COMPARISON OF RELAP5-3D/ATHENA AND ANSYS/FLOTRAN THERMAL-HYDRAULIC RESULTS

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A heat exchanger for a space reactor has been modeled by the codes RELAP5-3D/ATHENA (Ref. 1) and ANSYS/FLOTRAN (Ref. 2), and some thermal-hydraulic results have been compared with reasonably good agreement. The purpose of this comparison is to evaluate the ability to represent components designed and analyzed using coupled multiphysics tools like ANSYS/FLOTRAN and RELAP5-3D/ATHENA as part of an overall system analysis. If the components represented in RELAP5 match the performance predicted by ANSYS, then it is possible to accurately represent component performance in a broader system analysis, which may consist of a combination of many components developed with multiphysics tools. This will permit system analysis to be performed using more appropriate transient system analysis tools with control volumes representative of the detail designs. The important performance parameters to match are the total heat transferred within the component and the pressure drop across the component.

The heat exchanger modeled is an annulus made of stainless steel with inside and outside radii of 3.73 cm and 4.1 cm, respectively, and 15.6 cm long as shown in Fig.1. Wall thickness is 0.5 mm. Hot liquid metal will enter the heat exchanger through the top center pipe and will leave the heat exchanger through both side bottom pipes. Two different liquid metals have been considered: sodium and NaK, which is an eutectic mixture of 22% sodium and 78% potassium. The heat exchanger will transfer heat to helium circulated inside at a temperature of 800 K with an assumed heat transfer coefficient to the helium of 10,000 W/m^{2}K.

The transient analysis 3-dimensional (3-D) computer code RELAP5-3D/ATHENA can employ a variety of coolants in addition to water, the original coolant employed in early versions of the code. Liquid metals (sodium, potassium, NaK, lithium) and cryogenic fluids (hydrogen, helium, nitrogen) are some of the available coolants. The code can also use 3-D volumes and 3-D junctions, thus allowing for more realistic representation of complex geometries. This heat exchanger has been modeled as a 3-D volume with 3 radial nodes, 25 axial nodes, and 8 azimuthal (angular) nodes. Fig. 2 shows this model with the fluid temperature distribution at the end of the calculation employing sodium (Table 1). This model has been used as part of the system design to calculate flows, temperatures and pressure drops.

ANSYS is a multipurpose finite-element code that can perform a variety of calculations, including stress analysis, temperature distributions, and thermal expansions in solid materials. FLOTRAN is one of the computational fluid dynamics packages of the code and can perform thermal-hydraulic fluid calculations. The ANSYS/FLOTRAN representation of this heat exchanger with the calculated fluid temperature distribution using sodium is shown in Fig. 3. This model has been used for component design, to calculate stresses.

The results from both codes (RELAP5 and ANSYS) for different input conditions are shown in Table 1. The flow in all cases is 0.25 kg/s. The ΔT value is the temperature difference between the inlet and outlet flows to the test section. Two inlet hot temperatures are used with NaK: 850 and 900 K. Total heat transfer (Q) is calculated using the ΔT and the heat capacity and mass flow rate of the coolant. From these results, it appears that sodium can transfer more heat than NaK for the same mass flow rates and temperatures. Sodium has larger density, heat capacity and thermal conductivity than NaK. The last two cases of Table 1 are the results from the two codes that have been compared for the same input conditions. Figs. 2 and 3 show the calculated temperatures for the coolant inside the heat exchanger. RELAP5-3D/ATHENA calculates a larger ΔT (50 vs 39 K) and more heat transferred (22%) than ANSYS/FLOTRAN. Experiments with NaK are planned in the future for systems with comparable heat exchangers. Results from these experiments can be used to validate these codes.

The heat transfer correlation employed by RELAP5-3D/ATHENA for forced convection in liquid metals is the Seban and Shimazaki correlation (Ref. 3). Heat transfer coefficients calculated by RELAP5-3D/ATHENA varied between 18,000 and 24,000 W/m^{2}K for NaK, and between 44,000 and 53,000 W/m^{2}K for sodium.

In conclusion, both RELAP5-3D/ATHENA and ANSYS/FLOTRAN results appear to be in reasonably good agreement. Both codes are applicable to these calculations.

REFERENCES

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3. SEBAN, R. A, and T. T. SHIMAZAKI, "Heat Transfer to a Fluid Flowing Turbulently in a Smooth Pipe with Walls at Constant Temperature," *Trans. ASME*, **Vol. 73**, pp. 803-809 (1951).

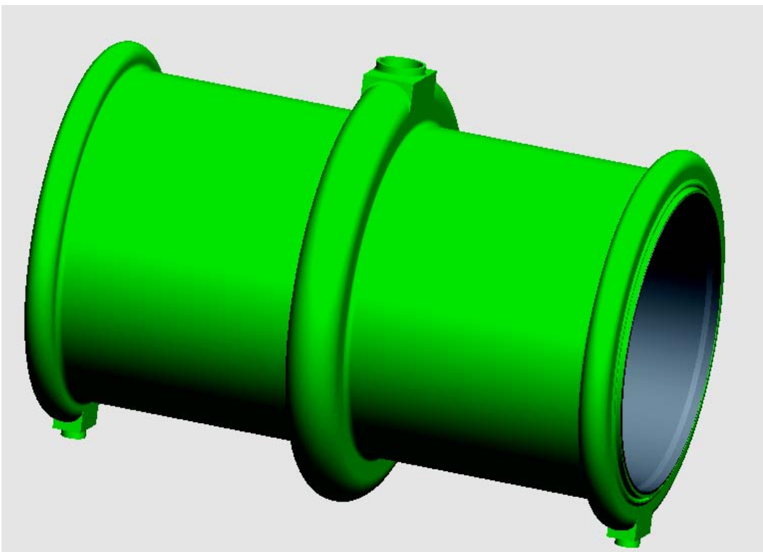

Fig. 1. View of the heat exchanger. Liquid metal inlet is at the top center, liquid metal outlets are at the bottom sides, and helium flows inside.

