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STRATIFIED HAIPIN CONDUCTORS FOR REDUCTION OF EDDY CURRENTS

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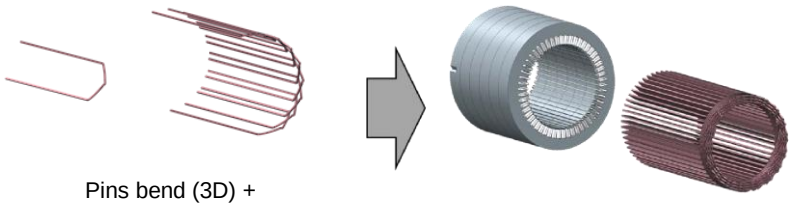
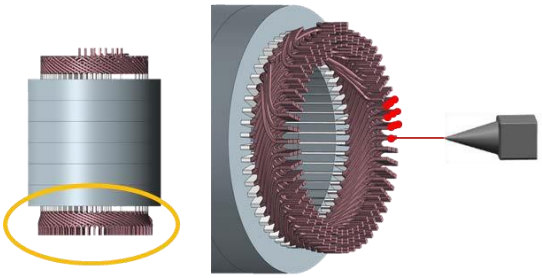
Technical task:
Wire coil around an electric machine.

Initial situation:
Stator windings of electrical machines can be designed in different ways. A variant is the winding with preformed elements (also called: flat wire winding, hairpin winding, shaped wire winding). With this winding, individual insulated wires are preformed and pushed together into so-called baskets into the stator core. These elements are bent on the reverse side and welded together according to a circuit. All pins are made with the same wire.



Pins bend (3D) + form baskets

Pressing in baskets

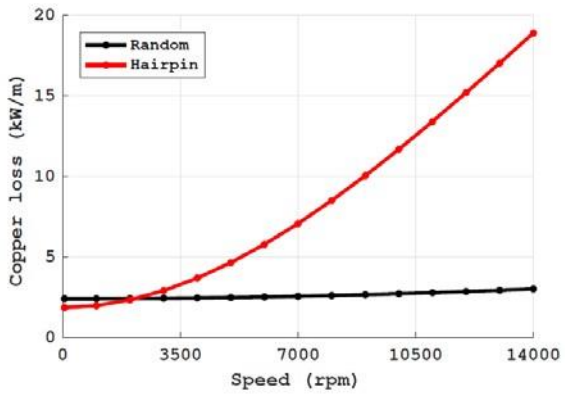


Pin-Pair welding
(laser- / electron beam welding)

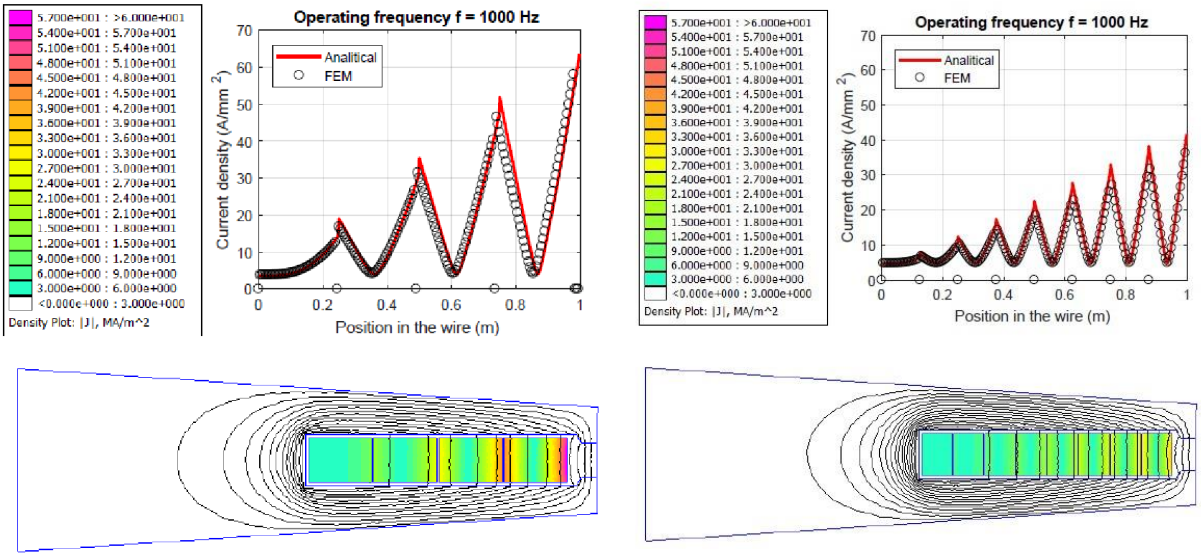
Variable-speed motors with high power density are usually operated at very high frequencies. The combination of hairpins and high frequencies leads to parasitic eddy current losses. On the one hand there are the high-frequency losses due to current displacement or the skin effect and on the other hand additional currents are induced by foreign magnetic fields, which also lead to additional losses (proximity effect). The total resistance is therefore frequency-dependent and consists of the sum of AC resistance and DC resistance:

$$R_{CU} = R_{DC} + R_{AC}(f)$$

The parasitic effects can therefore be described as frequency-dependent resistance increase. This significantly increases the copper losses:



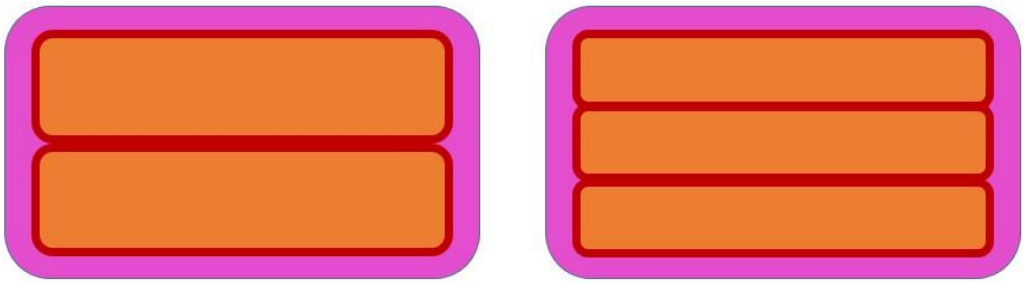
The current displacement occurs in particular near the air gap or the rotor. A suitable measure to reduce this effect is to increase the number of conductors per groove:



This cannot be done arbitrarily because the copper filling factor or the ratio of conductor and insulation becomes less favourable with increasing number of conductors in the groove and the DC resistance is thus worsened. Production is also becoming more and more complicated and, according to current estimates, is capped for 8 conductors per slot on the basis of economic considerations.

Solution:
A hairpin wire is to be developed that is already layered in itself. It consists of parallel wires, which are "simply insulated" against each other. The requirements for the insulating properties of the "inner" insulation are relatively low, as these partial conductors are welded together at regular intervals at the welding ends. The internal insulation must only insulate the parasitic induced voltage, which is very low.

The partial conductors are connected to each other by a further layer to form a new layered hairpin conductor. This layer can be applied either as lacquer or by extrusion. This layer is a non-conductor or a plastic.



Advantages:
The frequency-dependent copper losses are greatly reduced and the electrical machine becomes more efficient.