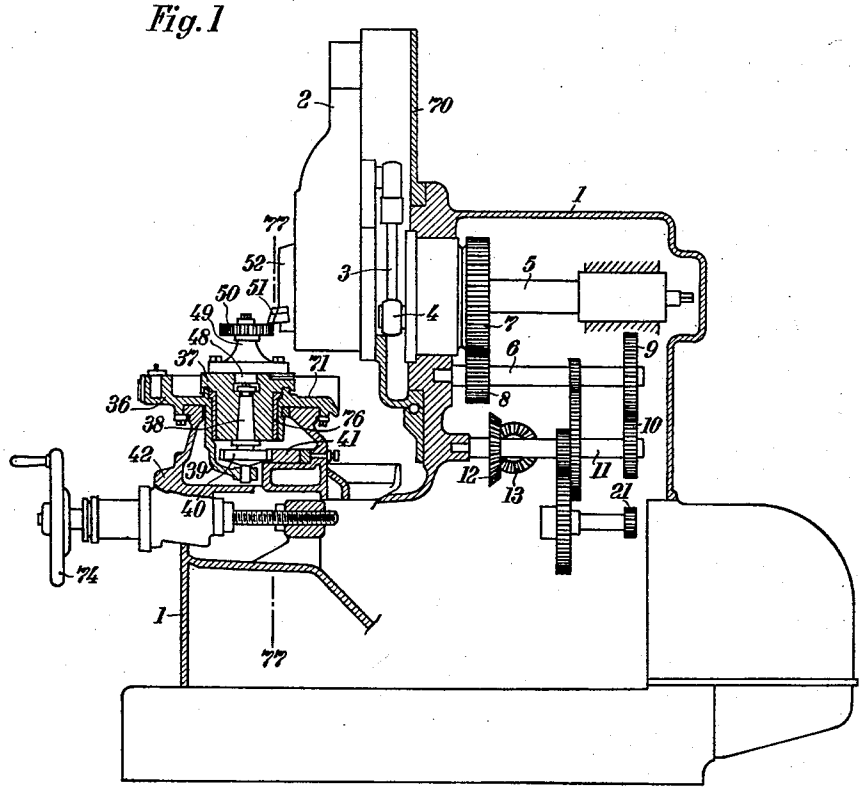
Sept. 9, 1941. A. AEPPLI 2,255,094

GEAR CUTTING MACHINE

Filed Nov. 7, 1938 3 Sheets-Sheet 1

Fig. 1



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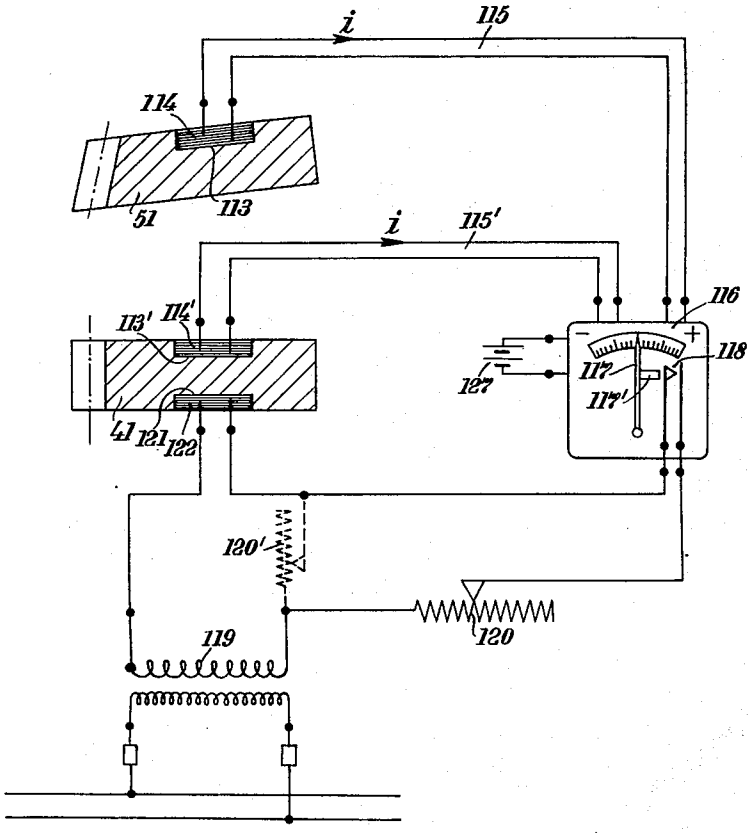
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GEAR CUTTING MACHINE

