COOLING AIR FLOW INDUCED THERMAL DEFORMATION OF THE MAGNET LATTICE GIRDER

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Abstract

This paper investigates the effect of cooling air flow on the positioning of magnet lattice at the Synchrotron Radiation Research Center (SRRC). By CFD simulation code, the air flow and temperature distribution between the two bending magnets of the magnet lattice were calculated. As the inlet air flow has 0.2°C temperature rise, the flow field and the heat transfer are calculated. This temperature variation will cause the thermal deformation of the girder. Such deformation will induce the relative displacement of the magnet girder and the ground. Through the thermal deformation analysis, the magnitude of the displacement is evaluated.

1 INTRODUCTION

Since 1997, the Taiwan Light Source (TLS) had started a series of experiments to find out the mathematical model and the relationships among the beam orbit position and the utility status include the cooling air temperature and cooling water temperature [1]. The results show the strong correlation between the beam orbit stability and the utility status as the temperature variation of the cooling water and the air exceed 1°C and 0.2°C,respectively.

In Japan, the RNCP cyclotron magnet field variation caused by the temperature change of the cooling water had been verified by the T. Saito et al [2]. The conclusion of the RNCP report is the variation of the cooling water temperature should be suppressed to 1°C. The results show the good coherence.

Comparing with the cooling water, the air temperature variation has the extensive effects. The non uniform temperature distribution due to the turbulent air flow on the girder and magnet support will cause the whole structure deformed.

The influences of the air temperature variation include the non uniform temperature distribution and the turbulent air flow velocity. It’s very difficult to measure the whole flow field. So we use the Computational Fluid Dynamic (CFD) program to calculate the air flow field. By the calculation results, the time- variant temperature distribution and the relative thermal displacement of the magnet lattice structure can be determined.

2 NUMERICAL MODELING

The CFD modeling was used to solve the flow field and heat transfer of the magnet lattice. It based on the finite volume equation derived from the continuity equation and the temperature equation

Integrating the equations and solve it in discrete form, we got the constraint equation - mass conservation and energy conservation. Under the constraints of the mass conservation and the energy conservation, the momentum equation can be solved with the iteration method. The reference [3] has a detailed explanation about the momentum equation solution and the turbulence modeling.

In this paper, the flow field of the magnet lattice section between two dipole magnet was solved. The numerical modeling and photograph of the calculated magnet lattice section are showed on the figure 1. This section has two air inlet and one outlet. The two small blue squares on the top of the computer modeling indicate the locations of the air flow inlets. The bigger one is the flow outlet. All structures are denoted by the text block. To prevent the radiation, the air inlet 2 and the outlet was blocked by the radiation shield shown on the photograph.

The calculation results are shown in the figure 2 and 3. The distribution plan is aligned with the central line of the air inlet. The figure 2 plots the air flow velocity distribution and the figure 3 is the temperature distribution.

This calculation condition is under the beamline system off. The cooling air flow rate of the inlet 1 is 270 cfm and the inlet 2 is 353 cfm. These flow rate were measured by the ALNOR air flow rate meter, the equipment serial number is 2245. The air temperature is time variant and the calculation results on the figure 2 and 3 are at the first time stage. Through the CFD simulation, the thermal process can be determined and the thermal deformations were calculated by the thermal strain analysis method described in the reference[4].

3 CALCULATION RESULTS

The calculation of the flow field is under the beamline off condition. Because the paper emphasis on the magnet lattice thermal deformation caused by the cooling air temperature variation.

The air flow rate of the inlet 1 is 270 cfm and the inlet 2 is 353 cfm. The air flow temperature was set to change from 19°C to 19.2°C in 20 time steps. Then the temperature kept stable for 30 time steps and the structure will go on deforming. During the 50 time steps, each thermal process will be determined by solving the numerical modeling of the flow field and heat transfer.

