 deg"
3790 LPRINT
3800 LPRINT "PITCH 'O'(mm)    =" USING "##.##";O
3810 LPRINT "R(mm)            =" USING "##.##";R
3820 LPRINT "P(mm)            =" USING "##.##";P
3830 LPRINT "Q(mm)            =" USING "##.##";Q
3840 FOR AW=1 TO AJ
3850 LPRINT "DIAMETER OF";AW;"NO. FINISHING TEETH (mm)  =" USING "##.##";AS(AH)+
2*BD(AW)
3860 NEXT AW
3870 LPRINT "DIAMETER OF";(AJ+1);"NO. FINISHING TEETH(mm)="USING"##.##";DE
3880 LPRINT
3890 LPRINT "********** INFORMATION FOR RESERVE TEETH **********"
3900 LPRINT
3910 LPRINT "NO. OF RESERVE TEETH                  = 5"
3920 LPRINT "PITCH 'O'(mm)                         =" USING "##.##";O
3930 LPRINT "R(mm)                                 =" USING "##.##";R
3940 LPRINT "P(mm)                                 =" USING "##.##";P
3950 LPRINT "Q(mm)                                 =" USING "##.##";Q
3960 LPRINT "DIAMETER OF ALL RESERVE TEETH (mm)="USING "##.##";DE
3970 LPRINT "LENGTH OF ALL RESERVE TEETH (mm)  ="USING "##.##";5*O
3980 LPRINT "GAMMA                                 =";T;"deg"
3990 LPRINT "ALPHA                                 =3 deg"
4000 LPRINT
```

