COOLING AND HEAT TRANSFER OF THE IRANCYC-10 TRANSMISSION LINE

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Abstract

For designing RF transmission line in cyclotrons, heat transfer study is crucial. Because of plenty amount of surface current on RF transmission line, despite high conductivity of copper, significant amount of heat which is enough for altering characteristic impedance and other desirable parameters for transferring RF power into RF cavity. So effective cooling system which is nourished by central chiller system is essential. For cooling system in RF transmission line suitable mass flow, appropriate geometry and confined temperature raises are prominent in order to avoid erosion and impedance changes. In this paper an attempt has been done for accurate analysing and simulating of heat transfer phenomenon for the 10 MeV cyclotron which is under construction at AmirKabir University of technology.

Figure 1: Surface Current Distribution in IRANCYC-10 RF Transmission line.

INTRODUCTION

IRANCYC-10 is a compact AVF cyclotron which is under manufacturing phases at AmirKabir University of Technology. This cyclotron has been designed for FDG production in PET Imaging. As one of the main part of the machine RF transmission line and cooling system is very important. In Table 1 relevant parameters of RF Transmission line is shown.

Table 1: Relevant Parameters

Parameter	Value
RF Power	15 Kw
Cavity Voltage	40 Volt
Characteristic Impedance	50 Ohm
Resonant Frequency	71 MHz

In this paper heat transfer and cooling of the RF transmission line has been simulated and its effects on Impedance illustrated. Microwave studio CST used for microwave simulations and CFD Analyze is done by Ansys CFX.

HEAT GENERATION

In RF transmission line the main part of heat generation is created by surface current. So by considering safety coefficient other factors in heat generation are negligible. Also pattern of the surface current can be useful in designing of the cooling line. Surface current distribution is shown in Fig. 1.
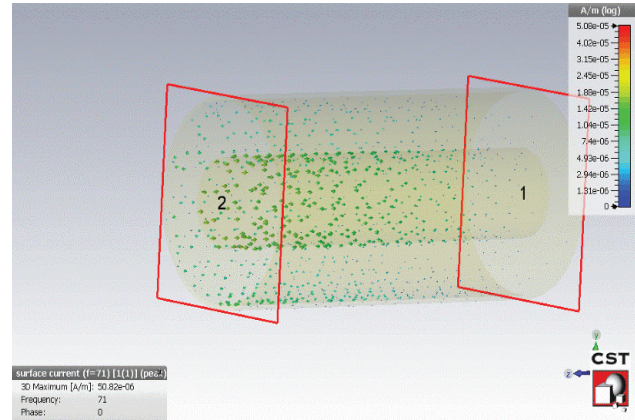
Total amount heat generation in this RF transmission line and its distribution extracted by Eq 1.

$$p_{Surface} = \frac{1}{2}\sqrt{\frac{\pi\mu f}{\sigma}} |H^2| \qquad (W/m^2) \qquad (1)$$

In this equation f is the frequency, μ permeability, σ Conductivity and H is tangential magnetic field [1]. Safety coefficient of 1.75 has been considered for heat generation in order to compensate other factors which can create extra heat.

CFD SIMULATION

The first step of the CFD simulation is creating accurate geometry. IRANCYC-10 RF transmission line is coaxial type and its geometry is shown in Fig. 2.
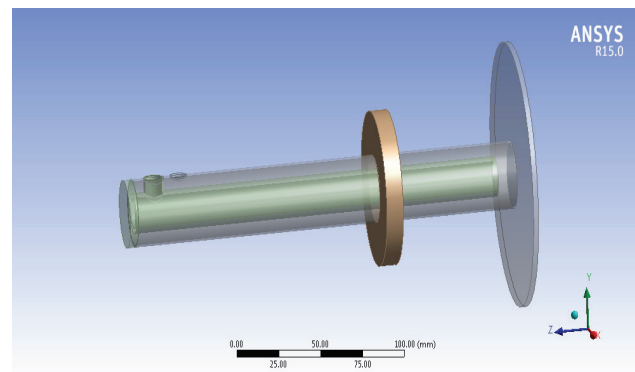

Figure 2: Geometry of RF Transmission line.

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The most important step of the CFD simulation is meshing. In fact high quality meshing can improve accuracy and calculation in CFD simulation. For this project tetrahedrons patch conforming method has been used for all parts and by applying suitable body sizing and inflation, desirable meshing has been done [2]. In Table 2 mesh statistics is shown.

Table 2: Meshing Statistics

Parameter	Value
Maximum skewness	0.88
Average skewness	0.18
Maximum aspect ratio	29
Average aspect ratio	3
Total number of elements	8980619
Total number of elements	5306479

In Fig. 3 inlet and outlet of the cooling line is shown. At inlet mass flow rate applied 90 gr / s and in outlet relative pressure 0 pa also initial temperature of the water is 293 kelvin.
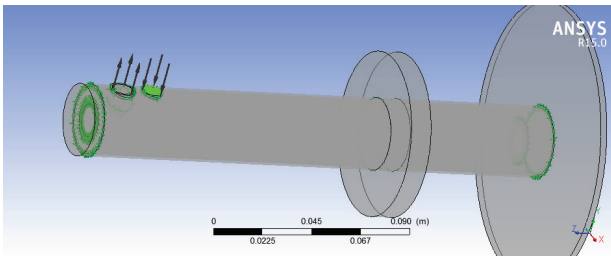

Figure 3: Inlet and Outlet of the Cooling Line.