At this study, the magnet lattice support girder deformation was calculated. The structure modeling is shown in the figure 4. For the sake of simplification, the screw between the horizontal plate and the column was ignored and become the whole structure look like the figure 4. The square denotes the position of the sexupole magnet.

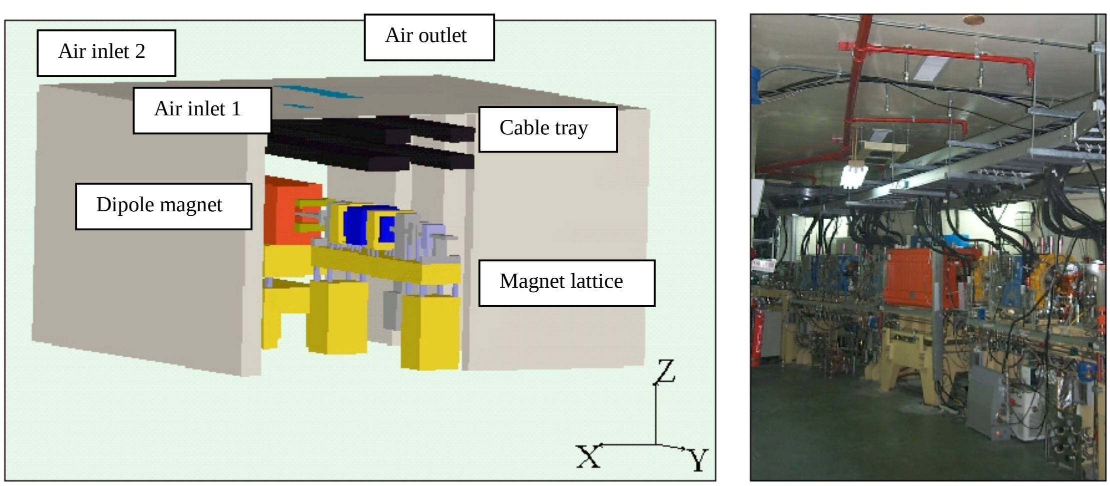
As the air inlet 1 and 2 temperature change from 19 to 19.2 ^{o}C during the first 20 steps and then keep stable for the last 30 steps, the flow field and heat transfer of each time step are calculated by the CFD modeling mentioned before. According to each time step thermal process, the thermal deformation is calculated by solving the thermal strain equation. The whole girder structure shown in the figure 4 has 288 cells and it's difficult to show all the calculation data. Just 9 points deformation data are shown in the figure 5. These points are in the sextupole magnet location square and in the central of the whole girder structure. Subsequently, they have the maximum displacement. The magnitude of the thermal deformation is expressed by the vertical displacement from the point to the ground. The structure also has the horizontal expansion but the results are not shown in this paper.

The locations of each point denoted by 1 ~ 9 are described in the figure 4. The cross line through points 1,4,7 is the side near the air flow inlet. The line cross through 3,6,9 is the side near the outlet. The relative geometry can refer to the figure 1.

4 RESULTS AND DISCUSSION

The thermal deformation calculation results show that

- Point 7 has the maximum displacement amount reach to 1.7 μm.
- The displacement of the point 1,2,3 i.e. the side neat the dipole magnet is much less than the other points.
- At the first stage, all points have the positive displacement. When the temperature keeps stable i.e. after the 20th step, points 4,7,8 and 9 have the negative displacement.
- The calculation results show that the girder has the complex shrink and expansion effects. The influence of the girder deformation on the beamline structure will be investigated in the future.
- Although the method can be used to estimate the thermal deformation of the beamline structure, it should be approved by the actual measurement results.



