Title: LIFTER WITH ELECTROPERMANENT MAGNETS

Abstract: A lifter with electro-permanent magnets comprises an external bearing structure (2, 3) closed at the bottom by a plate (10), provided with a heat shield (9), and pole pieces (5) secured under the respective poles (1) and protruding from said bottom plate (10), each of the electro-permanent magnets being composed of a reversible magnet (6) arranged on top of one of said poles (1), of a fixed polarization magnet (7) formed by a plurality of blocks placed along the lateral faces of the pole (1) and of a coil (8) arranged around the reversible magnet (6) to cause the reversal of the polarization of the latter by means of an electrical pulse, an airtight air gap (12) between 1 and 4 mm high being formed between each pole piece (5) and the respective pole (1) through the interposition of a plate (4) of thermal insulation material that resists high temperatures provided at each pole (1) with a rectangular window slightly smaller in size than the pole itself, the top sides of the pole pieces (5) and/or the bottom sides of the poles (1) being provided with peripheral recesses suitable to act as seats for the positioning of said plate (4).
LIFTER WITH ELECTROPERMANENT MAGNETS

The present invention relates to magnetic lifters, and particularly to a lifter with electro-permanent magnets capable of operating safely for a long time also on ferromagnetic materials at high temperatures up to 600-650°C such as billets, blooms, slabs and similar steel mill products.

It is known that magnetic lifters are divided into three classes depending on the type of magnets employed, i.e. permanent magnets, electromagnets and electro-permanent magnets, each type of magnets having its own advantages and drawbacks.

The lifters with permanent magnets have the advantage of an almost negligible power consumption and of a produced magnetic force which is reliably constant and independent of outer supply sources. On the other hand, it is not possible to increase the magnetic force if necessary and the magnets are exceedingly bulky for lifting heavy loads. Furthermore, the load release requires the application of a considerable mechanical power in order to create an air gap between the lifter and the load large enough to reduce the magnetic force to a value smaller than the load weight. Alternatively, the magnets have to be made movable so that they can be moved away from the load, thus decreasing the magnetic attraction, or it is necessary to provide compensator coils to temporarily generate in the load a magnetic flux opposite to the magnetic flux generated by the permanent magnets, as in FR 2616006.

On the contrary, in the lifters with electromagnets it is possible to freely vary the magnetic force by simply adjusting the current flowing in the windings which generate the magnetic field. However, any breakdown, even if very short, of the power supply immediately cancels the magnetic force and thus causes the release of the load. It is therefore evident that safety systems ensuring the supply continuity are essential.

The lifters with electro-permanent magnets succeed in overcoming the main drawbacks of the two above-described types of lifters by combining fixed polarization permanent magnets with permanent magnets of the reversible type, i.e. magnets in which the polarization is easily reversed through the application of an electrical pulse. When the polarization of the magnetic masses, fixed and reversible, results in a North-South-North-South series the magnetic flux is short-circuited within the lifter thus
making the latter inoperative, whereas when the polarization of the reversible magnets is in opposition, i.e. in parallel North-South-South-North, the magnetic flux splits up passing through the polar pieces into the ferromagnetic material to be moved and the lifter is operative. The reversible magnet thus generates an adjustable magnetic flux which can also direct the flux of a conventional non-reversible permanent magnet combined therewith, so as to short-circuit the two magnets when the lifter is to be deactivated or arrange them in parallel for activating the lifter.

Since just an electrical pulse but not a continuous supply is needed for reversing the reversible magnet, the safety problems affecting electromagnets are prevented. At the same time, even though permanent magnets are used, it is possible to vary the magnetic force within some limits, and the load release is easy to carry out with a minimum power consumption and without complex structures for moving the magnets.

However, the lifters with electro-permanent magnets manufactured until today have significant use restrictions as far as the temperature of the material that can be safely lifted is concerned. In fact the reversible magnets are usually made of an aluminium-nickel-cobalt alloy (Alnico) that has a Curie point of about 800°C, while the fixed polarization magnets are made of neodymium or ferrite that have a Curie point of about 310°C and 450°C respectively. This means that lifters with electro-permanent magnets of Alnico-neodymium operate without problems on ferromagnetic materials with temperatures not greater than 150-200°C, whereas those with magnets of Alnico-ferrite can operate on materials up to 350-400°C.

Moreover also the commutation coils that control the reversal of the polarization of the reversible magnets have their own maximum operating temperature, whereby upon achievement of even one of these three maximum temperatures (coils, fixed and reversible magnets) the lifter must be put to rest to cool down in order to ensure the integrity of the same, and the safety of the lifting and transport operations of the hot ferromagnetic products.

