Nov. 16, 1965 J. A. PSENKA 3,217,383

BROACH

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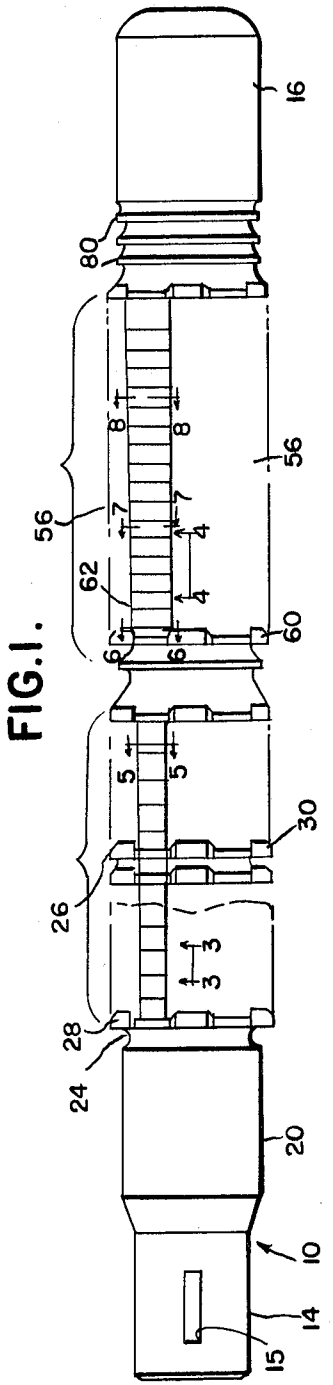

FIG. 1.

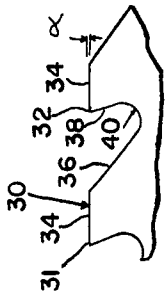

FIG. 3.

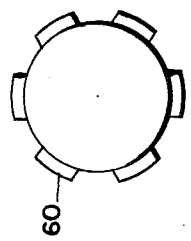

FIG. 2.

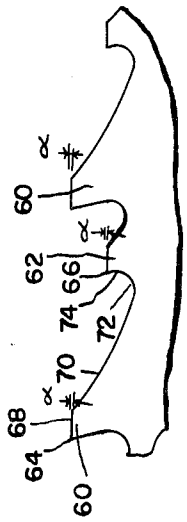

FIG. 4.

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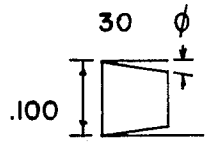


FIG. 5

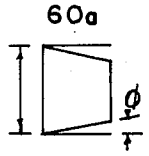


FIG. 6

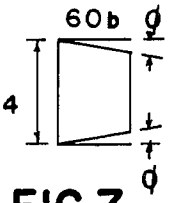


FIG. 7

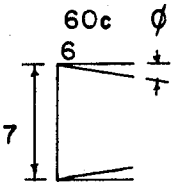


FIG. 8

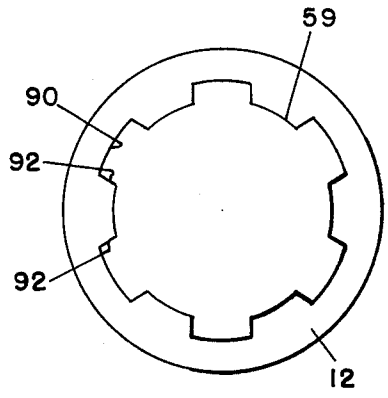
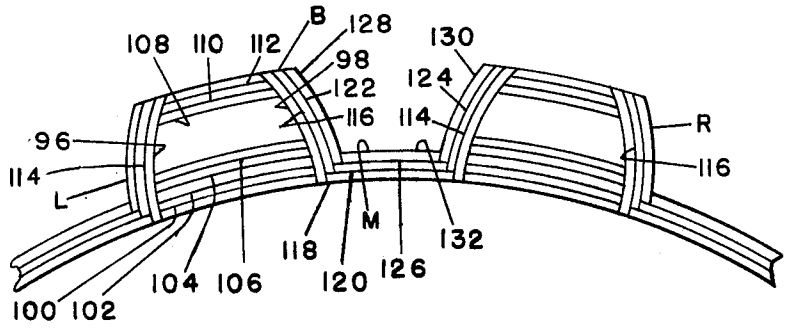


