AIR TEMPERATURE ANALYSIS AND CONTROL IMPROVEMENT FOR THE EPU 5.6 AT TLS

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Abstract

This paper presents the air temperature analysis and control improvement for area of the elliptically polarizing undulator EPU 5.6, in the Taiwan Light Source (TLS). To enhance uniformity of ambient air temperature, we applied mini environmental control and installed five cross flow fans in this area. Eight temperature sensors were installed around the EPU to monitor temperature variation. We also simulated the flow field and temperature distribution in this area by using of a computational fluid dynamics (CFD) code. The simulation results were validated by comparing to measured data. The temperature variation along time and spatial temperature difference were controlled within 0.1 ^{o}C and 0.5 ^{o}C, respectively.

INTRODUCTION

It has been studied and verified that thermal effect is one of the most critical mechanical factors affecting the beam stability [1]. The propagation routes from the temperature variation to the beam quality were also illustrated. Accordingly, TLS had made a series of thermal simulation and improvements on the air temperature control of the air-conditioning (AC) system for the storage ring [2]. The temporal temperature variation in the whole storage ring had been control within ±0.1^{o}C. However, spatial temperature uniformity is also important for some insertion devices. The EPU is one of the examples.

The insertion device can create a high quality and high photon flux light only when the field shimming was well done. The magnet block should be very carefully assembled on the supporter to keep from the mechanical error. Each magnet blocks were glued on the individual holder by the proxy. Meanwhile, the magnet block was fixed on the supporter by the clamp. Such precision assemble work can achieve the high mechanical accuracy. The mechanical alignment was conducted by using the laser interferometer and dial gauge in different phase position and gap. The 1 mm gap variation between two arrays on the lower/upper blocks can be maintained within ± 20 um. The reproducibility of the phasing and gap moving can be controlled within ± 1 um. However, the temperature difference will induce the mechanical distortion error. Thus, the EPU environment temperature shall be well controlled to reduce the thermal deformation of the EPU structure.

Thus, the mini environmental control had been applied for the EPU 5.6 [3]. In order to achieve better temperature uniformity and more detailed study, we installed some cross flow fans and more temperature sensors in the mini environmental control. We also applied the CFD technique in this study.

The CFD technique has been applied for the heating, ventilating, and AC (HVAC) industry for more than 30. To more effectively and precisely predict the temperature variation and air flow in air-conditioned rooms, we had applied CFD technique to the experimental hall, the storage ring tunnel, a technical zone and the booster area in TLS, respectively. All these simulation cases are assumed as 3D, incompressible and turbulent flow.

We used FLUENT 6.3.26, a CFD code, to perform the numerical simulation. The physical 3D model of the EPU was built by using GAMBIT, integrated pre-processing software. Because most of HVAC industry flows are turbulent, we applied the k-ε turbulence model and SIMPLEC to solve the velocity and pressure problem. However, we are interested in the mean values rather than the details of turbulence.

MINI ENVIRONMENTAL CONTROL FOR THE EPU AREA AND MEASURED DATA

For more accurately and efficiently control the ambient air temperature around EPU, isolating this local area and providing the independent air conditioning system, known as the mini environment control, is the best scheme.

Mini Environmental Control Scheme

To uniform the temperature on the EPU magnet arrays, five cross flow fans were employed to circulate the air around the magnet arrays. Four small fan units were located on the top and in front of the EPU device. Another fan was installed on the bottom and the back position. The air flow from the air handling unit can be draft down by the top fans and enwrap the EPU magnet arrays.

The insertion device was isolated by two transparent curtains, supported by the steel bar structure. There is a supply air exit on the ceiling and air is exhausted to voids of this isolated area. Figure 1 shows the photograph of the EPU isolation area.

Temperature Measurements

There were eight temperature sensors T1-T4 and B1-B4 respectively installed on the top and bottom of EPU magnet arrays. By the forced convection cooling, all the temporal temperature variations can be controlled within

±0.05 °C during over 40 hours' operation, as shown in Figure 2. Also, the spatial temperature difference of the EPU is about within 0.5 °C, also as shown in Figure 2. The histories data illustrate good temperature control and uniformity by the mini environmental control.

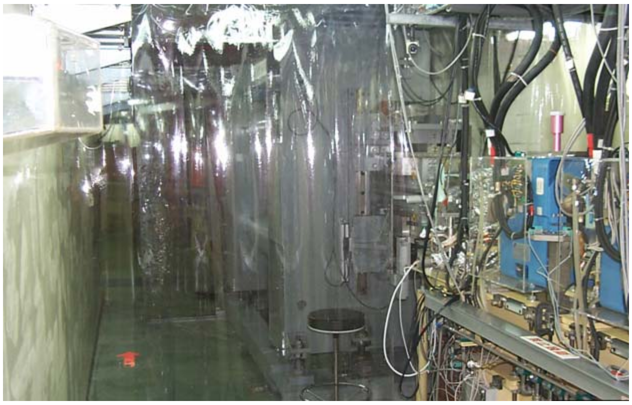

Figure 1: Photograph of the EPU isolation area.

