Research of multicentric ring coils in comparison to classic ring coils

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***Abstract*—The topic is about ring coils with eccentric orientated semi-windings for heating of parts with different diameters. These are compared to classic ring coils that only have one inner diameter and one center. Especially the efficiency is considered and compared between both types of coils.**

Keywords — induction heating, multicentric ring coil, simulation

I. Introduction

If a workpiece has different diameters or is built asymmetrically, it can still be heated with only one classic ring coil that has one inner diameter. This applies also if several workpieces with different diameters shall be heated. The result from that is a low efficiency for the workpiece areas where the coupling gap (distance between the inner diameter of the coil and the outer diameter of the workpiece) is large. Usually, the coupling gap shall be held to a minimum [1].

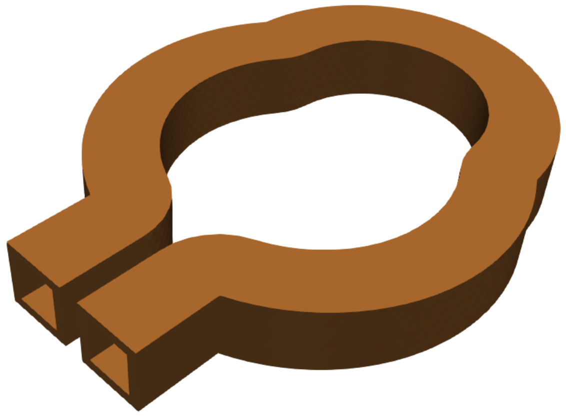

Fig. 1: Inductor with two eccentric orientated semi-windings (multicentric ring coil)

Another approach is to use different coils for each zone to be heated. Then, the coils are dimensioned individually for the areas to be warmed so one can achieve a small coupling gap. On the other hand, this makes further coils necessary and it leads to additional work in changing between the coils. In some cases, also another heating station might be required.

A good compromise solution seems to be coils that have two eccentric orientated semi-windings making it possible to have partly a small coupling gap for both zones to be heated by induction (see. Fig. 1). In practise, these types of coils are often referred as “snowman”- or “keyhole”-coils due to its shape. Since there are also coils possible, that do have more than two half windings, these types of coils will be defined in this elaboration as multicentric ring coils. An example of a multicentric ring coil for at least three different workpieces / workpiece zones is shown in Fig. 2.

Thus, there are several approaches about how to proceed when workpiece zones with different diameters have to be heated

II. Motivation

The aim of this study is a research of these types of coils. Especially, the efficiency is interesting and helps to find out if it is better to apply such a coil or if it is more feasible to use coils with different diameters. Besides that, also other aspects like rotation speed and inductance are considered. In this way, one can gain a clear view about the behaviour of multicentric ring coils and may find out how and when they shall preferably be applied.

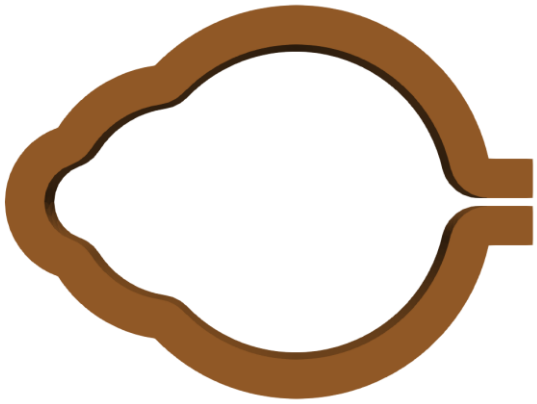

Fig. 2: Multicentric ring coil for at least three highly varying workpiece diameters

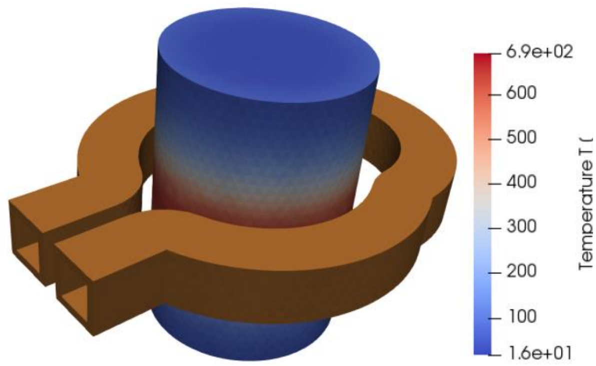

Fig. 3: Temperature distribution in the workpiece heated by a multicentric ring coil

III. Approach

Coils with different diameters are considered in this elaboration. Here, the efficiency of the version with two eccentric orientated semi-windings and classic ring coils are compared. For this, simulations have been done with multicentric ring coils for different workpieces (ø: 30 and 50 mm). For this research, simulations have been done with the software CENOS that does the calculations with finite element method [2]. An exemplary modelling result of the temperature field in the workpiece is shown in Fig 3. All simulations in this examination have been done in 3D. For many simulations, only the electromagnetic field has been regarded and calculated because the heat sources do already reveal the efficiency of the coil-workpiece constellation.