In practice this means that even a lifter provided with the best fixed polarization magnets of a samarium-cobalt alloy, which has a Curie point of about 770°C, must be put to rest after about two hours of operation in the handling of ferromagnetic materials at 600°C with a 60% operating cycle (i.e. 60% of the time in contact with the hot
material and 40% not). In fact after this time of operation the average temperature of the fixed SmCo magnets is about 350°C, which is also the limit temperature recommended by the manufacturers of such material, the temperature of the reversible Alnico magnets reaches 340°C and the commutation coils have an average temperature of 180°C, which is also close to the temperature limit.

This also depends on the fact that in traditional lifters the pole pieces are fixed to the poles with the circuit surfaces perfectly in contact with each other, i.e. without air gap, to reduce magnetic circuit leakage thus minimizing the magnetic reluctance. This arrangement, however, also facilitates the transmission of heat towards the interior of the lift when it is used in the lifting and transport of steel mill products with temperatures varying between 400°C and 650°C. As explained above, this heat transmission considerably reduces the operating time of the lifter because it leads to risky temperatures in relatively short times in its critical components namely, in chronological order, the fixed magnets, the reversible magnets and the commutation coils.

Therefore it is an object of the present invention to provide a lifter with electro-permanent magnets that overcomes the above-mentioned drawbacks. Such an object is achieved by means of a lifter in which the pole pieces are not in contact with the poles (i.e. the air gap is not zero) since airtight air gaps are present between the pole pieces and the poles so as to reduce greatly and for guaranteed times the transmission of heat from the hot materials to the above-mentioned heat-sensitive critical components. Other advantageous characteristics are recited in the dependent claims.

The main advantage of this lifter is therefore that of being able to significantly increase the range of the continuous safe operation up to times much higher than those that can be reached by present lifters with electro-permanent magnets so as to guarantee at least an operability over an 8-hour shift in a steel mill hot area.

Another important advantage of the lifter according to the present invention is provided by its structural simplicity, which makes it reliable and suitable also for the upgrade of existing lifters.

Further advantages and characteristics of the lifter according to the present invention will be clear to those skilled in the art from the following detailed description.
of an embodiment thereof, with reference to the annexed drawings wherein:

Fig. 1 is a transverse cross-sectional view along the midplane of a lifter according to the present invention, resting on a load to be lifted, with an enlarged detail; and

Fig. 2 is an enlarged detail of a bottom plan view of a corner of the lifter of Fig. 1.

With reference to these figures, there is seen that a lifter with electro-permanent magnets according to the present invention conventionally includes an external bearing structure, a plurality of electro-permanent magnets and an adjustment and control circuit.

The bearing structure consists of a top cover 2, provided with couplings for the connection to lifting means (e.g. a crane), two peripheral walls 3 and a bottom closure plate 10 provided with a heat shield 9 to protect the magnets from the heat radiated by the hot ferromagnetic materials to be lifted. Said structure is obviously made of high magnetic conductivity materials, typically carbon mild steel, in order to minimize the reluctance of the magnetic circuit, same as the circuit poles 1 and the pole pieces 5, intended to contact the load to be lifted, which protrude below the closure plate 10 and are secured to poles 1 through screws 11.

Each of the electro-permanent magnets includes a reversible magnet 6, arranged on top of a pole 1 and in contact therewith, and a fixed polarization magnet 7 formed by a plurality of blocks placed along the lateral faces of said pole 1. Around the reversible magnet 6 there is arranged a commutation coil 8 that controls the reversal of the polarization thereof, to commute between the condition of inoperative lifter illustrated in Fig. 1 with the poles in series North-South-North-South and the condition of operative lifter with the poles in parallel North-South-South-North.

The adjustment and control circuit preferably includes a device of the type described in EP 0929904 B1. In brief, said device includes for each polarity a first magnetic sensor arranged close to the base of pole 1 and a second magnetic sensor arranged between the fixed magnet 7 and the reversible magnet 6, so as to measure substantially only the magnetic flux passing through the reversible magnet 6, as well as a control unit for processing the signals transmitted by said magnetic sensors (not shown in the drawings) and obtaining the operating point of the lifter on the magnetization curve of the reversible magnet 6.
The above device guarantees absolute safety during any load lifting and transporting operation by checking that the sum of the reversible losses of the magnetic masses 6, 7 and of the decrease in magnetic permeability of the ferromagnetic circuit of the lifter, and in particular of the hot material to be lifted, still allows the lifter to attain the lifting safety coefficient according to the EN 13155 standard (or another similar standard applied in other countries).

