Aug. 29, 1939. H. SCHICHT 2,171,406

SPIRAL ROLLING GENERATING PROCESS FOR BEVEL GEARS AND APPARATUS THEREFOR

Filed March 19, 1937 3 Sheets-Sheet 1

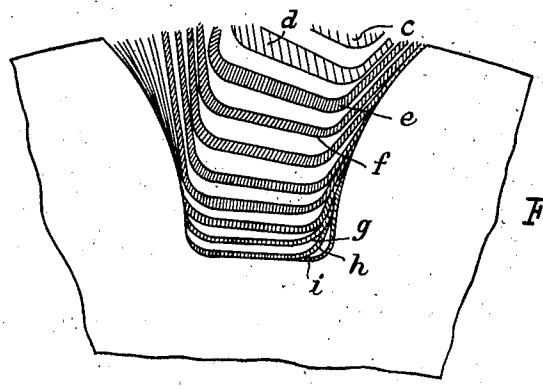


Fig.1

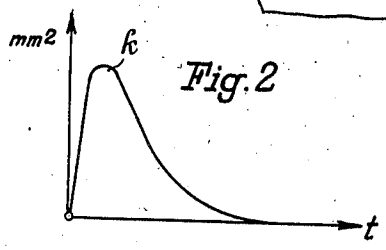
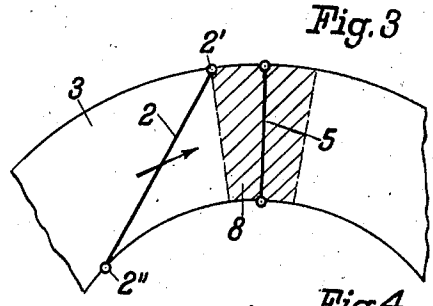


Fig.2

Fig.3



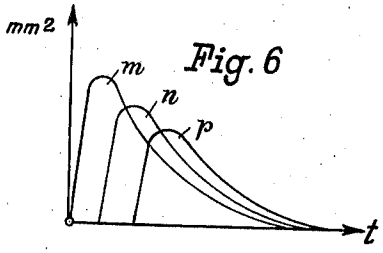


Fig.6

Fig.4

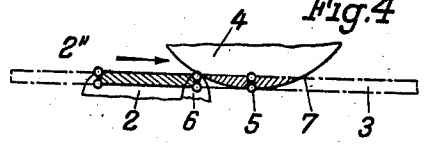


Fig.7

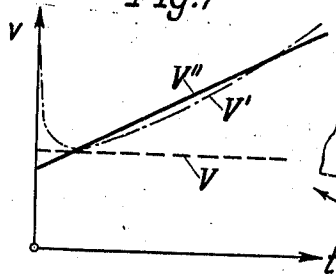
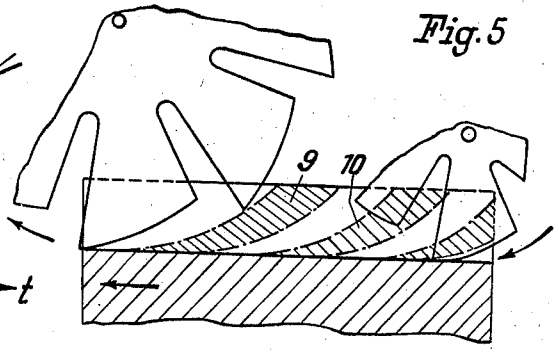


