July 20, 1965 K. A. WULF 3,196,244

INDUCTOR FOR THE SURFACE HEATING OF GEAR WHEELS

Filed Dec. 20, 1962 2 Sheets-Sheet 1

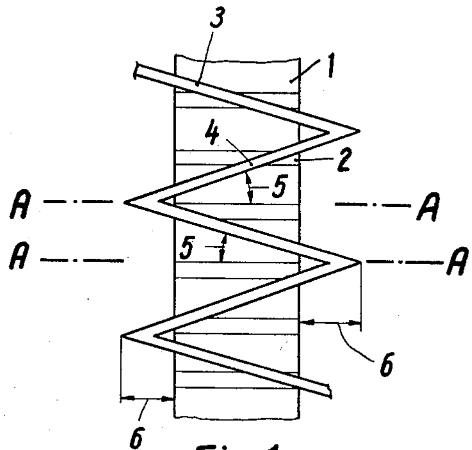

Fig.1

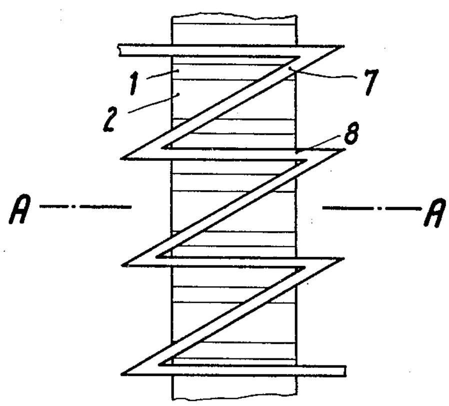

Fig.2

Karl Adolf Wulf
Inventor:

By Cushman, Darby & Cushman
Attorneys

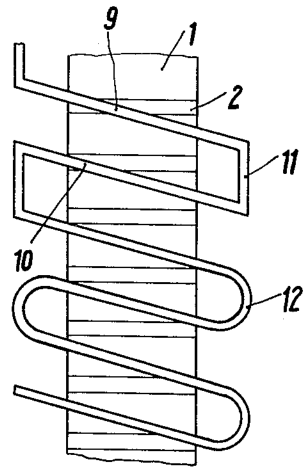

Fig.3

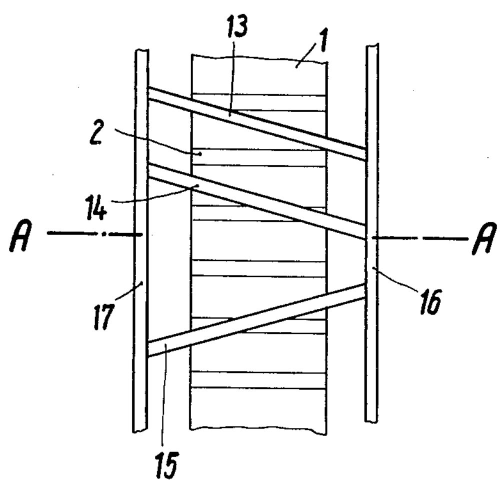

Fig.4

Karl Adolf Wulf
Inventor:
By Cushman, Darby & Cushman
Attorneys

United States Patent Office

3,196,244
Patented July 20, 1965

3,196,244
INDUCTOR FOR THE SURFACE HEATING OF GEAR WHEELS

Karl Adolf Wulf, Araijuku-Ita-ku, Tokyo, Japan, assignor to Deutsche Edelstahlwerke Aktiengesellschaft, Krefeld, Germany, and Allgemeine Elektricitats-Gesellschaft, Berlin-Grunewald, Germany

Filed Dec. 20, 1962, Ser. No. 246,031
Claims priority, application Germany, Jan. 11, 1962, D 37,892
9 Claims. (Cl. 219—10.59)

