Feb. 22, 1966 D. G. JONES 3,236,993

INDUCTION HEATING

Filed May 6, 1963

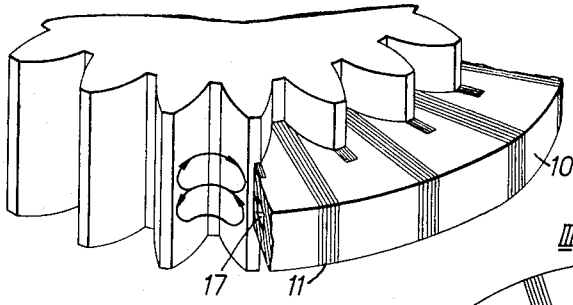


FIG. 1.

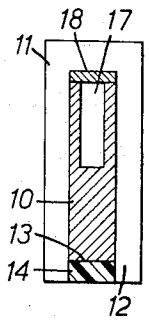


FIG. 3.

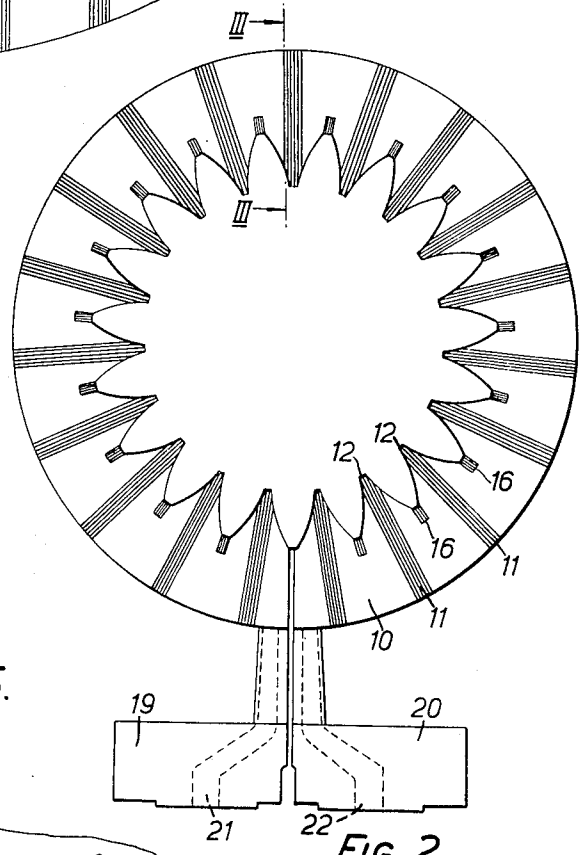


FIG. 2.

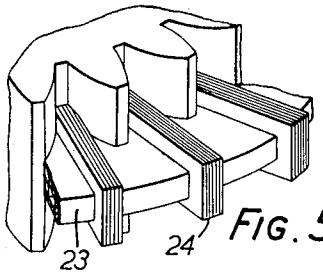


FIG. 5.

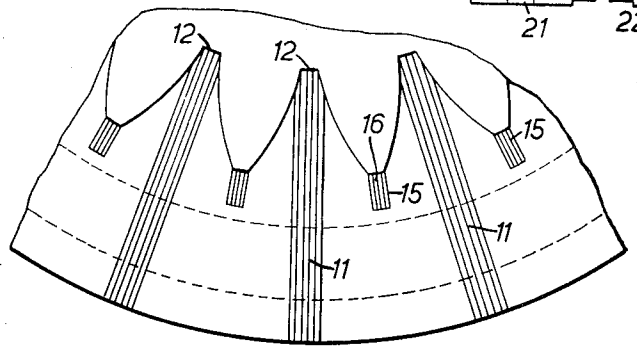


FIG. 4.

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INDUCTION HEATING

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Claims priority, application Great Britain, May 5, 1962, 17,355/62
10 Claims. (Cl. 219—10.59)

This invention relates to induction heating and in particular to methods of and apparatus for induction heating gears and other elements having a toothed or serrated periphery. The invention can be applied to heating either an external or internal periphery, and is of especially advantageous application to the case hardening of gear teeth and the splines of splined elements.

At present there are two general methods in use to produce a hardened surface of gear teeth employing induction heating. In the older of these methods the gear is encircled by a single or multi-turn helical inductor, and when the surfaces reach the required temperature the gear is quenched in water or other suitable medium. This does not result in true case hardening, as the teeth tend to be hardened throughout and due to the mass effect the roots of the teeth are not sufficiently hot when the teeth themselves reach hardening temperature; as a result the roots are not effectively hardened. There is also the so-called "striation" effect which results in alternating relatively hot and cool bands round the gear, with consequent variations in the case hardness and depth. The other method produces a hot line in a single tooth space, this line being scanned along the length of the gear and the scanning repeated for each tooth space. This method produces a much more even "case" but for mass production purposes has the disadvantage of being relatively slow, a disadvantage which it is the object of the invention to materially reduce.