Fig.5



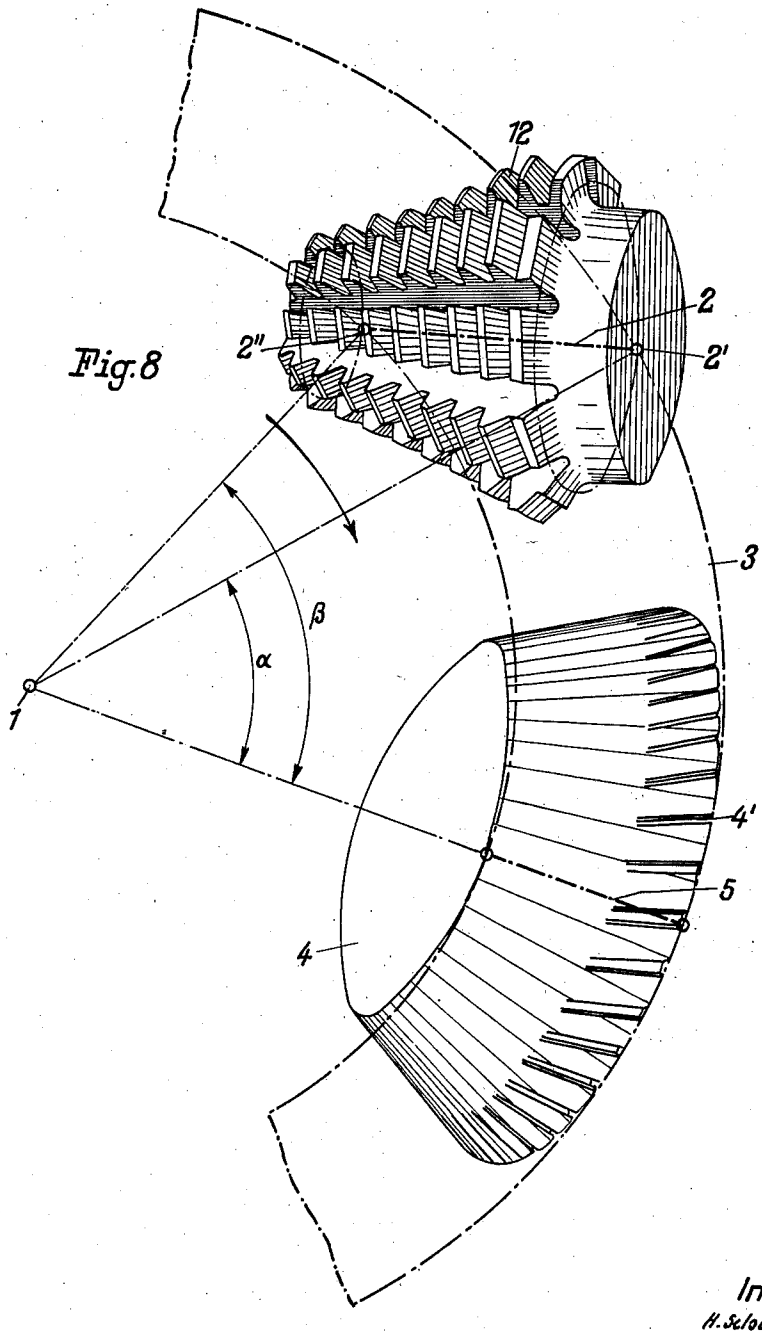
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Fig. 8



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SPIRAL ROLLING GENERATING PROCESS FOR BEVEL GEARS AND APPARATUS THEREFOR

