FERROUS YOKE CONSTRUCTION INFLUENCE ON PERMANENT MAGNETS PUMP EFFICIENCY

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Abstract. The influence of outer passive ferrous yoke construction on the efficiency of the cylindrical electromagnetic induction permanent magnets pump has been investigated with a pump experimental model. The main goal for such studies is to simplify the ferrous yoke as its construction and as the possibility of its assembling/reassembling taking into account rather strong magnetic attraction forces between the ferrous yoke and the magnetic rotor of the pump, especially for more powerful pumps and, correspondingly, at its larger bigger dimensions and very strong integral magnetic attraction forces.

1. Introduction.

Electromagnetic induction permanent magnets pumps (PMP) during last 15 years have been successfully used in practice and seem rather perspective for future power plants, where liquid metals will be used as coolants [1, 2], as such pumps have simpler design and higher efficiency in comparison with traditional linear inductors pumps. There are different design concepts of PMP, but more perspective if compared with the disc-type PMP are the cylindrical PMPs ensuring a wider range of productivity both for developed output discharge pressure and, in particular, for provided much higher flow rates [3]. To increase the efficiency of the cylindrical PMP, at its construction usually an outer passive laminated ferrous yoke (which is optional) is used. A ferrous yoke essentially increases the magnetic field strength in the liquid metal layer in the pump channel and the pump efficiency [4] as EM forces induced in liquid metal are proportional to the magnetic field strength in the second power.

Four types of ferrous yoke design have been investigated. The first ferrous yoke was made from the stator of a used AC motor of laminated construction, ensuring minimum heat losses. The second design type of the ferrous yoke was made with cuts in the solid ferrous plate. The third ferrous yoke design, having the same geometry, was made just from a solid ferrous plate when heat losses in the ferrous yoke were maximum. The fourth ferrous yoke construction from compounded carbonyl iron powder (depending on the allowable maximum operating temperature of the bounding component) can be used for liquid metals with low operating temperatures (such as mercury and liquid metals eutectics having low melting temperatures). Experimental investigations were carried out in a range of frequencies up to 75 Hz of the induced alternating magnetic field in a liquid metal layer in the pump channel.

2. Experimental results.

Experiments were carried out in a liquid metal (In-Ga-Sn) circulation loop using a cylindrical PMP model (fig. 1). Four different ferrous removable yokes (fig. 2) after their sequent changing were installed in the pump model and the total active power consumed by the motor for pump driving was measured at different rotation speeds of the motor adjusted by using a frequency converter. The first ferrous yoke was made from the stator of a used AC motor. The second ferrous yoke was made (by bending) from a flat ferrous steel sheet, with 1 mm cuts previously made in it 3 mm distanced from each other. The third ferrous yoke was made of solid ferrous steel. The forth ferrous yoke was made from a carbonyl iron powder mixture with epoxy. The experimental results, demonstrating total heat losses in the pump (in the liquid metal layer, in the pump channel electrically conducting stainless steel walls and in the outer ferrous yoke) are illustrated in the graphs (fig. 3).

Figure 1: Experimental In-Ga-Sn loop with an EM induction cylindrical permanent magnets pump model.

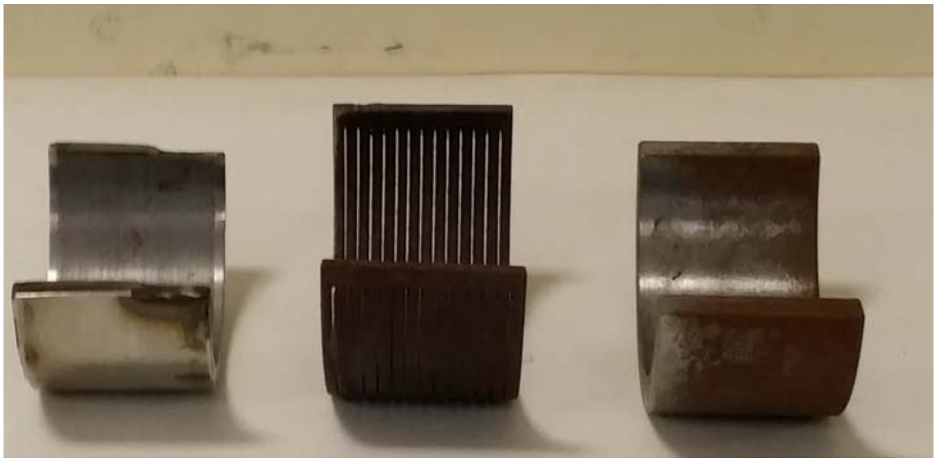

Figure 2: Different tested outer passive ferrous yokes: a) laminated; b) ferrous plate with cuts, and 3) solid ferrous yoke.

