NUMERICAL DESIGN AND OPTIMIZATION OF COOLING SYSTEM FOR 2MeV TRAVELING WAVE ACCELERATOR

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Abstract

Eliminating or reducing thermal deformation of an accelerator structure (caused by microwave power dissipated on the walls of RF cavities) to insure resonance frequency is an important topic in the design of the structure. A civil accelerator for killing anthrax bacilli must be small and compact, and so must its cooling system. This paper introduces the design and optimization of a cooling structure for an 0.57 m long, 2 kW, disk-loaded waveguide accelerator structure, for which the temperature distribution is required to be 30±3º C. All the parameters have been calculated and optimized by means of FEM (the Finite Element Method). The simulation is accomplished with software called I-DEAS (Integrated Design, Engineering, Analysis System). An optimized structure with a jacket style cooling chamber has been designed. The outside wall of the jacket is made of stainless steel and its external diameter is ϕ118mm.The flux of the cooling water is as small as 0.45 ton/hour. As a result, the temperature nonuniformity of the accelerator tube is better than ± 2.5º C. The system is also very robust against surrounding temperature shifts. The cooling system has been installed in a 2 MeV accelerator, and the facility is running well.

INTRODUCTION

The requirements for accelerators in the world market are diverse and changeable, which demands rapid response by the designers and manufacturers. Traditional procedures have not acclimatized themselves to these circumstances. Advanced technologies are emerging as the times require in this era of ours. Numerical simulation based on CAD/CAM (Computer aided Design /Computer aided Manufacture) is a most promising technology for rapidly designing new machines as market requirements change and for making them reliable.

The 2-kW traveling wave accelerator is used for scanning mail and killing potential anthrax bacilli, etc. Accelerating cavities are key parts of the accelerator. Thermal deformation of them, caused by dissipation of microwave power, deeply affects the operating frequency of the machine. Therefore, a cooling structure that can keep temperature distribution within a tolerance region is important. This paper describes an approach to designing the cooling structure by means of the TMG Thermal Analysis module of I-DEAS, which allows people to carry out sophisticated thermal analysis as part of a collaborative engineering process and get solid reliability. All of the thermal design attributes and operating conditions can be applied as history-supported entities in a 3D model geometry. Thus an optimized design of the system is possible.

COOLING STRUCTURE DESIGN

The accelerator will serve in a post office, a location that requires it to be as compact as possible. The design should have good adaptability to its surroundings, and the cooling water flux should be kept small in order to minimize both the whole-system cost of the cooling system and the operating expense. As a design goal, the flux of cooling water should be less than 0.5 ton per hour and the temperature nonuniformity should be better than ± 3º C.

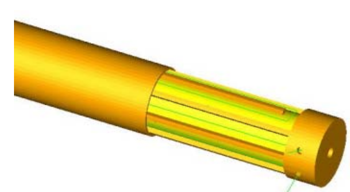

Fig. 1: Jacket type cooling structure

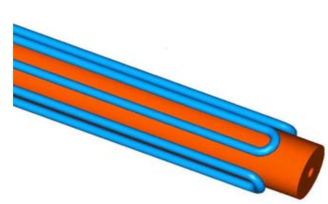

Fig. 2: Tube type cooling structure

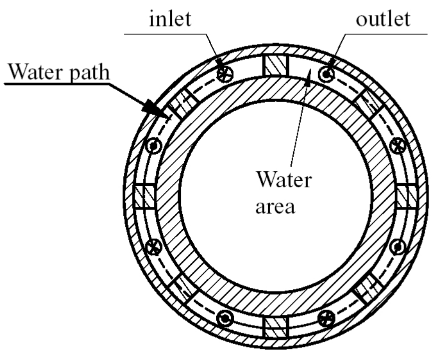

Fig. 3: Profile of the water jacket

The accelerating tube, composed of 19 cavities, is a constant impedance traveling wave accelerating structure. Generally, there are two types of cooling structures: jacket and welded tubes, as shown in Figures 1 and 2. Here certain things should be given attention. In order to diminish the inside diameter of the focus coil, a single-inlet waterway was chosen as early as possible in the design process. Considering its environment (a post office), the system must be able to deal with shifts in the ambient temperature. Because of the highly suitable manufacturing technology and the high stiffness of the structure, jacket type cooling structure has been adapted. the jacket is made of stainless steel. Calculation has shown that it is very robust against shifts in room temperature.