(a) (b)

Fig 1. The magnet lattice section : Computer modeling (a) and photograph (b)

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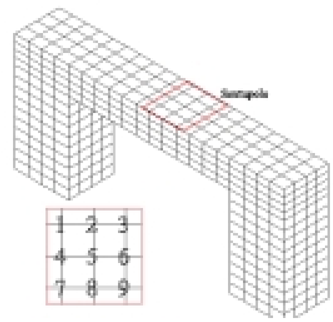

Fig 4. The magnet lattice support girder modeling

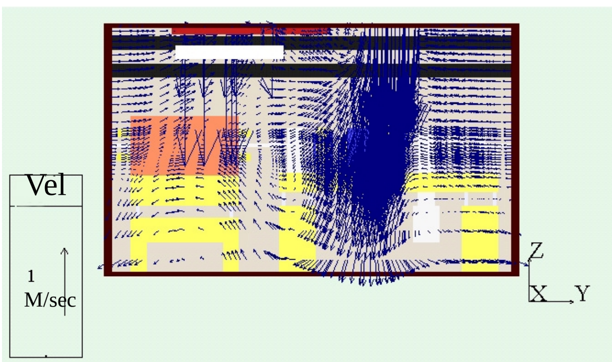

Fig 2. Air flow field calculation results

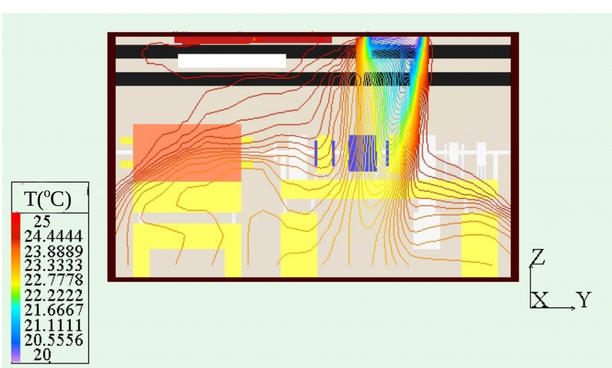

Fig 3. Temperature distribution calculation results

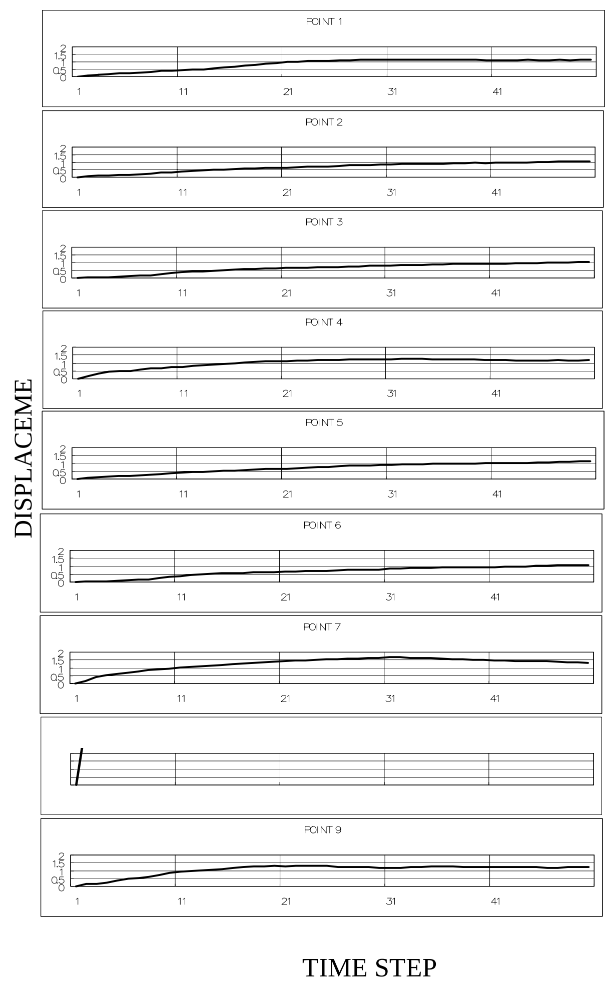

Fig 5. The calculation results of the thermal deformation