Oct. 21, 1969 J. F. COOPER 3,473,267

GEAR-GENERATING MACHINE

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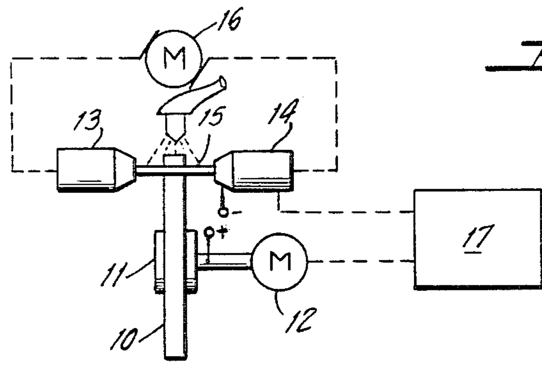

FIG. 1.

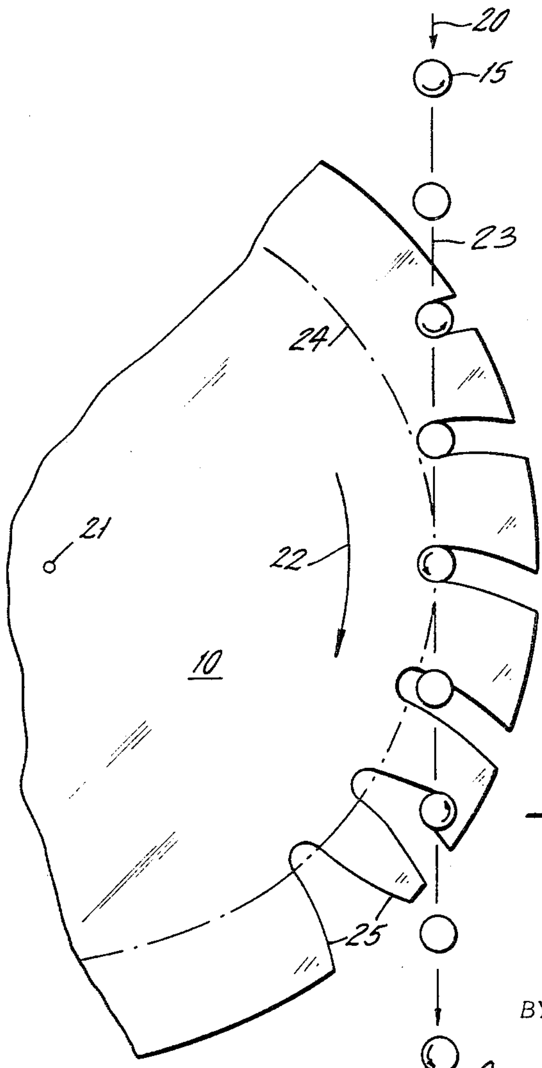

FIG. 2.

