Nov. 22, 1966 W. H. BIBBENS 3,286,593

METHOD AND APPARATUS FOR CHAMFERING TOOTHED MACHINE ELEMENTS

Filed Dec. 15, 1964 5 Sheets-Sheet 1

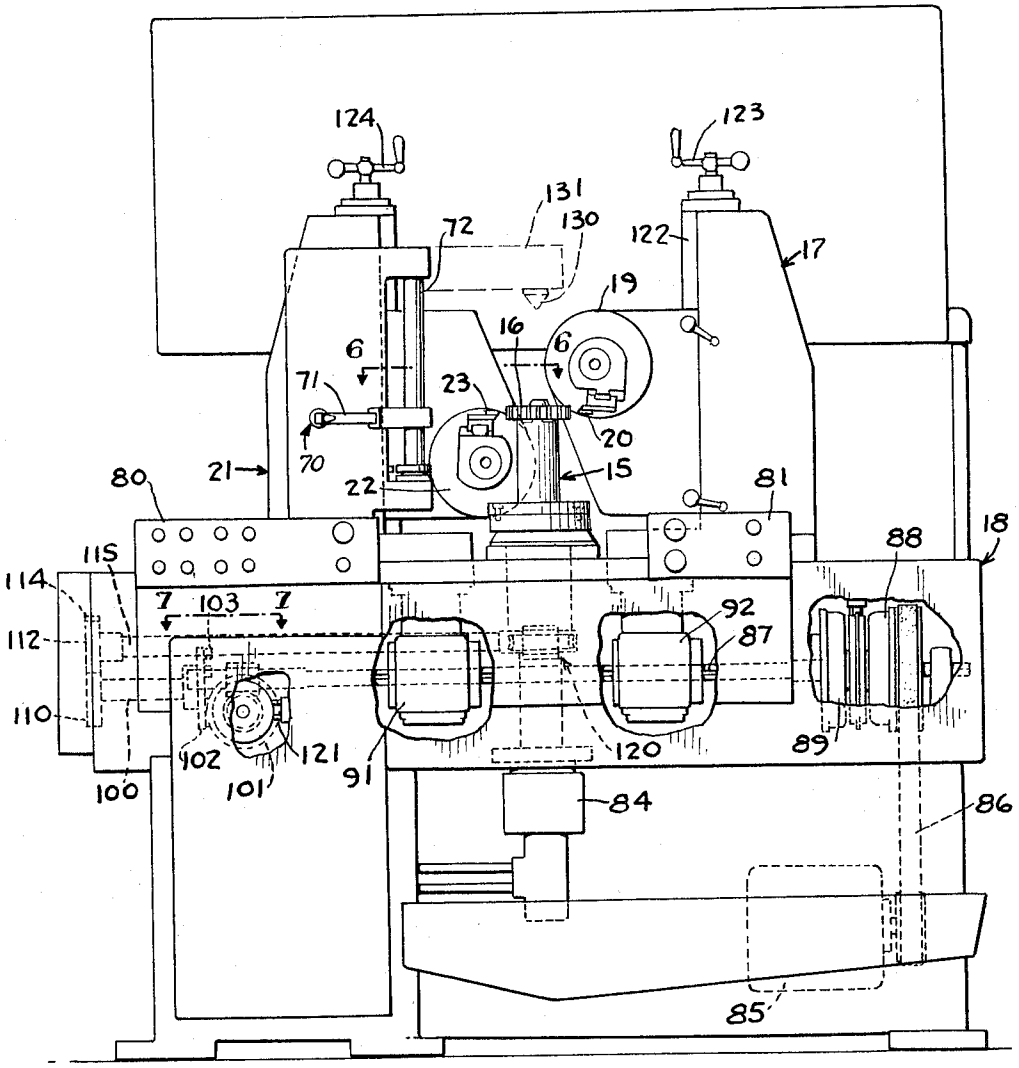

Fig. 1

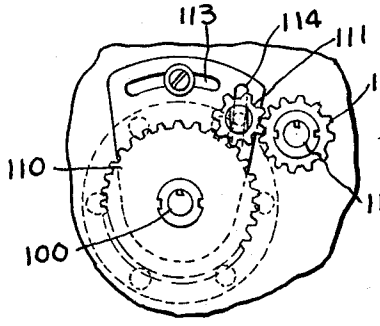

Fig. 2

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METHOD AND APPARATUS FOR CHAMFERING TOOTHED MACHINE ELEMENTS

Filed Dec. 15, 1964 5 Sheets-Sheet 2

