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(54) **Magnetic heating system**

Magnetische Beheizungssystem

Système magnétique de chauffage

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(56) References cited:
**EP-A- 0 439 900 EP-A- 0 619 692
US-A- 3 816 690 US-A- 5 352 872**

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Description

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

[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.

[0004] US3816690 discloses an induction heating device in which an inverter varies the voltage and frequency of the power supply in response to the sensed temperature of the article being heated. US5352872 discloses an induction furnace in which the voltage and frequency of a three-phase supply are controlled to heat an article. EP0439900A discloses an induction heating method in which a separate coil is energised by a respective phase of a three-phase supply. EP0619692A discloses an inductive heating system with feedback to control the frequency of the power supply to follow the resonance frequency of the heater. The power supply is cut off when a predetermined temperature is reached.

[0005] None of the above prior art provides an induction heating system that provides sufficiently accurate temperature control, especially under the circumstances mentioned in the introduction.

[0006] The invention therefore provides 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, whereby to heat an article; and sensing means for sensing the temperature of the article being heated; wherein the power supply comprises means for varying the voltage and frequency of the alternating current in the coil; and wherein the power supply is arranged to be controlled in response to the temperature sensed by the sensing means, characterised in that, in a first phase, the voltage gain of the power supply is controlled automatically so as to raise the temperature of the article to an offset temperature; and, in a second phase, the frequency is varied automatically, whereby to raise the temperature of the article from the offset temperature to a predetermined temperature and to maintain the temperature of the article at the predetermined value.

[0007] 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 are also provided in the power supply for regulating the voltage applied to the coil as well as the frequency.

[0008] 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.

[0009] 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.

[0010] The control system detailed above makes it 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.

[0011] With the system of the invention, precise control of the temperature of the article to be heated can be achieved, for example accurate to $\pm 2^\circ\text{C}$.

[0012] 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.

[0013] 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.

[0014] 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.

[0015] 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.

[0016] 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. 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.

[0017] 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 (4-6) of a magnetic material having a coil (2,3) wound around at least a part thereof, and a power supply (L1-L3) connected to the coil for supplying a low frequency alternating current thereto, whereby to heat an article (7); and sensing means (8) for sensing the temperature of the article being heated; wherein the power supply comprises means for varying the voltage and frequency of the alternating current in the coil; and wherein the power supply is arranged to be controlled (9) in response to the temperature sensed by the sensing means (8), **characterised in that**, in a first phase, the voltage gain of the power supply is controlled automatically so as to raise the temperature of the article to an offset temperature; and, in a second phase, the frequency is varied automatically, whereby to raise the temperature of the article from the offset temperature to a predetermined temperature and to maintain the temperature of the article at the predetermined value.
2. A magnetic heating system according to Claim 1, wherein the means for varying the frequency comprises an inverter (1).
3. A magnetic heating system according to Claim 1 or 2, wherein the offset temperature is less than the predetermined temperature.
4. A magnetic heating system according to Claim 3, wherein the offset temperature is 5 to 10°C less than the predetermined temperature.
5. A magnetic heating system according to any of the preceding claims, wherein the power supply is a three-phase power supply (L1-L3).
6. A magnetic heating system according to Claim 5, wherein the coil (2,3) is connected across two of the phases (U,V).
7. A magnetic heating system according to Claim 6,

wherein two coils (2,3) are wound on the same core (4-6), and the supply is connected to the coils in parallel.

