3D numerical simulation of temperature on Pitot tube

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Abstract: Multi-physics problem is considered for the Pitot tube located in uniform freon gas flow with high Mach number and the 3D numerical results of temperature on Pitot tube is given.The model is created by using structural module of ANSYS, the grids are obtained by ICEM,and the problem is solved and the data post-processing is done by CFX.
Keywords: Pitot tube, temperature, 3D numerical simulation, parallel computation

Introduction

The temperature on the head of Pitot tube is effected due to the variation of its profile and pose when the velocity of the high velocity flow is measured by this tube, too high temperature is not well for the use of Pitot tube. It is very difficult to measure its temperature experimentally, especially for small Pitot tube, therefore it is quite necessary to study numerically the effect of Pitot tube profile and pose on its temperature.

1 mathematical model

several hypotheses are give as follows:

a) inlet flow to Pitot tube is uniform;
b) thermal exchange due to the thermal radiation is not considered;
c) viscosity, thermal conductivity and specific heat are constant, independent of temperature.

Because of the multi-physics problem, it is needed that the temperature equation on the solid area and the N-S equations on the fluid area are solved together.

When solving this problem, the thermal flux to the interface between the solid and fluid areas are equal.

2 computing method

The computing model is created by using the structural module of ANSYS[1], because the geometric model relative to its half plane is symmetric it is only needed that the half of the model is created, and the computing model is showed in fig.1.

The computing grids of the model are meshed by ICEM CFD[2], using blocking topological method, hexahedral with 8 nodes, showed in fig.2 and fig.3.

The boundary conditions are given and the temperature equation for solid area and the N-S equations for fluid area are solved together by CFX[3], the Pitot tube located in uniform freon gas flow with 5 of Mach number, 600Pa of pressure and 20℃ of temperature. The boundary condition for the end of Pitot tube is 20℃.

The flow is considered as turbulent with shear stress transport(SST) model.

The parallel computing is used in CFX with PVM local parallel computing.

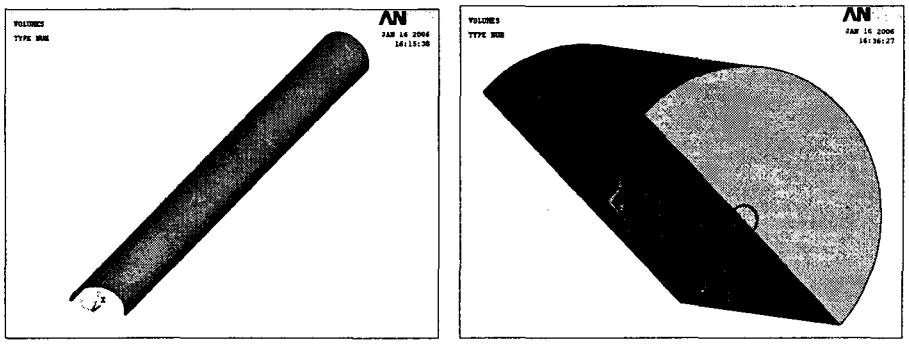

Fig. 1 computing model for solid area and fluid area

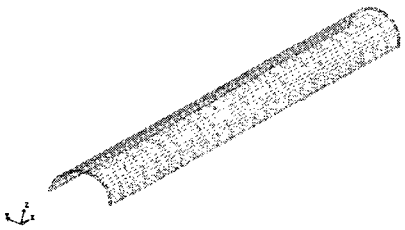

Fig. 2 computing grids for solid area

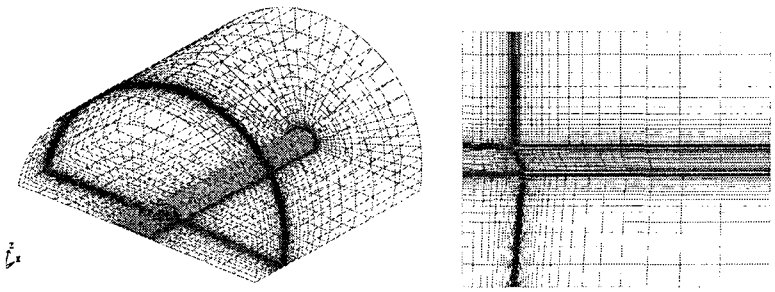

Fig. 3 computing grids for fluid area

3 Results and discuss

3.1 Head without the angle cut

The computing results are showed in Fig.4~Fig.6 when the head of Pitot tube is plane without angle cut and is located without attack angle:

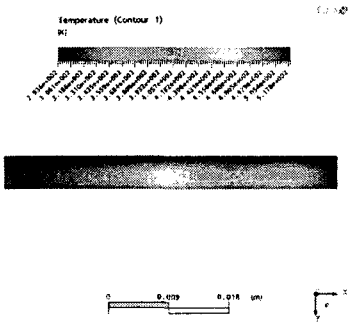

Fig.4 temperature on Pitot tube without angle cut

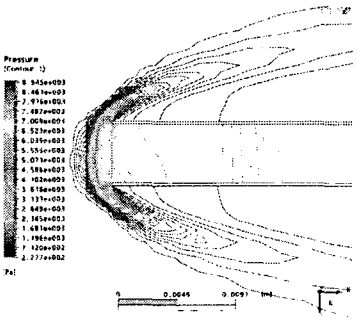

Fig.5 iso-pressure on the symmetric plane for Pitot tube without angle cut

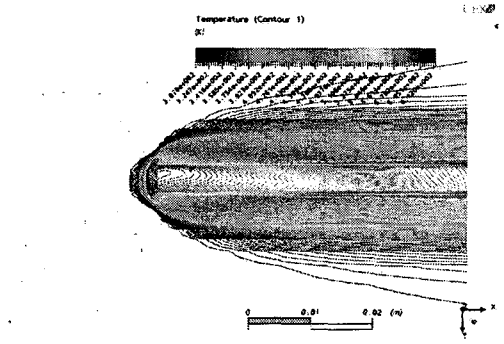

Fig.6 isothermal on the symmetric plane for Pitot tube without angle cut

According to the computing results the temperature on the head of Pitot tube is very high ,up to 247℃,then the temperature decrease along with the tube(cf. Fig.4). The normal shock is formed clearly before the head and showed in Fig.5 and Fig.6, the gas temperature around the head rises sharply up to 342℃ to make the temperature on the head rising sharply by means of the thermal convection.

3.2 Head with 70° of angle cut

The computing results are showed in Fig.7~Fig.9 when the head of Pitot tube is cut with 70° of angle and is located without attack angle:

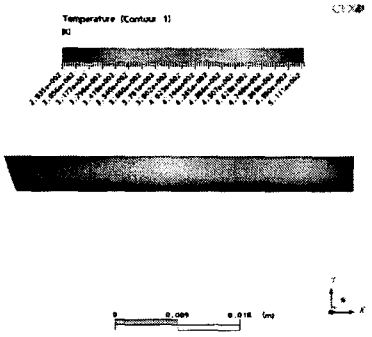

Fig.7 temperature on Pitot tube with 70° of angle cut

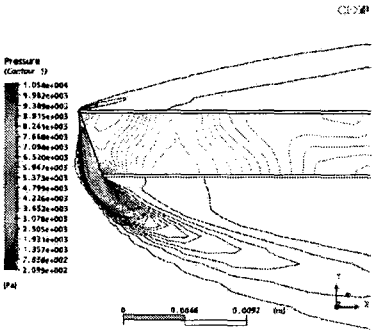

Fig.8 iso-pressure on the symmetric plane for Pitot tube with 70° of angle cut

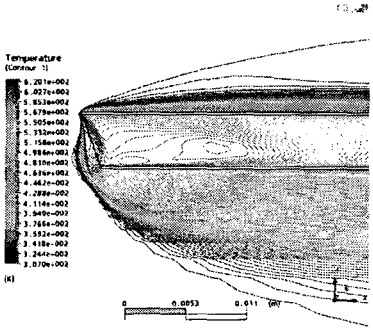

Fig.9 isothermal on the symmetric plane for Pitot tube with 70° of angle cut

According to Fig.7 the temperature on the head of Pitot tube is also high ,up to 240℃,then the temperature decrease along with the tube. The oblique shock is formed first then the local normal shock before the head (cf.Fig.8 and Fig.9), it is why the temperature on the head lower than that for the first case.

3.3 Head located with 5° of attack

The computing results are showed in Fig.10~Fig.12 when the head of Pitot tube is cut with 70° of angle and is located with 5° of attack angle:

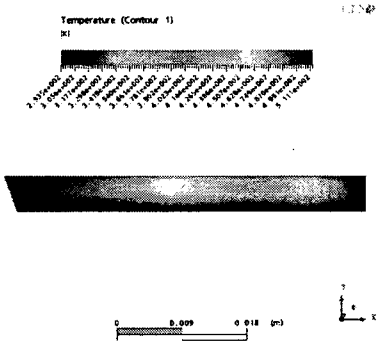

Fig.10 temperature on Pitot tube with 5° of attack

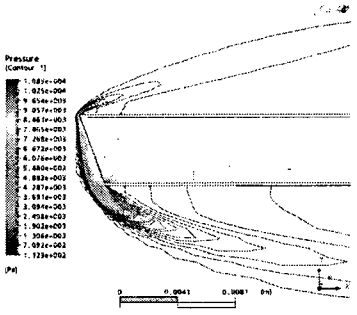

Fig.11 iso-pressure on the symmetric plane for Pitot tube with 5° of attack

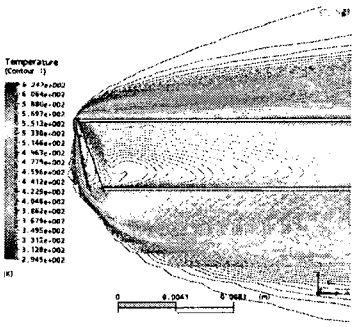

Fig.12 isothermal on the symmetric plane for Pitot tube with 5° of attack

when the head of Pitot tube is cut with 70° of angle and is located with 5° of attack angle the temperature on the head of Pitot tube is similar to that without attack(cf.Fig.10), there is no clear difference for the flow-field around the head between that with and without attack(cf.Fig.11 and Fig.12),it means that the attack (not larger than 5°)has hardly effects on the temperature on the tube and the flow-field around the head.

4 Conclusion

1) The temperature on the head of Pitot tube is high about 250℃ for the tube located in uniform freon gas flow with 5 of Mach number, 600Pa of pressure and 20℃ of temperature;
2) The head with the angle cut can make its temperature decrease effectively because of weakening the normal shock;
3) The attack (not larger than 5°)has hardly effects on the temperature on the tube and the flow-field around the head, thus it is permitted that the fixing error of tube is not larger than 5°.

Refference

[1] ANSYS, Inc. Theory, release 5.7, March 2001.

[2] ANSYS, Inc. ICEM CFD 5.1 Manual, Nov 2004.

[3] ANSYS, Inc. CFX CFD 5.7 Manual, Nov 2004.