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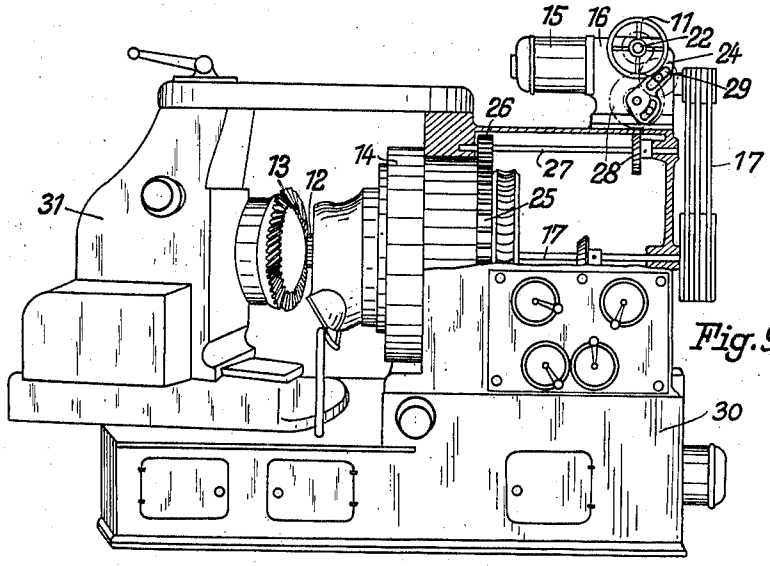
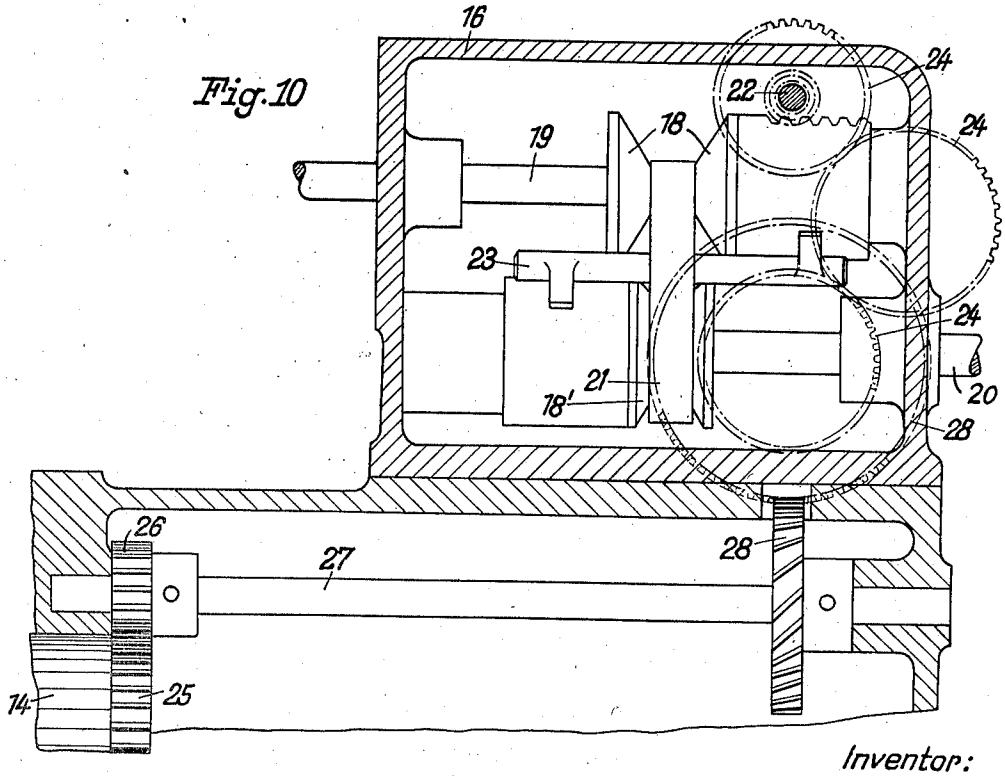


Fig. 9

Fig. 10



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UNITED STATES PATENT OFFICE

2,171,406

SPIRAL ROLLING GENERATING PROCESS FOR BEVEL GEARS AND APPARATUS THEREFOR

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Application March 19, 1937, Serial No. 131,920
In Germany March 24, 1936

8 Claims. (Cl. 90—5)

This invention relates to a process of generating bevel gears by a spiral rolling generating movement and to apparatus for carrying out this process. It is known in the prior art to produce bevel gears by a rolling generating movement utilizing a cutting tool in the form of a worm which meshes with the gear blank being generated, and which is oscillated about the axis of the imaginary crown gear during the generating movement.

Processes of generating gears according to this method are continuous and are characterized by great efficiency since the cutting operation takes place by progressive action from tooth to tooth. While spiral rolling generating processes have been materially improved, the theoretically possible maximum performance has not yet been accomplished. The reason for this is found in the fact that the possible cutting efficiency of the individual cutting points of the tool is not utilized to the utmost during the generating process.