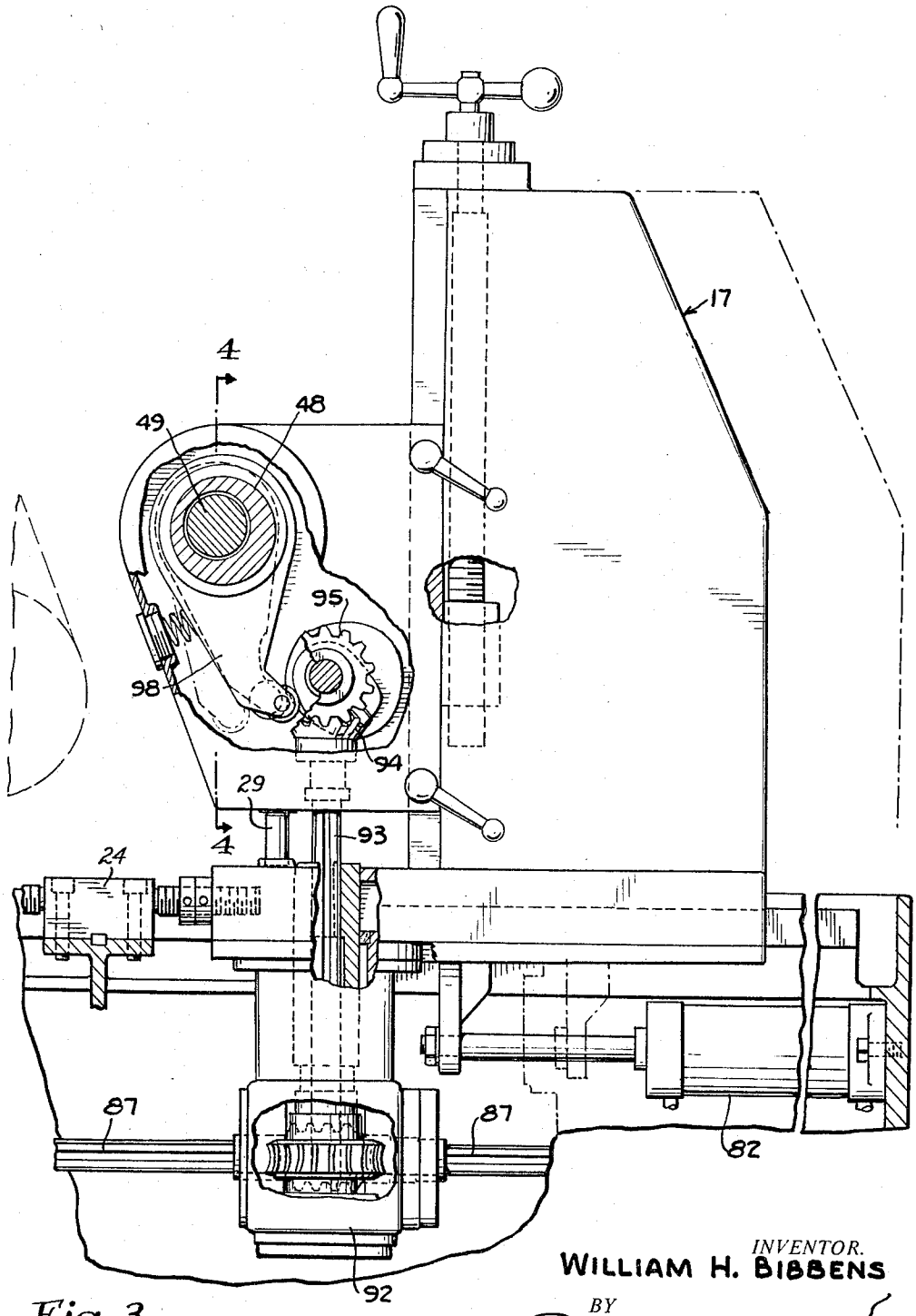

Fig. 3

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METHOD AND APPARATUS FOR CHAMFERING TOOTHED MACHINE ELEMENTS

Filed Dec. 15, 1964 5 Sheets-Sheet 3

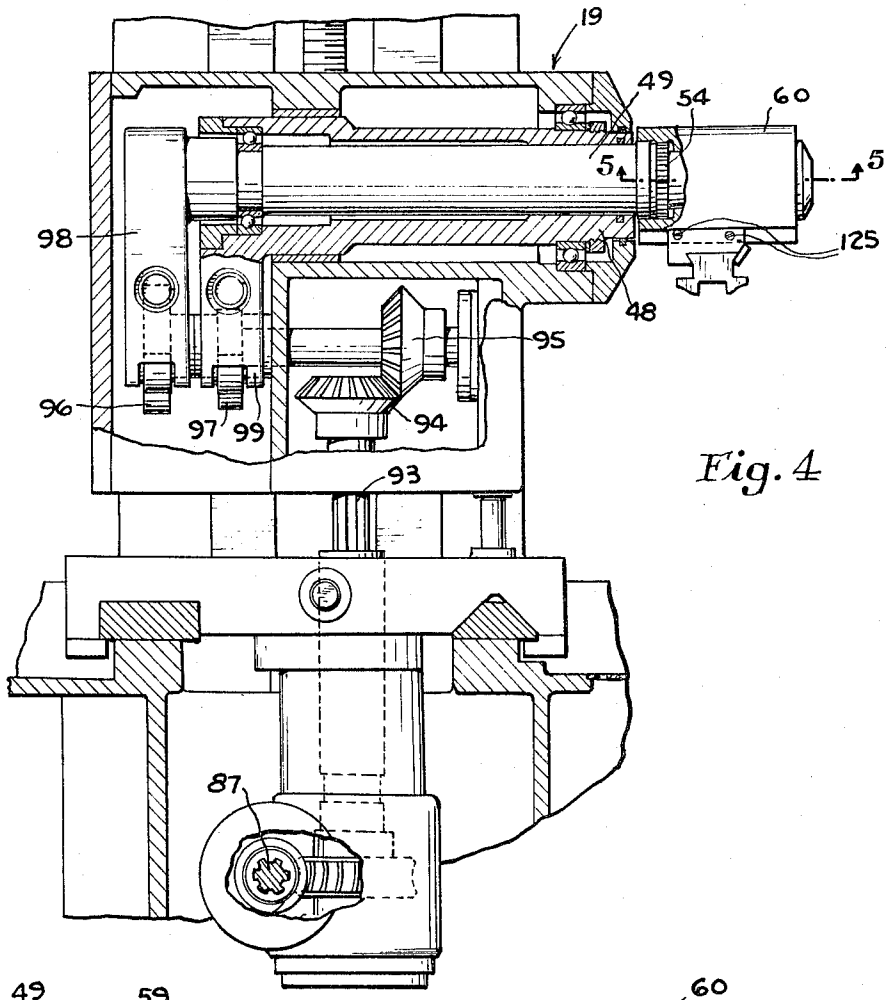

Fig. 4

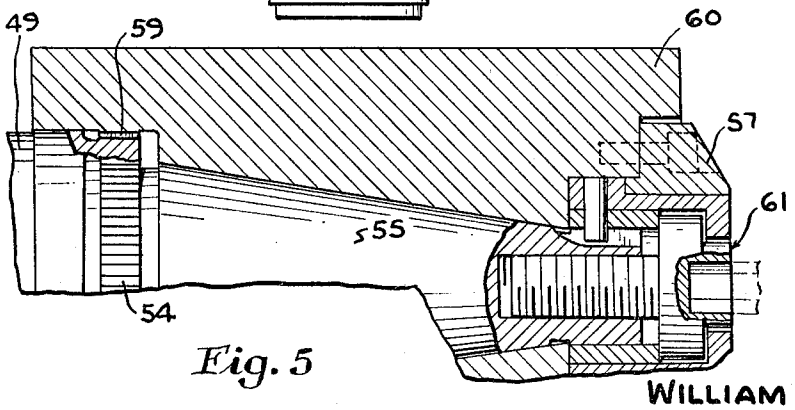

Fig. 5

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METHOD AND APPARATUS FOR CHAMFERING TOOTHED MACHINE ELEMENTS

