A MAFIA TO I-DEAS LINK FOR THERMAL STUDIES IN THE IPHI RFQ

P.Balleyguier, CEA/DPTA Bruyères-le-Châtel, France
F.Launay, CNRS/IN2P3 Orsay, France

Abstract

High power losses expected in the end of vane region of the IPHI RFQ required serious computations of thermal effects. After improving the accuracy of the MAFIA post processor, we developed a new tool for data transfer between MAFIA and I-DEAS codes. We are now able to compute realistic temperature, stress and displacement fields. In spite of an enforced cooling system, the maximum local stress still exceeds the copper elastic limit. As this occurs only over a small area and in a thin depth, we consider it should have no bad consequence on the operating cavity.

1 INTRODUCTION

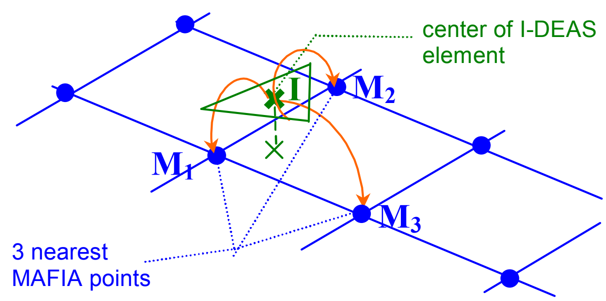
The new algorithm for RF losses computing in the MAFIA postprocessor was developed to give more realistic values for losses in re-entrant corners [1]. This algorithm has been established from theoretical considerations, and tested on different type of benchmarks: local analytical, global analytical, global experimental. As far as we could conclude, these tests confirmed the relevance of the new algorithm. Nevertheless, some care must be taken to interpret the results, particularly in areas where the MAFIA inherent "staircase approximation", generates fake rough surfaces. Applied to IPHI RFQ end of segment regions, it shows that power dissipations reach very high densities at certain spots.

2 HEAT TRANSFER

To predict the consequences on the mechanical structure from a thermal point of view, we have to use the local power as an entry in a thermal code before running it. As these data are very non-uniform, a manual transfer is very inaccurate and does not guarantee total power conservation. Moreover, such a transfer naturally enforces discontinuities (generating thermal gradient and stress) and is very sensitive to "human's feelings". Though such a method can be used in simple case like RF inputs [2], we needed an automatic algorithm for coupling plate and vane undercut regions.

What data should be transferred: power values or power densities? Projecting net power values (in Watt) from each surface element of the source model to the target model has the advantage of total power conservation. But it has some drawbacks: if the two models differ, some power spots could overlap after projection, while some areas of the target model could receive no power. And the problem would even be more critical if the source model have a wider geometrical extension than the target model.

We rather choose to start from the target model, and to interpolate the power density (in W/m^2). A limitation of this method is that some power densities on the source model might not be taken into account if the associated node is far from the target model. This could happen on re-entrant corners where power densities are especially high. So, geometrical models should be as close as possible, and the total transferred power must be checked.



$$p(I) = \alpha_1\, p(M_1) + \alpha_2\, p(M_2) + \alpha_3\, p(M_3),$$
$$(\textit{with}: \alpha_1+\alpha_2+\alpha_3=1,\ \textit{and}\ \ \alpha_1 IM_1=\alpha_2 IM_2=\alpha_3 IM_3)$$

Figure 1. Interpolation algorithme.

The heat transfer procedure starts with the generation of an RF loss data file with the MAFIA "#print" command in a "for" loop to scan the whole volume plane by plane. Zero loss-values points are eliminated by a UNIX procedure, as well as page titles. Followed by a standard "compress" command, the size of the original data file is reduced by a factor of 100.

A new I-DEAS module, called MAPFLUX was developed on our request by MAYA-HTT to use the RF loss data file. This module first reads the source data file, and apply some geometrical adaptation on the map if necessary (symmetry, shift of origin, scaling...). Then, heat power densities are interpolated from the 3 (or any other number) nearest points on the source model (fig. 1).

In order to check the result, a plot of the transferred power density is generated, and the sum of the global power over the whole target model surface is computed.