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FIG. 3

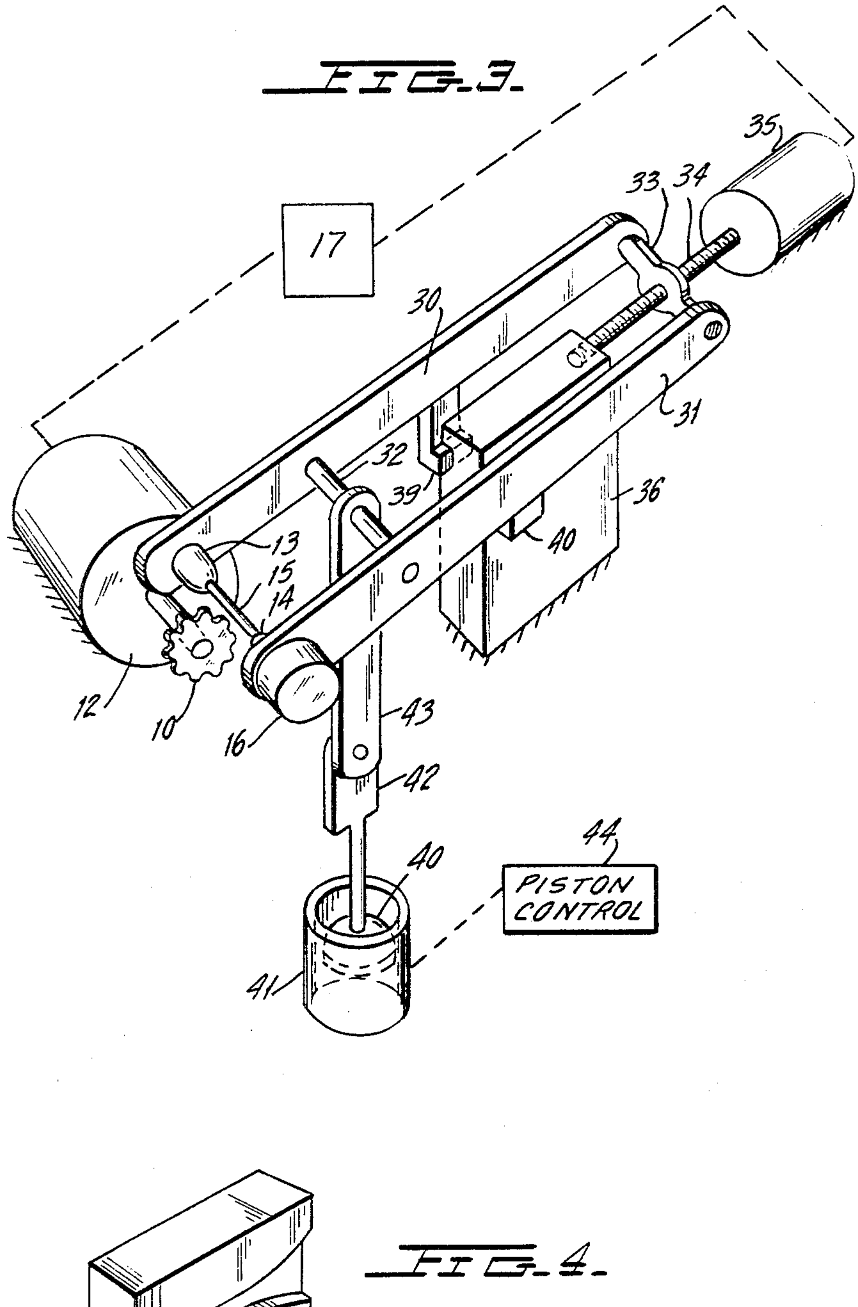
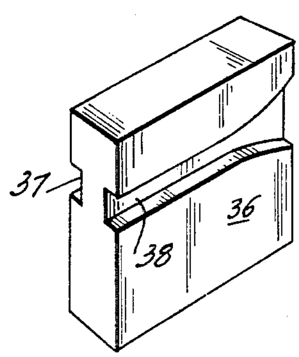


FIG. 4



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GEAR-GENERATING MACHINE

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Int. Cl. B24b *5/00, 1/00;* B23p *1/00*

U.S. Cl. 51—52 2 Claims

ABSTRACT OF THE DISCLOSURE

A gear tooth form is cut into a gear blank by an elongated cylindrical grinding element which is translated along a plane tangent to the base circle of the gear form which is to be cut into a gear blank. The gear blank is simultaneously rotated as the cylindrical grinding element translates into the outer periphery of the gear blank with the cylindrical grinding element being perpendicular to the plane of the gear blank. An electrolyte system can be used to incorporate electrolytic grinding techniques to assist in metal removal.

This application is a continuation-in-part of my copending application Ser. No. 244,394, filed Dec. 13, 1962, now abandoned, entitled "Gear Generating Machine," and assigned to the assignee of the present invention.

My invention relates to a novel arrangement for generating a gear-tooth profile in a gear blank, and more specifically relates to a novel machine for gear-tooth profile generation which uses principles taken directly from the involutometry of the spur gear.

In accordance with the novel invention, a tooth space is generated by a cylindrical grinding element which rotates about its axis which axis is parallel to the axis of a rotating gear blank when generating a spur gear. The cutting cylinder of the novel invention is made to address the work tangentially along a path coincident with the line of action of the gear which is ultimately formed. As the gear blank rotates, and the grinding element translates, the relationship between the movement of the grinding element and gear blank is that of the involute tracing point moving along the line of action as the base circle rotates. Thus, the path described through the gear blank by the grinding element is the involute to the base circle of the gear being generated.

Where desired, and in order to assist in the actual metal removal without placing an undue burden on the grinding element which would normally be a very thin grinding wire, the method is preferably adapted to use electrolytic grinding techniques wherein the grinding takes place in the environment of an electrolyte with an electrical current being conducted between the grinding element and the gear blank. In this process, the grinding element will remove approximately 10% of the metal by physical contact while the remaining 90% of the metal is removed by electrical erosion. Thus, the grinding element (and the tooth surface) carry only a fraction of the loads which would ordinarily be imposed under conventional grinding conditions.

The normal grinding technique described above will have very little effect on the surface and sub-surface crystalline structure of the tooth, and it has been found that cold working of the surface will be at an absolute minimum. Moreover, burrs will be reduced to a minimum because of the nature of electrolytic removal techniques which all but eliminates the need for brushing or other means for removing burrs. Thus, the tooth form will not be altered by deburring.

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Moreover, the electrolytic process permits grinding of non-ferrous metals such as aluminum or copper based alloys in addition to the steels. Furthermore, the surface finish produced by the novel grinding process will be extremely fine.