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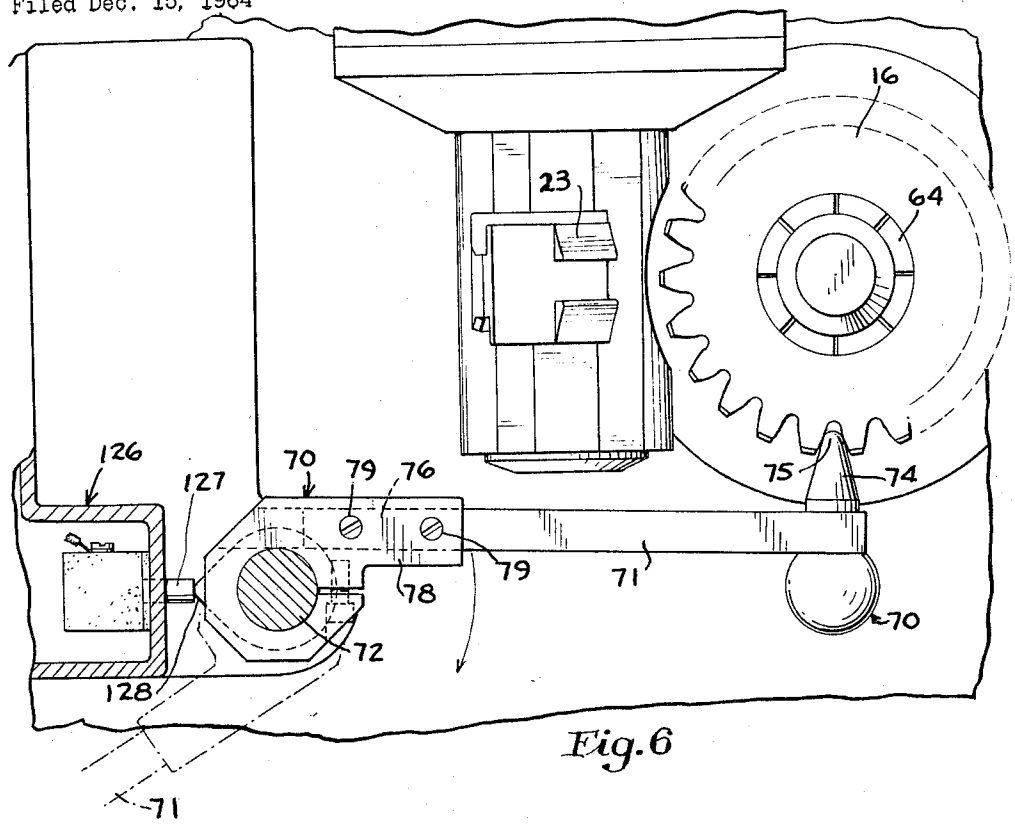

Fig. 6

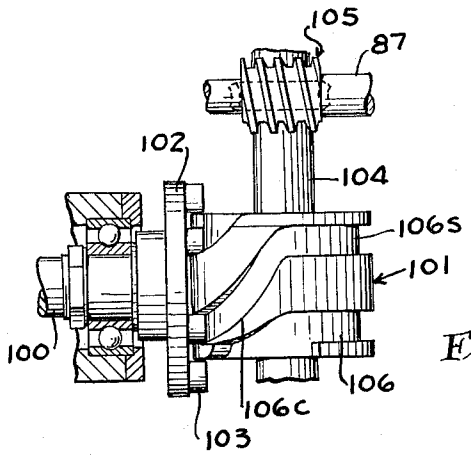

Fig. 7

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METHOD AND APPARATUS FOR CHAMFERING TOOTHED MACHINE ELEMENTS

Filed Dec. 15, 1964 5 Sheets-Sheet 5

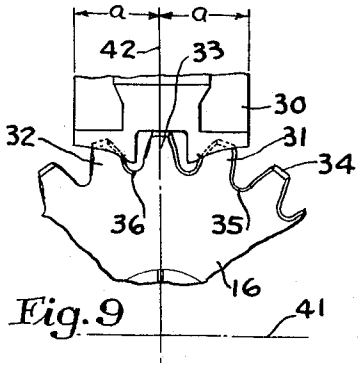
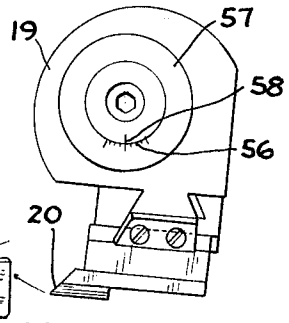