FIG. 9

FIG. 10



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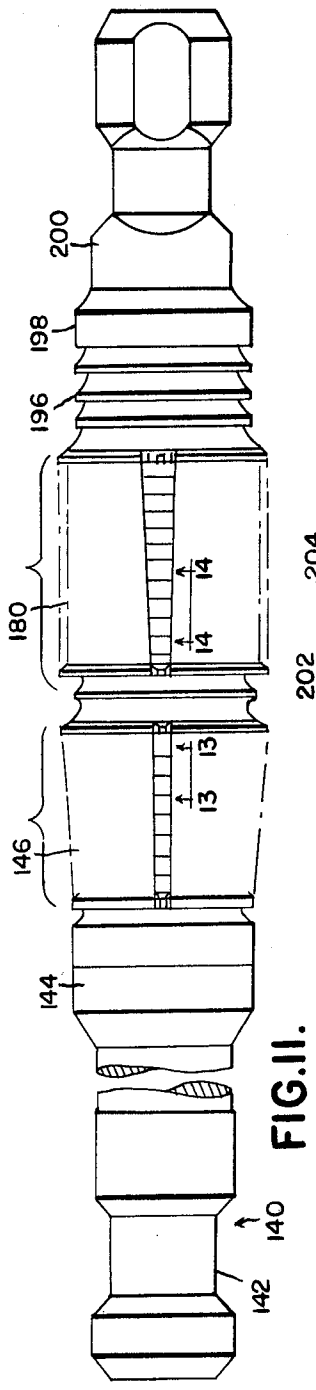

FIG. 11.

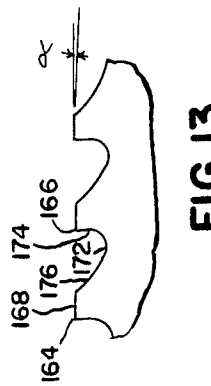

FIG. 13.

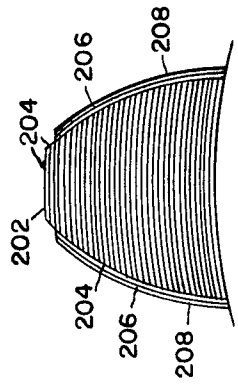

FIG. 15.

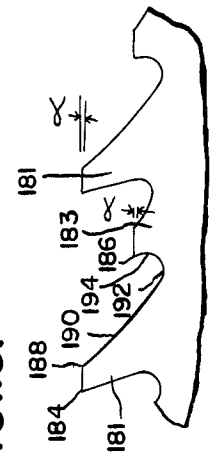

FIG. 14.

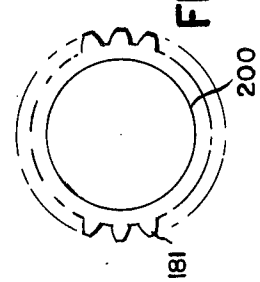

FIG. 12.

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3,217,383

BROACH

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Filed July 7, 1964, Ser. No. 381,616
19 Claims. (Cl. 29—95.1)

The present invention relates to a broach characterized particularly in the provision of a finishing section including alternated or interspersed round blades and spline teeth adapted to finish a work piece so as to provide substantially exact form and to maintain substantially exact concentricity between the tooth form of the work piece or its pitch diameter and the minor or inside diameter surfaces of the work piece.

The finishing section referred to may be provided as a separate broach but ordinarily it constitutes a final or trimming section of a broach, the leading portion of which may include a preliminary finishing section and a roughing section to form the teeth or splines out of round. Alternatively, of course, the final finishing section may be combined with a preliminary finishing section on a broach and adapted to follow a first broaching operation carried out with a roughing broach.

The final finishing section referred to may be an integral part of a unitary broach or it may be provided in the form of a shell which is removable and replaceable as indicated in my prior Patent 2,987,801, of which the present application is a continuation-in-part through intervening application Serial No. 89,424.

The importance of maintaining concentricity depends in large part on problems presented in manufacture or checking parts in production. Once a piece has been completed, it will normally be located on a mating part engaging its I.D., its pitch diameter or P.D., or its O.D., but not more than one of these. Consider for example the problems in making an involute spline gear for use on a spline shaft. If the spline hole in the part is first broached, the part may be mounted on an arbor locating on its I.D. for machining the gear teeth. In use, the part may locate on a spline shaft from its involute spline surfaces. Obviously, if the involute spline teeth on the part are not concentric with the I.D. surfaces, then the gear will exhibit eccentricity in operation.

The present invention relates generally to broaching internally toothed members, although certain aspects of the invention may be applied to the broaching of externally toothed members by broach assemblies referred to generally as pot type broaches. The parts which are broached by the broach disclosed in the present application may be internal gears adapted to operate as running gears, or they may be parts having internally spline openings for association with spline shafts or the like.

