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Heat transfer calculations on casing cooling pipes options

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Project Details	*This document is issued for the execution of the Agreement of Collaboration (AoC) between Fusion for Energy (F4E) and ENEA for supply of 18 TF coil casings*	
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Abstract	The shape of the cooling channels foreseen for the case cooling of the JT60SA TF coil has been modified by ENEA with respect to the reference one proposed by F4E. The present report discusses the impact of the modification proposed in terms of cooling capabilities. Not apparent differences have been noticed in the calculations.	

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Historical List of Document Revisions			
Rev.	**Description**	**Date**	**Summary of Modifications with Motivations and Notes**
0	Emission	20/10/2011	Original version
1	Revision	29/11/2011	Circular tube modifications: a – OD = 15 mm instead of 16 mm b – Thickness = 1.5 mm instead of 2 mm c – welds max thickness = 1.5 mm
	Revision		

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1 Outline

A pair of cooling channel have been placed in the casing design to provide adequate cooling to the casing mass during the cool-down phase of the magnets. The reference design of this channels consists of a square pipe (14x14 mm^2 outer dimensions with 2 mm thickness) welded on a steel wedge (having an angle of 10°). The wedge has been inserted to provide an horizontal plane for the square channels, which is also welded to the casing lateral wings in the inner side of the straight leg. The option proposed by ENEA consists of a circular pipe (OD=15 mm, thickness=1.5 mm) directly welded to the casing wings to easy the manufacture of the component. The present reports aim at quantifying the different behavior of the two options.

2 Results

Since a comparison of the two options was requested, the present analysis has been carried out with respect to a simplified model where only a part of the casing has been considered. This means that the results have a validity limited to the present comparison only and not have the aim at predicting the actual cooling time. Specifically, the model is a 2D model consisting in a trapezoidal steel plate 100 mm wide and 30 mm high that represents the casing lateral wing. The two channel options have been attached in the positions foreseen in the reference design. Note that at this stage of the analysis, the welds were not modeled in the reference option, whereas they are present in the circular one. Note also that the contacts among the different components is assumed perfect since a more realistic model depends on the experience and on the quality of the welds. Regarding the analysis, a transient heat transfer calculations has been performed assuming an initial uniform temperature of 20 K and then applying a film condition on the inner side of the pipes and sink temperature of 4.4 K. The corresponding heat transfer coefficients have been calculated on the base of the Dittus-Boelter correlation (see for instance van Sciver, p. 251, Eq. 7.32) assuming the following fluid- and thermo-dynamic conditions for the helium flow:

- P=0.6 MPa
- T=4.4 K
- MFR=5 g/s
- HTC=514 W/(m^2 K) → **square** pipe
- HTC=449 W/(m^2 K) → **circular** pipe

The following figures show the 2D model implemented in ABAQUS and the corresponding temperature maps at about 500 s after the start of the simulations