Fig. 9



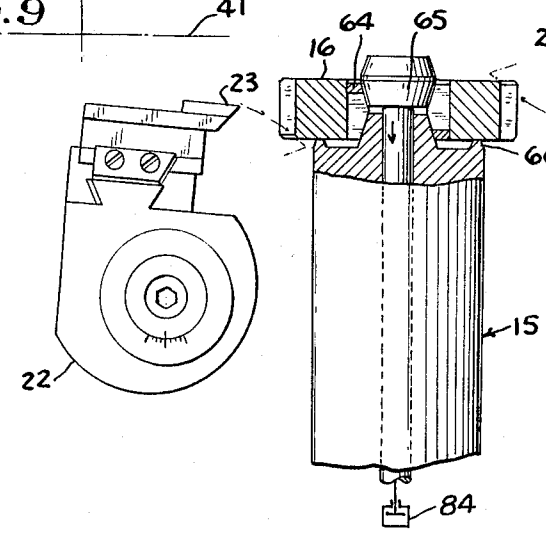


Fig. 8

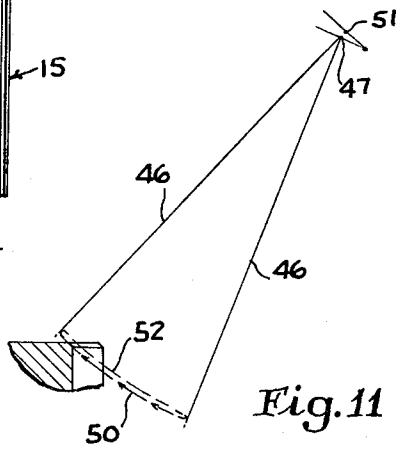


Fig. 11

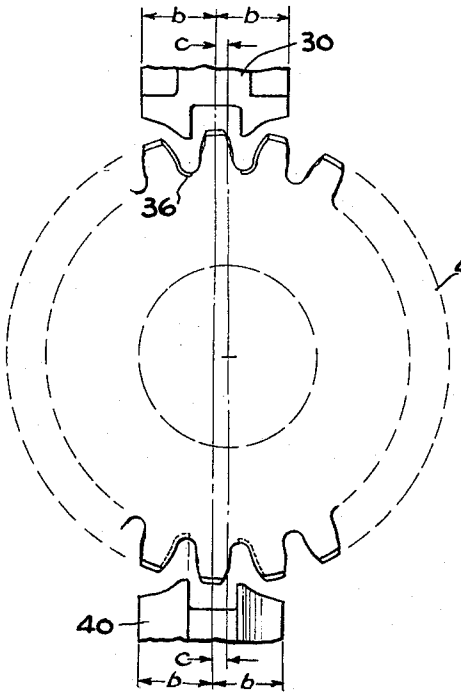


Fig. 10

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United States Patent Office 3,286,593
Patented Nov. 22, 1966

3,286,593

METHOD AND APPARATUS FOR CHAMFERING TOOTHED MACHINE ELEMENTS

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Filed Dec. 15, 1964, Ser. No. 418,501
10 Claims. (Cl. 90—1.4)

This invention relates to methods and apparatus for chamfering end edges of teeth of various toothed elements such as gears, splines, and the like. The present application is directed particularly to an improved machine of the universal type.

The advantages and often indispensable necessity of chamfering sharp edges of teeth of toothed machine elements, such as gears, splines, and the like have now been well appreciated in the art. In many responsible applications of such machine elements having their sharp edges, particularly at the end faces thereof, properly chamfered, is considered as indispensable for the proper operation and wear resisting characteristics of such elements, and lack of such chamfering is considered to be not a proper engineering design for such elements. In other applications of less responsible nature, advantages of having the sharp end edges of the teeth of such elements properly chamfered are such as to make chamfering at least very desirable.

Accordingly, requirements for chamfering gears and similar machine elements have increased very substantially within the last decade. With it increased the variety of types and sizes of such machine elements, presenting further problems and requirements.

More particularly, because of such increase in the variety of application of chamfering, the necessity of providing a chamfering machine of a more universal type than was heretofore available, has been clearly felt for quite a number of years. It can be understood that where the volume of production of a certain gear or a similar element is relatively large, use of a special machine designed and built for operating on that particular gear is usually justified as to its cost. On the other hand, when the volume of production of such a gear or a similar element is relatively small, or where that particular element is manufactured in a number of sizes, the cost of designing and building such a special machine for each type or size becomes prohibitive and makes application of chamfering and the attainment of the advantages thereof exceedingly difficult.

One of the objects of the present invention is to provide an improved machine for chamfering gears, splines, and the like whereby the above problems and disadvantages are overcome and largely eliminated without introducing other problems, or increasing in any appreciable manner the costs involved.

Another object of the present invention is to provide an improved gear chamfering machine which can be readily and economically changed to accommodate gears having various diameters, number of teeth, various diametral pitches, various types of teeth, such as straight teeth, as in the case of spur gears, or helical and spiral teeth, as well as spline teeth, and the like.

A further object of the present invention is to provide a universal gear chamfering machine which will deburr and chamfer the teeth of a workpiece, including end edges thereof which are virtually inaccessible, with at least one full tooth end edge profiled with the chamfering operations being performed simultaneously at opposite sides of the workpiece axis, at both end faces of a gear or other toothed workpiece, thus doubling the output of the chamfering machine just the combination of these particular features alone.

A still further object of the invention is to provide an

improved gear chamfering machine of the universal type in which, after the one chamfered workpiece gear is unloaded manually and a new workpiece gear is loaded, further operations forming the same cycle are performed automatically, with the operator required only to push certain control buttons and upon completion of the cycle to unload the chamfered gear.

A still further object of the present invention is to provide an improved fear chamfering machine in which after proper cutters for the gears to be chamfered have been developed and made, retooling and setting the machine for any specific gear or other similar workpiece can be done in a shop in a matter of a few minutes only.

A still further object of the present invention is to provide a gear chamfering machine of the universal type having improved locating means for the workpiece gear, together with a simple and rapid means of adjustment of the cutter-actuating and cutter-holding means, to establish the proper lateral and vertical position of the cutter paths in relation to the end edges of the workpiece to be chamfered.

A still further object of the present invention is to provide an improved gear chamfering machine which is safe and dependable in operation and in which novel safety features are provided, whereby the possibility of damage to a workpiece gear or of injury to the operator is reduced to a minimum.

A still further object of the present invention is to provide an improved gear chamfering machine of the foregoing character which is simple and rugged in construction, and which can be operated safely by unskilled persons.

In one of its other aspects, the invention contemplates providing an improved method for chamfering end edges of gears, splines, and similar toothed elements.

Further objects and advantages of this invention will be apparent from the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification, wherein like reference characters designate corresponding parts in the several views.

FIG. 1 is an elevational view illustrating an improved machine embodying the present invention, with the parts of the frame thereof being broken away to expose to view certain vital components thereof.

FIG. 2 is a fragmentary end view taken with the observer presuming to look on the left-hand end of the machine of FIG. 1, and illustrating the gear mechanism with the aid of which the machine can be set to cut a gear with any specific number of teeth within the range of the machine.