IV. Results

The results in Fig. 4. show that a multicentric ring-coil achieves a bigger efficiency at the small workpiece but a reduced efficiency at the big workpiece. Therefore, it needs to be checked where the high-power demand is expected or if two individual coils can be used. However, especially if the two diameters to be heated belong to the same workpiece, using of separated coils is often not possible. For example, at camshafts, there are asymmetrically formed cams and rotational symmetric formed bearings. There, one process approach is to heat the rotating cam with the big ring of the multicentric ring coil and the bearing with the small ring. One small single ring coil for heating the bearing cannot be used here because the cams would mechanically block the coil.

Another important result concerns the rotation speed. In general, multicentric ring coils require a higher rotation speed

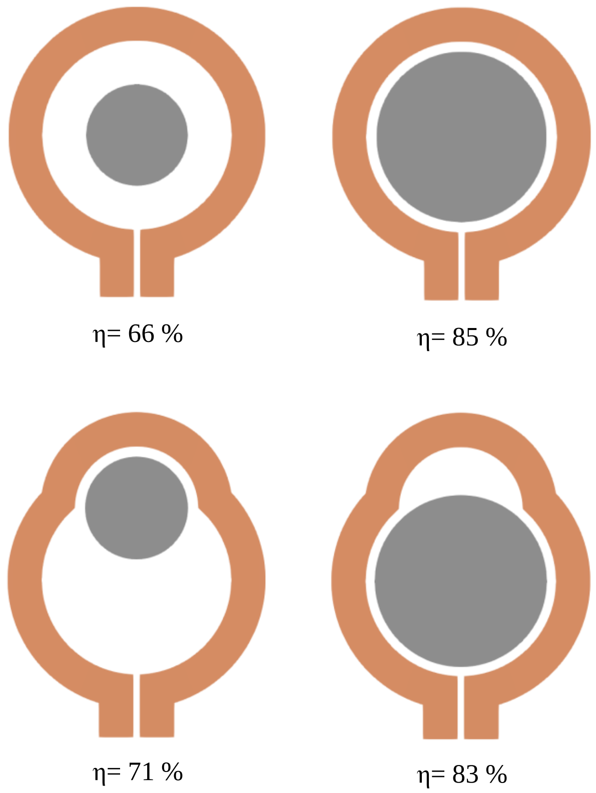

Fig. 4: Efficiency of different coil types

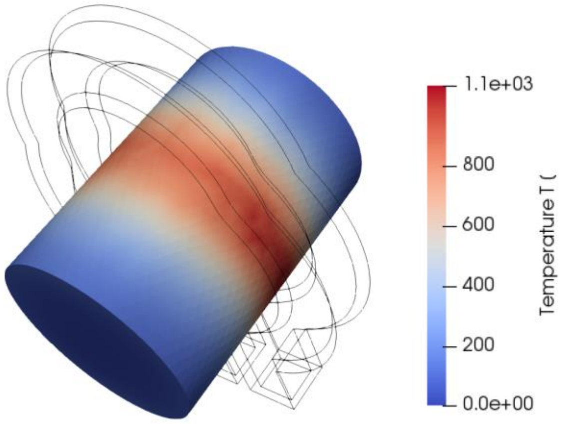

Fig. 5: Temperature distribution in the workpiece if it does not rotate. The coil is displayed schematically.

in comparison to typical ring coils where the workpiece is centred in the coil. The common rotation speeds that usual systems can provide are in most cases sufficient. Fig 5 shows the temperature distribution of the workpiece surface if it does not rotate. There, the inequal temperature distribution in tangential direction can be observed. This verifies that multicentric coils cannot be used at non-rotating workpieces.

The inductance of the coil is also increasing when compared to a standard ring coil. Therefore, it needs to be ensured that the converter is dimensioned right for the electric load. On the other hand, the change of inductance when different workpieces / workpiece zones are heated is smaller in comparison if coils with different inner diameters are used. This makes it in general easier to match the converter to the load when using a multicentric ring coil. Especially in cases where the output circuit (matching transformer, capacitors) behind the converter does not provide a possibility to be adjusted, the use of a multicentric ring coil can create advantages.

V. Conclusion

The simulation results reveal that coils with two eccentric semi-windings are quite efficient.

At present, still many applications with rotationally symmetrical workpieces of different diameters are heated with a big set of different coils. This creates a lot more cost and time to change the coils. Therefore, processes should be checked carefully, if a multicentric ring coil might not be the better alternative. In might be better to use such a coil than just to build one standard ring coil with a big diameter that shall also heat up the smaller workpieces / workpiece zones.

Finally, in processes where energy efficiency plays a superior role, it is still better to use different coils for the according workpieces. Therefore, it is a question of the process and the priorities which principle shall be applied.

[1] Rudnev, V. ; Loveless, D. ; Cook, R. ; Black, M.: Handbook of Induction Heating.. 1. Edition. New York, Basel : Marcel Dekker, Inc., 2003

[2] Website: CENOS - https://www.cenos-platform.com/ - Access: 27.02.2020