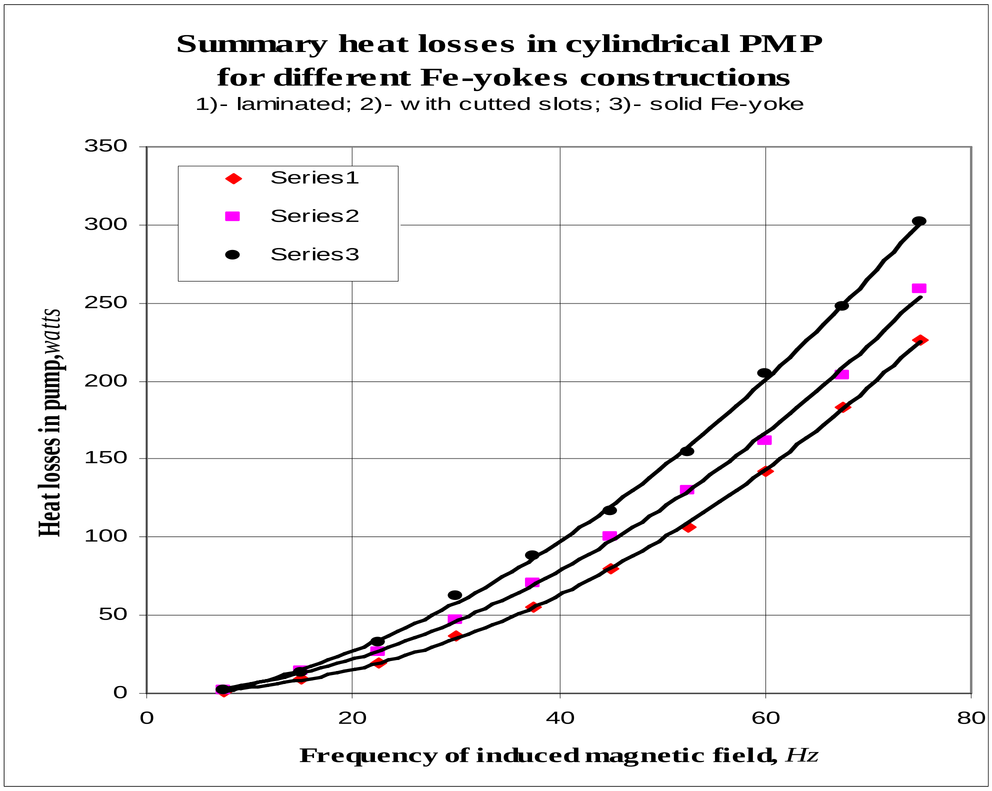

Figure 3: Comparison of heat losses in the pump model for different outer ferrous yoke designs.

As experimental results demonstrate, the difference in heat losses in the pump for different ferrous yoke constructions is not so dramatic. It is natural that with the solid ferrous yoke the pump efficiency is essentially lower, approximately by 25% at 75 Hz frequency in comparison with a pump with a laminated ferrous yoke (as used in standard electrical AC machines). In its turn, with the second ferrous yoke construction (with cuts in the ferrous plate), the pump efficiency is only by 12% lower. Experimental data extrapolation for higher frequencies of the induced alternating magnetic field in the pump (up to 150 Hz) demonstrate that the above-mentioned values of the pump efficiency drop by about 25% for the solid ferrous yoke and by about 12% for the ferrous yoke with cuts decrease, correspondingly, to 17% for the solid ferrous yoke and to 7% for the ferrous yoke with cuts.

3. Conclusion.

With the solid ferrous yoke design, the efficiency of the pump is essentially lower in comparison with a pump with a laminated ferrous yoke (as used in standard electrical AC machines). In its turn, with the second ferrous yoke construction (with cuts in the ferrous plate), the pump efficiency is higher in comparison with the solid ferrous yoke but a little lower in contrast to the accordingly laminated ferrous yoke. With the forth ferrous yoke construction (compounded carbonyl iron powder), the pump practically has the same pump efficiency (even a little higher) as a pump with a standard laminated ferrous yoke. So in many cases, at design and construction of more powerful pumps, the ferrous yoke may be produced from a solid ferrous material or from ferrous plates with cuts that essentially simplifies both the ferrous yoke production and its assembling/reassembling. In practice, for the EM pump installed in liquid metal circulations loop the efficiency of the pump may be so not crucial as, due to the higher heat losses in the pump, the power of the external loop heaters (for keeping a constant temperature in the loop) may be lower and, as a result, the lower pump efficiency practically has no influence on the efficiency of the whole integral liquid metal circulation loop.

4. References

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