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(54) **Magnetic heating system**

(57) A magnetic heating system comprises a core (4) of a magnetic material having a coil (2,3) wound around at least a part thereof, and a power supply (1)

connected to the coil for supplying a low frequency alternating current thereto. The power supply comprises means for varying the frequency of the alternating current in the coil.

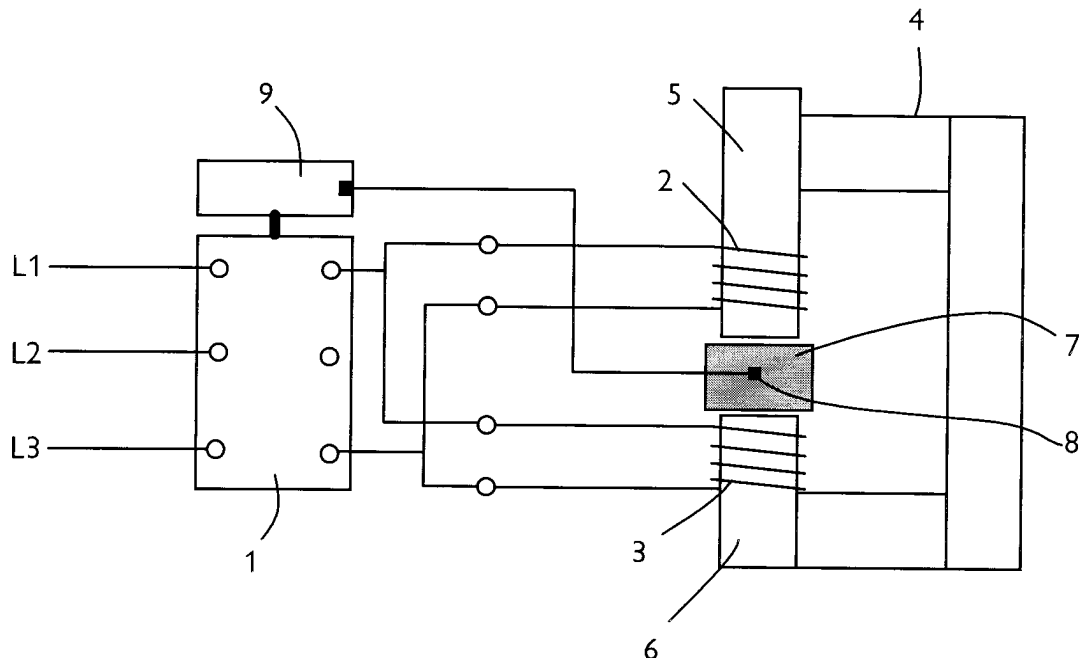


Fig 2

Description

Field of the Invention

[0001] This invention relates to a magnetic heating system, for example for use in heat treatment of metal components.

Background to the Invention

[0002] The use of low frequency alternating magnetic fields for the heat treatment of metallic articles has been known for many years. Examples of disclosures of such techniques are: US 1335453; US 3965321; US 4281234; US 4673781; US 4761527; US 4856097; EP 0183209; and EP 0459837. Control of the heating of the articles is typically achieved by varying the current through the coils, usually by varying the voltage applied.

[0003] A difficulty with conventional systems is in achieving a sufficiently accurate control of heating. For example, when heating aluminium billets in preparation for shaping operations, the plastic temperature of aluminium being close to the melting point, a relatively small variation in the power applied can result in molten aluminium flowing out of the heating device rather than a billet ready for working.

Summary of the Invention

[0004] According to the invention, there is provided a magnetic heating system comprising a core of a magnetic material having a coil wound around at least a part thereof, and a power supply connected to the coil for supplying a low frequency alternating current thereto, wherein the power supply comprises means for varying the frequency of the alternating current in the coil.

[0005] Preferably, the means for varying the frequency comprises an inverter, being a device supplied with an alternating current supply at a first frequency and arranged to output a selectively variable frequency current. Means may also be provided in the power supply for regulating the voltage applied to the coil as well as the frequency.

[0006] While single phase power supplies may be used for relatively low power applications, it is desirable to use three-phase supplies for higher power requirements. For a single phase heating device, therefore, it is necessary to use a transformer connected to the three-phase supply to provide a single-phase output to the coil. It has now been found that the use of a transformer may be dispensed with if an inverter is used, with two of the output phases from the three-phase inverter being connected to the coil. No connection is then made to the third phase. Preferably, two separate heating coils, on opposed pole pieces forming part of a C-shaped core, are used, the coils being connected in parallel or in series. An advantage of the use of the inverter in this way is that power factor correction can be

achieved.

[0007] The or each coil used in the heating system of the invention is preferably wound so as to provide a single layer winding, as this has been found to be of greater heating efficiency than multi-layer windings.