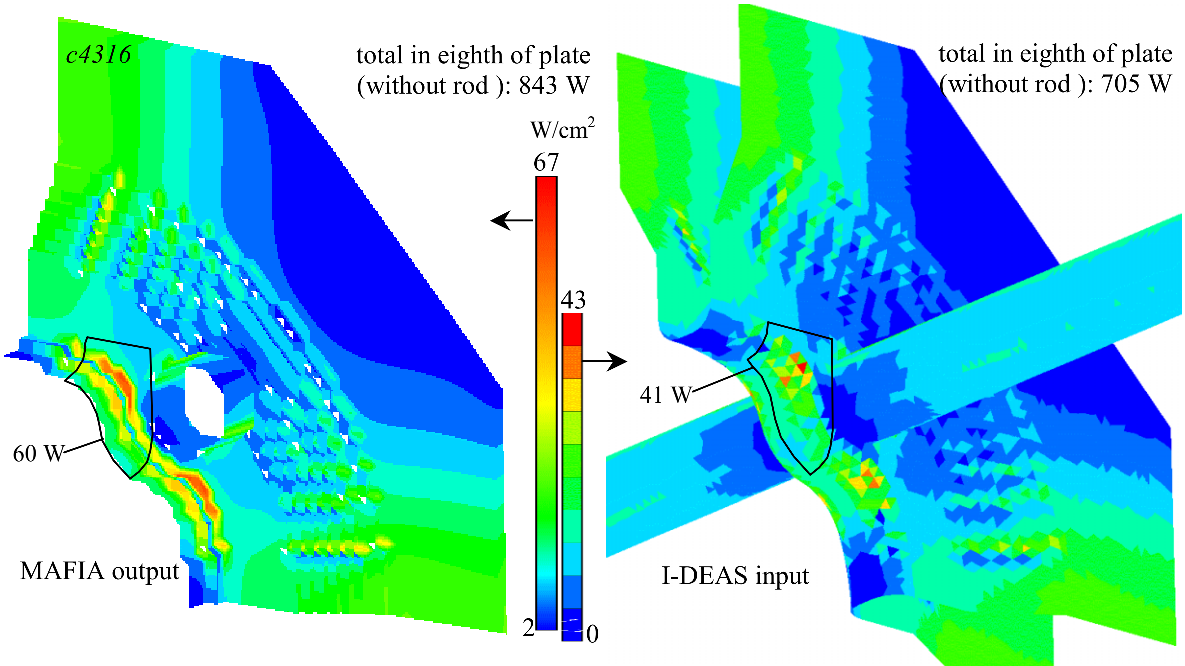


Figure 2. Power densities in the IPHI RFQ coupling plate transferred by MAPFLUX.

3 COUPLING PLATE

We applied the power density transfer procedure to the coupling plate of the IPHI RFQ (fig. 2). Though values are OK in plane parts of the surface, we observe a 20% lack of power after transfer (integrated on the whole plate). As the missing power in region of maximum density is reasonable (compared to global power) is mainly due to the overestimation of the area in MAFIA, caused by the roughness of the model in the rectangular grid. We admitted that, in this way, MAPFLUX would approximately correct the bias in MAFIA. We attributed this lack of power to the overestimation of the power computed by MAFIA due to the extra surface area generated by the staircase approximation in the MAFIA model. A careful analysis of the hot spot shows that the power missing on this area is reasonable, compared to the total power.

A thermo-hydrodynamic and mechanical analysis with I-DEAS has been carried out [3]. Flux of water in cooling channels was calculated as well as temperatures and stresses. Maximum temperature (58.6°C) occurs at the rod end (fig. 3). Slots must be performed to avoid huge stresses in the coupling plate (fig. 4).

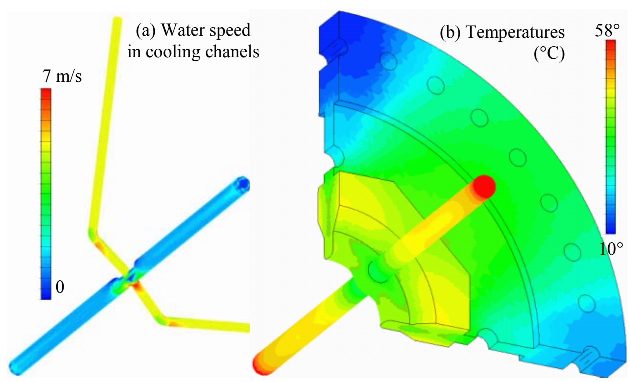


Figure 3. (a): Water speed in cooling channels; (b): temperatures in coupling plate and rod.

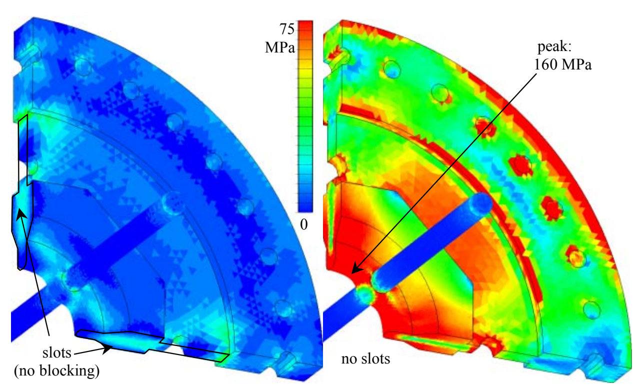


Figure 4. Stress in the coupling plate with/without slots.