```
4010 LPRINT
4020 CLS
4030 LPRINT "********** INFORMATION BURNISHING TEETH **********"
4040 LPRINT
4050 LPRINT "NO. OF BURNISHING TEETH            = 4"
4060 LPRINT "PITCH 'AL'(mm)                      =" USING "##.##";AL
4070 LPRINT "AM(mm)                             =" USING "##.##";AM
4080 LPRINT "AN(mm)                             =" USING "##.##";AN
4090 LPRINT "AO(mm)                             =" USING "##.##";AO
4100 LPRINT "f(mm)                              =0.8"
4110 LPRINT "DIAMETER OF ALL BURNISHING TEETH (mm)=" USING "##.##";DE
4120 LPRINT "LENGTH OF ALL BURNISHING TEETH(mm)="USING "##.##";4*AL
4130 CLS
4140 PRINT "DO YOU WANT TO CALCULATE ANYMORE (Y/N)";: INPUT AX$:BEEP
4150 IF AX$="Y" OR AX$="y" OR AX$="N" OR AX$="n" THEN GOTO 4170
4160 BEEP:BEEP:BEEP: GOTO 4140
4170 IF AX$="Y" OR AX$="y"  THEN GOTO 50
4180 GOTO 4230
4190 PRINT "THE DIAMETER IS TOO BIG";:INPUT AX$: GOTO 4230
4200 PRINT "THE DIAMETER IS TOO SMALL";:INPUT AX$:GOTO 4230
4210 PRINT "THE CUTTING LOAD IS TOO HIGH";:INPUT AX$: GOTO 4230
4220 PRINT "THE LENGTH OF THE BROACH IS TOO BIG";:INPUT AX$: GOTO 4230
4230 CLS
4240 SYSTEM
4250 END
```

440. The program is developed for designing broaches with diameter in the range between 3 to 100 mm.

The calculated value of the drill size should change with the standard drill size. This has been done from line 470 to 650. In line 530 the standard size of the drills are given which are in between 3 to 14 mm. The standard drill size should be just less than the calculated value. For the diameter in between 14 to 32 mm the standard drill size increases by 0.25 mm. From 32 to 51 mm the standard drill sizes increases by 0.5 mm and for the range 51 to 100 mm the standard drill sizes increases by 1 mm.

From line 660 to 760 the table is given to select the value of chip thickness. It depends on the material and the diameter to be broached.

From line 770 to 850 the table is given to read the chip volume factor and specific cutting speed. All those depend on the material and chip thickness.

The average height of the gullet is next to be calculated from the formula in line 870. Now this value should be standardized and depending on this the value of pitch should be selected. The table of pitch selection is given from line 880 to 1080.

Depending on the value of pitch different parameters of the gullet is calculated in lines 1100 to 1120.
The number of chip breakers are to be read from the table given from line 1130 to 1320. This value depends on the diameter of the broach.
The table to get the value of rake angle is given from line 1330 to 1430. This value depends on the material to be broached and the hardness of the material.

The number of teeth in contact with job at a time is to be calculated from the formula given in line 1450.

The cutting load is calculated in line 1470. This cutting load should be less than load capacity of the machine. If not then number of teeth in contact is reduced by one. Again the cutting load is calculated. The process will repeat until the cutting load is less than machine load capacity. If the number of teeth is zero then the program will show CUTTING LOAD IS TO HIGH. Line 1490, 1500 and 4190 perform this function.

The tolerance is calculated by the lines 1570 to 1690. This depends on the diameter of the job and the fit required. The number and dimension of the cutting and finishing teeth is calculated from line 1700 to 1890. And that of burnishing teeth is from line 1900 to 2070.