While it is possible to produce a broach with extreme accuracy, it has been found that the broach may fail to reproduce its accuracy in the finished work piece, due to certain negative factors which will subsequently be discussed and which are occasioned at a stage of the broaching operation preceding the final finishing stage.

The present invention relates to broaches adapted to produce straight splines or spur gears as well as angularly extending splines or helical gears, the cutting teeth of the broach being arranged in axial alignment for the production of straight splines or spur gears and in a helical configuration if the broach is for the purpose of producing helical splines or gears.

During the development of the broaching art, it has always been the ultimate goal of the industry to provide for concentricity of the inside or minor diameter, or the outside or major diameter of the broached part with the

pitch or form diameter regardless of whether the form of the broach be an involute spline, a straight sided spline, an angular spline, or a special form spline neither helical nor spur. Presently the industry is using a broach which is called a spline broach in which the finishing section includes a successive round and spline finishing section. Although it has always been the objective in the industry to obtain concentricity in the broached part between the minor diameter and form or the major diameter and form, and all three diameters, the ultimate object has not heretofore been attained. There are many reasons why the concentricity between the inside diameter and the other diameters of the broached part has been lacking.

The first reason is that the spline teeth in the roughing or spline generating broach section are relieved on each individual cut, leaving only about 1/64 to 3/64 inch of the profile at the crests of the teeth. This of course means that as the broach is moving through the work piece the guiding action between the work piece and the broach is contingent upon the small amount of form left at the crests of the teeth. This lack of guiding action results in a form in the work piece that may be deformed. If an involute form is desired, variations from the involute will be obtained due among other things to drift of the broach in the work piece. This drift may be due to lack of uniformity in sharpness of the cutting edges, misalignment of a broaching machine, failure to maintain the broach in satisfactory condition, or other reasons. In any case, the result of a deformed involute or other form is that when the alternate round and spline finishing section of the broach is in the work piece, location is actually taken on a deformed side surface or profile, and when the round teeth broach out the inside diameter of the piece, the resulting part or work piece lacks concentricity between the inside diameter and the other element of the spline including its pitch and major diameter.

The second reason for not obtaining the desired concentricity is that the spline broaches are normally ground with varying amounts of back taper. This means of course, that the spline form which is ground is wider at the front end of the broach than a corresponding diametral point at the rear of the broach. This makes for minimum contact between the work and the broach, which is very good as regards actual operating conditions, as the amount of drag between the broach and the work is minimized. However, it is a negative factor regarding control between the broach and the work and normally results in further distortion of the profile of the work piece than generated because of the relief factor heretofore explained.

Adding the first and second factors results in a part coming in contact with a normal design alternate round and spline broach in such a manner that a minimum of concentric relationship is established in the alternate round and spline section, because in the alternate round and spline section, the piloting or guiding area is at a minimum, due to the fact that there is clearance on practically the entire profile due to the back taper making the successive broach teeth narrower on their flanks than the width of the broached spline part.

Experience has shown that in very accurate broaching of internal gears a third reason or factor has to be considered and that is the condition of the cutting corners of the broach will greatly influence the form of the broach part. As the broach becomes worn and the cutting corners break down, off-center and possibly radial, drift is obtained which again results in form distortion and movement of the elements of the form off a common center line. Again, adding the aforesaid three factors together considerably decreases the possibility of ever maintaining the spline in a condition where the alternate round and spline section of the broach can maintain

concentricity between the inside diameter and the other elements of the form of the broached part.

A fourth reason is that machine misalignments adds another negative factor as regards form distortion and eccentricity of the splines within a desired center point. In many applications of spline broaching, follower supports are not used on the machines. This results in many cases in the machines being abnormally misaligned, further contributing to form distortion and an off-center drift condition.

A fifth reason is that improper face grinding techniques, such as not grinding the broach sufficiently, or allowing the broach to run out between centers when it is being ground, allowing one side of the broach to be sharp and the other side dull, will again accentuate any off-center drift condition and result in further form distortion.

The sixth reason is that damage done to the tool, either through careless handling or through broaching through hard spots or inclusions in the material, will again adversely affect the performance of the tool in the work piece as regards presenting a spline to the alternate round and spline section of the broach. Therefore, it can be seen that adding just a few of the aforesaid factors results in an undesirable condition as regards any possibility of maintaining very accurate concentricity of the inside diameter to the other elements of the tooth form of the broached work piece.

It is an object of the present invention to provide a broach which produces the desired concentricity in the broached part between the form and the minor or inside diameter, or in some cases between the form and the major or outside diameter.