Convergence has been attained after 200 iteration by RMS 5e-5. In Fig. 4 stream lines of the water flow can be seen.
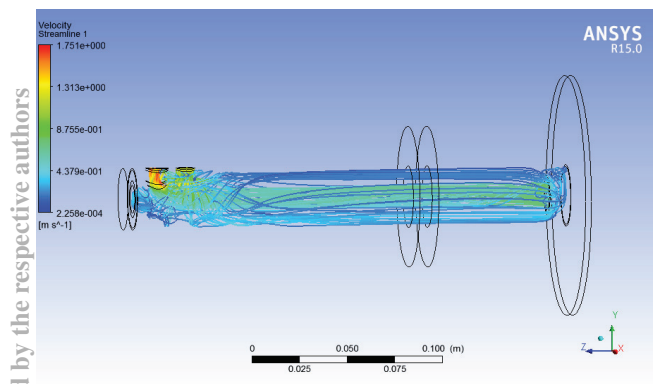

Figure 4: Stream lines of the Cooling Water.

As it can be seen in fig4 maximum velocity of the water in cooling line is 1.751 m/s which is safe for erosion problems in cooper [3].

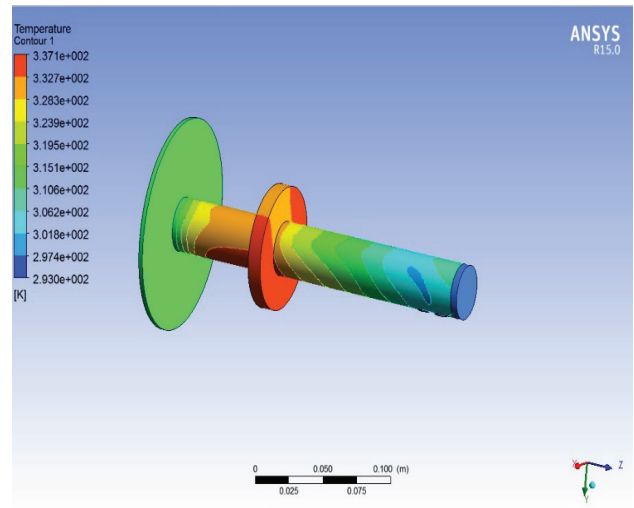In Fig. 5 temperature distribution can be seen.

Figure 5: Temperature Distribution in IRANCYC-10 RF Transmission Line.

It can be seen that the maximum temperature is occurred in RF window with value of the 337 kelvin.

TEMPERATURE RAISE EFFECTS

Ansys static structure has been linked to CFX and effects of the temperature raise on structure have been extracted. In Fig. 6 and Fig. 7 total deformation and von mises stress distribution are shown.
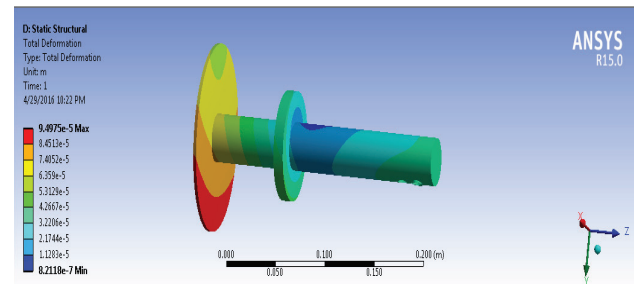

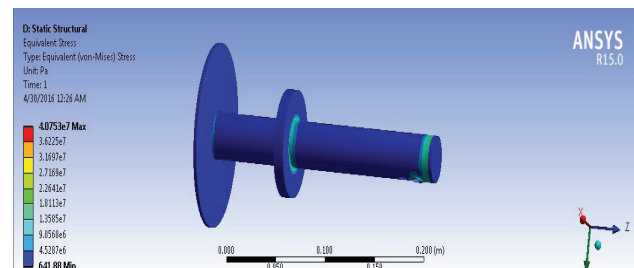Figure 6: Total Deformation Distribution.

Figure 7: Von Mises Stress Distribution.

Maximum amount of deformation is 100μm and maximum stress is 40.75 MPa.

Also by Microwave simulation by CST, new amount of impedance resulted.

In Fig. 8 the green plot is the impedance without temperature effects and the red one is resulted by Appling the temperature raise effects.
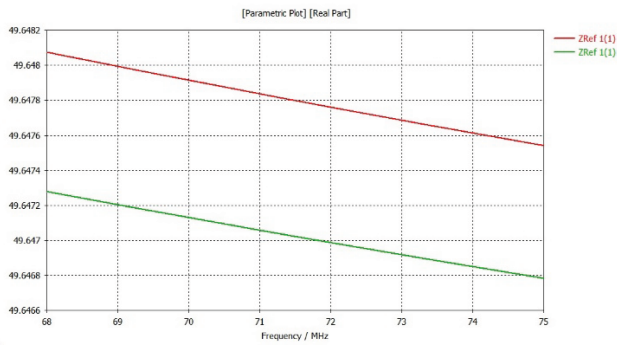
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Figure 8: Temperature Raise Effect on Impedance.

CONCLUSION

By considering all points which are illustrated, it can be comprehend that in this RF transmission line and cooling line , water with mass flow rate of 90 gr / s and initial temperature of 293 kelvin is effective and suitable for cooling of the RF transmission line

REFERENCES

[1] Jeremiah Holzbauer,'' RF Theory and Design – Notes'', US Particle Accelerator School, Grand Rapids June 2012, p 12-13.

[2] User documents ANSYS CFX.

[3] http://www.engineeringtoolbox.com/copper- pipes- water- velocities- d_1081.html.