Where there are grind marks in this high finish, such marks will be parallel to the normal plane instead of transverse to the normal plane of the tooth, as in the case of conventional gear grinding, hobbing, and shaping, which will significantly improve the surface frictional characteristics of the gear and consequently the reliability of the gearing of which it will be a part.

While the novel machine of the invention is generally applicable to the formation of any gear tooth, it is particularly useful in that part of the fine pitch gearing range which would be of the order of 120 DP to 180 DP.

A typical grinding element for this type of gear will be a nickel-plated tungsten wire having a diameter of 0.002 inch which serves as a matrix which receives a very fine grit diamond abrasive. The wire is then tautly mounted between two spindles which are spaced about ⅛ of an inch from one another, and the spindles rotate the wire at high speed. By way of example, the spindles can rotate at 20,000 r.p.m.

The optimum feed and speed values will, of course, be a function of material being ground as well as the electrical characteristics of the system when the electrolytic removal techniques are used.

An accurate indexing device and stepping mechanism which would be apparent to those skilled in the art, will then provide the required movement of the grinding element and work piece. In operation, a single pass of the tool will produce one complete tooth profile (one side). Two passes may be required in order to make a space with the proper profile spacing (two adjacent profiles) depending upon the relationship between the diameter of the grinding wire and the required profile spacing. The device will be provided with means for indexing the gear blank through the required angular increment which will permit generation of the adjacent or exit profile at the required index location with respect to the first or entrant profile.

It has been found that in using the novel machine, a single tooth space in a 180 DP gear will be produced in approximately six seconds. Thus, a 180 DP gear having 220 teeth will be completely ground in 22 minutes and will be virtually burr free.

In order to increase production, it is possible to stack several blanks such as 3 or 4 blanks so that they will be ground together, the limitation on the number of blanks being determined by the mechanical characteristics of the grinding wire and the thickness of the blanks.

It will be obvious to those skilled in the art that the system can be fully automated to provide step-by-step grinding of succeeding teeth where the automation will not affect the accuracy of grinding of the teeth. Moreover, it is apparent that any desired variation in tooth form can be generated by merely changing the program or relationship between the speed of rotation of the gear blank and speed of traverse of the cutting tool. Indeed, any number of curves and variations thereof may be produced by appropriate programming.

Accordingly, a primary object of this invention is to provide a novel machine for accurately forming a gear tooth profile.

Another object of this invention is to provide a high speed machine for grinding gear teeth to a high order of accuracy and surface finish.

Still another object of this invention is to grind gear tooth profiles in a gear blank by means of a rotating elongated grinding element which moves with respect to a rotating gear blank and moves along the line of action of the gear to be cut.

These and other objects of this invention will become apparent from the following description when taken in connection with the drawings, in which:

FIGURE 1 schematically illustrates the cutting equipment and controls for cutting a gear tooth in accordance with the present invention.

FIGURE 2 schematically illustrates a cylindrical grinding element in nine successive positions with respect to a rotating gear blank and illustrates the progressively formed tooth space.

FIGURE 3 is a perspective diagram illustrating one mechanism for moving the cylindrical grinding element with respect to the rotating gear blank.

FIGURE 4 is a perspective view of the guide block used in FIGURE 3.

Referring now to FIGURE 1, I have illustrated therein a gear blank **10** (which could be several stacked gear blanks) which is carried by an appropriate clamping means **11** which is connected to a motor **12** which causes blank **10** to rotate about its axis of rotation.

A pair of spindles **13** and **14** then carry a wire **15** which serves as the cylindrical grinding element and could, for example, be a nickel-plated tungsten wire having a diameter of 0.002 inch which is embedded with a fine grit diamond abrasive. The wire may have a length of approximately ⅛ of an inch between spindles **13** and **14**.

The spindles **13** and **14** are connected to a motor **16** which causes the spindles to rotate wire **15** at high speed, the actual speed depending upon the nature of the material of blank **10**.

An indexing means **17** which can be of any desired construction then controls the speed of motor **12** to determine the rate of rotation of blank **10** and also controls the rate at which a mechanism (to be described immediately below) which carries spindles **13** and **14** will cause the spindles and thus wire **15** to traverse in a direction perpendicular to the plane of the drawing.