It is a further object of the present invention to provide a broach which corrects eccentricity of the elements of the spline which may have been produced by the drifting normally encountered from the generating type of broach.

A further object of the present invention is to provide a broach which has a leading section having stepped longitudinally aligned series of cutting teeth and a following section having longitudinally aligned series of cutting teeth, with the cutting teeth on the leading section being substantially equal in width and the longitudinally aligned cutting teeth on the following section having a width which progressively increases longitudinally from the leading end of the following section toward the trailing end thereof, usually in equal increments.

It is a further object of the present invention to provide a broach of the type just described wherein each series of cutting teeth on the following section of the broach are of substantially constant diameter from the leading end to the trailing end thereof.

It is a still further object of the present invention to provide a broach consisting of a roughing section and a finishing section, said roughing section having stepped longitudinally aligned series of cutting teeth which are of equal width at any given radial measuring point, said finishing section having alternate interrupted and uninterrupted cutting blades, with the interrupted blades forming longitudinally aligned series of teeth, with the longitudinally aligned teeth increasing in width as measured at any given radial measuring point from the leading end to the following end of the finishing section.

It is a still further object of the present invention to provide a broach of the type just described wherein the uninterrupted or round cutting blades increase in diameter from the leading end to the following end of the finishing section.

Another object of the present invention is to provide a broach having a series of longitudinally aligned finish cutting teeth, said teeth having a radial height at least no greater than the radial height of the preceding broach teeth so as to eliminate top cutting, said teeth being of progressively increasing width, corresponding edges at both sides of said teeth being circumferentially stepped so as to cause each of said teeth to cut substantially entirely at the side thereof.

Another object of the present invention is to provide a broach having a series of longitudinally aligned finish cutting teeth, said teeth having a radial height at least no greater than the radial height of the preceding broach teeth so as to eliminate top cutting, said teeth being of progressively increasing width, corresponding edges at both sides of said teeth being circumferentially stepped and of full unrelieved form so as to cause each of said teeth to cut substantially entirely at the side thereof.

Another object of the present invention is to provide a broach having a series of longitudinally aligned finish cutting teeth, said teeth having a radial height at least no greater than the radial height of the preceding broach teeth so as to eliminate top cutting, said teeth being of progressively increasing width, corresponding edges at both sides of said teeth being circumferentially stepped and of full unrelieved form so as to cause each of said teeth to cut substantially entirely at the side thereof and to side cut substantially throughout the depth of spline in which it is cutting.

It is a further object of the present invention to provide a broach having a series of longitudinally aligned finish cutting teeth, said teeth being of less radial height than the height of the preceding cutting teeth so as to have top clearance with respect to the work piece, said teeth being of progressively increasing width, corresponding edges at both sides of said teeth being circumferentially stepped so as to cause each of said teeth to cut substantially entirely at the sides thereof.

It is a further object of the present invention to provide a broach as described in the preceding paragraph in which the side cutting edges of the stepped finishing teeth are unrelieved so as to provide full form cutting for substantially the entire depth of the slot, groove or other space being formed in the work piece.

It is a further object of the present invention to provide a simplified low-cost broach having certain advantages contributing to efficiency, reliability, and long life as well as ease of maintenance.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating preferred embodiments of the invention, wherein:

FIGURE 1 is a more or less diagrammatic view of a straight sided spline broach illustrating the arrangement of different operating sections thereof.

FIGURE 2 is a right hand end view of the broach.

FIGURE 3 is a partial side elevation on the leading end of the cutting teeth in the roughing section, taken substantially on the line **3—3**, FIGURE 1.

FIGURE 4 is a side elevation showing the alternate spline and round teeth in the finishing section, taken on the line **4—4**, FIGURE 1.

FIGURE 5 shows the width of a tooth of the roughing section taken on the line **5—5**, FIGURE 1.

FIGURE 6 shows the width of a tooth in the finishing section, taken on the line **6—6**, FIGURE 1.

FIGURE 7 shows the width of a tooth in the finishing section, taken on the line **7—7**, FIGURE 1.

FIGURE 8 shows the width of a tooth in the finishing section, taken on the line **8—8**, FIGURE 1.

FIGURE 9 is an end view of the resulting broach part.

FIGURE 10 is a diagrammatic view of a tooth space in a work piece showing the sequence of cuts taken by the teeth of the roughing and finishing sections of a gear tooth broach.

FIGURE 11 is another embodiment of the present invention showing a diagrammatic view of an involute spline broach illustrating the arrangement of different operating sections thereof.