For surface hardening the teeth of gear wheels it is the usual practice to heat the surface of the gear wheel inductively and then to harden the same by spraying it with or immersing it in a quenching medium. To this end inductors comprising one or more turns which embrace the gear wheel are used, and during the heating process the gear wheel is either kept stationary or it is rotated, according to which of these two alternative methods is considered most appropriate to the particular case. However, the described procedure has certain drawbacks due to the fact that a given frequency does not produce a temperature distribution leading to the contours of the gear wheel being hardened all over correctly except in the case of particular gear tooth contours and sizes and a particular module. A given frequency therefore permits only a tooth of particular size to be satisfactorily hardened. For instance, the ideal size of tooth for a frequency of 10,000 cycles is one having a module between 8 and 10. If the module is greater, the temperature rises more quickly at the crest and the root of the tooth is then insufficiently hardened. On the other hand, if the module is smaller, then the temperature rise at the root of the tooth is more rapid than elsewhere. Overheating of the crest or root of the tooth can then be avoided only by using a relatively low energy density, and this in turn results in a temperature distribution which does not correctly follow the entire tooth contour.

Although by using suitable case hardening steels or by preheating or heating in consecutive stages it is possible to harden gear wheels comprising a wider range of modules with a particular frequency, and although the requirements relating to the shape of the hardened zone can to some extent be relaxed in order to widen the range of possible modules, the hardening result is by no means ideal and the hardness achieved is not satisfactory in every respect. This drawback cannot be overcome by using inductors which on the inside are contoured to conform with the shape of the teeth. Inductors which thus embrace the work likewise fail to harden gear wheels embracing a wider range of modules ideally.

From the technological point of view the simplest answer would be the provision of a source of A.C. which is continuously variable. A generator driven by a continuously variable motor would suit this requirement. However, an objection to this proposal is the high cost of such plant which would also be called upon to operate somewhat inefficiently. Another possibility of hardening gear wheels embracing a wider range of modules would be to use two different frequencies for the electro-inductive heating process. However, this solution requires considerable equipment and involves major complexities. Relatively high power must be installed in order to deal with the wide differences in the sizes of the gear wheels which are to be hardened. Consequently the efficiency of such a plant would likewise be bad.

These difficulties explain why the method of hardening gear wheels by electro-inductive heating has not found much favour and why case hardening and nitriding are still the principal methods employed in actual practice.

It is the object of the present invention to propose a method which will largely avoid the drawbacks involved in using known equipment, and which will permit plant to be operated at a fixed frequency and yet allow a very wide range of gear wheels of different modules to be heated correctly throughout their contours and thus to be hardened as is desirable. In other words, the object which must be achieved is that the induced current should not be nearly exclusively concentrated in the region of the inner dedendum circle of the gear wheel when the frequency is too low for the gear wheel module. In such a case the principal buildup of heat is at the root of the tooth, in the gap of the tooth and in the region of the inner dedendum circle, whereas the temperature of the body of the tooth lags behind because the heat penetrates to those zones of the tooth only by thermal conduction. On the other hand, at a frequency which is too high for the size of the tooth the concentration of heat at the crest of the tooth and a higher rate of temperature rise at the crest must be avoided.

Surprisingly these difficulties can be overcome by a very simple step with the aid of an inductor which embraces the gear wheel of which the contours are to be evenly heated, and which is rotated during the heating process. The step now proposed by the present invention consists in arranging effective sections of the inductor at an angle to the inductor axis, which differs from 90°. The circumference of the inductor thus comprises a number of oblique inductor sections which extend at least across the width of a tooth. It is preferred that they should extend on each side beyond the width of the gear wheel which is located inside the inductor coil.