Table 1
Comparison of RELAP5-3D/ATHENA and ANSYS/FLOTRAN results

Code	Coolant	Flow (kg/s)	Tin (K)	ΔT (K)	Q (W)
RELAP5	NaK	0.25	850	28	6032
RELAP5	NaK	0.25	900	54	11657
RELAP5	Na	0.25	900	50	14900
ANSYS	Na	0.25	900	39	12240

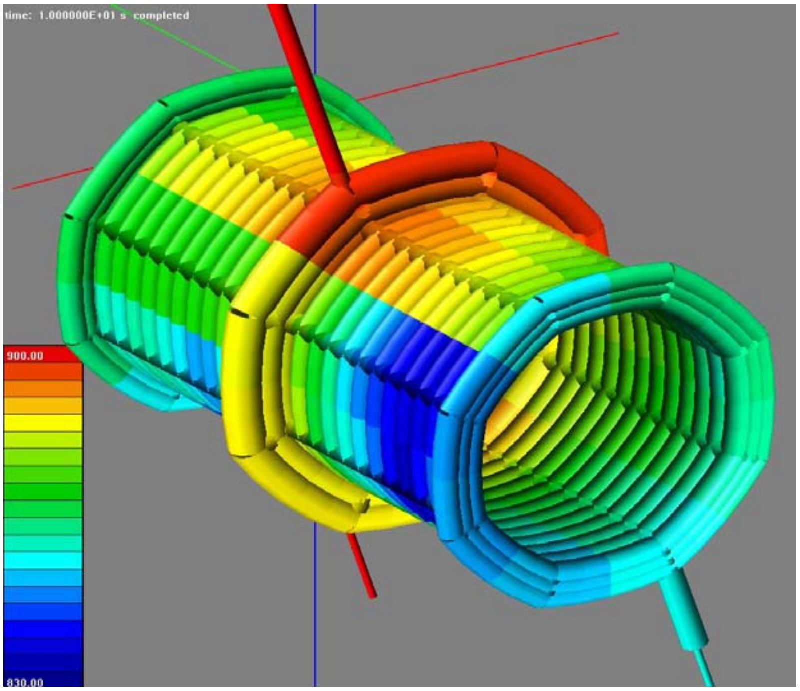

Fig. 2. RELAP5-3D/ATHENA model of the heat exchanger and calculated temperatures with sodium inlet at 900 K.

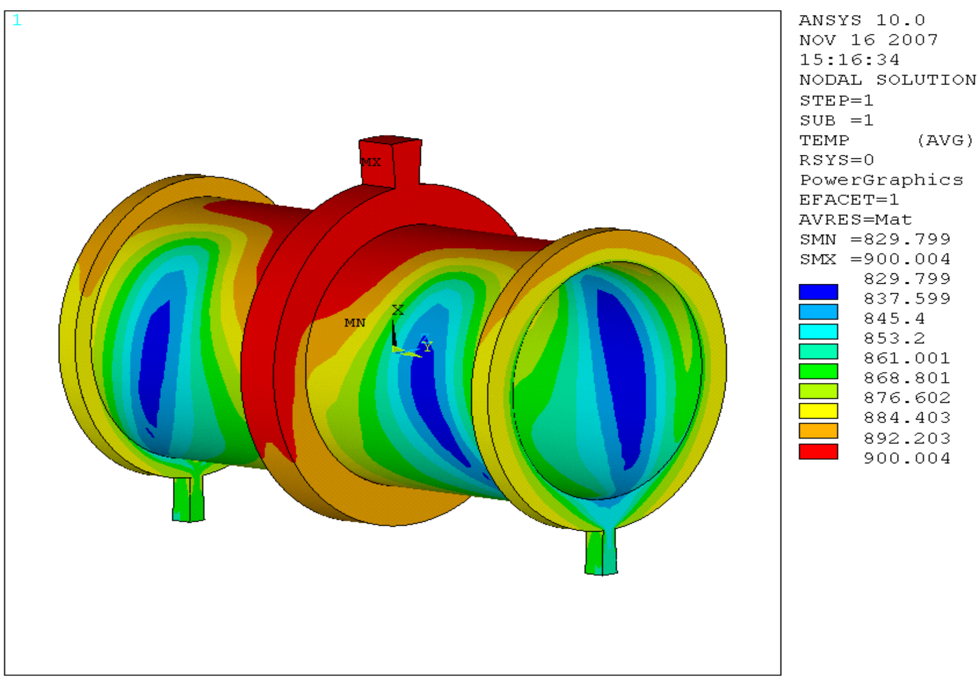

Fig. 3. ANSYS/FLOTRAN model of the heat exchanger showing the calculated temperatures with sodium inlet at 900 K.