FIGURE 12 is a right hand end view of the broach shown in FIGURE 11.

FIG. 13 is a partial elevational view of the teeth on

the roughing section, taken on the line 13—13 of FIGURE 11.

FIGURE 14 is a parital elevational view of the alternate spline and round teeth in the finishing section, taken on the line 14—14, FIGURE 11.

FIGURE 15 is a diagram showing the traces of side cutting finishing teeth.

Referring now to the drawings, there is illustrated diagrammatically at 10 in FIGURE 1 a straight sided spline broach designed to produce internal spline teeth on a work piece or gear 12, as shown in FIGURE 9, which is adapted to be received upon a spline shaft having a multiplicity of splines. For simplicity of illustration, it is assumed that the teeth of the work piece 12 are to be of straight parallel sided spline form, although the present invention is applicable to the formation of teeth of any desired shape. In fact, its greatest utility is in the field of involute splines of the type shown in FIGURE 15.

Broach 10 comprises a front head or pulling shank 14 at the leading end of the broach and a rear pilot 16 at the following end of the broach 10. The pulling shank 14 has a slot 15 therein adapted to receive a suitable key for locking it to a pulling head (not shown), for pulling the broach 10 through a hole in the work piece or gear 12. Rearwardly of the pulling shank 14 is located the cylindrical guide or pilot 20. The broach 10 is undercut at 24 between the rear end of the pilot 20 and the first group of spline teeth in the roughing section of the broach 10. The roughing section of the broach 10 is indicated generally at 26 in FIGURE 1. The roughing section 26 includes a series of progressively stepped blades 28, the blades 28 being interrupted to form separate cutting, straight sided spline teeth 30.

The teeth of the roughing section 26 are stepped rearwardly on diameter, depending on the particular application involved. The amount of rise per tooth between each succeeding series of spline teeth could vary depending upon the particular application.

The straight sided spline teeth 30 at the leading end of the roughing section 26, as is best illustrated in FIGURE 3, include cutting edges 31 and 32, the adjacent cutting edges being connected by land 34, tooth back 36, fillet 40 and tooth face 38.

As previously stated, the invention disclosed herein has overcome or at least minimized the distortion problem and has provided a broach which produces a part or work piece which has the inside diameter thereof concentric with all other tooth elements of the part. This is accomplished by designing the teeth of the broach in a predetermined manner such that all of the teeth of the roughing section have a standard tooth width at any radially fixed measuring point, so as to provide a selected tooth thickness at any measuring point, as for example .100 inch. This tooth thickness represents the tooth thickness in the generating and roughing portion 26 of the broach 10.

The finishing section 56 of the broach 10 includes a series of alternated spline teeth 60 and round cutting blades 62 which are adapted to trim the inner or minor diameter of the work piece 12 so as to shape the ends of the teeth or projections 59. The adjacent spline teeth and cutting blades 60 and 62 may have top cutting edges 64 and 66 respectively, as shown in FIGURE 4, which are connected by a land 68, tooth back 70, fillet 72, and tooth face 74. All of the teeth 60 in a longitudinally aligned series are of constant diameter from the leading end to the rear end of the finishing section 56 so that these teeth cut only on the side. The teeth are unrelieved on the side so as to be full form finishing. The tops of these teeth may be in metal-to-metal contact with the bottom of the groove cut in the work piece, or they may be shorter than the final roughing teeth so as to have top clearance. In addition, the spline teeth 60 are designed to increase in tooth thickness, as for example, from a thickness of .101 inch at the leading series of teeth in the finishing section to a tooth thickness of .107 inch by increments of one thousandth. Spline teeth 60 in the finishing section 56 are or may be backed off with a back-off angle alpha and increase in tooth thickness or width as previously described.

The continuous uninterrupted round blades 62 increase in diameter from the leading end of the finishing section 56 to the rear end thereof, depending on the particular application of the broach. In one example, the diameters of the round teeth may increase according to the following chart:

Tooth number:	Spline (inches)
1	1.9605
2	1.961
3	1.9615
4	1.962
5	1.9625
6	1.963
7	1.963
8	1.963
9	1.963
10	1.963

Intermediate the finishing section 56 and the rear pilot or shank 16 is located a plurality of round cutting blades 80. The use of the blades 80 is optional, their main function being to reduce the number of alternate round and spline teeth in the finishing section 56 which are necessary to provide the desired concentricity between the elements of the broach part 12.