OPTIMIZATION OF THE PARAMETERS

The shape of the section of the water jacket

The shape and size of the water channels is an important factor, not only for small flux but also for good cooling effect and even temperature field distribution. Comparing different sections, a profile of eight chambers is chosen. It is shown in Fig. 4. The simulation calculating results show that almost all of the 2 kW power dissipated is carried away by the water. The parameters in the bold-face column are important to the requirement.

Table 1 Calculating result of the eight-chamber structure (ambient 25º C, inlet water temperature 23º C)

Mass flux of water (kg/s)		0.10	**0.12**	0.14	0.16	0.18	0.20
Outlet water temperature (º C)		27.76	**26.97**	26.40	25.98	25.65	25.39
Temperature of the accelerator structure (ºC)	MAX	32.72	**31.60**	30.78	30.15	29.64	29.23
	MIN	28.00	**27.17**	26.58	26.14	25.79	25.51
	T	4.72	**4.43**	4.20	4.01	3.85	3.72
Energy carried by water (W)		1991	**1994**	1996	1997	1998	1999

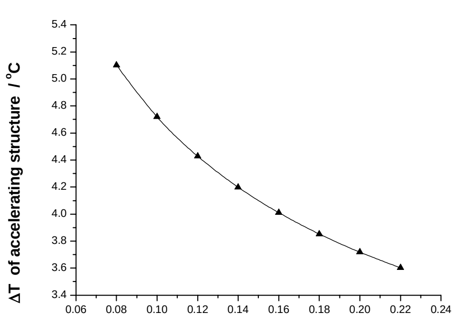

Fig. 4: Influence of mass flux on temperature distribution

Determination of the water flux

In order to cut the construction and operating costs of the cooling system, optimization of the mass flux of the water is another target. Fig. 5 shows that the relationship between the temperature distribution of the accelerating structure vs. the mass flux of the water is nonlinear. The mass flux of 0.12 Kg/s fits within the limit of 0.5 ton/h. In this case the temperature distribution is ± 2.2º C.

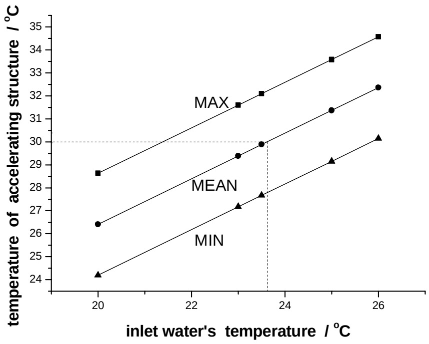

Fig. 5: Influence of inlet water's temperature on temperature of accelerating structure

Selection of Inlet water temperature

The distribution of the temperature should be kept around 30±8º C (which we consider the mean temperature) when the machine runs. Calculation shows that the mean temperature of the accelerating structure is almost a linear function of inlet water temperature (see Fig. 6). The results also indicate that the influence of ambient temperature on temperature dispersion can be ignored.

Robustness to the ambient temperature drift

The accelerator must be able to work in a room where the ambient temperature is not constant. The simulation reveals that the cooling water carries away more than 95% of the power dissipated on the walls of the cavities at room temperatures of 10-30º C. The change of the ambient temperature slightly affects the mean temperature and the distribution. Table 2 shows the details.

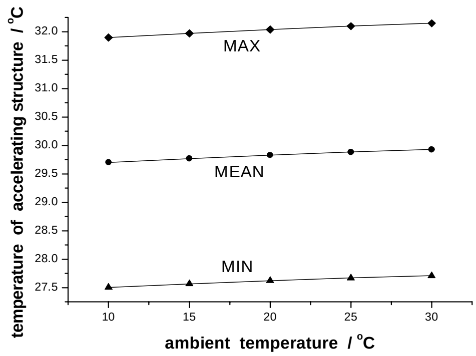

Fig. 6: Influence of ambient temperature on temperature of accelerating structure

Table 2 Simulation results under different ambient temperatures

(Mass flux 0.12 kg/s, inlet water temperature 23.5º C)

Ambient temperature (º C)		10	15	20	25	30
Outlet water temperature (º C)		27.33	27.38	27.42	27.46	27.50
Temperature of accelerator structure (ºC)	MAX	31.90	31.97	32.04	32.10	32.15
	MIN	27.51	27.57	27.62	27.67	27.71
	T	4.39	4.40	4.42	4.43	4.44
Energy carried by water (W)		1924	1949	1972	1992	2008

CONCLUSION

Integrating the above numerical simulations, a set of satisfactory parameters for the cooling system has been achieved. The system has been constructed and commisionde in the accelerator, which is running well.

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