Fabrication of First prototype of Water-cooling System of MFT

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Introduction

The Indian ALICE-upgrade Muon Forward Tracker (MFT) collaboration [1] has started to study MFT thermal studies fabricating the water-cooling prototype which is a high thermal conducting carbon panel where polyamide pipes of minimum diameter were embedded on it. The MFT thermal studies aim at designing a cooling system able to keep the temperature gradient along the electronics below 5^0C and below room temperature (25^0C).

Fabrication of the MFT water-cooling prototype

The fabrication of water-cooling prototype is a challenging work and first time in India. The carbon panel i.e. the mother component of the prototype was made gluing two thermal conducting carbon fibers keeping 90^0 with each other using standard resin. The carbon fibers were K13D2U, collected from CERN, Switzerland. The thickness of carbon panel was 280 µm. The water-cooling pipes are basically polyamide pipes of 1 mm inner diameter (ID) and each of 25 µm thickness. Three such water-cooling pipes were embedded on the carbon panel using thermal paper and structural paper of thickness 30 µm and 70 µm respectively. The structural papers were used to give the pipes mechanical rigidity for embedding on the carbon panel. There was no glue between polyamide pipes and carbon panel. The three pipes were placed perpendicular to the dummy electronics. The water-cooling pipes and the dummy electronics were put on the either side of carbon panel. This first Indian water-cooling prototype was made for MFT half plane of Half Disk0 among five MFT half disks.

The MFT Half Disk0/half plane can accommodate 11 ladders consists of 32 pALPIDE pixel sensors which is based on the CMOS monolithic pixel sensor technology [1, 2]. The one sensor ladder has been discarded by the collaboration. These ladders were replaced by the dummy electronics for the testing of this prototype. The physics information related active region is of 180 mm length where the dummy electronics were put.

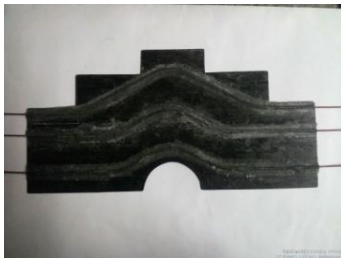

Fig. 1 The water-cooling prototype for MFT

The width of the ladder is 17 mm. For Half Disk0/half plane, there are 2 ladders of 93 mm length with 2 sensors and the 9 ladders of 123 mm length with 3 sensors [2]. Hence, the dummy electronics are the Cu-strip array of thickness 200 µm with resistance chains. The 20 resistances were needed for 11 Cu-strips. The Cu-strips were glued on the carbon panel and the resistance chains were glued on the Cu-strips. The thermal conducting glue Dow Corning SE 4486 was used for gluing the Cu-strip and the resistances.

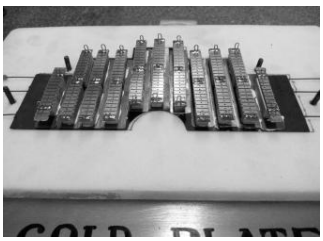

Fig. 2 The dummy electronics for prototype

The resistances of length 38 mm, width 10 mm, the weight of 10 gram and the capacity of 100 Ω (10 Watt) respectively. The Cu-strips were heated using supply voltage 7.94 Volt and current 900 mA through the resistance-chains. The total power consumption for 20 resistances was 7.15 watt and it accepts the total power consumption value for sensors in Half Disk0/half plane of MFT [2].

Testing of the prototype

The manifold, made of Perspex was joined with the water-cooling pipes to flow the water through the pipes.

Fig. 3 The prototype with water flow system

The distance of Manifold from water-cooling plate was 18 cm. The controlled water flow through pipe was 50 ml/minute [2]. The pressure to flow the water at Input slightly higher than 1 ATP. The pressure at Output was 1 ATP. Four temperature sensors were used at different positions.

Results and Discussions

The experimental data were taken from continuous observation during 11 hours. The water source was cooled to 14^0C keeping ambient at room temperature overnight. The dummy electronics (Cu-strip) heating reaches to 40^0C in 45 minutes when ambient was at 22^0C. The water flow started when Cu-strip at 40^0C, water source at 14^0C and the ambient at 22^0C. The dummy electronics reaches at 23^0C within 10 minutes due to cold water flow through the pipes. All the recorded temperatures were taken from the sensor kept at the middle of Cu-strip array. But again the temperature of the Cu-strip increased to 26^0C within three hours since source of cold and hot water was same and they mixed up. The sources of cold and hot water were separated out. It had been observed that the temperature 26^0C continued at steady state during next three hours.

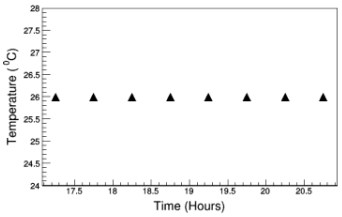

Fig. 4 The steady-state temperature during heating and cooling the system

The following improvements of testing the water-cooling system are to be taken care. The Manifolds are to be put adjacent to the water-cooling system. The dummy electronics has to be put in such way so that complete uniform heating could be done. The dummy electronics must be much thinner to ensure the contact with carbon panel. The Cold and Hot water sources are to be separated out. But continuous supply of cold water is to be ensured. It had been observed that Output temperature shows 1^0C higher with respect to Input when water flows to cool the hot dummy electronics. It can be foreseen that the steady state temperature may continue for a reasonable long time (~ 8/10 Hours) even at 23^0C at (below normal room temperature 25^0C). All the tests are to be done putting water-cooling system vertically instead of horizontally.

In the future plan, we have to measure temperature-mapping using calibrated Infra-red camera. We have to measure the water flow through each individual water pipe. A safety factor of 3 has to be calculated to measure the maximum tolerable pressure which water-cooling pipe of 1 mm ID can bear during water flow.

Reference

[1] DAE-BRNS Symp. on Nucl. Phys. **61**, 812 (2016) .
[2] ALICE-TDR-018 V4, May 30, 2015.