[0008] Preferably, the system comprises means for measuring the temperature of the article being heated and for signalling the temperature to control means for the power supply, the control means being programmed to control the frequency and the voltage applied to the coil or coils in accordance with the temperature signalled thereto. It has been found convenient to effect coarse control of the temperature by varying the voltage applied to the coils, and fine control by varying the frequency. It will be appreciated that increasing the frequency increases the reactance of the coils, thereby reducing the current in them.

[0009] With the system of the invention, precise control of the temperature of the article to be heated can be achieved, for example accurate to $\pm 2^\circ\text{C}$.

Brief Description of the Drawings

[0010] In the drawings, which illustrate an exemplary embodiment of the invention:

Figure 1 is a diagram of the electrical circuit employed; and

Figure 2 is a diagram of the complete apparatus.

Detailed Description of the Illustrated Embodiment

[0011] The system employs an inverter 1 having a three-phase alternating current input (L1, L2, L3) at the standard mains supply frequency (50 or 60 Hz) and providing a three phase output of selectively variable frequency and voltage. An example of such an inverter is the Hitachi J300 type, available in a range of power ratings. Inverters of this type will typically be provided with interface means permitting control by an external device of the voltage and/or frequency of the supply to the external load, and providing for monitoring of the current applied. Conventionally, such inverters are used in the control of electric motors. In the system of the invention, two coils 2 and 3 connected in parallel are driven by two phases from the inverter. This is done by omitting the connection to the centre phase. The coils may alternatively be connected in series, or a single coil could be connected in place of the two coils.

[0012] The inverter monitors its output current only on the two outer phases, using Hall effect transducers. The omission of any load on the centre phase of the inverter is therefore irrelevant to the inverter control circuit. It will be appreciated that the invention is also applicable to arrangements in which all three phases output by the inverter are employed, supplied to three different coils, or pairs of coils, causing heating through three separate cores, for example in the manner set out in our published

International Patent Application WO98/52385.

[0013] Figure 2 shows diagrammatically a practical application of this arrangement. The inverter 1 is connected to the two coils 2 and 3, which are wound on the same C-shaped core 4, on opposed pole pieces 5 and 6, the upper pole piece 5 being slidable vertically relative to the lower pole piece 6 so as to accommodate different sizes of article 7 to be heated.

[0014] A thermocouple 8 is attached to the article 7 to monitor its temperature. The thermocouple 8 connected to a controller 9 operatively linked to the inverter 1 so as to be able to vary the voltage and frequency of the supply to the coils 2 and 3 to control the power supplied to the coils and therefore the heating effect achieved. The controller may be any programmable device, for example a programmable logic controller (PLC) or a computer. The controller 9 also monitors the current supplied to the coils. The controller 9 may be linked to the inverter by any suitable means, for example by way of RS-485 standard interface. The controller can also serve to control other functions of the heating device, for example the pneumatic controls moving the slidable arm of the core and controlling the positioning of the workpiece. By feeding back the actual temperature of the article 7 to the controller 9, the power may be controlled to heat the article to the desired temperature with sufficient precision to ensure that, for example in the case of an aluminium billet, the plastic temperature is maintained without risk of melting.

[0015] It will be appreciated that other ways may be employed of monitoring the temperature of the article 7 than applying a thermocouple to the article. For example, the heat radiated by the article may be detected remotely by an infra-red detector.

[0016] Figure 3 illustrates the programming of the controller 9. At the start of the cycle, heating is carried out rapidly with an optimum coil current, which may be a maximum current available. The temperature of the article is detected and compared with an offset temperature which is a predetermined amount below the desired temperature, for example 5 to 10°C below. When the offset temperature is reached, the voltage gain on the inverter is reduced to a predetermined lower level and the temperature continues to be monitored. If the desired temperature, the set point, is not reached, the voltage gain is increased by a small increment and the temperature again measured. This is repeated until the set point is reached, as a result of which the voltage gain is reduced to a low level, below the predetermined lower level hereinbefore mentioned. After a delay, the effect on the temperature is again checked. If it is not decreasing, the frequency of the supply to the coils is increased by a predetermined amount, and the temperature checked after the delay. This is repeated until the temperature begins to decrease. If the temperature drops below the set point, the voltage gain is then increased, and the effect monitored as described hereinbefore. If the temperature does not drop below the set point, the

temperature continues to be monitored without the need for corrective action. In this way, the temperature of the article being heated can be controlled very precisely.