The object of the present invention is to improve the efficiency of rolling generating processes in which the tool and the blank are subjected to relative movement transversely to the axis of the blank. This improvement is based principally on the fact that the load points of the individual cutting points of the tool are distributed over the entire cutting operation in such a way that a progressive increase in efficiency is possible without excessively increasing the load imposed upon any particular cutting point. In this way, a better distribution of the cutting performed by the individual cutting points may be obtained throughout the various stages of the generating process.

In carrying out this invention, it is proposed to subject the cutting tool to variable oscillatory motion about the axis of the imaginary crown gear, that is, the oscillatory movement is irregular in character and is varied in accordance with the extent of the cut which is being made by the cutting tool at any given instant. It is also proposed, according to the present invention, to change the number of revolutions of the tool in accordance with the variations in the oscillatory movement of the tool in such a way that the number of generating cuts increases or decreases with the changes in speed of oscillation.

The invention will be better understood when the following specification is read in connection with the accompanying drawings, in which embodiments of the invention are illustrated. In the drawings:

Figure 1 is a diagrammatic view showing the steps performed in generating a tooth by means of a spiral rolling cutter manipulated according to processes of the prior art;

Fig. 2 is a diagram showing the cutting performance of a single cutting point of a tool;

Fig. 3 is a diagram illustrating the character of the oscillatory movement to which a tool is subjected in accordance with this invention;

Fig. 4 is a view looking upward toward Fig. 3 in the plane of the paper;

Fig. 5 is a diagrammatic view illustrating the operation of a cutter having different end diameters;

Fig. 6 is a diagram showing the cutting performance of several cutting points of a tool operating in succession upon the work;

Fig. 7 is a graph in which tool velocity during the oscillatory movement of generating gear teeth by a spiral rolling process is plotted as a function of time;

Fig. 8 is a diagrammatic view illustrating the relation of the cutting tool and the blank in generating a gear in accordance with the present invention;

Fig. 9 is a view in front elevation of one form of machine for carrying out methods embodying this invention; and

Fig. 10 is a fragmentary vertical section showing on an enlarged scale the governing means of the machine shown in Fig. 9.

It is well known that in cutting gear teeth the cutting points of the tool operate in succession on the work to produce a dense network of cuts which develop a smooth flank after successive actions of the cutting points take place. Fig. 1 of the drawings indicates diagrammatically the approximate character of the cuts made by individual cutting points of a tool during the generation of a gear tooth according to rolling generating processes of the prior art in which the oscillatory movements of the tool take place at constant speed. It will be clear from this figure that the character of the individual cuts varies during the process of tooth formation, the first cut *c*, for example, being very small and the succeeding cuts *d*, *e* and *f* increasing in extent. The extent of these cuts increases to about the point *f* and during the intermediate cutting steps remains approximately constant, and then during the latter portion of the generating process the cuts decrease in extent as indicated at *g*, *h* and *i*.

This variation in extent of cut will be understood more clearly by reference to Fig. 2 of the drawings in which the depth of cut is plotted on the Y-axis against time plotted on the X-axis. From this graph, it will be clear that in general the depth of cut increases rapidly from zero to a maximum value at *k* and then decreases in value, at first rapidly, and then more slowly to the last stage of generation. This illustration of Fig. 2 explains the efficiency of the action of a single cutting tooth and emphasizes the fact that the efficiency is characterized by a decided lack of uniformity throughout the generating process.

As stated generally heretofore, the purpose of this invention is to increase the cutting efficiency of the individual teeth in order to speed up the generating process without in any way altering its degree of perfection. As used in the specification the term "cutting efficiency" may be defined as the ratio between the amount of cutting performed by the tool and the amount of cutting which the tool is capable of performing.

Figs. 3 and 4 of the drawings illustrate how the oscillatory motion of the tool takes place, while Fig. 8 illustrates the relation of the tool to the work during the generating process, and also indicates the relation of the tool and work to the imaginary crown gear.