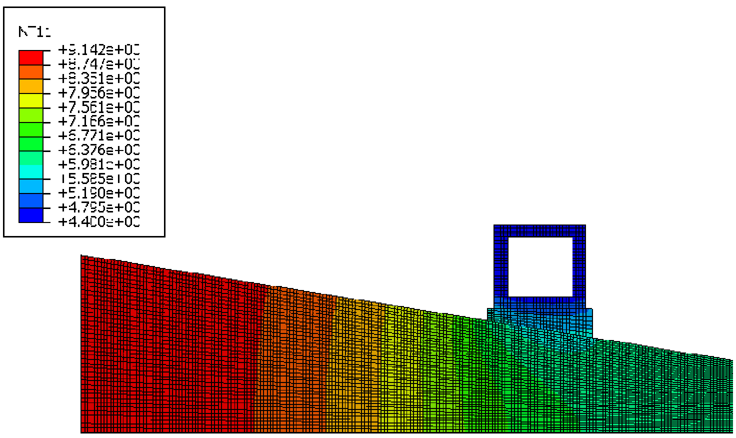

Figure 1 Temperature map in the square option model after 500 s of simulation

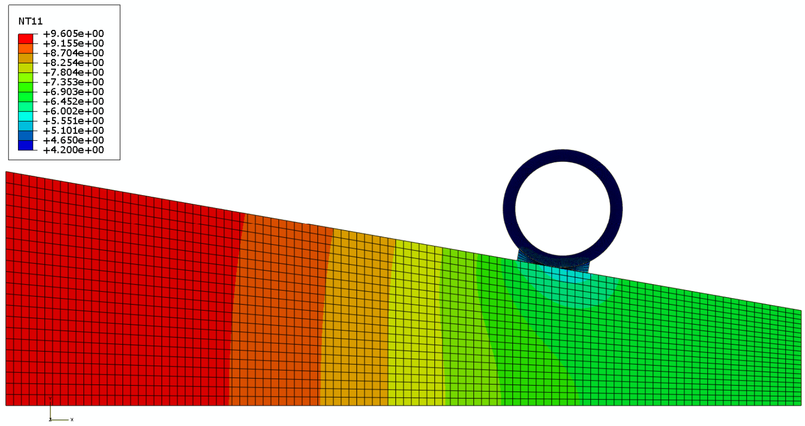

Figure 2 Temperature map in the circular option model after 500 s of simulation

Finally, the following figure shows the results in terms of temperature evolution at the upper corner of the steel plate during the simulation. Note that the two options behaves very similarly from the point of view of the cooling capabilities even if the circular pipes performs slightly better.

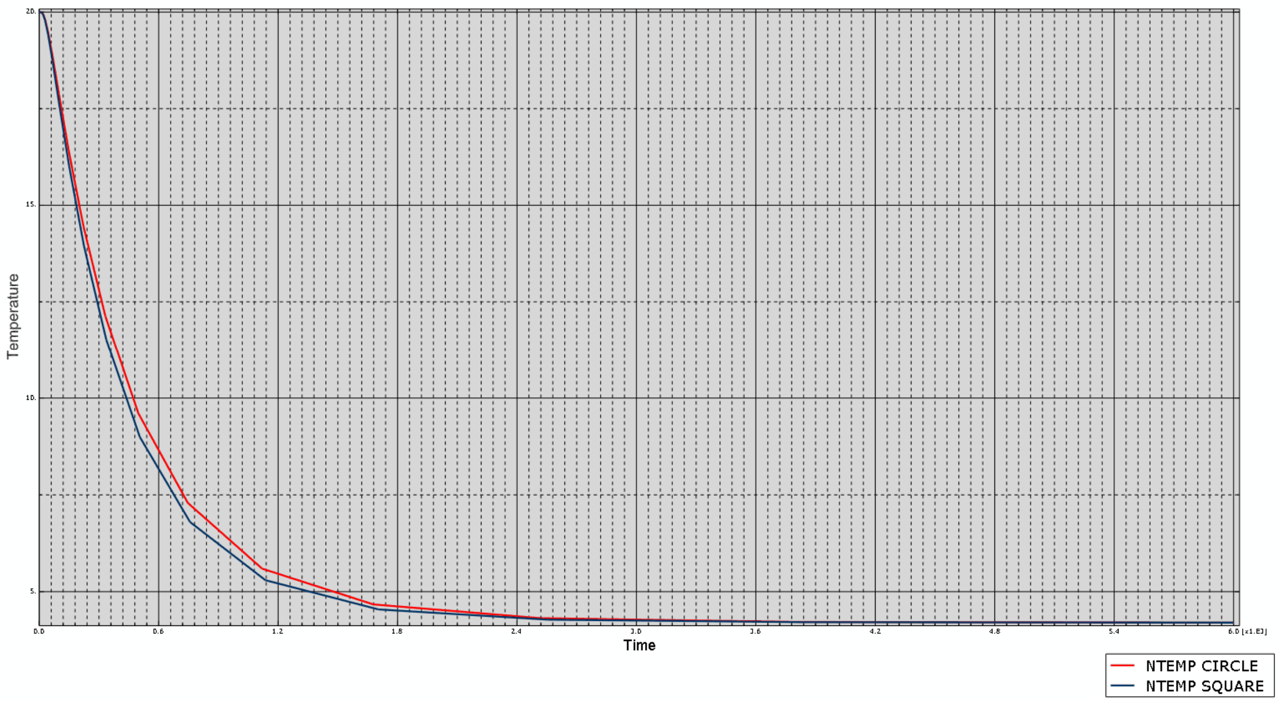

Figure 3 Temperature evolution in the upper corner of the steel plate

Note finally that, although the size of the welds in the circular option has been arbitrarily defined (but limited to 1.5 mm maximum corresponding to the actual size of the circular tubes), a small region between the pipe and the plate has not been attached to prevent numerical instabilities and to experience a more conservative operation.

3 Summary and conclusions

A comparison between the square and the circular options has been carried out in order to quantify the differences in the two models. Similar results in terms of cooling capabilities have been obtained.