FIG. 3 is a fragmentary elevational view of one of the cutter spindle actuating mechanisms mounted to a laterally slideable column or assembly and having provided thereon vertical ways for vertical adjustments of the cutter spindle head assembly. Also shown in said figure is the main drive line means for actuating the cam shafts and other devices producing intermittent motions of the work cycle of the machine.

FIG. 4 is a sectional view taken in the direction of the arrows on the section plane passing through line 4—4 of FIG. 3.

FIG. 5 is a fragmentary sectional view taken in the direction of the arrows on the section plane passing through the line 5—5 of FIG. 4.

FIG. 6 is a sectional view taken in the direction of the arrows on the section plane passing through the line 6—6 of FIG. 1, and illustrating the angular locating device for the workpiece gear.

FIG. 7 is a fragmentary sectional view taken in the direction of the arrows on the section plane passing

through the line 7—7 of FIG. 1, and illustrating the indexing device changing the continuous movement of the main drive shaft into intermittent movement required for indexing the workpiece-holding spindle.

FIG. 8 is a fragmentary elevational view illustrating the application of the opposing cutters to the workpiece gear at both end faces thereof, and on the opposite sides of its axis.

FIG. 9 is a fragmentary plan view illustrating application of one cutter to a workpiece gear having an even number of teeth.

FIG. 10 is a view similar in part to FIG. 9, illustrating the space relation of the cutters to a workpiece gear having odd number of teeth.

FIG. 11 is a diagrammatic view illustrating the movement of one point of the cutter in the process of one cycle, i.e. during the cutting, relief, return, and reposition strokes of the cutter.

It is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways within the scope of the claims. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and not of limitation.

It will be understood that the term "gear" as used in the following description and claims is intended to cover also other toothed elements, such as splines, and the like.

Referring specifically to the drawings, the machine illustrated therein comprises generally a workpiece spindle, generally designated by the numeral **15**, adapted to receive a workpiece gear **16**, to locate the same in a predetermined position, and to index said gear at least one tooth at a time. A laterally slideable column assembly **17**, mounted on the machine frame **18**, carries an upper cutter head **19** operating the upper cutter **20**, while a slideable column assembly **21** carries a lower cutter head **22** operating the lower cutter **23**. There are provided horizontal and vertical positioning blocks used to establish positions of the sliding assemblies **17** and **21** and, therefore, of the pivotal axes of the cutters **20** and **23** carried thereby with relation to the workpiece gear teeth during the cutting cycle. Such positioning blocks for the sliding assembly **17** are shown in FIGURE 3, wherein the horizontal positioning block is designated by the numeral **24** and the vertical positioning block by the numeral **29**. Driving means for said cutters are provided to operate said cutters **20** and **23** to produce simultaneous cutting strokes thereof, while the spindle **15** remains stationary, and to rotate said spindle **15** one tooth of the workpiece gear **16** at a time, as the cutters are returned and repositioned to their start cutting positions. Various adjustments for proper cutting of the workpiece gear **16** and for the cutters **20** and **23**, as well as other service devices determining the desired cycle of the machine are provided and are described in detail below.

The general concept of application of chamfering form cutters to the end edges of the workpiece gear teeth to be chamfered, is based on the disclosure of the U.S. Patent No. 2,668,480 to John M. Christman, as well as of the U.S. Patent No. 2,865,257 to John M. Christman and William H. Bibbens. The present application covers a further development of said concept disclosed herein and its application to chamfering workpiece gears simultaneously at both end faces thereof.

As illustrated in FIG. 9, the form cutter such as illustrated at **30**, is, in effect, a combination of two cutter teeth operating on two separate spaced gear teeth and cutting simultaneously at least two near side edges of such spaced teeth, such as edges of the teeth **31** and **32**, which are separated by at least one full tooth, such as **33**. The construction of the form cutters, such as cutter **30**, and development of their cutting edges, is disclosed in detail in the above-mentioned patents. It may be mentioned here, however, that cutting edges of the form cutters may be developed to cut, in addition to the near side edges, also portions of at least halves of the top edges, such as **34**, and of root edges, such as **35**. In the present embodiment of the invention, with the top edge **34** being already chamfered in the process of turning the blank of the workpiece gear, only a portion of the root edge is cut by the cutter **30**, as indicated at **36**.

It will be understood now that in the embodiment illustrated, the form cutter **30** cuts in one cutting stroke two side edges and two halves of root edges, which condition, considering that the top edge is already chamfered, gives in aggregate full chamfering of one complete tooth in one cutting stroke. Thus, if the workpiece gear is indexed the number of times equal to the number of its teeth, all of said teeth will be fully chamfered after being so indexed.

In accordance with the invention, a substantially identical form cutter, such as **40**, is provided in a substantially similar position on the other end face of the workpiece gear **16** diametrically opposite to the form cutter **30**, i.e. on the other side of the axis of the workpiece gear **16**. The similarity of positions of the cutters **30** and **40** are such that if, for example, we turn the cutter and the gear over 180 degrees around a center line **41**, perpendicular through the center line **42**, the cutter **30** and the teeth **31**, **32**, and **33** thereof would assume the exact position of the cutter **40** and corresponding gear teeth previously disposed at the opposite end face of the workpiece gear **16**. Referring to the elevational or front views of the drawings, such as FIGS. 1 and 8, wherein the exterior outline of the workpiece gear **16** appears as a rectangle, the illustrated arrangement of the cutters may be termed as providing for chamfering gear teeth ends at diagonally opposite gear ends, with the cutting strokes of the cutters being directed toward the axis of the workpiece gear.

With an even number of teeth, such as shown in FIG. 9, there generally will be a tooth disposed along the center line **42** on the other side of the workpiece gear **16**. However, if the workpiece gear, such as **44**, has an odd number of teeth, there will be a space at the other end of the center line, such as **42**, while the adjacent tooth on either side of such center line will be offset from said center line **42** for one-half of the tooth pitch. In order to attain proper results, the chamfering cutters, such as **40** and **30**, are equally offset toward one common side for the predetermined distance equal to at least one-quarter of the diametral pitch, as illustrated in FIG. 10. In other words, the cutters **40** and **30** will be offset with relation to the axis of the gear for a distance as indicated at *c* of FIG. 10, with *b*—*b* indicating location of the center line of the cutters.