The obliquity of the several sections permits the heating effect to be adapted to the frequency of the current supplied to the inductor or—since generally the frequency in any given plant is fixed—to be adapted to the different sizes and modules of the treated gear wheels. When the frequency is fixed the angle of obliquity should be the smaller the narrower the teeth. When the teeth are very small with straight-tooth spur gears it has been found that the angle of obliquity should approach or be zero, that is to say that the effective inductor section should be parallel to the crests of the teeth. The frequency for operating the plant should preferably be such that the gear wheel having the largest module can be heated in true conformity with its contours by an inductor with effective inductor sections which are sections which are substantially parallel to the inductor axis or set at a very small angle thereto. This therefore means that in such a case a normal embracing inductor will be used. For smaller modules the inductors employed must have effective inductor sections set at an appropriate angle. A few experiments will generally suffice to determine the required obliquity of the sections for dealing with different modules. In the case of helical gear teeth a corresponding procedure should be adopted. For wheels of the same module the angle of the heating conductors to the axis of the wheel is naturally greater than in the case of normal spur wheels having straight teeth.

Several possibilities are available for the practical embodiment of the inventive idea. For instance, the oblique sections of which a plurality is provided around the circumference may be directly connected in a zig-zag line. An alternative arrangement is to provide oblique sections alternating with axially parallel sections. Moreover, the oblique sections of which a plurality is provided around the circumference may all be geometrically parallel and electrically interconnected in series by angular or curved intermediate conductor sections located outside the width of the gear wheel. Whereas the latter as well as the preceding embodiment comprise effective inductor sections electrically connected in series, an arrangement may also be chosen in which the oblique inductor sections are electrically connected in parallel. To this end two current feeder rings may be located outside the width of the gear wheel and the oblique sections placed in parallel between the two rings, either all at the same angle or at different angles of obliquity to the inductor axis.

Preferred embodiments of the invention are illustratively shown in the drawings in which both the gear wheel and the inductor are shown developed in the plane of the paper. The developed gear wheel is marked 1 in all the drawings and 2 indicates the tooth crests.

With reference to FIG. 1 an inductor embracing the gear wheel comprises sections 3 and 4 which extend at an angle 5 to the inductor axis and hence to the direction of the crests of the teeth, said angle being less than 90°.

Consecutive sections 3 and 4 form a zig-zag line and the ends of the sections project beyond the sides of the gear wheel 1 as indicated at 6. The projection of the section ends affects the distribution of heat and hence the pattern of the hardened zone. The distance the sections should thus project can be readily found by a few simple trials.

For a given frequency the angle 5 must be greater when the module of the treated gear wheel is greater and, conversely, angle 5 must be smaller when the module is smaller.

In the embodiment shown in FIG. 2 oblique sections 7 alternate with sections 8 which are parallel with the line of the crests AA of the teeth. An inductor of this particular kind is particularly suitable for treating gear wheels with helical, double helical or helicoidal gear teeth.

In the embodiment of the inductor according to FIG. 3 the oblique sections 9 and 10 are interconnected by sections which may either be angular, as shown at 11, or rounded, as shown at 12. The individual sections 9 and 10 may, as illustrated in the drawings, be geometrically parallel. However, deviations from parallelism might be permissible. The connecting sections 11 and 12 place the sections 9 and 10 electrically in series.

Whereas in the embodiments according to FIGS. 1 to 3 the individual oblique sections are electrically connected in series, FIG. 4 shows an arrangement in which the several oblique sections 13, 14 and 15 are connected in parallel between feeder rings 16 and 17. The rings 16 and 17 are located outside the width of the treated gear wheel. As shown, the angles formed by the oblique sections with the direction of the tooth crests AA may be different according to the particular requirements of the case. If desired, the angularity of the sections may be arranged to differ in different groups.

In each of the illustrated embodiments, which may be combined in various ways, the essential feature is that the width of the heating conductor in the circumferential direction of the treated gear wheel is chosen with due reference to the gear wheel module. If the heating conductor is narrow in relation to the module, then the surface at the crests of the teeth is preferentially heated. On the other hand, if the inductor is wide, the heating effect will affect more especially the flanks and the roots of the teeth. This effect is all the more pronounced the smaller the angles between the inclined sections and the lines AA.

The speed of rotation of the gear wheel during the heating process must be determined according to circumstances. In the case of small gear wheel the heating times may be 0.1 and 10 seconds and the speeds of rotation should then be between 200 and 5000 r.p.m. Decisive in each particular case is that the entire periphery must be evenly heated and that the selection of a suitable speed of rotation will contribute towards ensuring that this is the case.

