3D Numerical Simulation of Flow and 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 the 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..

Key-Words: - Pitot tube, flow, temperature, 3D numerical simulation

1 Introduction

The temperature on the head of the Pitot tube is effected due to the variation of its pose when the velocity of the high velocity flow is measured by this tube, too high temperature is not well for the use of the 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 the Pitot tube pose on its temperature.

2 Mathematical Model

Several hypotheses are give as follows:

a) inlet flow to the 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.

3 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 the 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.

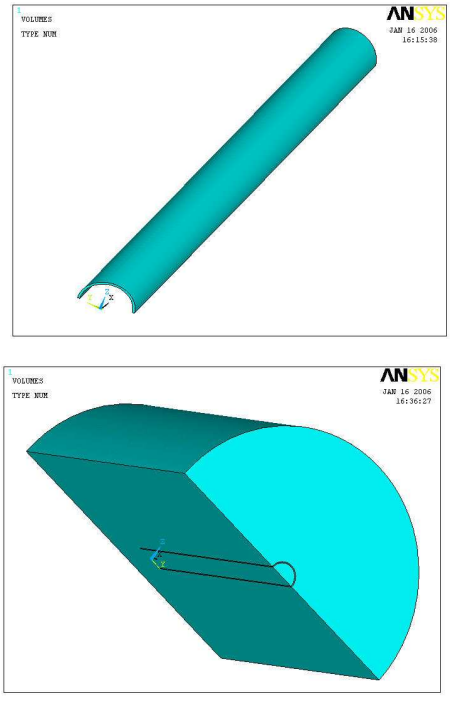

Fig.1 computing model for solid area and fluid area

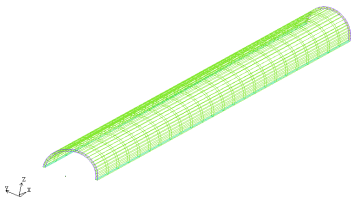

Fig.2 computing grids for solid area

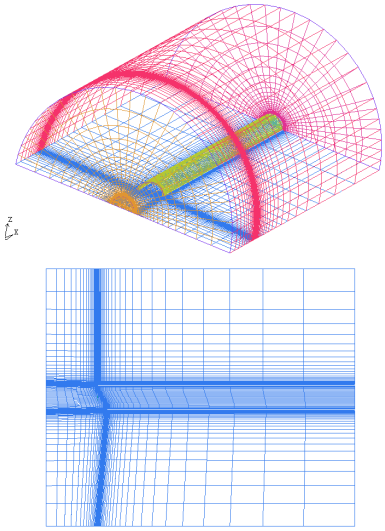

Fig.3 computing grids for fluid area

4 Results and Discuss

4.1 Head Located without Attack Angle

The computing results are showed in Fig.4~Fig.7 when the Pitot tube is located without attack angle:

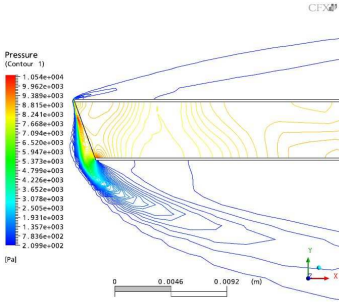

Fig.4 iso-pressure on the symmetric planefor Pitot tube without attack angle

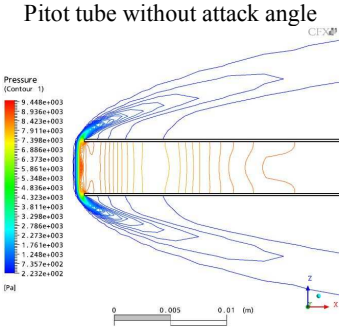

Fig.5 iso-pressure on the transverse plane for Pitot tube without attack angle

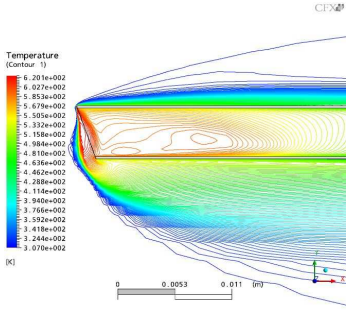

Fig.6 temperature on the symmetric plane for Pitot tube without attack angle

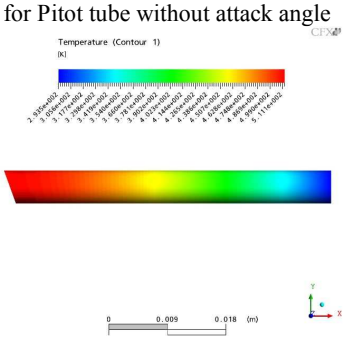

Fig.7 temperature on Pitot tube without attack angle

According to the computing results the temperature on the head of the Pitot tube is very high , up to 240□, then the temperature decrease along with the tube(cf.Fig.7). The oblique shock is formed first then the local normal shock before the head and showed in Fig.4 and Fig.5, because of the shock the gas temperature around the head is rises sharply(cf.Fig6) to make the temperature on the head rising sharply by means of the thermal convection.

4.2 Head Located with 5° of Attack Angle

The computing results are showed in Fig.8~Fig.11 when the Pitot tube is located with 5° of attack angle:

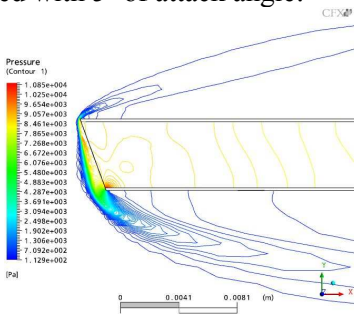

Fig.8 iso-pressure on the symmetric planefor Pitot tube with 5° of attack angle

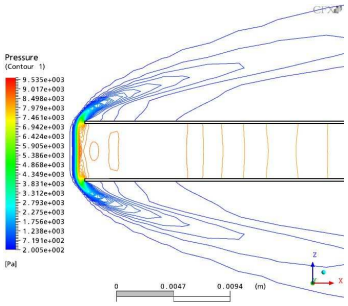

Fig.9 iso-pressure on the transverse plane for Pitot tube with 5° of attack angle

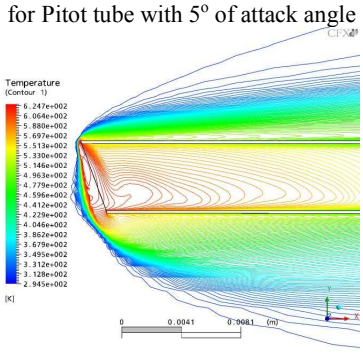

Fig.10 temperature on the symmetric plane for Pitot tube with 5° of attack angle

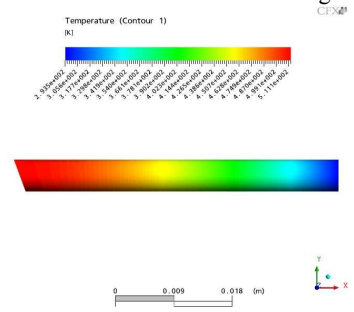

Fig.11 temperature on Pitot tube with 5° of attack angle

When the Pitot tube is located with 5° of attack angle, the temperature on the head of the Pitot tube is similar to that without attack(cf.Fig.11), there is no clear difference for the flow-field around the head between that with and without attack(cf.Fig.8 Fig9 and Fig.10), 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.

4.3 Head Located with 15° of Attack Angle

The computing results are showed in Fig.12~Fig.15 when the Pitot tube is located with 15° of attack angle:

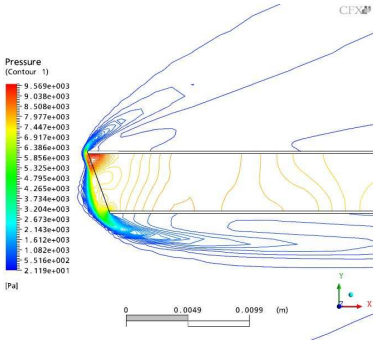

Fig.12 iso-pressure on the symmetric planefor Pitot tube with 15° of attack angle

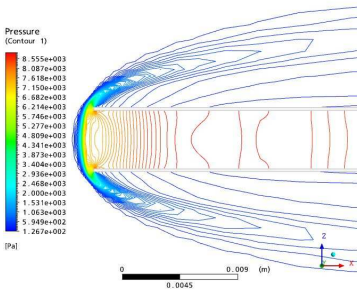

Fig.13 iso-pressure on the transverse plane for Pitot tube with 15° of attack angle