FIGURES 3 and 4 illustrate one mechanical embodiment for moving the cylindrical grinding element **15** with respect to the gear blank **10**. Referring to FIGURES 3 and 4, the blank **10** is illustrated as carried on the fixed motor **12** while the cylindrical grinding element **15** and its spindles **13** and **14** are rotatably carried at the end of spaced links **30** and **31**. The motor **16** is physically carried on link **31** and is directly connected to spindle **14** in order to cause rotation of the grinding element **15**. The two links **30** and **31** are held in spaced relation to one another by a fixed rod **32** and a rotatable member **33** which is pivotally supported to the rear of links **30** and **31** as illustrated and has a central threaded opening. The central threaded opening of member **33** receives a drive screw **34** which extends from drive motor **35**, whereupon rotation of screw **34** by motor **35** in one direction or the other will cause member **33** to translate along the axis of screw **34**, thereby to cause links **30** and **31** and thus grinding element **15** to move in a direction parallel to the axis of screw **34**, with the axis of grinder **15** always perpendicular to the plane of blank **10**. Note that motor **35** is a reversible motor, as will be described later.

A guide block **36**, which is suitably stationarily mounted, has opposing guide slots **37** and **38** on its opposing surfaces which receive guide fingers **39** and **40** which extends downwardly from links **30** and **31**, respectively. The guide slots **37** and **38** thus cause the accurate axial movement of links **30** and **31** over the range in which the spindle **15** is to engage the gear blank **10**.

Once the grinding element **15** has completed its cut and has progressed beyond the gear blank **10**, the members **39** and **40** clear the end of slots **37** and **38** and a lifting mechanism comprised of a piston **40** carried in cylinder **41** causes the links **30** and **31** to rotate upwardly, pivoting around rod **33** and the direction of rotation of motor **35** is reversed to cause the entire mechanism to retract. It will be noted that this lifting mechanism includes the links **42** and **43** which are pivotally connected to one another and are connected to the piston **40**, rod **32** respectively, where the connection between link **43** and rod **32** is a pivotal connection.

After the motor **35** has retracted links **30** and **31** and the guide members **39** and **40** have moved to the rear of guide block **36**, a suitable piston control **44** permits the dropping of links **30** and **31** such that members **39** and **40** can enter into the rear of slots **37** and **38**, shown in FIGURE 4, with the motor **35** again reversing in direction so that a new tooth form can be cut in blank **10**.

The manner in which the grinding element will operate is best understood from FIGURE 2 which shows the grinding wire **15** in nine successive positions. Thus, in FIGURE 2, the grinding wire **15** (which is shown rotating counterclockwise, as indicated by the arrows) is caused to traverse in the direction indicated by arrows **20** thus undergoing movement in a relative translational straight line manner with respect to the axis of the gear blank such that the axis of the grinding element passes through the gear blank. The gear blank **10** which has an axis of rotation **21** is caused to rotate in the direction shown by arrow **22**.

Accordingly, as the grinding element **15** advances to the third position from the top, it enters the gear blank, as shown, with the axis of rotation of wire **15** falling in the plane of the line of action **23** of the gear to be cut, which is tangent to the base circle **24** of that gear.

As the gear blank continues to rotate and the cylindrical grinding element continues to translate, the tooth space is eventually formed, as illustrated, with a tooth space **25** wherein both profiles of the tooth space are involutes of the base circle **24**.

In order to cut the next tooth, it is only necessary to reset the mechanism in a manner described above.

The system of the novel invention is particularly useful when the grinding is carried out in the atmosphere of an electrolyte with an electrical current being passed between the grinding element and the gear blank. By way of example, the ordinary coolant used in a grinding operation is replaced by a water solution of non-corrosive electrolytic salts, while an electrical power power supply is connected from the gear blank **10** to one of the spindles such as spindle **14** which is electrically connected to wire **15**, while spindle **13** is insulated from this electrical circuit.

Although this invention has been described with respect to its preferred embodiments, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred, therefore, that the scope of the invention be limited not by the specific disclosure herein, but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. A gear-generating device comprising support means for carrying a gear blank, grinding means comprising an elongated cylindrical grinding means rotatable about is own axis at high speed, means for rotating said gear blank about the axis of said gear blank, means for translated the axis of rotation of said cylindrical grinding means along a plane tangent to the base circle of a gear to be generated from said gear blank, and means horizontally mounting both said grinding means and said gear blank; said plane of translation of said grinding means intersecting a portion of said gear blank; said gear blank being rotated simultaneously with translating of said cylindrical grinding means when said cylindrical grinding means grinds said blank.

2. A device for machining a predetermined tooth space profile in a gear comprising first positioning means for rotating an elongated wire-like grinding element about a central length-wise axis thereof;

second positioning means for rotating a gear blank in a gear plane that intercepts the axis of said grinding elements;

third positioning means for producing relative movement between said first and second positioning means to effect relative translational straight line movement between the axis of said grinding element and the axis of said gear blank such that the axis of the grinding element passes through said gear blank in a plane that is tangent to a predetermined interior circular locus of the gear blank during said relative translational straight line movement;

and indexing means operably interengaged between said second and third positioning means for synchronizing rotational movement of said gear blank with said relative translational straight line movement for controlling the gear tooth space profile cut by said grinding element.

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51—287; 204—143