The selection of the angle of chamfer, and therefore the angle at which the cutter is applied to the gear teeth, is also disclosed in detail in the above-mentioned patents.

As can be seen from an examination of FIG. 8, the upper cutter **20** and the lower cutter **23** move along an arcuate path determined by the distance from the cutting edges to the center of the cutter spindle shafts, such as the distance indicated in FIG. 11 by the numeral **46**.

It will be understood at this point that in order to relieve the cutting edge on its return stroke and eliminate its rubbing against the cut chamfer, the center of the cutter head spindle or shaft is made moveable by the provision of the eccentric sleeve, such as one illustrated at **48** in FIGS. 3 and 4 and actuated independently of the shaft **49**. The cutting movement of the cutter, such as **20**, is produced by the reciprocal rotation of the shaft **49** with the position of the sleeve **48** being as illustrated in FIGS. 3 and 4. In such a condition, the center of the cutter rotation is in the lower position as indicated at **47** in FIG. 11. Upon completion of the cutting stroke, as illustrated by the line **50** in FIG. 11, the sleeve **48** is reciprocally actuated to raise said shaft, and therefore

the center of its rotation, to the point **51**, whereupon the return stroke of the cutter proceeds along the line **52** in order to clear the chamfer on the return stroke of the cutter.

In order to provide uniform chamfering for varying conditions of geometric forms of end edges of gear teeth, adjustable means are provided for varying the location of the arcuate paths of the form cutters, such as shown at **20** and **23**. In the present embodiment such means are exemplified by the tapered end **55** of the shaft **49**, with the measurements of the degree of adjustment appearing on the dial, such as **56**. The indicator knob **57** having a reference mark **58** is secured to the tapered end **55** of the shaft **49**, as illustrated in FIG. 5. For more secure orientation, the adjustment is made in small increments determined by the external serrations **54** provided on the shaft **49** and cooperating with complementary serrations **59** provided in the main toolholder **60**. Anchor screw **61** is used to secure the adjusted toolholder assembly at its respective selected position.

The workpiece spindle **15** is adapted to receive the workpiece gear **16**. A locating stop **66** positions the workpiece for vertical location. Centering location is determined by means of the centering expanding type locator **64**. After the workpiece gear **16** is centered in the spindle **15** and bears with its lower face on the end locator **66**, said gear is thus thereupon located angularly and locked or chucked in this position in order that the cutters **20** and **23** may chamfer the selected profile of the end edges of the gear teeth in the proper manner.

The angular locating device is exemplified in the present embodiment by a swinging arm device generally designated by the numeral **70**. The device **70** includes an elongated articulated arm **71** having one of its ends clamped at a predetermined and adjustable height on the cylindrical bar or pivotal shaft **72**. The free end of the arm **71** carries a locating finger **74** having a ball end **75** adapted to enter the space between two adjacent teeth of the workpiece gear **16**, and thus to locate the same angularly with respect to the cutters **20** and **23**, see FIG. 6. The length of the arm **71** is adjustable by sliding its end **76** in the bracket **78** and securing it in the adjusted position with the aid of screws **79**. Adjustment of the distance between centers of **72** and **74** provides for the proper angular positioning of the gear teeth in relation to the workpiece axis and the cutters **20** and **23** when the dieffrent workpiece gears have different diameters and diametral pitches. Adjustment of the height of the swinging arm **71** on the pivotal shaft **72**, mentioned above, provides for adjusting said arm at predetermined height as may be required by the nature of the workpiece gear. Such adjustment is effected by loosening the screw of the split bracket **78** embracing the pivotal shaft **72** journaled in the assembly **21** as shown, moving the brackets **78** to any desired height on the pivotal shaft **72**, and tightening said screw.

The arm **71** is swingable into its workpiece locating position, such as shown in FIG. 6, thus providing for chucking said workpiece **16** and then away from the workpiece **16**, i.e. into its retracted position, such as indicated in phantom lines in FIG. 6. Clearing the workpiece **16** sets up the electrical circuit for the work cycle.

Various electrical control buttons are assembled on the panels **80** and **81**. These buttons control electric circuits energizing an electric motor **85** providing mechanical drives for the described mechanisms, energizing various valve controlling solenoids and an electric motor driving a hydraulic pump which operates hydraulic cylinders, such as cylinders **82**. Operation of the hydraulic cylinders **82** moves the cutter head assemblies advancing the cutter heads into their operative positions. The hydraulic cylinder **84** operates the means locking and unlocking the workpiece gear in the spindle **15**. Both manual and automatic circuitry is provided by selector controls for manual set up cycling and automatic cycling.

The main drive motor **85** is mounted at the bottom of the machine and it drives with the aid of a belt **86** a spline shaft **87**. The shaft **87** is provided with an electrically controlled clutch **88** and an electrically controlled brake **89**. Worm-and-gear mechanism **91** drivingly connects the shaft **87** with the lower cutter head **22**, while the drive **92** connects said shaft with the upper cutter head **19**. Describing only one such driving connection in detail, the worm-and-gear mechanism **92**, connects said main drive shaft **87** with a vertical spline shaft **93**, see FIGS. 3 and 4, operating through a set of beveled gears **94** and **95**, see FIG. 4, cams **96** and **97**. The cam **96** operates a crank **98** secured to the cutter shaft **49** and imparts to it a swinging motion to produce the cutting and the return strokes of the cutter. The cam **97** operates a crank **99** secured to the eccentric sleeve **48**, adapted to raise the shaft **49** after the cutting stroke is completed, in order to cause the return stroke of the cutter to proceed along the line **52**, as illustrated in FIG. 11.

The construction of the drive for the lower cutter head **22** is substantially similar to that of the upper cutter head **19**, described above, and such description need not be repeated.

It will be noted, however, that in both of these constructions, the continuous rotary motion of the spline shaft **87** is converted into a reciprocating rotation of the shaft **49** by the cam-and-crank mechanisms described above with reference to the upper cutter head **19**.

