NUMERICAL SIMULATION AND AIR CONDITIONING SYSTEM STUDY FOR THE STORAGE RING OF TLS

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Abstract

The stability of air temperature in the storage ring tunnel is one of the most critical factors. Therefore, a series of air conditioning system upgrade studies and projects have been conducted at the Taiwan Light Source (TLS). The global air temperature variation related to time in the storage ring tunnel has been controlled within ±0.1°C for years. This study is aimed at more precision temperature control. Some temperature control schemes are applied on this study. We also performed computational fluid dynamics (CFD) to simulate the flow field and the spatial temperature distribution in the storage ring tunnel.

INTRODUCTION

We had studied on the utility thermal effects on the beam quality, especially on the stability of the electron beam orbit. [1] [2] Propagation routes from the temperature variation to the beam quality were also illustrated. Accordingly, we have improved the air conditioning (A/C) system of the storage ring tunnel by increasing the cooling capacity. [3] Since then, we had globally controlled the air temperature variation in the storage ring tunnel within ± 0.1°C. However, the temperature difference between different locations is as high as 2-3 °C. Thus, we applied mini environmental control on the insert device section to achieve better spatial temperature uniformity and the temporal temperature variation within ±0.05 °C.

In addition to the control of air temperature variation within ± 1°C in the steady state of machine normal operation, we also care air temperature variation during transient period after machine starts. We improved temperature control during the period of machine shutdown to shorten the transient state in this study.

To more efficiently and precisely predict the temperature variation and air flow in air-conditioned rooms, we also had applied CFD technique to simulate the three dimensional flow field and temperature distribution inside the storage ring tunnel. [4] In this study, we simulate the actual case (A) and a modified case (B) with different air exhausts locations to check if that rearrangement can achieve better air circulation effect.

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TEMPERATURE CONTROL IMPROVEMENT IN THE MACHINE SHUTDOWN PERIOD

There are two air handling units (AHUs) serve for the whole storage ring tunnel at TLS. Figure 1 shows the control system of the AHU. As shown in the figure, return air from the storage ring tunnel is mixed with outdoor air then flows through a cold water heat exchanger, which is controlled by a cold water control valve. Cooled air then flows through a hot water heat exchanger, which is controlled by a hot water control valve to control the mixed air temperature to 17 °C. The specifications of the AHU are listed in Table 1.

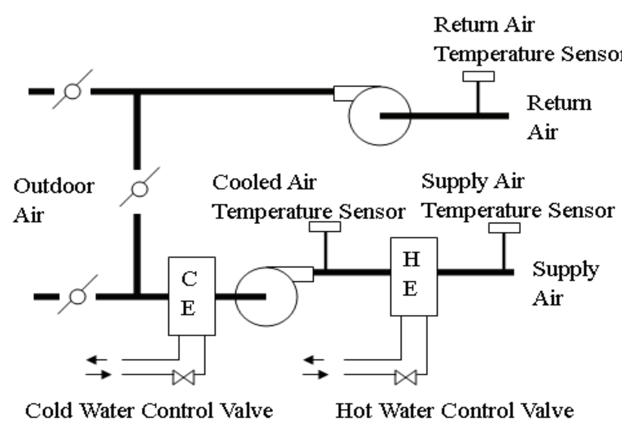


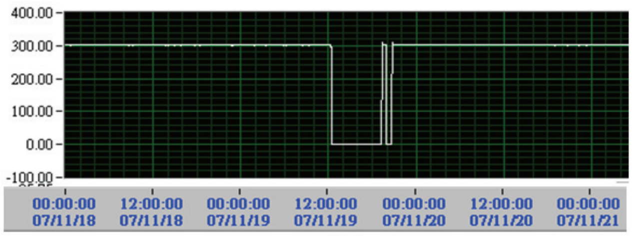
Figure 1: Control system of the AHU.