Such a device also monitors the efficiency of coils 8 that are preferably made of an aluminium strip or a copper strip so as to minimize their volume and to optimize the thermal dissipation due to Joule effect. Coils 8 are designed such that they can operate correctly with reversal pulses that are either constant in current or constant in voltage, although given the critical operating conditions of high temperature of the material it is preferable to use a constant current apparatus.

The adjustment and control circuit employs also the signals of thermal probes (not shown in the drawings) extending inside the various critical components of the lifter to check that it is possible to perform safely the operations.

Turning now to the specific novel aspects of the present lifter, the applicant has found that for the particular application for which the present lifter is intended it is advantageous to have the pole pieces 5 not in contact with poles 1 but leaving a small air gap, even if this implies an increase in the magnetic reluctance of the circuit and an increased magnetic circuit leakage. Overcoming this rooted technical prejudice, the applicant has verified through tests that at the operating temperatures requested to the lifter to operate on ferromagnetic materials at high temperatures up to 600-650°C, the disadvantage due to the increased magnetic reluctance is substantially offset by the reduced transmission of heat through the air gap which allows it to operate with the same loads of a traditional lifter but for much longer times without having to put it to rest after a couple of hours to let it cool down.

More specifically, returning to the example mentioned above of a traditional lifter equipped with fixed polarization magnets of samarium-cobalt alloy which moves the ferromagnetic material at 600°C with a 60% operating cycle, after two hours of operation its maximum strength lifting was reduced to 44% compared to 100% which it had at 20°C at the start of the operation. Furthermore, the temperatures reached by the
critical elements prevent to continue to safely use the lifter that must be put to rest to cool down.

A lifter according to the present invention, which faces the same operating conditions and is provided with airtight gaps 2 mm high, initially starts with a maximum force at 20°C reduced to 82% due to the air gap but after two hours of operation still retains 43% of the force. This means that despite the air gap of 2 mm, thanks to the presence of the airtight air gaps, the reduction of losses due to the heating of the magnetic masses after two hours of operation limits the difference between the forces of the two lifters to 1% against the initial 18% (and taking into account the safety factor of 3 of EN 13155 this difference in practice is 0.33% and 6% respectively).

However, the present lifter is still able to operate safely, as opposed to a traditional lifter, as shown by the following table which shows the temperature increase of the critical elements that even after 16-18 hours of operation have not yet reached the limit values, so that the lifter still retains about 38% of the force.

<table>
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<tr>
<th>Time (h)</th>
<th>Temperature SmCo (°C)</th>
<th>Temperature Alnico (°C)</th>
<th>Temperature coils (°C)</th>
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<tr>
<td>2</td>
<td>106</td>
<td>90</td>
<td>65</td>
</tr>
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<td>6</td>
<td>200</td>
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<td>255</td>
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<tr>
<td>18</td>
<td>286</td>
<td>260</td>
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The enclosed drawings show the preferred embodiment or best mode of the invention in which the airtight air gaps are obtained by interposing between the pole pieces 5 and poles 1 a plate 4 of thermal insulation material resistant to high temperatures, for example a laminated material commercially known as Pamitherm and consisting of sheets of muscovite coupled by means of silicone resin. In correspondence of each pole 1 there has been formed in plate 4 a rectangular window of a size slightly smaller than the pole itself, while in the top sides of the pole pieces 5 and/or in the bottom sides of poles 1 peripheral recesses were obtained, for example 7-12 mm wide.
and 3-6 mm high, which form seats for the positioning of plate 4.

Subsequently, the magnetic poles 1, the pole pieces 5 and plate 4 have been brought to a temperature of at least 150°C to eliminate any presence of moisture and the mounting screws 11 of pieces 5 have been tightened so as to compress adequately plate 4 such that it acts as a gasket for the airtight sealing of the air gaps 12 thus formed. These air gaps 12, which are preferably between 1 and 3 mm high depending on the temperatures and on the operating times, greatly reduce the transmission of heat received from the lifted material at temperatures up to 650°C thanks to the extremely low thermal conductivity of dry air that is around \( \lambda = 0.026 \text{ W*m}^{-1}\text{*K}^{-1} \).

The material of which plate 4 is composed can operate between 450°C and 800°C, has a resistance to compression \( \geq 300 \text{ MPa} \) and a very low thermal conductivity \( \lambda = 0.18 \text{ W*m}^{-1}\text{*K}^{-1} \) (although materials with \( \lambda \) up to 0.32 \( \text{ W*m}^{-1}\text{*K}^{-1} \) are suitable). The temperature values in the above table were obtained using a lifter according to the preferred embodiment comprising a plate 4 having these parameters.