Claims

1. A magnetic heating system comprising a core of a magnetic material having a coil wound around at least a part thereof, and a power supply connected to the coil for supplying a low frequency alternating current thereto, wherein the power supply comprises means for varying the frequency of the alternating current in the coil.
2. A magnetic heating system according to Claim 1, wherein the means for varying the frequency comprises an inverter.
3. A magnetic heating system according to Claim 1 or 2, wherein means are provided in the power supply for regulating the voltage applied to the coil as well as the frequency.
4. A magnetic heating system according to Claim 1, 2 or 3, wherein the power supply is a three-phase power supply.
5. A magnetic heating system according to Claim 4, wherein the coil is connected across two of the phases.
6. A magnetic heating system according to Claim 5, wherein two coils are wound on the same core, and the supply is connected to the coils in parallel.
7. A magnetic heating system according to any preceding claim, wherein sensing means are provided for sensing the temperature of the article being heated, and wherein the power supply is arranged to vary the frequency automatically in accordance with the temperature sensed by the sensing means, whereby the temperature of the article may be controlled to a predetermined value.
8. A magnetic heating system according to Claim 7, wherein the power supply also varies the voltage in response to the sensed temperature.
9. A magnetic heating system, substantially as described with reference to, or as shown in, the drawings.

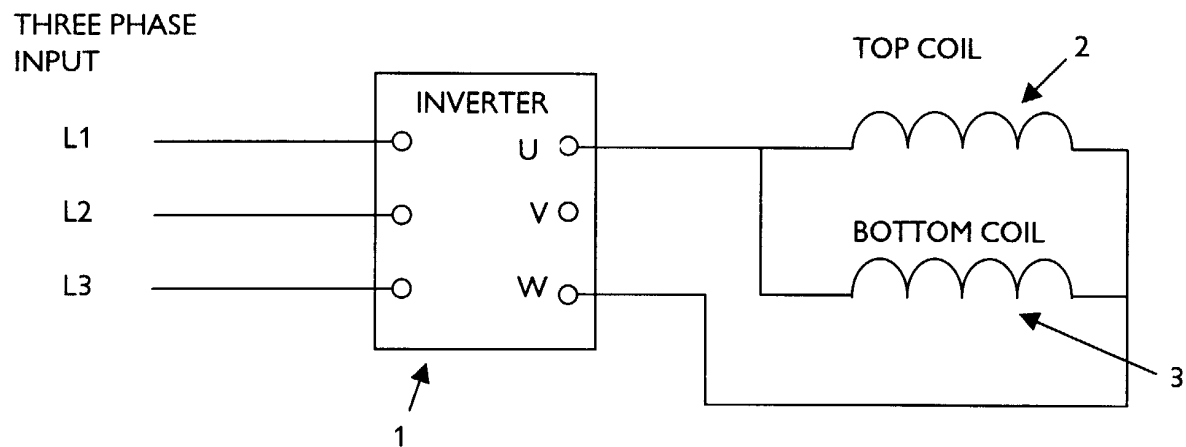


Fig 1

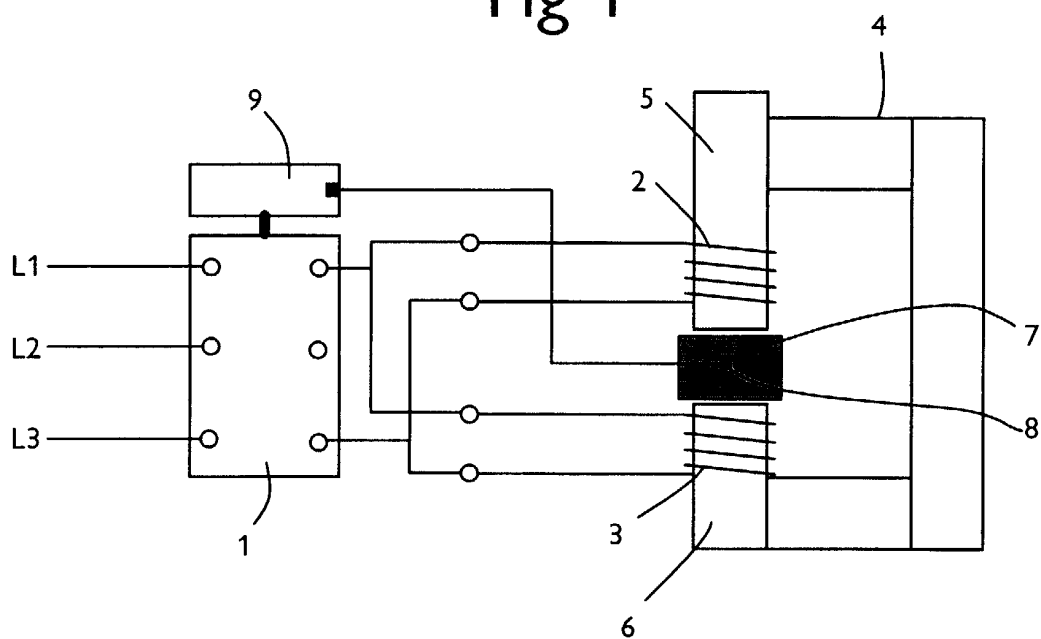


Fig 2

Fig 3

