CFD Application to SST Propulsion System

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Introduction

The SST propulsion system will operate in the range from takeoff to high Mach number. The high speed fight causes very high inlet air temperatures and pressures and the high inlet air temperatures and recovery pressures inside the engine make cooling for elements of the engine mandatory to keep the best available construction materials operating satisfactorily. Technology for satisfied cooling requires to understand the heat transfer in the engine, however there are many difficulties to understand detail phenomena occurred in the engine from limited measurement.

In order to understand the mechanisms of heat transfer in the engine and to explain test data results, CFD was found to be extremely helpful and important. CFD has also contributed to some new technical innovations. This paper describes some CFD applications in a SST engine development.

Analysis of secondary flowfields inside turbine disc cavities

Flows inside a turbine disc cavity tend to be very complex because of its complicated geometries (see Fig.1). Heat transfer to the turbine disc is strongly influenced by the flow structure in the cavity. Therefore it is essential to know the flowfield inside the cavity for accurate prediction of the heat transfer.

In this study, a three-dimensional Reynolds-averaged Navier-Stokes code was applied to simulate the flows in the turbine disc cavity. The study is focused on the effect of bolts in the cavity on the flowfield and resultant heat transfer.

30 bolts are located on the rotating wall surface of the turbine disc. One thirtieth domain of the annulus is calculated using the periodic boundary conditions at the circumferential ends. Only one bolt exits in the computational domain (see Fig.2).

Figure 3, 4 and 5 respectively show velocity vectors, distributions of temperature and swirl ratio inside the turbine disc cavity for the cases both with bolts and without bolts respectively. These figures show that flows inside the cavity are strongly influenced by existence of bolts inside the cavity. Swirl ratio is defined as swirl velocity of fluid divided by swirl velocity of the rotating surface at the same radial position. In the case with bolts, large differences of temperature and swirl velocity between the fluid and the heated surface of the cavity exist at the measurement point in figure 1. On the other hand, the differences of temperature and swirl velocity become smaller in the case with bolts there.

Comparing thermal conductivity calculated using numerical results between both cases, value of the case with bolts becomes 1.3 times of the case without bolts. Considering head transfer at that region, smaller thermal conductivity for the case with bolts is explained for the reason that differences of temperature and velocity become smaller. These results indicate that heat transfer is strongly influenced by the detail shape of the surface inside the cavity.