Total length of the broach is calculated by the line 2090. If the length is greater than the length of the machine then the program will go to line 4200 and show THE LENGTH OF THE BROACH IS TOO BIG.

Lines 2120 to 2550 show all the input dimensions on the screen.

Lines 2360 to 2450 shows all the general information on the screen which include THE YIELD STRESS OF THE TOOL MATERIAL, THE TOTAL LENGTH OF THE BROACH and THE DIAMETER TO BE DRILLED BEFORE BROACHING.

From lines 2460 to 3160 gives all information about the cutting teeth, finishing teeth, burnishing teeth and reserve teeth are obtained.

The program then ask whether the result will be printed on the printer or not in line 3170. If Y or y is pressed in case of yes then all the calculated values will be printed on the printer.

3.3 The calculated parameters of the Broach.

To check the suitability and accuracy of the program a test sample of a broach was taken.

To calculate the parameters of the broach, data has been entered and the following results has been obtained:

Example:

Design a broach for a hole of diameter 48H8; Length of job= 72mm; material is Cast Iron; Strength of material 230 BHN; Capacity of the machine is 25 ton and the machine can accommodate a length of 1.8 M. The clamping length of the tool is 155 mm. The diameter of the clamping portion is 33 mm and the length of the rear end is 25mm.

*************INPUT DATA*************

DIAMETER OF HOLE TO BE BROACHED(mm) 18

TOLARENCE H6

LENGTH OF THE JOB(mm) 72

MATERIAL TO BE BROACHED CI

HARDNESS OF THE MATERIAL (BHN) 240

CAPACITY OF THE MACHINE (Ton) 20

STROKE LENGTH OF THE MACHINE(mm) 1000

CLAMPING LENGTH OF THE TOOL(mm) 100

DIAMETER OF THE CLAMPING PROFILE(mm) [illegible]

LENGTH OF THE REAR END(mm) 25

*********** GENERAL INFORMATION **********

THE YIELD STRESS OF THE TOOL MATERIAL MUST BE> 17.2528 Kg/Sq-mm

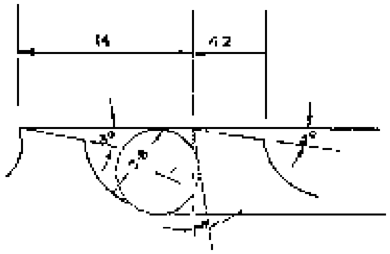
THE TOTAL LENGTH OF THE BROACH= [illegible]

DIAMETER TO BE DRILLED BEFORE BROACHING= 16 mm

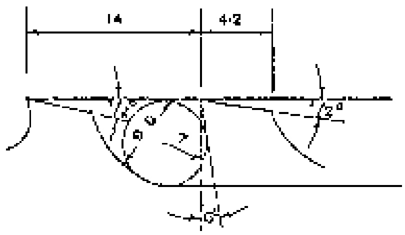
**********INFORMATION FOR THE CUTTING TEETH**********

NO. OF CUTTING TEETH= 23
PITCH 'C'(mm) =14.00
P(mm) = 4.20
P(mm) = 9.80
G(mm) = 7.00
DIAMETER OF 1 NO. CUTTING TEETH (mm)=16.01
DIAMETER OF 2 NO. CUTTING TEETH (mm)=16.09
DIAMETER OF 3 NO. CUTTING TEETH (mm)=16.09
DIAMETER OF 4 NO. CUTTING TEETH (mm)=16.18
DIAMETER OF 5 NO. CUTTING TEETH (mm)=16.27
DIAMETER OF 6 NO. CUTTING TEETH (mm)=16.36
DIAMETER OF 7 NO. CUTTING TEETH (mm)=16.45
DIAMETER OF 8 NO. CUTTING TEETH (mm)=16.54
DIAMETER OF 9 NO. CUTTING TEETH (mm)=16.63
DIAMETER OF 10 NO. CUTTING TEETH (mm)=16.72
DIAMETER OF 11 NO. CUTTING TEETH (mm)=16.81
DIAMETER OF 12 NO. CUTTING TEETH (mm)=16.90
DIAMETER OF 13 NO. CUTTING TEETH (mm)=16.99
DIAMETER OF 14 NO. CUTTING TEETH (mm)=17.08
DIAMETER OF 15 NO. CUTTING TEETH (mm)=17.17
DIAMETER OF 16 NO. CUTTING TEETH (mm)=17.26
DIAMETER OF 17 NO. CUTTING TEETH (mm)=17.35
DIAMETER OF 18 NO. CUTTING TEETH (mm)=17.44
DIAMETER OF 19 NO. CUTTING TEETH (mm)=17.53
DIAMETER OF 20 NO. CUTTING TEETH (mm)=17.62
DIAMETER OF 21 NO. CUTTING TEETH (mm)=17.71
DIAMETER OF 22 NO. CUTTING TEETH (mm)=17.80
DIAMETER OF 23 NO. CUTTING TEETH (mm)=17.89
LENGTH OF ALL CUTTING TEETH (mm)= 322
NO. OF CHIP BREAKERS= 22
DETAILS OF CHIP BREAKER
CHIP BREAKERS ARE NORMALLY MADE AROUND 1.5 mm
DEEP AND 0.5-2.0 mm WIDE
GAMMA= 6 deg

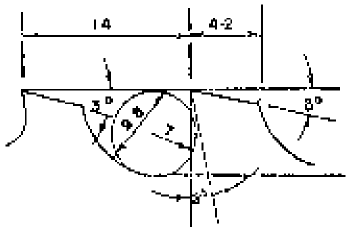
```
ALPHA = 3 deg