Referring to Fig. 8 of the drawings, the reference character **1** designates the axis of the imaginary crown gear, the pitch plane of which is designated **3**. The cutting tool is illustrated as of conical form having different end diameters each indicated by dot-dash lines placed in coincidence with the pitch surface of the series of teeth at the two ends of the tool. It will be seen that the pitch mantle line **2** of the tool contacts with the pitch plane of the crown gear and that the blank **4** being generated also has its mantle line **5** in the pitch plane of the crown gear. The term "pitch mantle line" used in this specification is synonymous with the term "pitch line" and designates a line drawn through the pitch points of successive teeth of a hob or gear longitudinally of the body. If the body were rotated on its axis this line would generate a pitch cone with a conical hob or a pitch circle with a cylindrical hob. In the illustration of Fig. 8, the pitch mantle line of the wheel blank or work **4** is radially directed toward the crown gear center **1**. However, it is to be understood that if hypoid gears are being generated, the pitch mantle line will not be in coincidence with a radius of the crown gear. The mantle line **2** of the cutter or tool is tangent to a circle described about the crown gear center **1** and lies proportionately close to the inside diameter of the crown gear. As a result of this, the two final points **2'** and **2''** of the pitch mantle line **2** of the cutter are not equi-distant from the pitch mantle line **5** of the blank. The point **2'** makes an angle α with an extension of the mantle line **5** of the blank whereas the point **2''** makes an angle β with the line **5**. In consequence of this, individual points on the pitch mantle line of the cutter, as the cutter oscillates about the crown gear center, do not pass through the pitch mantle line **5** simultaneously, but in succession, the point **2'** being the first to intersect and the point **2''** the last to intersect the line **5**. Consequently, not only do the cutter teeth come into action successively but, in the example illustrated, the teeth at the large diameter of the cutter engage the blank first and the teeth at the small diameter of the cutter engage it last. The sequence of contact between the cutter and the blank could be reversed by oscillating the cutter with its small end in advance instead of its large end.

In cutting gear teeth in the manner illustrated in Fig. 8, the cutting points of the tool do not come into initial contact with the work at the moment when the mantle line of the tool intersects the mantle line of the wheel blank. This is illustrated in Fig. 4 of the drawings, wherein the relation of the blank to the blank pitch line and the cutter pitch line is indicated diagrammatically, using the same reference characters as those of Fig. 8. It will be seen from Fig. 4 that contact between the cutting points of the tool and the work begins at the moment when the first cutter tooth touches the mantle of the wheel blank at the head end indicated **6**, and ends when the last cutter tooth **2''** reaches the point **7**. As a consequence of this engagement, the generating process is carried out over the area of contact indicated **8** in Fig. 3 of the drawings.

The individual teeth of the cutter have variable cutting efficiencies and the amount of their cutting decreases as their line of contact with the work approaches the crown gear center. The reason for this is that the teeth lying nearer to the center of the crown gear contact over a part of their lengths with the tooth spaces which have already been previously cut by the teeth lying further outside on the cutter. As indicated in Fig. 8, the teeth first cut at the larger diameter of the blank 4. The spaces 4' are cut first and are then cut through to the tooth spaces extending over the full breadth of rim of the blank. The difference in cutting efficiency of different teeth becomes particularly great in the case of a cutting tool having different diameters at the two ends. Under such conditions the working efficiency of the teeth at the large diameter is greater than of those at the small diameter because the teeth at the large diameter end describe a larger cutting orbit than the teeth at the smaller end. The smaller the diameter in which the teeth lie, the smaller the cutting orbit. This is illustrated in Fig. 5 of the drawings in which the areas are section-lined to indicate the transverse sections which are contacted by teeth of variable orbits. In this view, the area **9** is greater than the area **10**, the area **10** being contacted by teeth of the smaller orbit.