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Fig. 2



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GEAR CUTTING MACHINE

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Fig. 3

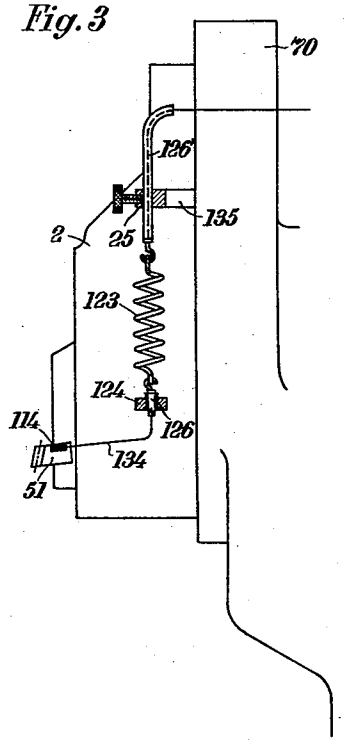


Fig. 4

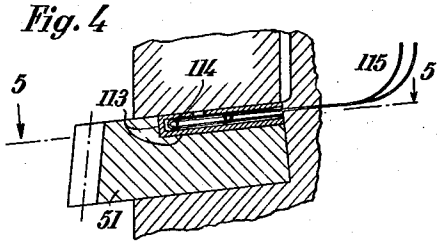


Fig. 5

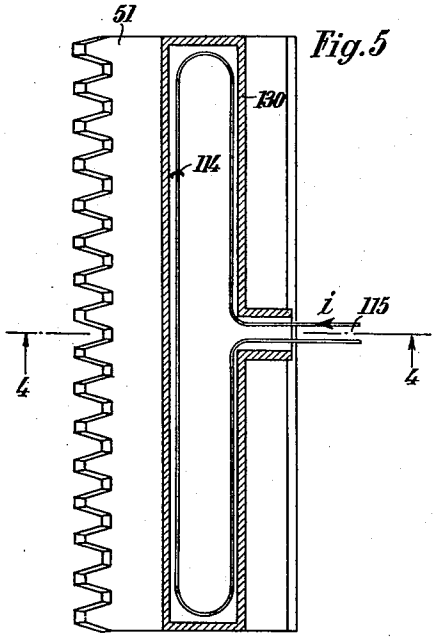


Fig. 6

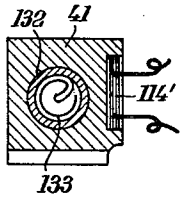
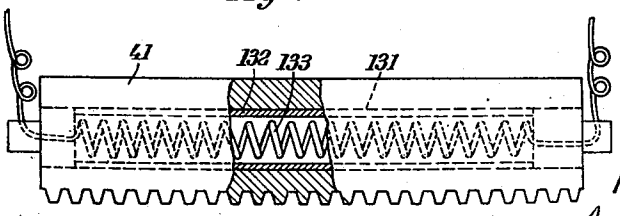


Fig. 7



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Patented Sept. 9, 1941 2,255,094

UNITED STATES PATENT OFFICE

2,255,094

GEAR CUTTING MACHINE

Albert Aeppli, Zurich, Switzerland, assignor to Maag-Zahnräder und-Maschinen A. G., Zurich, Switzerland

Application November 7, 1938, Serial No. 239,198
In Germany November 9, 1937

6 Claims. (Cl. 90—8)

My invention relates to a gear cutting machine and to an improved method of operating the same. More particularly, my invention is concerned with a gear shaping machine having a tool of rack form and operating on the rolling principle.

In machines of this type, the accuracy of operation and of the product obtained is liable to be adversely affected by heat expansion of the tool. This applies particularly to machines where the tool has a length not less than the circumference of the blank thus cutting all of the teeth of the blank in a single rolling cycle without requiring any intervening indexing motion.

The object of my invention is to provide a method of operating gear cutting machines in which improved accuracy of operation is secured by eliminating the influence of heat expansions of the tool.

Another object is to provide an improved machine in which the difference between the temperatures of the tool and of the rolling elements producing the rolling motion is kept substantially constant.

I attain these and other objects of my invention by measuring the thermal conditions of the tool and of the rolling mechanism and by so controlling the temperature of the latter as to keep the heat expansions of the tool and the rolling mechanism substantially equal.

My improved method and a machine capable of carrying out the same will be described hereinafter by reference to the drawings in which a preferred embodiment of the machine is illustrated.