Intermittent or indexing movements of the spindle **15** is imparted to said spindle from the continuously rotating main drive shaft **87**. The continuous rotation of the shaft **87** is converted into intermittent rotative movement of the first auxiliary shaft **100** by the indexing drive mechanism illustrated in detail in FIG. 7. Said device includes a cylindrical cam **101** mounted on a shaft **104** and connected to the shaft **87** through a worm-and-gear mechanism **105**. A circular plate **102** mounted on the shaft **100**, carries a plurality of followers **103** running in slots, such as **106**, provided on said cylindrical cam **101**. The followers **103** operate to rotate the plate **102** when the respective follower is in the curved portion **106***c* of the slot, and to keep the plate **102** stationary when the respective follower is in the straight portion **106***s* of the cam.

On the end of the first auxiliary shaft **100** there is mounted a time gear **110** connected with the aid of an idler pinion **111** with a change pinion **112**. The pinion **112** is interchangeable and may be substituted by pinions having different number of teeth. The slots **113** and **114** provided on the mounting brackets of the gears, in a manner well known in the art, are provided for adjustment of the gears in the process of substitution of the change gear **112** because of different diameters thereof. The second auxiliarly shaft **115**, on which the change pinion **112** is mounted, extends parallel to the first auxiliary shaft **110** with its opposite end being connected, with the aid of a worm-and-gear mechanism **120**, with the spindle **15** to rotate the same intermittently.

The purpose of the provision of the timing gear mechanism, including the gears **110** and **112**, is to impart to the spindle, with each step of its rotation, such angular movement as to index the workpiece gear through one pitch distance. This distance varies in different workpiece gears, depending on their respective diameters and the number of teeth. By a proper selection of the change pinion **112**, such distance, computed in advance and translated into its corresponding angular value, may thus be properly produced.

An electric counter, generally designated by the numeral **121**, see FIG. 1, is provided in order to set the machine for a definite number of step movements corresponding to the number of teeth in the workpiece gear. By operation of this device, when the operator presses the corresponding control button, the machine will start and index through a number of steps equal to the number of teeth, with the cutters going through equal number of chamfering and return strokes, and will stop with

the cutters being in their outward position and out of contact with the gear. Stopping of the machine is effected by the electrically controlled clutch **88** and brake **89**. Thereupon the cutter head carrying assemblies will move by the operation of the hydraulic cylinder **82** away from the workpiece gear and will stop in their retracted positions.

Setting the machine for a definite workpiece gear, after the cutters therefor have been developed, is exceedingly simple and may be accomplished in only a few minutes.

The change pinion **112**, of a predetermined number of teeth, is first put in place, and the electric counting device, such as **121**, is set for the number of teeth equal to that of the workpiece gear. The workpiece gear is then placed in position in the spindle **15**, and located therein along the axis of the spindle, to bring the workpiece gear to a proper height with respect to the cutters **20** and **23**. Substantial adjustments of the cutters with respect to the workpiece gear are attainable by moving the cutter heads in the vertical slides such as **122** of the assembly **17**. Moving the cutter head up or down is attained by using the screw-operating handle **123** for the head **19**, and handle **124** for the head **22**. The angular locating device is moved to locate the gear angularly, as described above, in a preliminary manner. Thereupon the cutters are adjusted laterally in dovetail adjusting slides and secured in their adjusted position by screws, such as **125**. After preliminary adjustments, the above parts may be readjusted in a more percise manner to produce chamfer of proper depth. Actual experience indicates that such adjustments can be easily made by a workman having only average skills.

Operation of the machine includes merely loading the workpiece gear into place, pressing the prescribed control buttons and unloading the chamfered gear, and such operation can be successfully carried on by a workman having only average skills of a production worker, or even by unskilled workmen. When the machine stops, the cutter heads and the cutter stop in their retracted positions, which is a feature of serious importance, for many reasons. Thereupon the workman merely presses the button unlocking the workpiece gear and removes it from the machine. Thereupon he loads the new workpiece gear, locates it angularly by moving the angular locator to the position of contact with the gear, as described, presses the button locking the gear in the spindle, and swings the angular locator into its retracted position. Thereupon he presses the button actuating the driving means, for which operation the use of both hands is required for the purposes of safety.

An additional feature of safety is found in the provision of the circuit breaker switch, such as **126**, see FIG. 6, operated by the angular locating device. As shown in FIG. 6, when the locating finger **74** is in contact with the gear, the switch button **127** is pressed in by the high spot **128** of the cam provided on the bracket **78** of the anguler locator device, causing the circuit energizing the driving motor **85** to be disconnected, and electric starting buttons ineffective to start the motor. It is not until the arm **71** is moved by the operator into the position illustrated in FIG. 6 in phantom lines, that the interrupter switch closes, whereupon pressing two additional electric control buttons will start the motor.

By virtue of such a construction, the possibilities of damage to the workpiece gear or injury to the operator are reduced to minimum.

In cases where the workpiece gear is made integral with long shafts, it may be necessary to support the upper end of the shaft with the aid of a center, similar to that provided in the tail stock of a lathe. Such a supporting center, indicated in phantom lines in FIG. 1 and designated therein by the numeral **130**, may be provided on an attachable arm, such as **131**, to have such center disposed co-axially with the spindle **15**. Such supporting center device is removed when the workpiece gear is in the form such as workpiece gear **16**, illustrated herein.

By virtue of the above disclosed method and machine, the objects of the present invention listed above and numerous additional advantages are attained.

I claim:

1. In a machine for chamfering end edges of teeth of a workpiece gear, said machine comprising a spindle adapted to receive the workpiece gear leaving it teeth exposed for chamfering at both of its end faces and to locate said gear axially, a locating member adapted to engage at least one tooth of the workpiece gear when moved in a position of contact therewith and to locate said workpiece gear on said spindle angularly, means to lock the workpiece gear on the spindle in the located position, means to move said locating member out of contact with the gear, two swinging cutters disposed one at each of the two end faces of the workpiece gear in similar space relation to the respective faces of the workpiece gear, each of said cutters adapted to chamfer two near side edges and at least a portion of each of the adjacent respective root edges of two spaced teeth separated by at least one full tooth, cam-and-follower means, one for each of said cutters adapted to actuate the same through similar reciprocating paths to produce successive chamfering and return strokes, and means to index the spindle one tooth at a time until completion of chamfering of all teeth on both end faces of the workpiece gear.