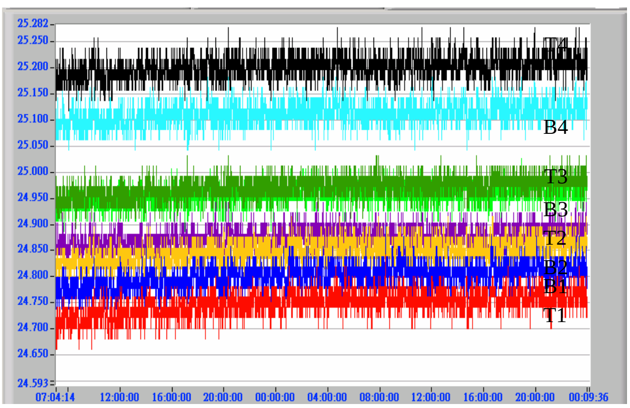

Figure 2: Air temperature histories of 8 temperature sensors installed on the EPU.

NUMERICAL SIMULATION

The modelling and the simulation analysis procedure are described as follows.

1. Set up the physical shapes, sizes and boundary conditions according to the actual measurement.
2. Generate adequate grids according to the model shape and set the corresponding boundary and initial conditions.
3. Choose the computation model and set the boundary conditions. The k-ε turbulence model is applied to the simulation.
4. Check if the computation results converge. If yes, then conduct the post-processing to draw the flow field and the temperature distribution.

There are some assumptions made to simplify the computation. The simulation is assumed as a 3-D, steady, viscous and incompressible problem.

Grid Generation and Boundary Conditions

The EPU magnet arrays, an overhead cable tray, vertical and horizontal supports, air exits and exhausts of the isolated area and each cross flow fan were all built in the model. The heat sources include magnet arrays, the cable tray and cross flow fan. Although the shapes of those heat sources are simplified and some trivial piping system and small apparatuses are neglected, the simulated results would not be affected too much. Total 117,561 tetrahedral grids were generated in the simulated area. The simulation model is shown in Figure 3. The blue and red rectangles on the ceiling, voids under two side curtains and cross flow fans show air exits and air exhausts, respectively.

The boundary conditions are set according to the actual site measurement and heat load estimation.

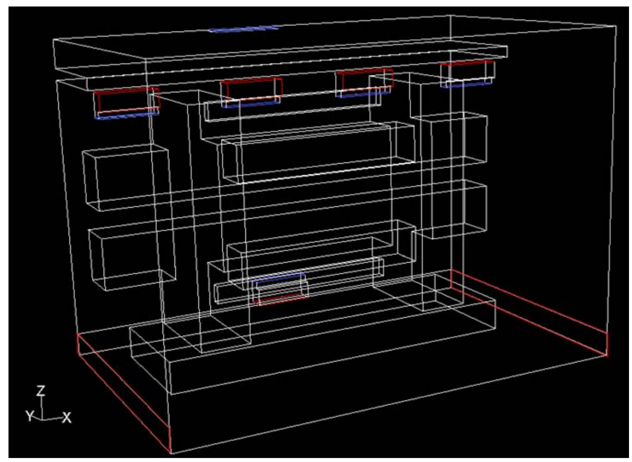

Figure 3: Simulation model.

Simulated Temperature Distribution

Figure 4 illustrates simulated temperature distribution. Apparent relative high temperature occurs on the back sides of the upper magnet array. The temperature distribution ranges from about 32 °C to 20 °C.

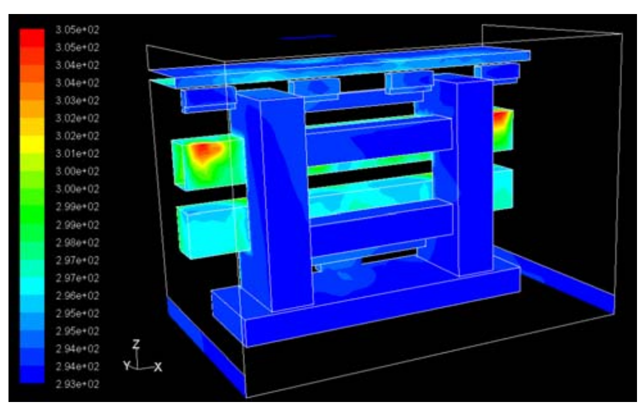

Figure 4: Simulated temperature distribution.