In order to better illustrate the invention reference is now made to FIGURES 5–8. As previously mentioned, the spline teeth 30 of the roughing section are all of the same width at any given radial fixed measuring point, as for example .100 inch, as indicated in FIGURE 5. The finishing teeth 60 are arranged in longitudinally aligned series (either straight or helical) and the first tooth 60*a* of each series, as shown, may have a tooth width of .101 inch at a predetermined radially fixed measuring point which represents an increase in width from the teeth of the roughing section by an increment of .001 inch. Any practical increment may be utilized.

As illustrated in FIGURES 6 and 7, successive teeth 60*a*, 60*b* and 60*c* represent an increase in tooth width of .003 inch from .101 to .104, to .107 inch. The teeth 60 in the finishing section 56 are backed off with a back-off angle phi. If desired, there may be a final series of straight back-off teeth to give tool life.

As previously mentioned, the broach illustrated is particularly adapted for forming in the inner periphery of a gear or spline work piece 12 grooves 90 of the type which are formed by the spline teeth from the broach 10 just described. The side walls 92 of the grooves 90 are straight sided. The continuous round cutting blades 62 increase in diameter from the front end of the finishing section 56 to the rear end and the aforesaid blades 62 are adapted to trim the inner periphery of the work piece 12 so as to properly shape the ends of the projections 59 which are located between the grooves 90.

FIGURE 10 is a diagrammatic view of successive cuts taken to form tooth spaces of involute form. The full tooth space as finally cut has a bottom surface B and right and left side surfaces R and L. The minor or inside diameter (I.D.) is represented by the letter M. The first tooth of the roughing section cuts a shallow channel in the surface of the work piece between lines 96, 98 and 100. The next axially aligned tooth of the roughing section of the broach moves through the first channel as previously described, and in addition cuts material from the work piece between the lines 96, 98 and 102. In like manner, the next following axially aligned tooth of the roughing section follows through the aforesaid channels and removes material from the work piece between the lines 96, 98 and 104.

Following roughing teeth cut along lines **96** and **98** to increasing depth as indicated by lines **106**, **108**, **110** and **112**. Lines **96** and **98** represent the desired gear tooth form or profile, normally involute. Each roughing tooth cuts only at its top, except for the side surface determined by the depth of cut. Each roughing tooth has its sides relieved except for a short section at its tip, normally 1/64–3/64 inch.

Thereafter, the final finishing section of the broach comes into action. It will be understood that due to some or all of the factors described at the outset, the desired involute form sides of grooves may not have been attained. The finishing section, having full form finishing side cutting spline teeth alternated with round teeth or blades, corrects the form and produces substantially exact concentricity between the splines and the crest of the teeth on the work, or in other words, its minor diameter or I.D.

Specifically, the spline teeth **60** of the finishing section **56** cut only on the sides thereof. In addition, the round cutting blades **62** of the finishing section **56** cut on the top thereof to further trim the projections **59** and minor or inside diameter of the part. The first spline tooth **60** of the finishing section **56** removes material from the work piece **12** between the lines **96** and **114** and lines **98** and **116**. The axially adjacent round tooth **66** removes material between lines **118** and **120**.

Thereafter, the second side cutting spline teeth removes material from lines **120** between lines **116** and **122** and between lines **114** and **124**. Following this the second round blade removes material between lines **120** and **126**. The next side cutting spline teeth remove material from line **126** between lines **122** and **128** and between lines **124** and **130**. Finaly, another round blade removes material between lines **126** and **132**.

The pitch of the teeth and blades is substantially less than one-half the thickness of the piece or assembly of pieces, and hence the full tooth form is being shaved or cut at the same time that a cut is being taken on the minor or inside diameter. The full tooth form cut extends to the crest of the tooth on the broach for the full depth of the involute spline or space, so that any form error due to drift or otherwise produced by the roughing section is completely eliminated. There is thus produced accurate and accurately spaced involute forms which are necessarily concentric with the minor or inside diameter as defined by the crests of teeth on the work piece.

Another embodiment of the present invention is shown in FIGURES 12–14. The broach is illustrated diagrammatically at **140** in FIGURE 11 and shows an involute spline pull broach designed to produce internal involute spline teeth on a work piece or gear. Broach **140** comprises a front head **142** at the leading end of the broach which is adapted to be connected to a device for pulling the broach **140** through a hole in the work piece. Rearwardly extending from the pull end of the broach **140** is a cylindrical front pilot **144**. Rearwardly of the front pilot **144** is the roughing section of the broach **140** as indicated generally by the numeral **146** in FIGURE 1. The involute spline teeth of the roughing section are stepped rearwardly on diameter, depending on the particular application, and have equal tooth thicknesses at any measuring point, as was explained in connection with the other embodiment.