In the drawings,

Fig. 1 is a side view of the machine partly in section;

Fig. 2 shows cross-sections through the tool and through one of the rolling elements and the coordinated circuit arrangement;

Fig. 3 is a portion of Fig. 1 showing elements not illustrated therein;

Fig. 4 is a partial cross-section through the tool holder and the tool inserted therein taken along line 4—4 of Fig. 5; and

Fig. 5 is the section taken along line 5—5 of Fig. 4;

Fig. 6 is a cross-section through a modified form of the rack; and

Fig. 7 a plan view of this rack partly shown in section.

In the machine shown in Fig. 1, a tool is used the length of which corresponds to the pitch circle circumference of the blank, the tool cutting all of the teeth on the blank in the course of a single uninterrupted rolling cycle of the blank. In this regard the machine differs from machines using a rack-shaped tool of a shorter length in which the tool must be withdrawn and the blank must be indexed whenever one or several teeth have been completely cut.

The rolling motion is preferably produced by a rack of a length equal to the length of the tool. A master gear coaxially connected to and rotatable with the blank rolls along this rack thus producing the required relative rolling motion between the blank and the tool.

The accuracy of the teeth to be cut depends largely on the exact agreement in length between the tool and the rack. This exact agreement is required in order that the entire circumference of the work piece will have been properly operated upon when the master gear has completed one revolution in rolling along the rack. The tool, however, is liable to expand in operation owing to the heat produced in the cutting operation and to become longer than the rack. If this happens, the spacing of the first tooth flank cut into the blank from the last tooth flank will be too small; thus, the tooth pitch will become inaccurate. It is the object of my invention to avoid such inaccuracy, and I attain this object by expanding the rack in accordance with the expansion of the tool.

While I wish it to be understood that my invention is applicable to any gear cutting machine of the type in which the tool and the blank perform a relative rolling motion, I shall describe it hereinafter as applied to the machine shown in Fig. 1.

The bed 1 of this machine is provided with an upright having a swivel member 10 rotatable about a horizontal axis and provided with a guide extending in a vertical plane. On this guide there is slidingly mounted a ram 2 carrying a tool 51 of the rack-shaped type. The ram is reciprocated by means of a connection rod 3 and a crank 4 of the shaft 5. The shaft 5 is driven through gears 7, 8, 9, 10 which are fixed on the crank shaft 5 and two parallel gear shafts 6, 11 respectively. Moreover, on the shaft 11 there is fastened a bevel gear 12 meshing with bevel gear 13 fixed on a drive shaft. A second drive serving to produce the rolling motion is derived from shaft 6 and is operative to impart a reciprocating motion to a slide 36 carrying the blank. This slide 36 is movable on longitudinal guides 71 which are provided on the support 42 and extend horizontally at right angles to the crank shaft 5.

The slide 36 is provided with a vertical bearing 76 having a comparatively large diameter for a purpose to be explained hereinafter. In this bearing, there is journalled a circular bearing member 37 constituting a rotary work table or work spindle. This member has a conical bore accommodating a mandrel 38 fixed therein. The downwardly projecting cylindrical end of this mandrel is journalled in a depending portion 39 of the slide 36. On the mandrel there is fixed a master spur gear 40 engaging a rack tool 41. This rack and the rack 51 are located within a common plane indicated by the dotted line 77 which extends parallel to the axis of the work spindle 37 and is preferably vertically disposed. This is the plane in which the tool 51 performs its reciprocating cutting motion relative to the work spindle 37, while the slide 36 moves in a direction parallel to the tool 51 causing the master gear 40 to roll along the rack 41, whereby the blank 50 is revolved.

For a more detailed description of the machine reference may be had to the application of Georg Fischer Ser. No. 226,415 filed on August 24, 1938.

Let us assume that z' represents the number of teeth of the master gear 40 connected to and rotatable with the blank 50; t' the pitch of the master gear 40 and of the coordinated rack 41; z the number of teeth of the gear to be cut; t_R the proper pitch of the gear to be cut and t_w the pitch of the tool 51. Then the following equations result:

$$(1)\quad z \cdot t_R = z \cdot t_w = z' \cdot t'$$

$$(2)\quad t_w = \frac{z'}{z} \cdot t'$$

Since the ratio

$$\frac{z'}{z}$$

is constant, I obtain the following equation:

$$(3)\quad t_w = k \cdot t'$$

When the heat produced in the cutting operation raises the temperature of the tool 51 so that the latter expands and becomes longer than the rack 41, this equation (3) is no longer complied with and the pitch of the work piece produced will become inaccurate. I avoid this disadvantage by expanding, by application of heat, the rack 41 to cause the rack to expand to the same extent as the tool 51. As a matter of principle, it is immaterial if the temperatures of the two racks are the same or are different provided that the equation (3) is complied with.