Table 1: Specifications of AHUs for the storage ring tunnel

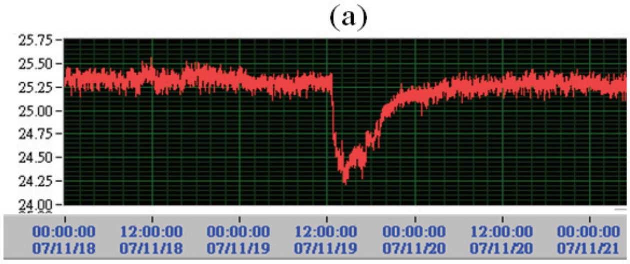
Air flow (cfm)	Fan (RPM)	Fan static pressure (in WG)	Motor (HP)	heat exchange area (ft^2)
12800	1962	3.5	20	26.9

Although temperature variations in the storage ring tunnel have been controlled within ±0.1°C in the steady state of machine normal operation, it takes long time to reach such a steady state after machine starts. Thus, we modified the control scheme to shorten the transient period.

Figure 2 shows beam current (a) and temperature history (b) during machine shutdown before temperature control improvement, i.e., setting a constant supplied air temperature. The cooling load decreased as the machine was shut downed and consequently air temperature in the tunnel dropped about 1 ^{o}C, as shown in the figure. Then the air temperature rose as the tunnel was opened. The air temperature kept rising more slowly as the machine started. It took about two days to reach to the steady state.



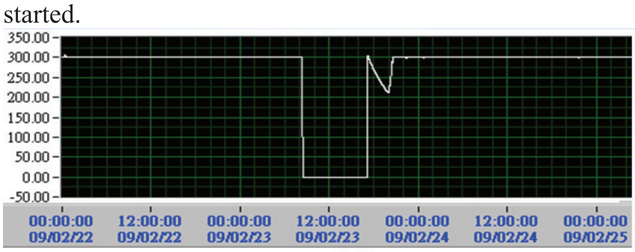
(a)



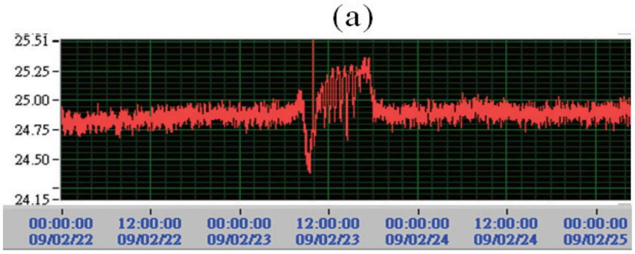
(b)

Figure 2: Beam current (mA) (a) and temperature history during machine shutdown before temperature control improvement (b).

Figure 3 shows beam current (a) and temperature history (b) during machine shutdown after temperature control improvement, i.e., setting a constant room air temperature. Although the air temperature in the tunnel also dropped about 1 ^{o}C as the machine was shut downed, the air temperature rose soon and fluctuated as the tunnel was opened, as shown in the figure. The air temperature reached to the steady state very soon as the machine started.



(a)



(b)

Figure 3: Beam current (mA) (a) and temperature history during machine shutdown after temperature control improvement (b).

NUMERICAL SIMULATION

We performed CFD numerical simulation by using FLUENT 6.2, commercial CFD software. The physical three dimensional model of the storage ring tunnel is built by using GAMBIT, integrated pre-processing software. The simulation is assumed as a three dimensional steady, viscous, incompressible problem.

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

1. Set up the physical shapes, sizes and boundary condition 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.

The geometric model of the storage ring tunnel was set up according to actual sizes of 120m in circumference and 2.8m in height. The cooling loads along the storage ring tunnel, including every kind of magnets, radio frequency chambers and cables overhead were all built in the model. More than three hundred thousand tetrahedron grids were generated in the simulated area.

Sixteen supplied air exits and 8 air exhausts all distributed on the ceiling were set in the model according to the actual locations and sizes. However, according to our simulation results, we found shortcut phenomenon of air flow in this case because of short distances between air exits and air exhausts. Thus, we also simulated another case that 8 air exhausts were located on the bottom of inner walls to check the flow pattern in this study.

The boundary conditions are set according to the actual measurement. Heat load estimation is referred to ASHRAE Handbook Fundamentals. The boundary conditions are listed in Table 2.

Table 2: Boundary conditions for the simulation

	Assumed condition	Set value
air exit	velocity inlet	1.49 m/s,22.12 ^{o}C
air exhaust	pressure outlet	0 Pa
cable tray	wall	882.59 W/m^3
magnets	wall	964.38 W/m^3
side wall	wall	Adiabatic

Because of the truncation error of the numerical computation, there exists difference between values of next two iterations, known as the residual value. The residual value is thus used as the index of the convergence criterion in the numerical simulation. We set this value as 1×10^{-6} for all physical parameters.