The finishing section **180** includes alternate involute spline teeth **181** and continuous cutting blades **183** for trimming the projections of the work piece in the manner described for the other embodiment. The involute tooth **181** has a cutting edge **184** and the continuous blade **183** has a cutting edge **186**. The cutting edges **184** and **186** are connected by a land **188**, tooth back **190**, fillet **192** and tooth face **194**.

Rearwardly of the finishing section **180** is located a plurality of continuous round cutting blades **196** which are optional as in the other embodiment. A rear pilot

198 is provided and has axially extending rearwardly therefrom a shank portion **200**.

The broach **140** is adapted to be pulled through the work piece for forming in the inner periphery of the work piece involute shaped grooves. The teeth of the broach move through the grooves provided in the work piece in the manner described for the other embodiment. The end result is that the side walls of the grooves of the work piece conform in curvature with the curvature of the broach teeth which the grooves are to receive. The teeth of the roughing section cut primarily on the top. In addition, the teeth **181** of the finishing section, which increase in width as in the other embodiment, cut only on the sides and the alternate continuous cutting blades **183** which increase in diameter are designed to cut and trim the inner periphery of the work piece so as to properly trim the ends of the projections which are located between the grooves in the work piece. In the event the last uninterrupted blade **183** does not produce the required minor diameter, the continuous cutting blades **196** provide the final means for trimming the aforesaid projections in the work piece to the required minor diameter. As an example, the diameters of the round teeth may increase according to the following chart:

Tooth number:	Round (inches)
1	2.3435
2	2.346
3	2.348
4	2.350
5	2.3515
6	2.3525
7	2.3529
8	2.3529
9	2.3529
10	2.3529
11	2.3529
12	2.3529

The unique construction of the broach, whether a straight sided spline broach or an involute broach or any other type of form broach, has provided a means for producing in the broach part concentricity between the minor diameter, major diameter and the form.

The present invention is also adaptable to a broach of the type described which has a finishing section designed to cut only on the sides and on the inside diameter of the part, wherein the teeth of the finishing section are of less height than those of the roughing section so that the top portions of the teeth of the finishing section are thus able to pass in clearance through the grooves or slots in the broach part while cutting on the sides. The round teeth cut on the inside diameter of the broach part, or on the tops of the teeth or splines between spaces in the work piece.

Referring to FIGURE 15, slot **202** is provided at the bottom of each tooth space cut by the roughing broach or section. The teeth of the finishing broach or section are of less height than those of roughing broach or section and hence, cut only on the sides. Thus, the surface **204** of FIGURE 15 may represent the outline cut by the teeth of the roughing broach, and surfaces **206** and **208** represent surfaces but by succeding finishing teeth which have their top portions passing in clearance through the grooves or slots **202**.

The spline teeth which cut surfaces **206** and **208** may of course have round blades intermediate them to cut on the minor or inside diameter in the same manner as illustrated in FIGURE 10, thus positively insuring concentricity between the tooth form or pitch diameter, and the minor or inside diameter.

Although this invention has been described in connection wtih a solid type of broach, it should be understood that the alternate round and spline section with full form side cutting teeth could be made as a replaceable shell which is affixed to and located on the rear end of the

broach following the roughing section. In addition, the invention is applicable to splines or gears with a zero degree helix angle (spur) or to helical broaches as well.

In addition, while the drawings have illustrated only a solid broach having external teeth adapted to form teeth or splines at the inner surface of an opening through a work piece, it will of course be apparent that many of the problems solved by the present invention are common to externally toothed broached parts as well as internally toothed broached parts. The relationship is obvious and the series of longitudinally aligned finishing teeth in general, are of increasing width with opposite side edges laterally spaced so as to provide side cutting top cutting is eliminated, either by providing top clearance or by providing teeth which are of a uniform height at least no greater than the height of the preceding teeth. Moreover, the side cutting edges of the teeth are formed without relief so that they provide for full form finishing, operating for the full depth of the space being cut in the work piece.

Reference has been made to the pitch of the teeth and blades as compared to the thickness of a work piece. For this purpose it will be apparent that an assembly of two or more blanks, fixed against relative movement, constitutes a work piece.