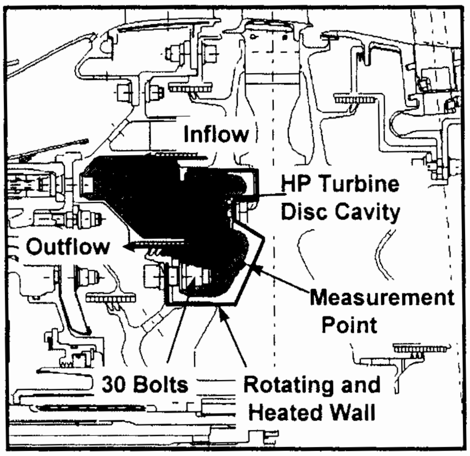


Fig. 1 Schematic of a HP turbine disc cavity

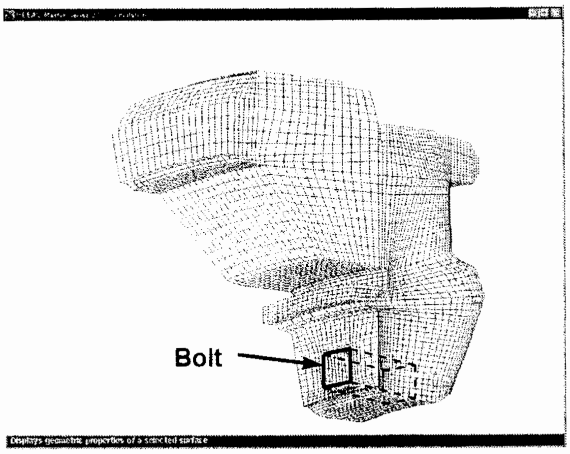


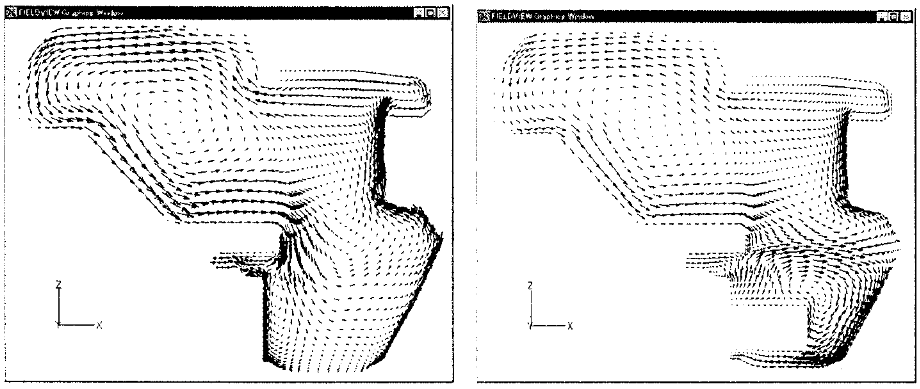
Fig.2 Numerical grid of turbine disc cavity (configuration with bolt shape)

Conclusion

The three-dimensional viscous numerical simulations of flowfield inside a turbine disc cavity including heat transfer are shown in this paper. The results indicate that the heat transfer to the turbine disc is affect by the detail shape of the surface inside the cavity like bolts and the correct modeling of the shape of the cavity must be considered in order to predict the flowfield and resultant heat transfer accurately.

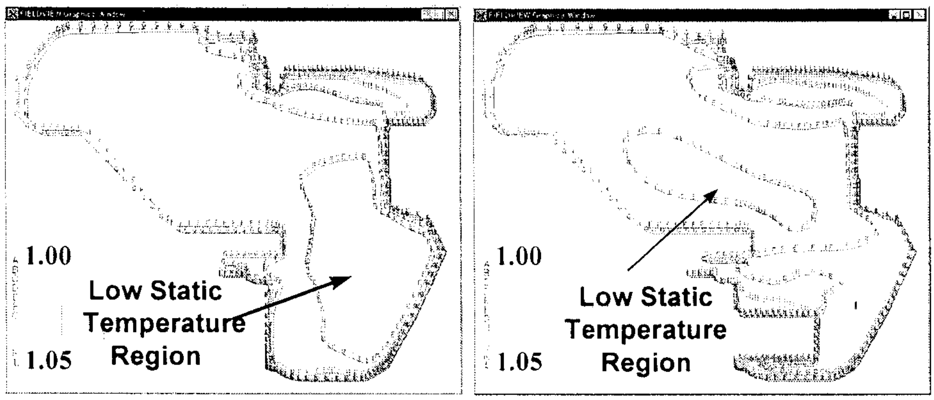
References

[1]Yamawaki, S., Ohkita, Y. and Kodama.H., "CFD Contribution to Development of HYPR engine",AIAA Paper 99-0886



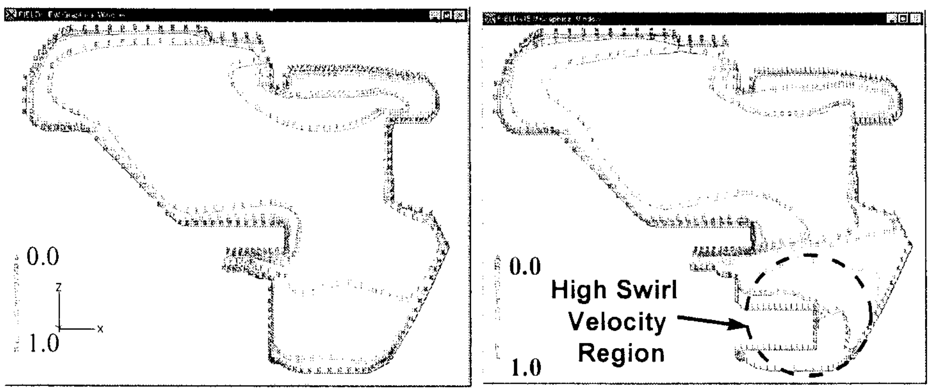
(a)without bolts (b)with bolts

Fig. 3 Velocity vectors inside turbine disc cavity



(a)without bolts (b)with bolts

Fig. 4 Distributions of temperature inside turbine disc cavity



(a)without bolts (b)with bolts

Fig. 5 Distributions of swirl angle ratio inside turbine disc cavity