2. In a machine for chamfering end edges of teeth of a workpiece gear, said machine comprising a spindle adapted to receive the workpiece gear for operation of chamfering cutters at both of its end faces, stop means on said spindle adapted to locate the workpiece gear at a predetermined position along the axis of the spindle, an angular locating device to locate the workpiece gear angularly for proper registry of the teeth thereof with the chamfering cutters, said device comprising an articulated arm having one of its ends pivoted and its free end carrying a locating finger adapted to enter the space between two teeth of the workpiece gear and to engage said teeth for locating the workpiece gear angularly in a positive manner, two swinging cutters disposed one at each of the two end faces of the workpiece gear in similar space relation to the respective faces of the workpiece gear, with each of said cutters adapted to chamfer two near side edges and at least a portion of each of the adjacent respective root edges of two spaced teeth separated by at least one full tooth, means to actuate said cutters through similar reciprocating paths to produce successive chamfering and return strokes of said cutters, electric driving means for said cutter actuating means, and a switch operated by said angular locating device and adapted to render the cutter-actuating means inoperative until the locating finger thereof is moved out of contact with the workpiece gear and the arm thereof is moved into a retracted position of non-interference with loading and unloading of the workpiece gear on said spindle.

3. The machine defined in claim **2**, with the arm of the angular locating device being adjustable as to its length to accommodate work gears of various dimensional specifications.

4. In a machine for chamfering end edges of teeth of a workpiece gear, said machine comprising a rotatable spindle adapted to receive a workpiece gear and to hold it by its middle portion but leaving its teeth at both of its end faces exposed to the action of chamfering cutters, stop means to locate the workpiece gear on said spindle a predetermined position along the axis thereof, a locating finger means for locating the workpiece gear angularly, hydraulically actuating locking means to lock the workpiece to said spindle for rotation therewith, two slidable assemblies movable in and out of the respective operation positions at said spindle, adjustable stop means for each of said assemblies at the operation position, a cutter head carried by each of said assemblies, each of said head

carrying an oscillatable shaft, a swinging cutter mounted on said shaft and adapted, when the respective assembly is in operation position, to chamfer two near side edges and at least a portion of the adjacent respective root edges of two spaced teeth of the workpiece gear separated by at least one full tooth, a continuously driven auxiliary shaft, a cam-and-follow means transferring continuous rotation of said auxiliary shaft into oscillation movements of said oscillatable shaft to move its respective cutter and thus to produce a cutting stroke and a return stroke thereof, an eccentric sleeve operatively interposed between said oscillatable shaft and the follower of the cam-and-follower means to raise the cutter on its return stroke.

5. The machine defined in claim 4 and including angularly adjustable means between said oscillatable shaft and the cutter.

6. The machine defined in claim 4, with each cutter head including slide-and-screw means adapted to move said head bodily along the axis of the spindle for adjustments, and locking means for locking the head in its adjusted position.

7. The machine defined in claim 4, and including electric switch-and-cam means to start the chamfering cycle after the workpiece gear is located and locked in the spindle, and the angular locating finger is withdrawn from contact with the workpiece gear, to carry the cycle until completion of chamfering of all of the teeth of the workpiece gear, and to stop the cutters in their return position.

8. In a machine for chamfering end edges of teeth of a workpiece gear, said machine comprising a spindle adapted to receive a workpiece gear leaving its teeth exposed at both of its end faces to the action of chamfering cutters and to locate the workpiece gear axially, a locating tapered finger adapted to be moved between two adjacent teeth of the workpiece gear to locate the same angularly and thereupon to be moved out therefrom, means to lock the workpiece gear on said spindle for rotation therewith, two swinging cutters adapted to operate simultaneously at both end faces of the workpiece gear to chamfer the teeth thereof, driving means for said cutters, said driving means comprising a continuously rotating main drive shaft, first intermediate shaft, a cam-and-follower means adapted to convert the continuous movement of said main drive shaft into intermittent movement of said first intermediate shaft, a second intermediate shaft arranged parallel to the first intermediate shaft, an interchangeable gear train connecting said intermediate shafts and providing for selectively changing the angular velocity of the second intermediate shaft, and a worm-and-gear mechanism connecting the workpiece gear receiving spindle with said second intermediate shaft to rotate said spindle intermittently to index the workpiece gear in time relation to the movements of the chamfering cutters.

9. In a machine for chamfering end edges of teeth of a workpiece gear, said machine comprising a rotatable articulated work spindle adapted to receive a workpiece gear and to hold it in a predetermined position along the axis of said spindle leaving its teeth at both of its end faces exposed in predetermined respective positions to the cutting path of chamfering cutters, stop means to locate the workpiece on said spindle in said predetermined position, an adjustable locating finger means for locating the workpiece gear angularly, with guide means providing for predetermined settings of said locating finger means both parallel and at right angle to the axis of said spindle, locking means to lock the workpiece gear to said work spindle for rotation therewith, two assemblies movable in and out of the respective operation positions at said spindle, each of said assemblies carrying a swinging cutter, one cutter to operate at one face end of the workpiece gear and the other to operate at the diagonally opposite face end thereof, adjustable stop means for said assemblies to locate the same and the cutters carried thereby in space relation to the workpiece gear both with respect to its position along the axis of said spindle as well as with respect to the distance from said axis as determined by the end edge of the workpiece gear tooth to be chamfered.

10. The machine defined in claim 9 and including interlocking circuitry to make operable the means to hold the workpiece in proper relationship to the predetermined path of the cutters passing through a predetermined cutting arc, said interlocking circuitry adapted to keep the machine in non-starting condition until the locating finger means has been retracted from said workpiece and putting the machine into starting condition after the retraction of said locating finger means, all in combination with the means for adjusting the locating finger means in relation to the axis of the workpiece.

References Cited by the Examiner

UNITED STATES PATENTS

2,150,313	3/1939	Bauer	90—1
2,668,480	2/1954	Christman	90—1.4
2,950,654	8/1960	Straw	90—1.4

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