Analysis of Air Cooling Performance in the Coil Stack Assembly for APR+ CEDMs

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1. Introduction

The control element drive mechanisms (CEDMs) are electromechanical devices for withdrawing, inserting, holding or tripping the control element assemblies (CEAs). The driving power for CEDMs is supplied by the coil stack assembly mounted on the motor housing assembly [1]. The Coil Stack assembly is heated by the motor housing assembly contacted with reactor coolant as well as electric resistance of coil. The CEDMs are cooled by air ventilation. The cooling air around the CEDMs flows into the individual cooling shroud and extracts heat from the coil stacks while it passes between the shroud and coil housing [2]. The cooling performance of the CEDMs is closely related to the geometry configuration of coil stack assembly. The expansion of air passage and additional cooling fins are considered to improve the cooling performance of APR+ CEDMs. In this study the optimal design conditions of APR+ CEDMs are investigated by flow analysis.

2. Flow Analysis

2.1 Geometry of Coil Housing and Cooing Shroud

The cooling air path depends on the shape of coil housing. Circular section is considered for the shape of coil housing rather than square section. It has the advantage of thermal conduction because of uniform thickness and better cooling performance. Individual cooling shroud and plenum plate are needed for the circular sectional coil housing.

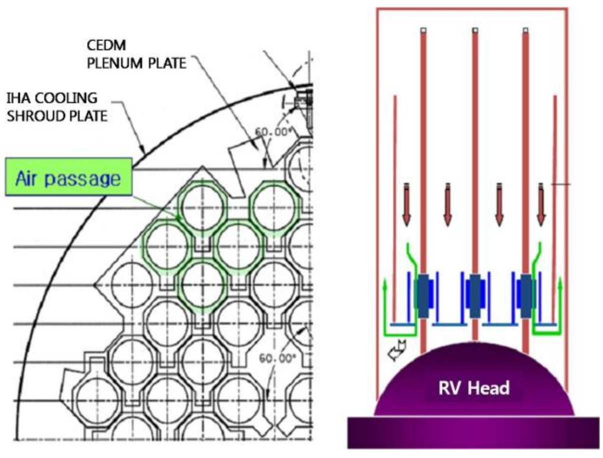

Fig. 1 Cooling air flow in the CEDMs

For the shape of cooling shroud, octagonal section is appropriate for both structural stability and uniform flow of cooing air as shown in Fig. 1. Cooling fin is able to improve cooling efficiency as increasing the heat exchange area.

2.2 Analysis Condition

The computational fluid dynamics (CFD) analysis is performed by using FLUENT program to find the optimal condition of coil cooling.

The basic design of APR+ CEDMs is assumed to be same with that of APR1400 CEDMs. Fig. 2 shows the assembly of cooling shroud and coil housing. Cooling air is 120°F initially and surface temperature of coil housing is assumed uniformly 400°F. The air flow provided to the coil stack assembly is 600 SCFM±10% as shown in Table 1. The characteristics of cooling air such as density, specific heat, viscosity and conductivity are considered.

Analysis is performed to calculate the changes of exit temperature at the plenum plate and pressure drop while the cooling air pass through the coil stack assembly with different design conditions. The effect of cooling air path is analyzed by different gap size between coil housing and cooling shroud. 0.425 inch of APR1400 design and 0.5 inch are considered in here. The number of cooling fins influences on cooling performance. Zero, 8 and 16 of cooling fins are considered. Also, the cooling fin thickness is considered as 0.2, 0.3 and 0.4 inch.

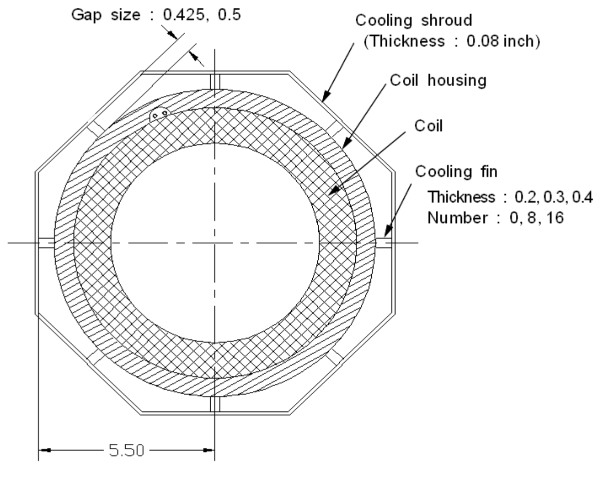

Fig. 2 Coil housing and cooling shroud

Table 1 Initial condition for flow analysis

Inlet air temp. (°F)	120
Coil housing surface temp. (°F)	400
Air flow measurement (SCFM)	540 ~ 660

2.3 Results and discussion

Flow analysis is performed to find optimal design parameter for air cooling of APR+ CEDMs. If the cooling fins are not considered, when gap size is increased to 0.5 inch, outlet air temperature decreases very little by 0.6% compared with the result of 0.425 inch gap size. On the other hand pressure drop between inlet of cooling shroud and outlet of plenum plate decreases by 11.3% due to the increased area of cooling air path. These results mean that the increase of flow air path is effective in reducing the pressure drop with little loss of cooling performance.

The effect on cooling performance as different number and thickness of cooling fin is analyzed with 0.5 inch gap size. If 8 cooling fins are considered, the outlet air temperature increases by 2.8% to 3.3% compared with no cooling fins. In the case of 16 cooling fins under the same other conditions, the outlet air temperature increases by 7.5% to 8.0%. The difference of outlet temperature as cooling fin thickness is about 0.5%. When 16 cooling fins are considered, the pressure drop varies 15.3%, 30.2% and 48.1% with the variation of cooling fin thickness as 0.2, 0.3 and 0.4 inch. The results show that the cooling fins can improve cooling performance by expanding heat exchange area. But adding the cooling fins causes the increase of pressure drop due to the reduction of air path area and increase of friction accompanying air flow velocity increase. The effect on the cooling performance as different cooling fin thickness is very small but relates to the pressure drop.

The effect of cooling fin with 0.425 inch gap size which is APR1400 design value is also analyzed. Comparing with 0.5 inch gap size, the results show better cooling performance under the same other conditions. If 8 cooling fins are considered, the outlet air temperature increases by 4.6% to 5.1%. In the case of 16 cooling fins, the outlet air temperature varies by 9.5% to 10.1%. On the other hand, the values of pressure drop are greater than that of 0.5 inch gap size. It varies 46.0%, 65.0% and 88.0% when 16 cooling fins are applied. This is because the area of cooling air flow is smaller and the air flow velocity is faster. In this case, cooling performance is inversely proportional to the cooling fin thickness due to the decrease of air path area.

3. Conclusions

The analysis of air cooling performance in the coil stack assembly with the various conditions of gap size, number of cooling fins and thickness is performed. The cooling fins have a positive influence on the cooling performance because heat exchange area is increased. The results show that 16 cooling fins have better cooling performance than 8 cooling fins at both gap size of 0.425 and 0.5 inch. The increased pressure drop due to the cooling fins can be reduced by increasing the air path area. The variation of cooling fin thickness has little influence on the cooling performance regardless of gap size and number of cooling fins. The coil stack assembly configuration with 16 cooling fins and 0.2 inch thickness has best cooling performance for APR+ CEDMs.

REFERENCES

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[3] Fluent Inc., FLUENT User's Guide, Ver. 6.3, 2006.