MAGNETIC HEATING OF BILLETS

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ABSTRACT

This paper deals with new technology in industrial heating processes – magnetic heating of billets. The aim of the paper is to explain the principle of this technology, construction of the industrial device and differences between classical induction heating and magnetic heating of billets. Further I want to describe the advantages of magnetic billet heating.

KEYWORDS

Magnetic heater, billet, induction heating, refridgerator, superconductor.

1. INTRODUCTION

In July 2008 the new technology – magnetic billet heater – was put into commercial operation in Germany (German aluminium extrusion works Weserlau GmbH & Co. KG). The second system has been ordered by Italian subsidiary of Sapa in Bolzano. The beginnings of this technology can be found in 2004. Companies Zenergy Power and Bültmann received funding from Germany´s environmental funding agency DBU (Deutsche Bundesstiftung Umwelt, www.dbu.de) to develop a new technology for billet heating. The first prototype was shown in April 2005 at the Hannover Fair. Further with the support from the DBU, the device was manufactured and put into service at Weserlau.

2. HISTORY AND ADVANTAGES OF MAGNETIC HEATING

Classical induction heating (AC heating) has been used in industry since 1920s. DC powered heating system were first mentioned in 1950s. After more than thirty years (1990) US inventor publicized a method for DC induction involving strong magnets. This project had many advantages over the conventional method but it was not possible to build the device (required technologies were not available at the time). Today, required components (superconducting wire, solid state electric motor drive) are commonly made in industry and it is possible to build DC powered heating device.

Magnetic billet heating has many virtues – it is technically simple and energy efficient heating process. Billets can be rapidly brought to a uniform temperature level, damages caused by surface overheating are prevented. Heating can be used for a wide variety of materials and provides a possibility to reach precisely defined temperature gradients in the workpiece.

3. CONVENTIONAL INDUCTION HEATING (AC HEATING)

Electrically conductive materials are today heated or melted in conventional induction heating devices. Billet is placed inside copper coil. The coil is supplied by AC current and generates electromagnetic field that changes direction in time. The field induces eddy currents in the workpiece (Faraday´s law) and eddy currents heat up the billet due to its electrical resistivity (Joule´s law). In both parts of the device (inductor coil, workpiece) electrical losses occurs. The heating of the coil is the main source of energy losses in conventional AC induction heating systems. Hence, coil must be cooled with water to prevent from melting. The extent of the losses depends on the ratio of the resistances of the coil and the billet. The efficiency of the system is 50 – 60%. Conventional devices have some disadvantages. AC heaters operating with common power grid frequencies generate eddy currents mostly close to the surface of the workpiece – it delays the time of heating. AC induction heating further requires a medium voltage power supply and VAR compensation.

4. DC MAGNETIC HEATING

Magnetic heater in Weserlau consists of DC powered superconductive magnetic coil cooled to low temperature. The coil generates a sufficiently strong magnetic field with a power input of 10W. Magnetic field of a DC powered coil is not varying in time, the billet is rotated within the field in order to induce eddy currents. Eddy currents work to oppose the rotation and create a strong braking torque. This is overcome by industrial electric motors of a size of 100 – 50 kW. Motors are supplied by standard frequency converters (losses 2-3% of the total power consumption of the heater). Cooling system and power supply consume about 13 kW, the total efficiency (including all losses caused by peripheral technical devices) is greater than 80%. The heating process is faster, more homogeneous and precisely controllable. The system doesn´t require large cooling installations, complex energy supply and VAR compensation.
The heater consists of four main components – superconducting magnet, refridgerator, motor and heating chamber. The main component is the superconducting magnet that is kept at its operating temperature by the refridgeration system. The billets rotate in two thermally insulated heating chambers, the rotational energy is provided by electric motors on either side. The motors can slide in and out to accommodate different billet lengths. No component in the heater is subjected to significant temperature increase, vibrations or any other mechanical stress factors.

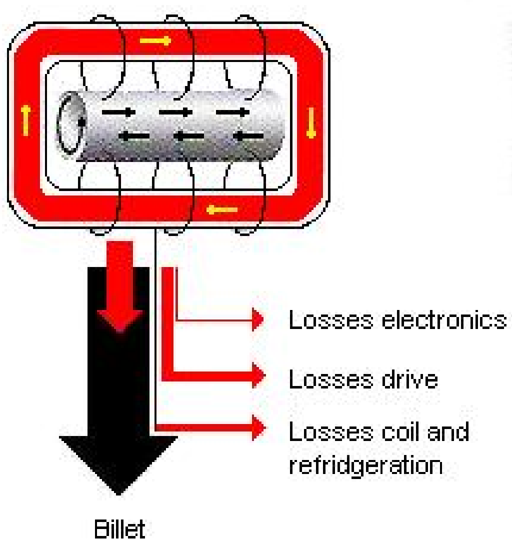

Figure 1 – Magnetic heater scheme [1].