Patentansprüche

1. Magnetisches Heizsystem, welches einen Kern (4 - 6) aus einem magnetischen Material mit einer Spule (2,3) aufweist, die um zumindest einen Teil desselben gewickelt ist, und eine Stromversorgung (L 1-L 3), die mit der Spule zum Versorgen mit einem niederfrequenten Wechselstrom verbunden ist, wodurch ein Artikel (7) beheizt wird, und eine Sensoreinrichtung (8) zum Erfassen der Temperatur des Artikels, der beheizt wird, wobei die Stromversorgung Einrichtungen zum Variieren der Spannung und Frequenz des Wechselstroms in der Spule aufweist, und wobei die Spannungsversorgung derart angeordnet ist, um in Reaktion auf die erfaßte Temperatur, die durch die Sensoreinrichtung (8) erfaßt wird, geregelt (9) zu werden, **dadurch gekennzeichnet, daß** in einer ersten Phase der Spannungszuwachs der Stromversorgung automatisch geregelt wird, um die Temperatur des Artikels auf eine Offsettemperatur anzuheben und in einer zweiten Phase die Frequenz automatisch variiert wird, wodurch die Temperatur des Artikels von der Offsettemperatur zu einer vorbestimmten Temperatur angehoben wird, und um die Temperatur des Artikels bei dem vorbestimmten Wert zu halten.
2. Magnetisches Heizsystem nach Patentanspruch 1, wobei die Einrichtung zum Variieren der Frequenz einen Inverter (1) aufweist.
3. Magnetisches Heizsystem nach Patentanspruch 1 oder 2, wobei die Offsettemperatur geringer ist als die vorbestimmte Temperatur.
4. Magnetisches Heizsystem nach Patentanspruch 3, wobei die Offsettemperatur 5 bis 10° Celsius geringer ist, als die vorbestimmte Temperatur.
5. Magnetisches Heizsystem nach irgend einem der vorstehenden Patentansprüche, wobei die Stromversorgung eine drei Phasen Stromversorgung (L 1 - L 3) ist.
6. Magnetisches Heizsystem nach Patentanspruch 5, wobei die Spule (2, 3) über zwei Phasen (U, V) verbunden ist.
7. Magnetisches Heizsystem nach Patentanspruch 6, wobei zwei Spulen (2, 3) um den selben Kern (4 - 6) gewickelt sind, und wobei die Versorgung mit denen Spulen parallel verbunden ist.

Revendications

1. Système de chauffage magnétique comprenant un noyau (4-6) d'un matériau magnétique ayant un bobinage (2, 3) enroulé autour d'au moins une partie de celui-ci, et une alimentation en courant (L1-L3) connectée au bobinage pour alimenter celui-ci en courant alternatif basse fréquence, pour chauffer de cette façon un article (7) ; et un moyen de détection (8) pour détecter la température de l'article qui est chauffé, dans lequel l'alimentation en courant comprend un moyen pour faire varier la tension et la fréquence du courant alternatif dans le bobinage ; et dans lequel l'alimentation en courant est disposée pour être commandée (9) en réponse à la température détectée par le moyen de détection (8), **caractérisé par le fait que**, dans une première phase, le gain de tension de l'alimentation en courant est commandé automatiquement de façon à élever la température de l'article à une température compensée ; et, dans une seconde phase, la fréquence est amenée à varier automatiquement, pour augmenter de cette façon la température de l'article de la température compensée à une température prédéterminée et pour maintenir la température de l'article à la valeur prédéterminée.
2. Système de chauffage magnétique selon la revendication 1, dans lequel le moyen pour faire varier la fréquence comprend un inverseur (1).
3. Système de chauffage magnétique selon l'une des revendications 1 ou 2, dans lequel la température compensée est inférieure à la température prédéterminée.
4. Système de chauffage magnétique selon la revendication 3, dans lequel la température compensée est de 5 à 10°C inférieure à la température prédéterminée.
5. Système de chauffage magnétique selon l'une quelconque des revendications précédentes, dans lequel l'alimentation en courant est une alimentation en courant triphasé (L1-L3).
6. Système de chauffage magnétique selon la revendication 5, dans lequel le bobinage (2, 3) est connecté à travers deux des phases (U, V).
7. Système de chauffage magnétique selon la revendication 6, dans lequel deux bobinages (2, 3) sont enroulés sur le même noyau (4-6), et l'alimentation est connectée aux bobinages en parallèle.

