HEAT TRANSFER STUDY AND COOLING OF 10 MeV CYCLOTRON CAVITY

S. Saboonchi, H. Afarideh*, Department of Energy Engineering & Physics, Amirkabir University of Technology, Tehran, 15875-4413, Iran
M. R. Asadi, Islamic Azad University (PPRC) Science and Research Branch of Tehran, Tehran, 147789-3855, Iran
M. Ghergherehchi, J. S. Chai, Department of Energy Science/School of Information & Communication Engineering, Sungkyunkwan University, Suwon 440-746, Korea

Abstract

The most important problem in mechanical design of RF cavity of cyclotron is generated heat by RF power loss. An optimized cooling system for cavity is necessary to prevent Dee damaging and minimizing error function of cyclotron created by displacements. Also optimization of water circuit and water flow is essential because it affects unwanted vibrations and manufacturing. In this paper an attempt has been done to design an optimized cooling system for the cavity of a 10MeV cyclotron using ANSYS CFX and CST MICROWAVE STUDIO software.

INTRODUCTION

This paper describes the simulation and design methodology of cooling line for a single-stem, room temperature, copper resonator operating on the fourth harmonic. The RF system is designed to accelerate H− ions to 10MeV with the relevant performance requirements outlined in Table 1.

Table 1: Relevant Design Parameters

Parameter	Value
Resonant Frequency	69 MHz
Dee Tip Voltage	50 kV
Water flow at inlet	0.180 kgr / sec
Diameter of cooling line pipe	7 mm

Using the 3D CAD program Solid Works. Model of the resonator was created. This model (Figure 1, 2) consists of the copper resonant structure; all copper is oxygen-free high conductivity (OFHC).

For this study, mechanical interfaces between components are considered perfectly connected, both thermally and mechanically .stability of temperature is essential during the operation of cyclotron .cooling lines in Dee and stem considered perfectly connected it means there is a single cooling line used per quarter of RF cavity. Cooling line inters form stems and at the first it is crossed stem in spiral shape because the hottest part of RF cavity are stems after stem passed from middle of Dee near the boundary and surface then water exits form the centre of stem this is general shape of cooling line in RF cavity . We analysis too geometry of cooling line and compare them. In designing we considered two important problems first the cooling line can decrease temperature in acceptable range to avoid displacement without generating considerable Vibration and it can be fabricated easily. Vibration occurs because of flow of water in cooling line special in spiral part of it in stems. Generally in experimental velocity of water in this type of pipe has to be under 10 m/s but this is only the limitation of velocity in pipe, for decrease the vibration this value must be more less than 10 m/s , by trying and error in cooling line geometry we tried to archive optimized design in cooling system. These two designs of geometry of cooling line in Dee and stem are shown in Figure 1 and Figure 2. In Figure 1 step of spiral cooling line in stem is changed along the stem but in Figure 2 cooling line has a same step along the stem. First design is harder to fabricate but has less unwanted vibrations and second design is easier to fabricate and has more efficiency in heat transfer but it has more vibration than first one.

Figure 1: Geometry of cooling line first design.

*corresponding author: hafarideh@aut.ac.ir

Figure 2: Geometry of cooling line second design.

POWER LOSS DISTRIBUTION

Many factors can generate heat in RF cavity but the most part of it created by surface current at surface of Dees and stems so we calculated power loss distribution on RF cavity by surface current in CST MICROWAVE STUDIO.ANSYS CFX can take this power loss distribution point by point, for this operation we needed to Coordinate implementation between these two software. Figure 3 shows surface current distribution in RF Cavity.

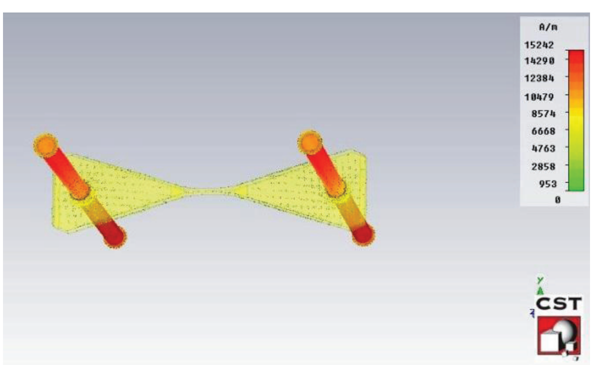

Figure 3: Surface current for RF Cavity.

COOLING LINES

The hottest part of RF Cavity in cyclotron are stems as can been seen in Figure 2 surface current reach to it maximum value in this area, spiral shape of cooling line in this area can help and increase efficiency of heat transfer, but there are some notes in designing first being practicable in easy way and unwanted vibrations because it can effect on operation and increase error functions in many part of cyclotron. Usually in spiral cooling line design the critical point for heat transfer is the area that stems are connected to Dees because in this area surface current is too high and unlike the other area of stems temperature of water is somewhat increased.

SIMULATION

ANSYS CFX has been used to simulate heat transfer and cooling system. Maximum velocity of water in this type of pipe must be under 10 m/s or with diameter of 7 mm mass flow must be under 0.384 kg/s but in these simulations mass flow at inlet is 0.180 kg/s or 4.687m/s , velocity under 5 m/s decrease unwanted vibrations in acceptable range.

Thermal distributions in cavity for first cooling line have been showed in Figures 4, 5, and 6.