5. MAGNETIC HEATING ADVANTAGES

5.1. Low frequencies

Power grid frequency AC induction heaters induce eddy currents mostly close to the surface of the workpiece. Deeper penetration can be reached by using lower frequencies or more powerful magnetic field. For magnetic heaters it is favourable to rotate the billets at speeds between 240 rpm and 750 rpm (frequencies 4 – 12 Hz). Energy penetration is three times as deep as with AC induction heater. The heating is much more uniform, faster and doesn´t involve a risk of locally melting the material.

5.2. Wide material range

The magnetic heater is optimized for a wide range of materials. Tests took almost one year. Machine was tested for various materials - copper, aluminium, brass, magnesium, titanium, Inconel and a great number of special alloys. No crack formation or spalling was observed during the tests as a consequence of thermal stress. Tests proved that magnetic billet heating is applicable for a wider range of materials than AC induction heating.

5.3. Temperature tapers

Magnetic heating can provide precisely controllable and adjustable temperature tapers within the billets. With a magnetic heater temperature tapers can readily be established. The magnet is tilted mechanically to take an angular position towards the billet. As the strength of the magnetic force depends on distance between billet and magnet, a magnetic gradient is created in the billet. When the billet is rotated, the intensity of the heating effect depends on the strength of the magnetic field. Thus, an approximately linear temperature taper can be built in the material. The taper can be easily adjusted by simply changing the tilting angle of the magnet.

5.4. Low maintenance requirements

In Weserlau, the heater has shown its favourable properties due to its simple mechanical design. The machine has a simple hydraulic system (to supply the clamping pressure of the motors to the billets), cooling system (keeps the magnet at its operational temperature) and heating chamber. The cooling system consists of standard components, which are commercially used in refridgeration technology. The heating chamber contains no complex moving parts for billet transport. Drives are completely thermally shielded from the heated billet.

Compared with conventional AC heaters the maintenance requirement of the machine is minimal. Important factor is the longevity of the superconductive magnet. The superconductor is not subjected to high temperatures, vibrations or mechanical friction. Vibrations do not occur in DC magnet and stress effects on wire insulation are negligible (low consumption of power – 10W). The operative lifecycle of the magnet is estimated more than 20 years. During this period no replacement should be expected.

Further magnetic heater requires no coil maintenance (major problem for AC heaters).

5.5. Reliability

No part of the heater outside the heating chamber ever exceeds 70°C. The temperature of the most parts stays below 50°C. The only part used in this machine operating teams in industry may not be familiar with is the cooling system. The system contains two refridgerators, so the machine can tolerate an unexpected failure or a planned maintenance of one of the units. The machine can work with one off-line refridgerator. If both refridgerators are shut down, it takes more than one hour for the temperature in the magnet to rise into dangerous values. It is caused by the container – it provides very effective thermal insulation. If the failure is resolved within this time period, the machine could resume productive operation immediately.

6. EXPERIENCE FROM WESERLAU

The magnetic heater in Weserlau is optimized for 6-7´´ billets with a length of 27´´. Its electric drives have a power input of 360 kW, the machine has a capacity of 2.2 tons per hour when heating aluminium. Heating of one aluminium billet takes only 75 seconds. The heater requires no medium voltage power supply, VAR compensation and large cooling devices. Integration into the existing production layout was facilitated by the machine´s compact dimensions.

The quality of surface finishes has been improved. Further the increase of productivity amounts to an average 25% across a variety of profiles and the cost of heating was reduced by 50% compared with conventional AC heating. Achieving these results did not involve any significant additional expense. The combined economic effect of energy savings and productivity improvements resulted in a payback period of less than two years.

7. CONCLUSION

Considering current economic development, the risk potential of long-term industrial investments decisions needs to be controlled very thoroughly. The effects of eventual changes of laws must also be taken into account. In environmental law, alterations appear to be imminent and metal manufacturing (one of the most energy consuming industries) will probably be challenged to improve energy efficiency and reduce its carbon footprint. The magnetic billet heater could be an interesting option for metal industry – not only because of its energy efficiency. Also because of the increase of productivity and decreasing investment risks.

REFERENCES

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