Two horizontal cross sections of Y direction were generated to exam the simulated results, as shown in Figure 5. It can be observed that the temperatures of most area of these two cross sections are close to 20 °C. This result apparently does not meet the real case. Some simplified assumptions of the simulation or accuracies and locations of temperature sensors should be possible factors causing the difference. However, the tendency of simulated results is still referable. Slight temperature gradient occurs near the magnets. The surfaces of the overhead cable tray and cross flow fans also show slight temperature variation.

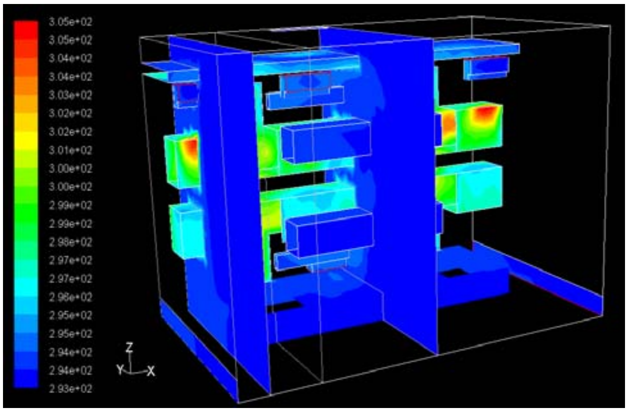

Figure 5: Temperature distribution on two cross sections.

Simulated Velocity Vectors of Air Flow

Figure 6 shows the simulated velocity vectors of air flow in the isolated area. The air velocity from the air exit on the ceiling is about 7 m/s. This is also the area where the highest velocity appears. The air flow uniformly circulates from top to bottom and enwraps the EPU magnet arrays by the operation of cross flow fans.

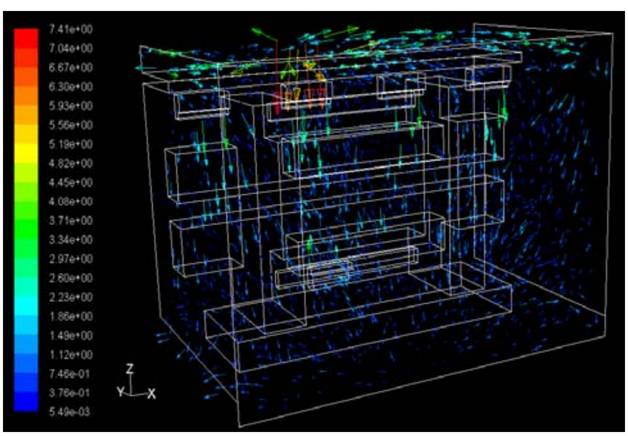

Figure 6: Simulated velocity vectors of air flow in the isolated area.

The flow circulation is more clearly observed on two cross sections, as shown in Figure 7. The air velocity vector density also shows the flow density. Thus there is no vector shown inside the magnet arrays. Relative high air velocity, about 2.5 m/s, appears near the magnet arrays. Figure 7 also illustrates the air velocity vectors on each air exit and air exhaust. The air velocity on the exit of each cross flow fan is about 4 m/s.

In the whole isolated area, there is only one air exit, locating on the ceiling, extracting outside air and two air exhausts, locating under two side curtains, venting air outsides. The air velocity on the two air exhausts under side curtains is about 2.2 m/s.

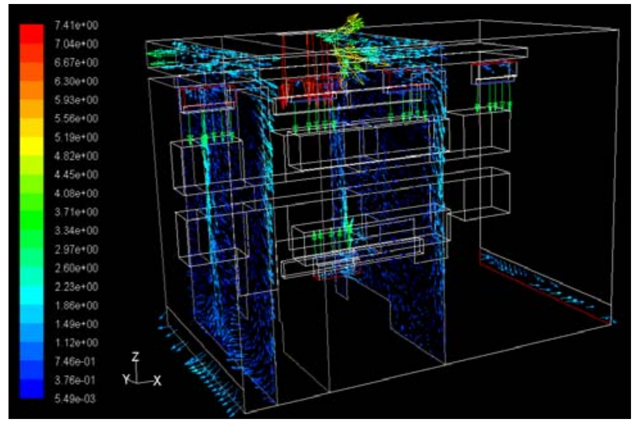

Figure 7: Simulated velocity vectors of air flow on two cross sections and each air exit and exhaust.

CONCLUSION

The mini environmental control was applied on the EPU area to achieve better temperature control and uniformity. Measured temperature results show the temporal temperature variation is about ±0.05 ^{o}C during over 40 hours' operation, and the spatial temperature difference of the EPU is about 0.5 ^{o}C.

Numerical analysis was performed to simulate the air temperature distribution and air flow velocity. The simulated temperature distribution ranges from 32 ^{o}C to 20 ^{o}C. The simulated flow circulation is clearly observed on two cross sections.

ACKNOWLEDGEMENT

Authors would like to thank colleagues in the utility group of NSRRC for their assistance.

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