SIMULATED RESULTS AND DISCUSSION

The temperature distribution and air flow in the storage ring tunnel were simulated. The simulated flow pattern and temperature distribution of case A is shown in Figure 4. In this case, we set up the model based on the actual layout of the air exits and air exhausts, all distributed on the ceiling. Shortcut phenomenon is clear as shown in the figure. The supplied air from air exits cannot fully reach lower area of the tunnel. Thus the supplied air cannot efficiently remove waste heat from magnets and other cooling loads.

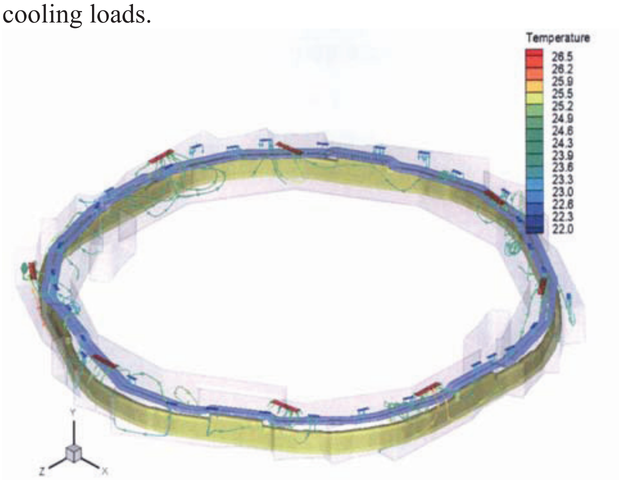


Figure 4: Simulated flow pattern and temperature distribution of case A.

For a better effect of flow circulation in the storage ring tunnel, we modified the model by rearranging the air exhausts on the bottom of inner wall, labelled as case B. Figure 5 shows the simulated flow pattern and temperature distribution of case B. The temperature variation of streamlines from air exits to air exhausts is clear. It indicates better flow pattern that supplied air can flow through cooling loads and remove more waste heat.

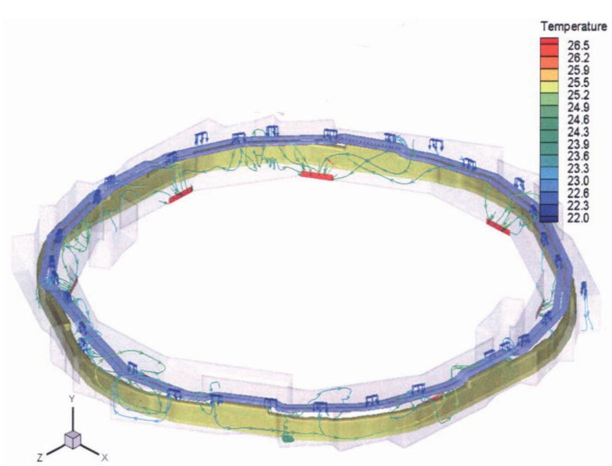


Figure 5: Simulated flow pattern and temperature distribution of case B.

CONCLUSION AND FUTURE WORKS

We have modified the temperature control scheme during the machine shutdown. This modification shortens the time of air temperature rising to the steady state after machine start. This improvement saves the transient period of two days and makes the machine operation more stable.

We also simulated the flow field and temperature distribution of the storage ring tunnel. An actual case and a modified case, i.e., cases A and B, were modelled and simulated. Simulated results show the supplied air shortcut forming between the supplied air exit and air exhaust in case A is improved in case B.

Although the air temperature variation along the time in the storage ring tunnel has been controlled within $\pm 0.1^{o}$C, the spatial thermal uniformity still needs to be improved. We have upgraded the FLUENT 6.2 to ANASYS 12.1 for more precise simulation to improve the AC system. Our future works are summarized as follows:

1. We will try to implement a new control scheme for the case of unintentional beam loss period in the future.
2. Supplied air direction has to be modified to avoid the supplied air shortcut phenomenon.
3. We will perform transient CFD simulation to check the variations of temperature and flow field with time.
4. The models of the magnets, chambers, and cable trays will be set up more precisely for better simulation.

ACKNOWLEDGEMENT

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