In order to carry out my improved process I provide the tool 51 (Figures 3, 4 and 5) with a recess 113 extending the entire length of the tool. This recess 113 accommodates a thermometric element 114 which is preferably formed by a heat-conductive ribbon of a material the electrical resistance of which varies considerably when the temperature changes. Similarly, the rack 41 (Figs. 2 and 6) is provided with a recess 113' accommodating a thermometric element 114'. The terminals of the two elements are connected by suitable conductors 115 and 115' with a source of current 127 of constant voltage e. A measuring instrument 116 interposed between the source of current 127 and the conductors 115 and 115' is responsive to the difference of the currents flowing through the thermometric elements 114 and 114'. As instruments of this type are well known in the art, a detailed description thereof need not be given herein. As the resistance of each of the two elements 114, 114' amounts to $r = r_0(1+\alpha t)$ and thus is proportional to the temperature t, the currents amount to

$$i = \frac{e}{r} = \frac{k}{1+\alpha t}$$

Therefore, the currents depend on the temperature of the elements.

A second recess 121 provided in the rack 41 accommodates an electrical heating element 122. This heating element is connected to the output terminals of a transformer 119, the input terminals of which are connected with a source of alternating current. Within the circuit of the heating element 122 there is included an interrupter 118 which is normally opened but may be closed by engagement of a stop 117' therewith attached to the indicating hand 117 of the instrument 116. Preferably, an adjustable resistance 120 is included in the heating circuit.

The operation is as follows: When the temperature of the tool 51 rises owing to the generation of heat by the cutting process, the resistance of the element 114 is increased, whereby the current flowing through the conductors 115 tends to decrease. At the same time, the current flowing through the conductors 115' tends to remain constant. Therefore, the hand 117 will move towards the right thus closing the circuit of the heating element 122 through the contact 118. The current thereby supplied to the heating element 122 raises the temperature of the rack 41 until the resistance of the element 114' increases to the same extent as the resistance 114 with the result that the current flowing through the conductor 115' decreases until the hand 117 moves to the left disengaging and permitting the contact 118 to move to circuit opening position and thus interrupting the circuit of the heating element 122.

The contact 118 is adjustable towards and away from the stop 117'.

Owing to the control of the heating circuit by the thermometric elements 114 and 114', so much heat is applied to the rack 41 as is required to effect expansion of the rack equal to the expansion of the tool 51. The function is entirely automatic and maintains the rack 41 and the tool 51 substantially at the same temperature.

As shown in Fig. 5, the recess 113 of the tool 51 is preferably provided with an insulating lining 130 in which the resistance 114 is embedded.

In Figs. 6 and 7, I have illustrated a preferred form of the rack 41. This rack is provided with a longitudinal bore 131 extending through the entire length thereof. This bore is provided with an insulating lining 132 within which a heating coil 133 is embedded. This design has the advantage of a more uniform distribution of the heat through the entire rack.

As the rack 41 is stationary in operation, the supply of current thereto does not offer any difficulties. Special means are required, however, to supply current to the thermometric element associated with the tool 51 as this is mounted on the reciprocating ram 2.

In Fig. 3 the current supplying means used for this purpose are illustrated. One terminal of the thermometric element 114 is connected by a conductor 134 to a hook 126 which is adjustably mounted in a bracket 124 attached to the ram 2. This hook is connected by a metallic helical spring 123 with a member 126' which is adjustably mounted in a bracket 135 attached to the swivel member 70. The other terminal of the thermometric element 114 and one terminal of

the source of current are preferably grounded in the material of the machine which completes the electric circuits. The brackets 124 and 135 are made of insulating material. When the ram reciprocates up and down, the spring 123 is expanded and contracted accordingly. The member 126' may be adjusted in accordance with the stroke of the ram.

As shown in Fig. 2, I may shunt an adjustable resistance 120' across the resistance 120 and the interrupter 118. This resistance 120' permits a constant amount of current to be supplied to the heating element 122 so that the surplus of heat only need be regulated by the instrument 116.

If for some reason or the other, the tool 51 should have at normal temperature a length less than that required for accurate operation or, in other words, if the rack 41 should be too long, the contact 118 is so adjusted as to be opened only when the tool has reached a certain temperature above normal. In the event the rack 41 should be too short, the contact 118 is so adjusted as to be normally closed and not opened until the rack 41 has attained a temperature above normal. In this event, the resistance 120' may be so adjusted as to keep the rack 41 substantially at the required temperature.

The lengths of the tool 51 and the rack 41 are preferably measured by measuring the pitch of a work piece cut by the machine. On the basis of measurement the interrupter 118 and the resistances 120 and 120' may be adjusted to meet the requirements.

