2D Magnetostatic Analysis and 3D Thermal Analysis of an Electromagnet.

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A DC electromagnet for a directional control valve is characterised by the presence of a cylindrical guide for the mobile core.
This electromagnet is used to drive a directional control valve with a maximum pressure of 75 bars.
A magnetostatic study has been carried out with FLUX2D for the optimisation of the force in the nominal working conditions, and a thermal study with FLUX3D to obtain the optimised magnetic circuit to reduce temperature in order to increase, in fine, the force.
The difficulty of the design consists in the necessity to obtain a curve of sufficient force to gain the total resistant force for cold or hot device, with the respect of project bonds.

2D Magnetostatic analysis

This phase of study is fundamentally useful to optimise the geometry of the cylindrical guide and the core. The magnetic circuit is of armored type and can be approximated to axial-symmetrical type in FLUX2D, considering an equivalent thickness for the external part that gives the same useful section for the flux flow. In figure 1 we can see the description of all regions in a 2D cross section of the magnet central section. Only the upper coil is energised. The electromagnet is bidirectional and both displacements are 3,0 millimetres long.
The coils nominal power was set initially to 50W and a nominal voltage source of 12V.
Shape and dimensions of the bronze soldering, diameters and lengths of the cylindrical guide and the core have been optimised.

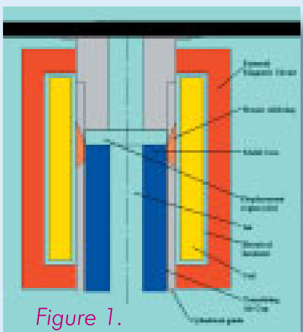

Figure 1.

Figure 2 represents the flux density map of the whole device and figure 3 shows a zoom in proximity of the welding.
The observation of the magnetic pressure vectors demonstrates the function of the triangular tip of the welding, that concurs to obtain a starting force approximately twice than the one obtained without tip.

3D Thermal analysis

Due to the geometry of the electromagnet, a bi-dimensional axis symmetrical approximation is not enough to obtain definitive results: this is due to the external embedding in polymeric resin containing the device. Considering the correct right external surfaces and thickness of such insulating shield is fundamental to get the right heat exchange and so precise temperature results.
Volume regions are represented in the figure 4:
We can see the external magnetic circuit with the cylindrical guide.
For symmetry reasons, half of the device is represented.

Physical properties

The coil region has been defined like a heat source. To obtain results under high temperature condition, the power of the same coil has been set up as a function of the state variable TEMPERATURE (Celsius degrees temperature). The coil power function is showed below:
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where the numerator is the power at the ambient temperature (20°C), 0.0039 is the temperature coefficient of copper and 1.4326.10-5 is the volume (m^3) of the half part of the designed coil. With this formulation the heat power generated of the coil depends on the temperature of the same region.
After setting the geometric parameters up and defining the heat sources, the convection coefficients have been assigned to the air-contact surfaces, making opportune distinctions between vertical and horizontal surfaces.
Formula used in order to define the convection (natural in air) and radiation coefficients for the three superficial regions:

$$\alpha = K\cdot\sqrt[4]{\frac{T_1-T_a}{T_a\cdot h}} + 2.65\cdot\sqrt[4]{T_1-T_a}\ \left[\frac{W}{m^2\cdot K}\right]$$

Where:
T1: wall temperature [K]
T2: ambient temperature [K]
h: wall characteristic dimension [m]

The K coefficient is assigned as function of the type of wall: for a vertical wall it is 5.6, for a horizontal wall under a device is a 20% less (4.48), while for an upper vertical wall it is 20% more (6.72).

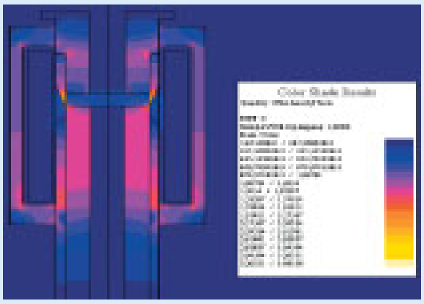

Figure 2.