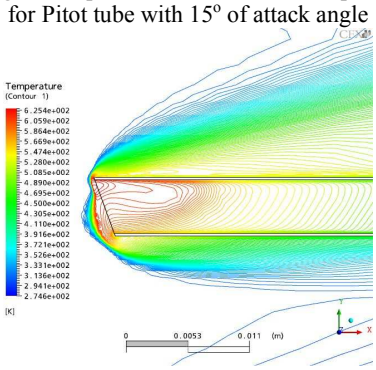

Fig.14 temperature on the symmetric plane for Pitot tube with 15° of attack angle

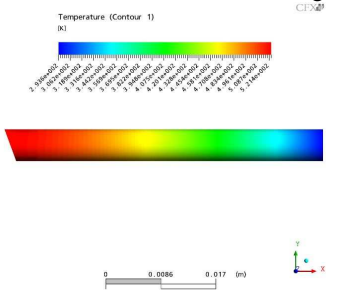

Fig.15 temperature on Pitot tube with 15° of attack angle

When the Pitot tube is located with 15° of attack angle, the temperature on the head of the Pitot tube is up to 250□. However the oblique shock is formed first then the local normal shock before the head(cf.Fig12), the normal shock is more obsviously than that with 5° attack angle and without attack(cf.Fig.9 and Fig.5). This is the reason that the head temperature of the Piot tube is much higher than before. It shows that the head

temperature of the Pitot tube will be effected obsviously when the chang range of the attack angle is increased.

4.4 Head Located with 20° of Attack Angle

The computing results are showed in Fig.16~Fig.19 when the Pitot tube is located with 20° of attack angle:

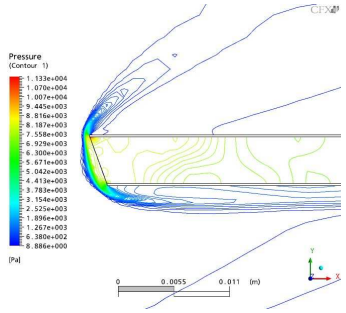

Fig.16 iso-pressure on the symmetric planefor Pitot tube with 20° of attack angle

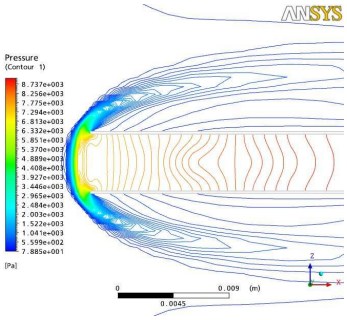

Fig.17 iso-pressure on the transverse plane for Pitot tube with 20° of attack angle

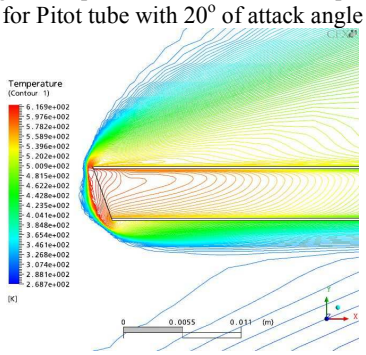

Fig.18 temperature on the symmetric plane for Pitot tube with 20° of attack angle

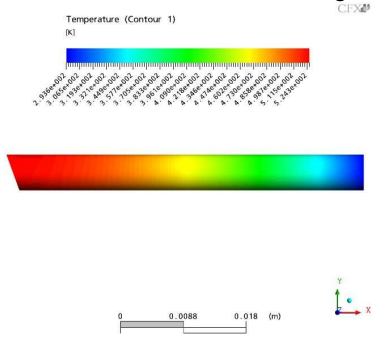

Fig.15 temperature on Pitot tube with 20° of attack angle

When the Pitot tube is located with 20° of attack angle, the temperature on the head of the Pitot tube is up to 253□. There is no clear difference for the flow-field around the head between that with 15° attack(cf.Fig.16 Fig17 and Fig.18), it also means that the chang range of the attack angle(not larger than 5°)has hardly effects on the temperature on the tube and the flow-field around the head.

5 Conclusion

Some conclusions can be drawn according to the computing results:

a) The temperature on the head of the 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;

b) The flow-field around the head of the Pitot tube is that the oblique shock is formed first then the local normal shock before the head. Along with the increasing of the attack angle, the normal shock is more and more obviously and the temperature on the head of the Pitot tube is also higher and higher;

c) The chang range of the attack angle (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°.

References:

[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.