The drawings and the foregoing specification constitute a description of the improved broach in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What I claim as my invention is:

1. A broach comprising a leading roughing section having a plurality of series of longitudinally aligned cutting teeth arranged in laterally aligned groups, the cutting teeth in each series progressively increasing in height in the rearward direction, a following finishing section having a plurality of series of accurately formed longitudinally aligned finish cutting teeth in longitudinal alignment with said plurality of series of teeth in said roughing section, said finish cutting teeth being arranged in laterally aligned groups and of less height than the final group of teeth on said roughing section so as to have top clearance with respect to the work piece, the finish cutting teeth in each of the series of the finishing section being of definitely predetermined progressively increasing width in the rearward direction, corresponding edges at both sides of each of said finish cutting teeth being circumferentially stepped and shaped so as to cause each of said finish cutting teeth to cut entirely at the sides thereof, with the sides of each of said teeth cutting simultaneously in the work piece throughout substantially their entire height.

2. A broach as defined in claim 1 in which said finish cutting teeth have side clearance in back of the cutting edges.

3. A broach as defined in claim 1 in which the teeth of the roughing section are of equal width at measuring points radially spaced equal distances from the axis of the broach.

4. A broach as defined in claim 1 wherein said finishing section includes a plurality of progressively radially stepped round blades, said round blades each being located between a pair of adjacent groups of finish cutting teeth, said round blades providing a final trimming operation on the inside diameter of the work piece.

5. A broach as defined in claim 4 in which the pitch of the blades and finish cutting teeth is substantially less than one-half the thickness of a work piece for which the broach is designed so that round blades and finish cutting teeth are cutting simultaneously.

6. A broach as defined in claim 1 in which the sides of said finish cutting teeth are of gear tooth form.

7. A broach as defined in claim 1 in which the sides of said finish cutting teeth are of involute form.

8. In a broach, a finishing section having a plurality of finishing series of longitudinally aligned side cutting full form finishing teeth arranged in annular groups and adapted to pass through spaces formed in a work piece by a preceding series of broach teeth, the teeth in said finishing section having a height measured radially of the broach axis which is at most no greater than the corresponding height of the final teeth in the preceding series so as to avoid top cutting, the finish cutting teeth in each of said finishing series being of definitely predetermined increasing width in the rearward direction, corresponding edges at both sides of each of said cutting teeth being circumferentially stepped and shaped so as to cut substantially entirely at the sides thereof, said finishing teeth having side clearance in back of the side cutting edges thereof, said finishing teeth being unrelieved full form side shaving teeth adapted to cut the sides of the spaces in a work piece for substantially its full depth, and circular uninterrupted cutting blades interspersed with annular groups of finishing teeth, said cutting blades being progressively radially stepped to take successive cuts on the crests of the teeth formed on the work piece.

9. Structure as defined in claim 8 in which the sides of said finishing teeth are of gear tooth form.

10. Structure as defined in claim 8 in which the sides of said finishing teeth are of involute form.

11. Structure as defined in claim 8 in which said circular blades and said annular groups of teeth are alternated.

12. Structure as defined in claim 8 in which said finishing section is elongated and in which said teeth and blades are provided on its exterior to broach teeth and spaces in an opening in a work piece.

13. Structure as defined in claim 8 in which the pitch of said blades and annular groups is substantially less than one-half the thickness of a work piece for which the broach is designed.

14. A finishing broach section adapted to follow a preceding broach section having a plurality of series of longitudinally aligned teeth, said finishing section having a plurality of series of longitudinally aligned finish cutting teeth which constitute the final tooth form cutting elements thereon, said finish cutting teeth being arranged in annular groups and of less radial height than the corresponding radial height of the last aligned teeth in the preceding broach section to provide top clearance, the cutting teeth in each series being of definitely predetermined progressively increasing width in the rearward direction, corresponding edges at both sides of each of said cutting teeth being circumferentially stepped and shaped so as to cause each of said cutting teeth to cut entirely at the sides thereof, said cutting teeth having side clearance in back of the cutting edges, the cutting edges of each of said finishing teeth being unrelieved full form finishing and adapted to cut simultaneously in the work piece throughout substantially their entire height so as to provide a final side trimming operation on the sides of the corresponding tooth in the work piece.

15. A finishing broach as defined in claim 14 in which the side cutting edges of said finishing teeth are of gear tooth form.

16. A finishing broach as defined in claim 14 in which the side cutting edges of said finishing teeth are of involute form.

17. A broach section as defined in claim 14 comprising uninterrupted circular blades alternated between the annular groups of finishing teeth, said circular blades being progressively radially stepped to provide a final trimming operation on the ends of the teeth formed on the work piece by the broaching operation.

18. A broach as defined in claim 1 in which said finishing section is elongated and in which said teeth and blades are provided on its exterior to broach teeth and spaces in an opening in a work piece.

19. A broach as defined in claim 14 in which said finishing section is elongated and in which said teeth and blades are provided on its exterior to broach teeth and spaces in an opening in a work piece.

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