The power density when using an inductor according to the invention should be as high as possible, preferably exceeding 3 kw./sq. cm. of surface, related to the generator output.

It is thus possible to ensure that the heating times are short and that the heat generated has no opportunity of conductively penetrating the tooth interior. When the wheel has been heated it must be quenched in a quenching device with a minimum of delay. This can be done by spraying the gear wheel or by lowering it into a bath. The media used for quenching are the well known media conventionally employed in the art of induction heating. When building inductors such as have been described it is a matter of importance for reasons of maintaining efficiency to provide the heating conductors with luminated preferably U-shaped, conductor-embracing strips. At frequencies under 5000 cycles/sec. mouldings (ferrite cores) may likewise be used.

In forms of construction, such as that illustrated in FIG. 3, sheet metal rings in the form of the laminations used for the stators of electrical machines can be used, said rings being provided with axial grooves for the reception of the heating conductors. Obliquity of the grooves in the stack can be easily produced by relatively twisting consecutive rings in the stack, in such manner that the angle of twist increases from sheet to sheet.

By way of example, according to one embodiment, using the inductor as shown in FIG. 1, a straight-toothed spur gear having a module of 5 is rotated at a speed of 120 r.p.m. and subjected to the heating action of the inductor for a period of 1.2 seconds. The inductor is supplied at a frequency of 10,000 cycles/sec. and at a power density of 3.2 kw./sq. cm. The angle 5 of the inductor sections is 50°. If the width of the inductor sections is narrow, say 6 mm., the crests of the teeth will be preferentially heated and if wider inductor sections are used, say 15 mm., the flanks and the roots of the teeth will be more heated. The heated spur gear is then immediately water quenched.

The angle 5 will generally not exceed 75°, and for treating most gear wheels it will exceed 20°.

What I claim is:

1. An inductor for embracing a gear wheel for accurately surface hardening the contours thereof including defined sections which lie substantially on an imaginary cylinder and disposed obliquely to the axis of the inductor, said sections being in circumferentially spaced relation to one another and permitting rotation of the gear wheel within the inductor with the said section across the width of the wheel and in such vicinity to the teeth thereof as to permit inductive heating thereof and hardening.

2. An inductor according to claim 1, in which at least certain of said sections are at an angle to the axis of the said cylinder.

3. A single layer inductor according to claim 1 in which said defined sections are serially connected in circumferential order to form an acute angled substantially cylindrical zig-zag.

4. An inductor according to claim 1, in which the said sections comprise sections making an angle to the axis of the said cylinder and sections parallel to the said axis.

5. An inductor according to claim 1, in which said sections are disposed at an angle to the axis of the said cylinder and are geometrically parallel to one another and electrically interconnected in series by alternating end connections.

6. An inductor according to claim 1 comprising two end current feeder rings and said defined sections bridging the said rings in circumferentially spaced arrangement from one another obliquenly to said axis and electrically connected in parallel by said rings.

7. An inductor according to claim 6, in which said sections are parallel to one another.

8. An inductor according to claim 1, in which said sections are at different angles to the axis of the inductor.

9. The combination of an inductor, as set forth in claim 1, and a gear wheel wherein said gear wheel is rotatable within said inductor.

References Cited by the Examiner

UNITED STATES PATENTS

2,299,934	10/42	Sherman et al.	219—10.59
2,390,559	12/45	Sherman	219—10.59
2,402,186	6/46	Sherman	219—10.59
2,428,303	9/47	Wood	219—10.59
2,460,855	2/49	Somes	219—10.59
2,845,377	7/58	Seulen et al.	148—150
2,930,724	3/60	Rudd	148—150
2,961,747	11/60	Lyman	336—223

FOREIGN PATENTS

1,151,084	1/58	France.
900,463	12/53	Germany.

RICHARD M. WOOD, *Primary Examiner.*

ANTHONY BARTIS, DAVID L. RECK, *Examiners.*