4 VANE END

The method has also been applied to study the vane undercut region of the IPHI RFQ output where losses are highest. As this complex shape could not be generated directly by MAFIA, we imported it from the I-DEAS model through a stereo lithography (.STL) file to compute power losses, like in [4] (fig.5). Then, these data were sent back to I-DEAS via MAPFLUX for thermo-mechanical calculations. A peak value up to 170 kW/cm^2 is expected.

This 1/8 vane end simulation showed that the new cooling channel would be benefic in some region (temperature in bottom part of fig. 6 dropped by 14 degrees.), but would have no major effect on peak temperature.

The high thermal load and the negative curvature of the surface induce a high stress spot (106 MPa) exceeding the elastic limit of copper (fig 7). A thin analysis in cut planes shows that this occurs only in thin depth.

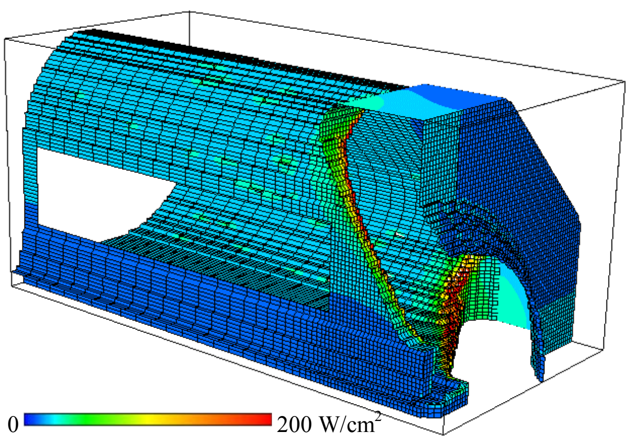


Figure 5. Power losses in RFQ output region.

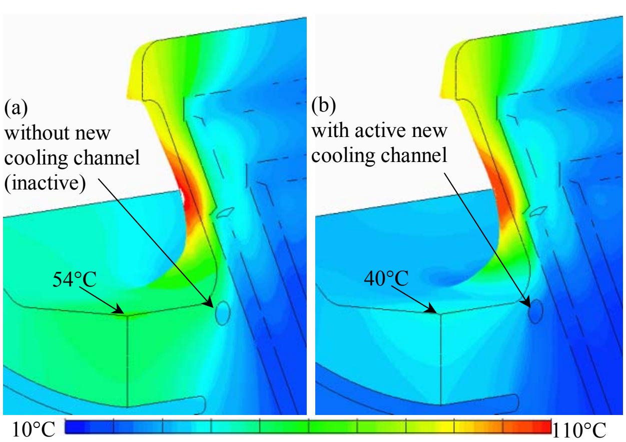


Figure 6. Effect of new cooling channel on temperatures.

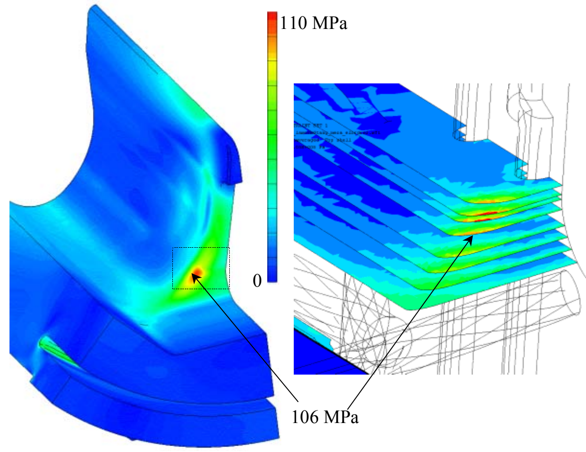


Figure 7. Stress on surface and in volume (cut planes).

5 CONCLUSION

Our new tool permits us to study thermal problems in the IPHI RFQ with the use of MAFIA and I-DEAS in a full electromagnetic and hydro-thermomechanic analysis.

Applied to IPHI RFQ coupling plate, it comes out that these pieces need to be slotted to avoid a huge stress in them. Applied to vane ends at the RFQ output, some rather important stress is expected too. It is very uneasy to predict the long-term behavior of copper under such condition. The fact that the elastic limit is exceeded only in a shallow skin, and that the LEDA RFQ in Los Alamos did not experience any trouble on this point make us confident.

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