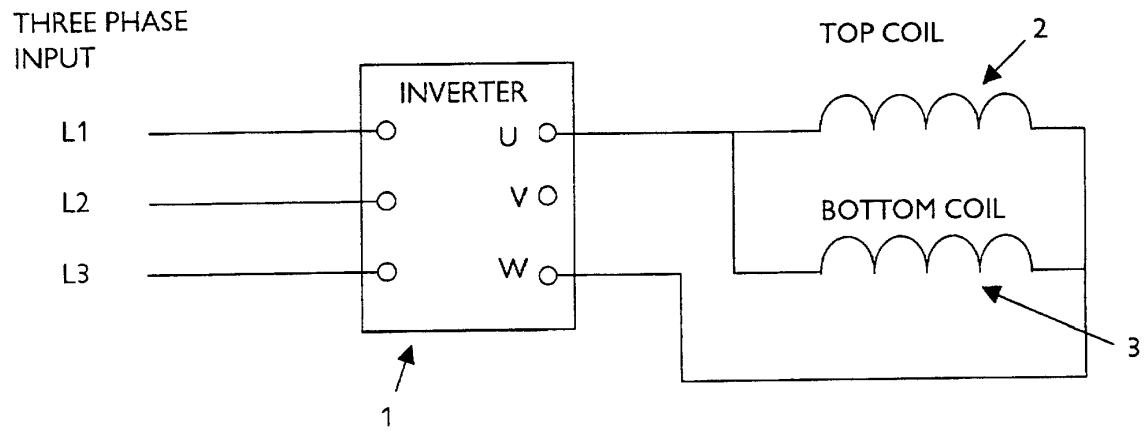


Fig 1

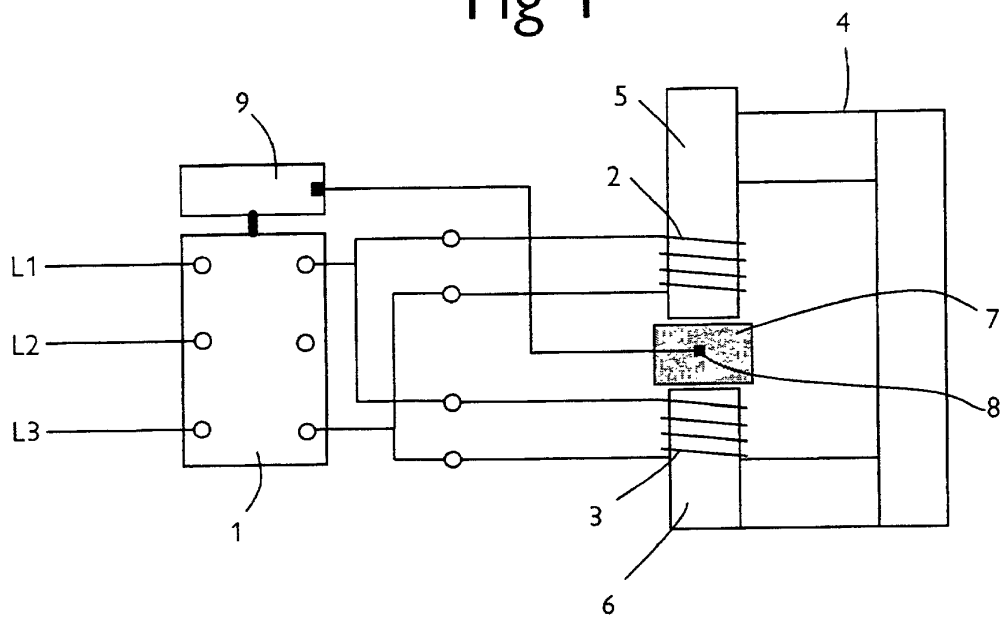


Fig 2

Fig 3