**********INFORMATION OF FINISHING TEETH**********

NO. OF FINISHING TEETH= 3
LENGTH OF ALL FINISHING TEETH (mm)  33.00
GAMMA              = 6 deg
ALPHA              =1.5 deg

PITCH 'O'(mm)     =11.00
R(mm)             = 1.20
P(mm)             = 0.80
Q(mm)             = 7.00
DIAMETER OF 1 NO. FINISHING TEETH (mm)  =17.95
DIAMETER OF 2 NO. FINISHING TEETH (mm)  =18.01
DIAMETER OF 3 NO. FINISHING TEETH(mm)=18.02

*********** INFORMATION FOR RESERVE TEETH **********

NO. OF RESERVE TEETH                    = 5
PITCH 'O'(mm)                           =11.00
R(mm)                                     1.20
P(mm)                                   = 0.80
Q(mm)                                   = 7.00
DIAMETER OF ALL RESERVE TEETH (mm)=18.02
LENGTH OF ALL RESERVE TEETH (mm)   =70.00
GAMMA                                    = 6 deg
ALPHA                                    =3 deg


********** INFORMATION BURNISHING TEETH **********

NO. OF BURNISHING TEETH                 = 1
PITCH 'AL'(mm)                           = 5.00
AH(mm)                                  = 1.50
AN(mm)                                  = 0.70
AO(mm)                                  = 0.25
F(mm)                                   =0.8
DIAMETER OF ALL BURNISHING TEETH (mm)=18.02
LENGTH OF ALL BURNISHING TEETH(mm)=20.00
```



Information of Cutting Teeth



Information of Finishing Teeth



Information of Resurve Teeth

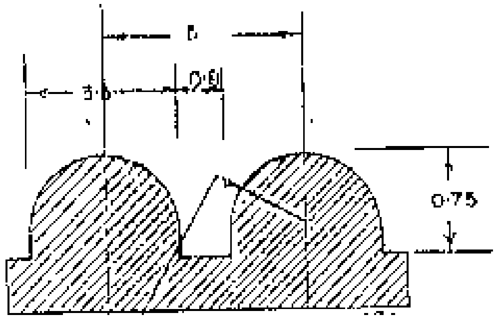


Figure 7. Details of a Designed Broach

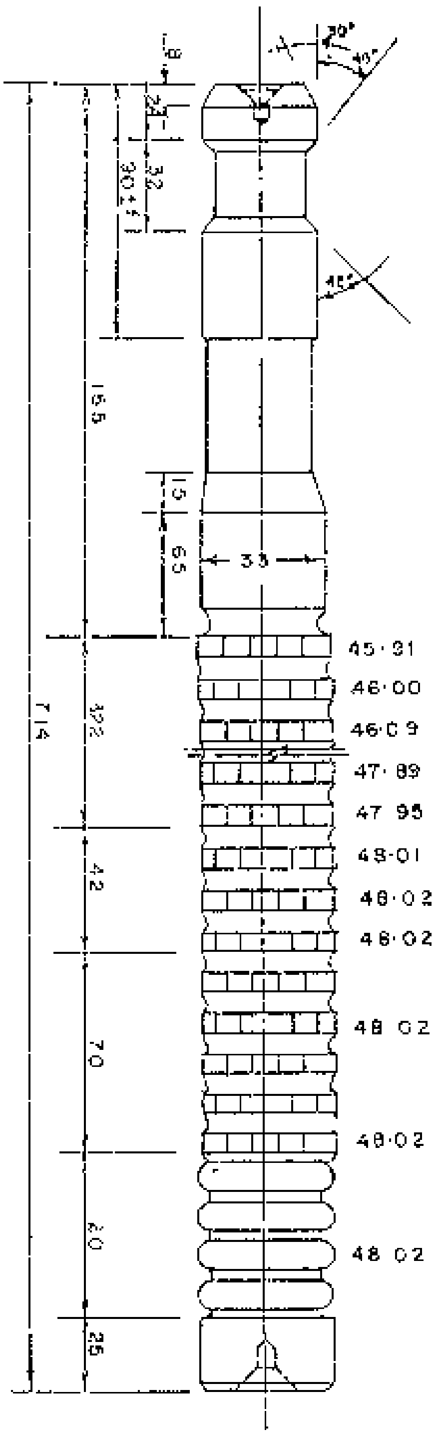


Figure 8. A Complete Broach

CHAPTER 4

CONCLUSION AND SCOPE FOR FUTURE WORK

4. CONCLUSIONS AND SCOPE FOR FUTURE WORK

4.1 CONCLUSIONS:

From the present study the following conclusion can be drawn:

A) A software for designing broaches has been developed for BMTF. Which made the job easier.

B) The design of broach will take 60% less time thus reduces cost of production by 32% (According to the study in BMTF).

4.2 SCOPE OF FUTURE WORK:

The broach design has a number of limitations. Depending on those limitations future work can be done. Those limitations are as follows:

a) Only round broaches can be design by this program

b) Broach diameter should be within 3 mm to 100 mm

c) Only three types of tolerance has been used depending on the type of fit. Those are H6, H7 and H8

d) Here the length of the broach has been considered less than the stroke length of the machine.

The future work can be done to eliminate the first limitation. To do this spline or any other type of broach can be considered.

Broach diameter range can be increased more then 100 mm. This can be done by adding few more tables of the diameter of the standard drill, table of pitch etc.

To increase the type of fit only the tolerance table should be added.

Now in this case if the length of the broach becomes more than the stroke length of the machine then the program will show a limitation. Practically this case may arrive when a number of broaches will be required to perform a single operation. This limitation can be eliminated by developing the program.

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