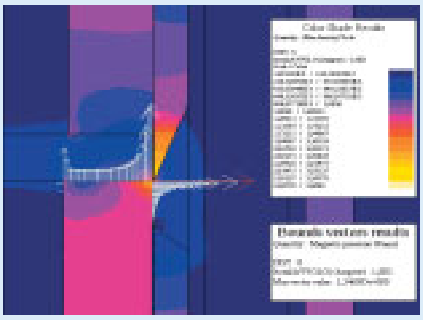

Figure 3.

In the same way h is the height of the vertical wall, or in case of an horizontal wall, half its width. In all the formulae the first term regards convection, while the second regards radiation.

Thermal analysis results

Therefore the problem has been solved to verify the evolution of

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$$P_{avol} = \frac{50}{1+0.0039\cdot(TEMPERATURE-20)\cdot 1.4326\cdot 10^{-5}}\ [W/m^3]$$

(continued on page 13)

APA towards new horizons.

Thomas Maillard - CEDRAT TECHNOLOGIES.

In the country of rising sun ...

KEYSTONE INTERNATIONAL Co. Ltd signed an agreement of promotion and distribution of our standard piezo products in JAPAN. Mister Tamioshi KUROSAWA, Marketing Director of Keystone, and Mister Norio TATE, Sales Engineer, would like to express to the Flux magazine readers their feelings about this new collaboration:

"We are very pleased to have received our recent initial order from CEDRAT TECHNOLOGIES. Having received the order of two APA S series from Tohoku University became the first work for us Keystone International for CEDRAT TECHNOLOGIES.

We were impressed the quality of product when it was unpacked, all members at Keystone International were pleased that the quality verification would lead to generate more customers. We think that it is a very important element for developing the business in the future. When CEDRAT TECHNOLOGIES would respond the demand of Japanese customers, we will be pleased to fulfil our responsibility".

And also in Switzerland.

DIWAG AG signed an agreement of promotion and distribution of our standard piezo products in Switzerland. Mister Jean Jacques WAGNER, president of DIWAG, is also the inventor of an innovating optical encoder called «Dicod». By distributing Cedrat Technologies piezo products, Mr Wagner is willing to enlarge the DIWAG technological offer in the micro-positioning field.

These two agreements will launch for the first time a full and exclusive commercial activity for our piezo products in Japan and Switzerland. These agreements also supplements our precedent agreements covering the Benelux countries, Italy, Poland, Germany, Austria, USA and India. The search for partners in other countries (UK, Spain, Scandinavia) still continues.

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Celsius temperatures on all the volume regions (figure 5) and on the longitudinal section .

Two sensors have been created for the calculation of the temperature of the coil section center (temperatures on support point) and for the computation of the power integral on the coil volume. Under high temperature conditions power is equal to 32.9 Watt. The maximum temperature on the excited coil is equal to 153°C. This implies that high temperature current is 66% of the nominal current.

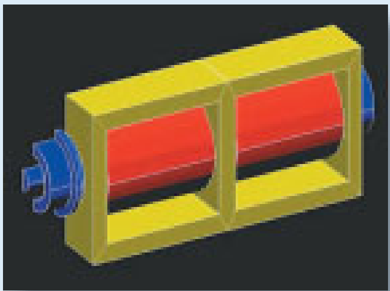

Figure 4.

Conclusion

The important results obtained from the thermal analysis allowed to observe the negative infuence of the superficial resin (low thermal conductivity coefficient) on thermal exchange. The thermal analysis has concurred to preview the value of the magnetizing current at high temperature condition and therefore a new magnetostatic analysis with FLUX2D has been carried out in order to verify if the force of under high temperature condition was sufficient to gain total resistant force.

Experiences have confirmed the theoretical forecasts, with minimal discrepancies (always comprised within 10%) on forces and temperatures results.

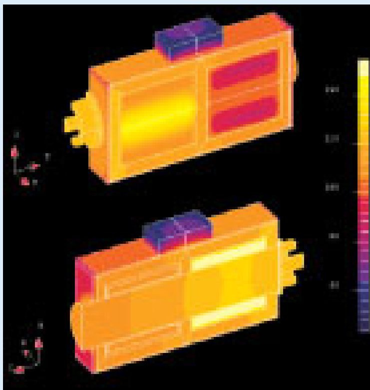

Figure 5.