The typical size of a magnetic pole 1 is preferably included between 200 and 350 mm in width and between 800 and 1400 mm in length, and in the illustrated embodiment the portion of plate 4 compressed between pieces 5 and poles 1 forms a frame 10 mm wide and 5 mm high that although being of reduced area transmits heat more readily since it has a thermal conductivity about 7 times higher than the dry air of the airtight air gap 12. To minimize this amount of heat it is preferable to install heat sinks 13 between the pole pieces 5, below plate 4 of heat-insulating material, each heat sink 13 being formed by a plurality of transverse elements arranged between a pair of longitudinal elements which extend along the opposite side walls of two adjacent pole pieces 5. Note that half-sized heat sinks 13' are arranged also on the outer side walls of the outermost pieces 5 to achieve maximum efficiency in heat dissipation, and that heat sinks 13, 13' are preferably made of copper whose thermal conductivity coefficient is \( \lambda = 390 \text{ W*m}^{-1}\text{*K}^{-1} \).

A lifter with electro-permanent magnets thus manufactured and operated is therefore capable of safely moving for long periods materials such as billets, blooms, slabs, etc. at a temperature of 600-650°C and is therefore suitable for the discharge operating cycle of the cooling plates located at the outlet of the hot rolling line of said
products in a steel mill.

It is obvious that the above-described and illustrated embodiment of the lifter according to the invention is just an example susceptible of various modifications. In particular, the exact number, shape and arrangement of the magnetic polarities may vary depending on the specific application, for example by providing a lifter with a single magnetic dipole or three or more magnetic dipoles rather than the two magnetic dipoles illustrated in the present embodiment.

Moreover the air gaps 12 can be obtained in other ways, for example by arranging between pieces 5 and poles 1 gaskets of suitable material and adequate height housed in specific seats.
CLAIMS

1. Lifter with electro-permanent magnets comprising an external bearing structure (2, 3) closed at the bottom by a plate (10) provided with a heat shield (9), and pole pieces (5) secured at the bottom of respective circuit poles (1) of said electro-permanent magnets and protruding from said bottom plate (10), characterized in that it further includes an airtight air gap (12) between each of said pole pieces (5) and the respective pole (1) to which it is secured.

2. Lifter according to claim 1, characterized in that the height of the air gap (12) is comprised between 1 and 4 mm.

3. Lifter according to claim 1 or 2, characterized in that the airtight air gaps (12) are formed in a plate (4) of thermal insulation material that resists high temperatures arranged between the pole pieces (5) and the poles (1) and provided at each pole (1) with a window slightly smaller in size than the pole itself, the top sides of the pole pieces (5) and/or the bottom sides of the poles (1) being provided with peripheral recesses suitable to act as seats for the positioning of said plate (4) of thermal insulation material.

4. Lifter according to the preceding claim, characterized in that the material of which the thermal insulation plate (4) is made is suitable to operate between 450°C and 800°C, has a compression resistance ≥ 300 MPa and a thermal conductivity comprised between 0,18 and 0,32 W*m⁻¹*K⁻¹.

5. Lifter according to the preceding claim, characterized in that the material of which the thermal insulation plate (4) is made is a laminated material made up of muscovite sheets coupled through silicone resin.

6. Lifter according to any of claims 3 to 5, characterized in that the peripheral recesses are 7 to 12 mm wide and 3 to 6 mm high, preferably 10 mm wide and 5 mm high.

7. Lifter according to any of the preceding claims, characterized in that it further includes heat sinks (13), preferably of copper, arranged between the pole pieces (5) under the plate (4) of thermal insulation material.

8. Lifter according to the preceding claim, characterized in that each heat sink
(13) is made up of a plurality of transverse elements arranged between a pair of longitudinal elements extending along the opposite side walls of two adjacent pole pieces (5).

9. Lifter according to any of the preceding claims, characterized in that it is provided with an adjustment and control circuit comprising thermal probes.

10. Method of manufacturing a lifter with electro-permanent magnets according to any of claims 3 to 9, characterized in that the circuit poles (1), the pole pieces (5) and the plate (4) of thermal insulation material are taken at a temperature of at least 150°C so as to eliminate any trace of moisture and then the pole pieces (5) are secured on the poles (1) through mounting screws (11) sufficiently tightened as to compress the plate (4) such that it acts as a gasket for the airtightness of the air gaps (12).
INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/056267

A. CLASSIFICATION OF SUBJECT MATTER
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Category
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Minimum documentation searched (classification system followed by classification symbols:)
B66C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.

See patent family annex.

Date of the actual completion of the international search
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Date of mailing of the international search report
07/12/2015

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Faymann, L
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