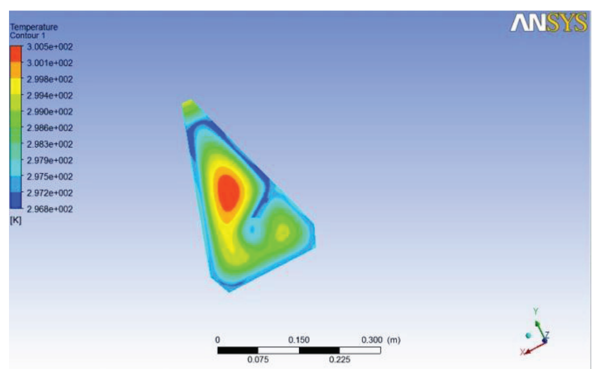

Figure 4: Thermal distribution in Dee.

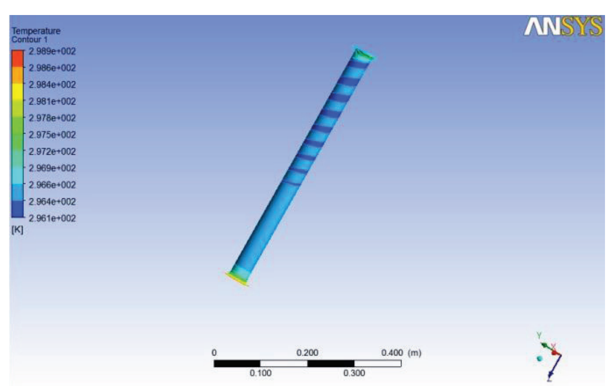

Figure 5: Thermal distribution in stem.

ISBN 978-3-95450-128-1

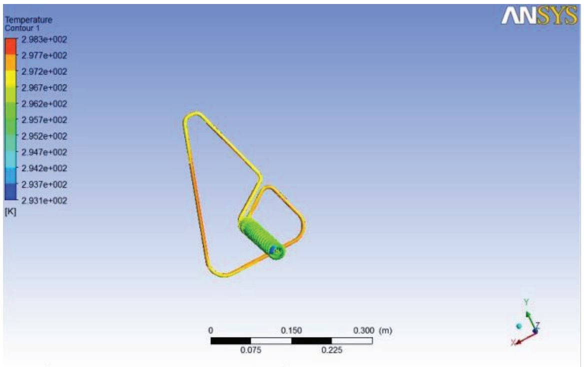

Figure 6: Thermal distribution in cooling water.

Table 2: Temperature Changes for First Design

Part	Max temperature change(kelvin)
Dee	3.7
Stem	2.8
Water	5.2

Thermal distributions for second cooling line have been showed in Figures 7, 8 and 9.

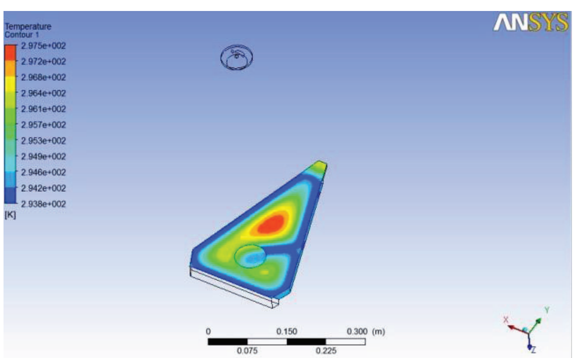

Figure 7: Thermal distribution Dee.

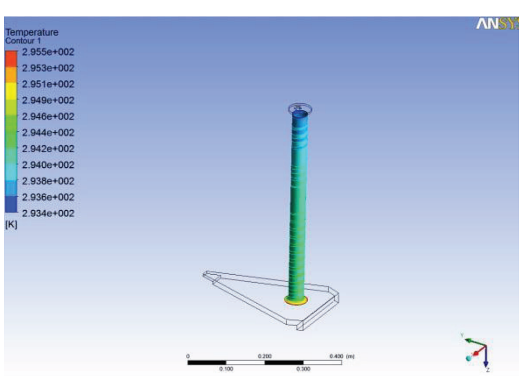

Figure 8: Thermal distribution in stem.

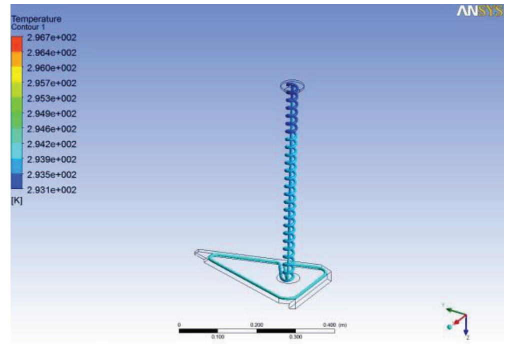

Figure 9: Thermal distribution in cooling water.

Table 3: Temperature Changes for Second Design

Part	Max temperature change(kelvin)
Dee	3.7
Stem	2.1
Water	3.6

CONCLUSION

Thermal effects on RF cavity can change many parameters in operation also it can damage whole system. In this article detailed analysis of the heat transfer has been performed for designing of cooling system in RF cavity and two shapes of cooling line has been designed. First one has less unwanted vibrations but it seems it is fabrication is more difficult. As can be seen in second design , temperature changes is small and fabrication is simple, therefore, according to results and analysing them we recommend second design.

REFERENCES

[1] Frank P. Incropera, David P. DeWitt , Theodore L. Bergman, Adrienne S. Lavine, .Introduction to Heat Transfer (first published January 28th 1985).

[2] G. Gold, R. R. Johnson, B. F. Milton, V. Sabaiduc, Best Cyclotron Systems Inc., Vancouver V6P 6T3, Canada, IPAC2012, New Orleans, Louisiana, USA.

[3] William T. Thomson, Marie Dillon Dahleh, Theory of Vibration with Applications (5th Edition, August 17, 1997),.

[4] User document of CFX.

[5] User document of CST studio suit.