The sequence in which the cutting points come into contact with the work is plotted in Fig. 6 of the drawings, in which the depths of the cut of the individual teeth are plotted against time for three cutting points. The three curves *m*, *n* and *p* represent the rate of cutting performed by teeth on a conical hob of the character shown in Fig. 8, the curve *m* being for a tooth near the larger end of the hob, and the succeeding curves *n* and *p* being teeth successively nearer to the smaller end of the hob. Reference to this figure shows clearly that the efficiency of the teeth varies from one to another as indicated by the varying heights of the curves *m*, *n* and *p*. In this figure, characters *m*, *n* and *p* designate the transverse sections which are cut by the particular teeth plotted.

In Fig. 7 of the drawings, the velocities of oscillatory movement of the tool about the crown gear axis are plotted as ordinates against the X-axis indicating time. It will be seen at once,

by referring to the line V indicating uniform velocity of oscillation, that the cutting efficiency of all of the teeth of the tool cannot be utilized satisfactorily in this manner. On the other hand, the efficiency of the cutting can be improved considerably if the oscillatory motion of the tool is not uniform. If, for example, the cuts shown in the diagram of Fig. 6 were commenced at a higher velocity of oscillation according to the curve V' of Fig. 7, and then this velocity decreased rapidly and accelerated again up to the conclusion of the working process, the cutting efficiency of the tool would be materially increased. On the other hand, however, it may be advisable to obtain simpler ratios of motion and to preserve the tool at the first cutting by subjecting the tool to uniform acceleration indicated by the solid black line V'' in Fig. 7.

In order to secure the full advantage of accelerated feed of the cutting tool, it is expedient to change the number of revolutions of the cutter in such a way that the number of generating cuts and also the lengths which are worked at higher speeds, is not smaller than on the lengths of the preliminary working stages. This regulation is particularly effective in working with a tool having different end diameters, because in spite of the increase in the number of generating cuts, which take place toward the end of the work process, uniform cutting velocity is obtained throughout the entire process. This is in marked contrast to known methods in which the cutting velocity of the tool decreases toward the end of the process, and in which the number of generating cuts remains constant, for in addition to the number of revolutions of the tool, this is also dependent on the number of teeth in each turn of the tool which, in the case of the tools employed, are uniform at the large and small diameter ends.

Figs. 9 and 10 of the drawings illustrate one type of machine which is suitable for carrying out processes embodying the present invention. As shown in Fig. 9, the frame 30 of the machine carries a rotatable support 31 upon which the work blank 13 may be mounted and subjected to rotation. Also mounted upon the base 30 is an oscillatable face-plate 14 which permits the tool 12 to be subjected to oscillatory movement with respect to the blank 13, and at the same time to cause rotation of the tool about its own axis. The drive for rotating the tool 12 and the face-plate 14 may be carried out by any suitable means here illustrated as an electric motor 15 cooperating with a revolution governor and including a belt drive 17. The governing mechanism is designated generally by reference character 16 as mechanical in form. It is, however, to be understood that various other types of governor may be utilized be they hydraulic or electric.

The details of the governing mechanism are illustrated more clearly in Fig. 10 of the drawings, in which the governor 16 is shown as carried within a housing including a drive shaft 19 connected to the motor 15 and having mounted on it axially displaceable conical discs 18. Also rotatably mounted in the governor housing is a second shaft 20 in displaced parallel relation to the main drive shaft 19 and carrying a second pair of axially displaceable conical disks 18'. The two pairs of discs are enclosed by a ring 21 which transmits the rotating movement from the driving shaft 19 to the driven shaft 20. The axial distance between the two discs of each pair can be changed by rotating a shaft 22 by means of a hand-wheel 11. By moving the discs of one pair close together, limited movement of the discs of the other pair is brought about through the coupling member 23. In this way, the effective diameter of the conical discs is altered and, consequently, the number of revolutions of the driven shaft 20 may be altered. Control of the number of revolutions imparted to the driven shaft 20 may be carried out not only by the hand-wheel 11 shown in Fig. 9, but also mechanically through the gears 24.