In the process above described, the rack 41 only is heated while the master gear 40 remains a little cooler. This will cause a definite even though very small difference between the tooth pitches of the master gear and the rack. This difference, however, has no influence on the accuracy of the gear to be cut since the master gear always performs one complete revolution after all of its teeth will have been brought to engagement with the rack succesively, the length of the rolling path $z' \cdot t'$ equalling the length $z \cdot t_w$ of the tool.

Preferably, the adjustment of the rack 41 towards and away from the master gear 40 by suitable means (not described) may be accomplished after the gear has been warmed up into its average operating temperature by a suitable adjustment of the resistance 120'.

My invention is not restricted to the embodiment thereof described hereinabove. Other rolling elements may be used instead of the rack 51 and the master gear 40. Also, other heating and measuring means may be used than electrical resistances. Instead of determining the temperatures of the tool 51 and the rack 41, I may measure the conditions thereof by determining their relative lengths by suitable measuring instruments and may control the application of heat to the rack 41 in dependence on any difference in lengths.

Also, the tool 51 could be maintained at a predetermined operating temperature above that of the rack 41 by controlled application of heat. In this event, the tool 51 would be made so much shorter than the rack 41 as to expand to the same length upon being heated to its operating temperature.

Further possible modifications will be readily apparent to anyone skilled in the art. Therefore, my invention is not limited to the details thereof hereinabove described but is to be broadly interpreted in accordance with the appended claims.

What I claim is:

1. A gear cutting machine which comprises a blank holder, a cutting tool, means including an element rotatable with the blank adapted to have rolling movement relative to a member coextensive with said tool and cause said blank to have rolling motion relative to said tool, thermometric elements coordinated to said tool and said element, a heating element associated with said rotatable element, and means governed by said thermometric elements and controlling said heating element, whereby inaccuracies owing to heat expansion of said tool are compensated by expansion of the rotatable element.

2. A gear shaping machine operating on the rolling principle which comprises a blank holder, a gear connected thereto, a rack meshing with said gear, a rack-shaped tool, means causing said gear and blank to have rolling movement relative to said rack and tool, thermometric elements coordinated to said tool and said rack, a heating element associated with said rack and means controlled by said thermometric elements and regulating said heating elements so as to maintain a constant differential between the temperatures of said tool and said rack.

3. A gear shaping machine operating on the rolling principle which comprises a blank holder, a gear connected thereto, a rack engaging said gear and having a longitudinal bore, a rack-shaped tool, means causing said gear and said rack to perform a relative rolling motion, thermometric elements associated with said tool and said rack, an electrical heating element provided within the bore of said rack, and means governed by said thermometric elements and controlling said heating element so as to maintain the difference between the temperatures of said tool and said rack constant.

4. In a machine for shaping spur gears, the combination comprising a tool of the rack-type, a rack located in a common plane with said tool and coextensive therewith, a slide adapted to move parallel to said rack, a work spindle journalled in said slide and extending parallel to said plane, a spur gear attached to said work spindle and meshing with said rack, said tool having a length not less than the circumference of said spur gear, means for producing a relative reciprocatory cutting motion between said tool and said work spindle within said plane, thermometric measuring elements associated with said tool and said rack, and a heating element coordinated to said rack and controlled by said thermometric elements so as to maintain the difference between the temperatures of said tool and said rack constant.

5. In a machine for shaping spur gears, the combination comprising a support provided with a guide, a rack mounted on said support extending parallel to said guide, a longitudinal slide movably mounted on said guide, a work spindle journalled in said slide and extending transversely to said rack, a spur gear mounted on said work spindle in engagement with said rack, whereby said work spindle will be rotated upon movement of said slide, a shaping tool of the rack-type extending within a plane parallel to said rack and said work spindle and having a length not less than the circumference of said spur gear, a second guide extending parallel to said plane, a reciprocatory ram mounted on said guide and carrying said tool, a thermometric electrical measuring element associated with said tool, means conducting current through said

measuring element including a helical spring extending between a point of said ram and said support, a thermometric measuring element and an electrical heating element both associated with said rack, an interrupter controlling said heating element, and means governed by said thermometric elements and controlling said heating element so as to maintain the difference between the temperatures of said tool and said rack constant.

6. A gear cutting machine which comprises a blank holder, a cutting tool, means including a rolling element coextensive with said tool and causing said blank holder and said tool to perform a relative rolling motion, said cutting tool having at normal temperature a length less than that required for accurate operation, and heat controlling means adapted during the cutting operation to maintain the temperature of said tool at a substantially constant level above the temperature of said rolling element so as to compensate by heat expansion for the normal shortage in length of said tool.

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