According to the invention an inductor for induction heating a toothed or serrated surface of an element, comprises a single turn current carrying loop generally profiled to suit the surface and having projections which project into the spaces between the teeth or serrations when the element and the inductor are coaxially arranged, each projection being associated with a U-shaped magnetic core which straddles the inductor loop with the free ends of the limbs of each core extending in the same direction as the respective projection.

Preferably the cores are of laminated form to withstand thermal shock which can be great when rapid rates of heating are used. However, dust composition cores may be used, or they may be moulded from ferrite material.

The laminations preferably lie in planes perpendicular to the adjacent part of the current carrying loop.

According to a preferred feature of the invention the magnetic cores are housed in slots formed in the surface of the current carrying loop.

Preferably the free ends of the limbs of each core extend somewhat beyond the edge of the corresponding projection on the current carrying loop.

In use the inductor of the invention produces current loops in the spaces between the teeth or serrations and also a circulating current which is induced round the complete periphery of the element. The effect of the circulating current may be reduced to a relatively low value by cutting away the inductor between the projections thereof, for example by machining slots in the inductor. The effect of these slots is to increase the effective diameter of the inductor current path, leaving the cores acting as flux intensifiers in said spaces. The slots are preferably filled with a ferro-magnetic material, for example iron laminae. The axial width of the inductor

and the width of the cores are suitably designed to produce overlapping circulating current paths at the roots of the teeth or serrations, such overlapping producing an additional heating effect where it is most needed.

According to another aspect of the invention a method of induction heating an element with a toothed or serrated periphery comprises the steps of arranging the element and a single turn annular inductor in axial alignment, the inductor having spaced projections each associated with a U-shaped core which straddles the inductor with the ends of the core limbs and the projections aligned with the spaces between the teeth or serrations, energising the inductor to induce heating current loops in the peripheral surface of the element in said spaces, and causing relative traversing movement of the inductor and the element along the length of the latter.

By the method of the invention heating current loops are produced in each of said spaces, and when the inductor has completely traversed the element the flanks of all the teeth or serrations are effectively heated. Preferably overlapping current loops are produced in each space, the overlapping of the loops producing an increased heating effect at the roots of the teeth or serrations, thus compensating for the "mass effect" in those positions.

The invention may be performed in various ways and two specific embodiments will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a perspective view partly broken away showing part of an inductor according to the invention in position surrounding a gear to be heat treated,

FIGURE 2 is a plan view of the inductor of FIGURE 1,

FIGURE 3 is a cross-sectional view on the line III—III in FIGURE 2,

FIGURE 4 is an enlarged fragmentary plan view showing the arrangement of the laminated cores on the current carrying loop, and

FIGURE 5 is a perspective view corresponding to FIGURE 1 showing a modified form of the invention.

In these examples the inductors are designed for use in case hardening an external toothed gear wheel. As seen in FIGURES 1 and 2 the inductor comprises a single turn current-carrying loop in the form of a copper ring **10** machined with an internal profile generally inverse to the gear profile so providing projections which extend into the toothed spaces and lie closely adjacent the tooth flanks of the gear when the gear and the inductor are coaxially located.

The copper ring **10** is formed with radial slots on both annular faces and an axial slot on its external cylindrical surface, in the region of each projection. At each projection a U-shaped laminated ferro-magnetic core is pressed into position in the slots, the core being so dimensioned that the external surfaces of the laminations **11** are flush with the radial and external faces of the copper ring, as seen in FIGURE 1. The free ends **12** of the limbs of these laminations extend somewhat beyond the tips of the projections on the inductor loop (**13** in FIGURE 3). The space between the projecting ends of the limbs may be filled with a heat resistant insulating material **14**. It will be noted that the laminated cores are supported over most of their length by the projections on the copper ring and these projections also tend to weaken the magnetic flux around the inductor between the laminated cores and to intensify the field between the tips of the limbs of the cores. This increases the heating effect at the roots of the teeth on the gear wheel.

Between each of the projections the copper ring is slotted or cut back on its internal surface as shown at **15** and each slot so formed is filled with a ferro-magnetic material, preferably iron laminations **16**. This arrange-

ment further reduces the magnetic flux adjacent the tips of the teeth on the gear wheel by providing a magnetic bypass around the current-carrying loop.