Mechanical control for actuating the gears 24 is transmitted from the face-plate 14 through a ring gear 25 which it carries and a cooperating gear 26 mounted on shaft 27. Gears 28, one of which is mounted on shaft 27, transmit the connection to the gears 24. It will be understood that the particular size of gears shown is not essential and that the pair of gears 28 may be changed to vary the number of revolutions imparted as occasion demands.

In the machine illustrated, alteration of the velocity of the oscillatory movement of the face-plate 14 is carried out in proportion to the change in the number of revolutions of the tool. If the face-plate is brought back to its starting position by putting the return stroke mechanism in operation when a gear is finished, the revolution governor automatically adjusts itself again to the initial number of revolutions. The return stroke motion is accelerated and for this purpose a special drive may be provided, although it is feasible to employ the revolution governor for accomplishing this purpose.

It will be understood that the invention is not limited to the specific examples described. Variations and modifications within the scope of the appended claims may be carried out without departing from the spirit and scope of the invention. For example, separate speed governors could be provided for the feed and for controlling the cutting velocity of the tool. Likewise, the control of the governor could be carried out by a curve slide or similar apparatus instead of a rim gear wheel. Although the invention is illustrated in connection with the generation of bevel gears, it may find application for the generation of spur gears and screw gears. In this case, the ring gear wheel 15 of the face-plate would be replaced by a gear rack fixed to the table carrying the tool or the work.

What is claimed is:

1. The method of generating bevel gears by a continuous rolling generating movement between a cutting tool having different end diameters and a gear blank, which comprises bringing the rotating tool into contact with a rotating blank, subjecting the tool to oscillatory movement about the axis of the imaginary crown gear, and varying the speed of tool oscillation in accordance with the progress of the cutting operation to produce a uniform rate of cut throughout the generating process.

2. The method of generating bevel gears by a continuous rolling generating movement between a cutting tool having different end diameters and a gear blank, which comprises bringing the rotating tool into contact with a rotating blank, subjecting the tool to variable oscillatory movement about the axis of the imaginary crown gear, and then varying the number of tool revolutions in proportion to the change in velocity of the tool during its oscillatory movement to produce

a uniform rate of cut throughout the generating process.

3. In a machine for generating spiral bevel gears by a continuous process; a work support; work rotating means on said support; a tool support; means for rotating said tool about its axis; means for oscillating said tool about the axis of the imaginary crown gear; and means controlled by the rate of tool rotation for varying the speed of movement of said oscillating means.

4. In a machine for generating spiral bevel gears by a continuous rolling process; a work support; work rotating means; a tool support; means for rotating said tool on its support; means for oscillating said tool support about the axis of the imaginary crown gear; and means controlled by the tool rotation for varying the speed of movement of said oscillating means in accordance with the rate of rotation of the tool.

5. In a machine for generating spiral bevel gears by a continuous process; a work support; work rotating means on said support; a tool support; means for rotating said tool about the axis of the imaginary crown gear; and means responsive to changes in the rate of cutting of said tool for controlling the rate of movement of said oscillating means.

6. The method of generating gears by a continuous rolling generating movement between a rotating cutting tool and a gear blank, which comprises bringing the rotating tool into contact with a rotating blank, subjecting the tool to oscillatory movement about the axis of the imaginary crown gear, and varying the speed of tool oscillation in direct accordance with the instantaneous character of the cutting operation to produce a uniform rate of cut throughout the generating process.

7. The method of generating bevel gears by a continuous rolling generating movement between a cutting tool and a gear blank, which comprises bringing the rotating rool into contact with a rotating blank, subjecting the tool to oscillatory movement about the axis of the imaginary crown gear, and increasing the rate of oscillatory movement and the rate of tool rotation as the generating process approaches completion.

8. In a machine for generating bevel gears, a frame; a rotatable work support on said frame; a tool support operatively associated with said work support; means for rotating said tool about its axis; means for subjecting said tool support to oscillatory movement about the axis of the imaginary crown gear at variable rates; and means for automatically increasing the speed of oscillatory movement of the tool as the generating process approaches completion.

HEINRICH SCHICHT.