The current-carrying loop may be provided with an internal cooling water channel 17 which is conveniently formed by machining an external groove in the loop and brazing a band of copper 18 around the external surface, before the laminated cores are applied.

The copper ring is radially split midway between two of the projections as shown in FIGURE 2 and provided with terminal members 19, 20 by which the high frequency electric current is applied. These terminals are also formed with passages 21, 22 by which cooling water is circulated through the channel 17.

In the modification illustrated in FIGURE 5 the current-carrying loop 23 is formed with projections to lie between the teeth of the gear wheel, as in the previous example, but the laminated cores 24 are not housed in slots in the loop but are fitted over its external surface. This construction is suitable for specific applications.

In some applications it is also desirable to provide a supply of quenching water and this can readily be delivered by providing apertures communicating with the cooling water passage 17.

I claim:

1. An inductor for induction heating a toothed or serrated surface of an element, comprising a single turn current-carrying loop providing a continuous conductive path with a gap between its ends, said inductor being generally profiled to suit the surface and having projections which project into the spaces between the teeth or serrations when the element and the inductor are coaxially arranged, said projections extending radially outwardly a distance greater than the gaps between said projections, and a plurality of U-shaped magnetic cores individually associated with said projections, each magnetic core straddling the inductor loop with the free ends of the limbs of each core extending in the same direction as the respective projection and the other ends of the limbs extending radially outwardly a distance greater than the gaps between said projections.

2. An inductor as claimed in claim 1, in which the magnetic cores are laminated.

3. An inductor as claimed in claim 2, in which the laminations lie in planes perpendicular to the adjacent part of the current carrying loop.

4. An inductor as claimed in claim 1, in which the free ends of the limbs of each core extend somewhat beyond the edge of the corresponding projection on the current-carrying loop.

5. An inductor as claimed in claim 1, in which the axial dimensions of the inductor loop and the axial spacing between the limbs of each core are appreciably smaller than the axial dimensions of the element to be heated so that overlapping circulating current paths are induced in the surface of the element.

6. An inductor for induction heating the peripheral surface of a toothed article such as a gear wheel, comprising a single turn conductor loop providing a continuous conductive path with a gap between its ends, said inductor being profiled to suit the surface and coaxially surround the latter, said conductor loop having spaced projections which project into the spaces between the teeth on said surface and radial surface slots aligned with said projections, said projections extending radially outwardly a distance greater than the gaps between said projections, and a plurality of U-shaped magnetic cores engaging said slots and straddling the conductor loop with the free ends of the limbs of each core extending in the same direction ts the respective projection and slightly beyond the edge thereof and the other ends of the limbs extending radially outwardly a distance greater than the gaps between said projections.

7. An inductor for induction heating a toothed or serrated surface of an element, comprising a single turn current-carrying loop providing a continuous conductive path with a gap between its ends, said inductor being generally profiled to suit the surface and having projections which project into the spaces between the teeth or serrations when the element and the inductor are coaxially arranged, said projections extending radially outwardly a distance greater than the gaps between said projections, the loop being cut away between the projections so as to reduce the heating effect at the tip of each tooth on the element and a plurality of U-shaped magnetic cores individually associated with said projections, each magnetic core straddling the inductor loop with the free ends of the limbs of the core extending in the same direction as the respective projection and the other ends of the limbs extending radially outwardly a distance greater than the gaps between said projections.

8. An inductor for induction heating a toothed or serrated surface of an element, comprising a single turn current-carrying loop generally profiled to suit the surface and having projections which project into the spaces between the teeth or serrations when the element and the inductor are coaxially arranged, the loop being formed with slots between the projections so as to reduce the heating effect at the tip of each tooth on the element, a filling of ferro-magnetic material in each such slot, and a plurality of U-shaped magnetic cores individually associated with said projections, each magnetic core straddling the inductor loop with the free ends of the limbs of the core extending in the same direction as the respective projection.

9. An inductor according to claim 8, wherein each filling of ferro-magnetic material is in the form of iron laminations.

10. An inductor for induction heating a toothed peripheral surface of an element such as a gear wheel comprising a single turn current-carrying loop providing a continuous conductive path with a gap between its ends, said inductor being generally profiled to suit and coaxially surround the surface and having projections which project into the spaces between the teeth or serrations when the element and the inductor are coaxially arranged, said projections extending radially outwardly a distance greater than the gaps between said projections, and a plurality of U-shaped laminated magnetic cores individually associated with said projections, each magnetic core being disposed radially of and straddling the inductor loop with the free ends of the limbs of each core extending in the same direction as the respective projections and the other ends of the limbs extending radially outwardly a distance greater than the gaps between said projections.

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