

Numerical Simulation Research on Pressure Probe

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Abstract. This article presents an investigation on the flow characteristics of the air in complex probe. The flow fields around the complex probe in different Mach numbers is simulated to analysis the relation between flow field structure and text parameters. The investigation on complex probe shows that the Mach numbers has influence on the characteristic of complex probe. The flow field around the probe and shock wave distribution transform with the change of Mach number. The calibrate coefficient has disparate transformation law in subsonic speed flow field, near-sonic speed flow field and supersonic speed flow field.

Introduction

Aerodynamic probes are widely applied in turbine text to measure the flow parameters such as total pressure, static pressure, airflow direction and so on. The probe which is researched in this article is a kind of complex probe which has quick response ability. The probe has a sharp wedge structure with five holes to measure pressure. The simplified structure is showed in figure 1. The hole which is marked as 1 in figure 1 is applied to measure the pressure along the direction of probe. The hole which is marked 3A and 3B is applied to measure the static pressure around the probe. The hole which is marked 2A and 2B is applied to measure the pressure on the surface of wedge. The total pressure and airflow direction can be finally calculated according to the relationship of five pressure which is introduced above.

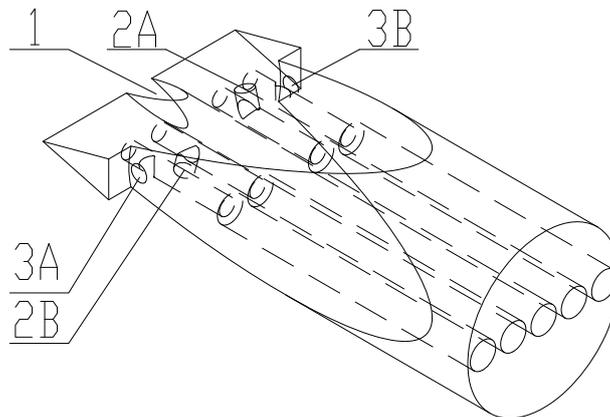


Figure 1. Schematic diagram of complex probe

The final test parameters which is measured by complex probe is acquired by the relationship of different directly measure parameters. The difference of probe structure will generate different relationship between the final parameter and directly measure parameter, which brings difficulties in probe designing. This article present a numerical simulation method to evaluate the performance of complex probe.

Numerical Simulation Analysis

Calculation Domain and Mesh Generation

The complex probe is disposed in the passageway of tester in practice. The windward area of probe is much less than the flow passage area of tester passageway. In numerical simulation, the numerical simulation process can be simplified to be the problem that is far field flow parameters measurement. The calculation domain is accordingly simplified to be the structure of probe in a cubic fluid domain. The surface of cubic field is set as pressure-far-field boundary which has steady flow velocity parameter and pressure parameter. The contact surface between probe structure and fluid is set as wall boundary which is no slip and heat insulation.

The unstructured grid is applied to divide calculation domain. Approximately 2000000 unstructured grids are used to express the structure of calculation domain. The grids around the structure of probe is refined particularly to describe the subtle structure of probe. According to local grid refinement, the unstructured grids which are applied to divide calculation domain are high-quality. The global grid and local refined grid is showed in figure 2.

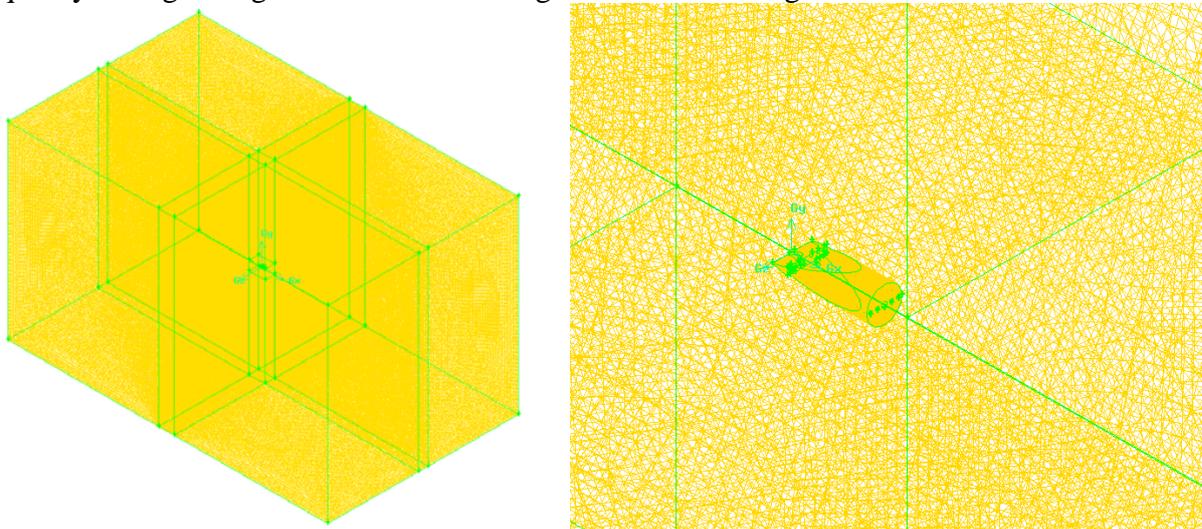


Figure 2. Schematic Diagram of calculation domain and global grid

Numerical Simulation Model

The numerical simulation process is accomplished by ANASIS FLUENT. According to the characteristic of calculation domain, a Spalart-Allmaras model which allow to gave pressure-far-field boundary condition is designated to describe the flow field. The Spalart-Allmaras model is adept in solving flow process around wing section in open flow field, which is able to provide exact solution of flow field in both subsonic boundary condition and supersonic speed boundary condition.

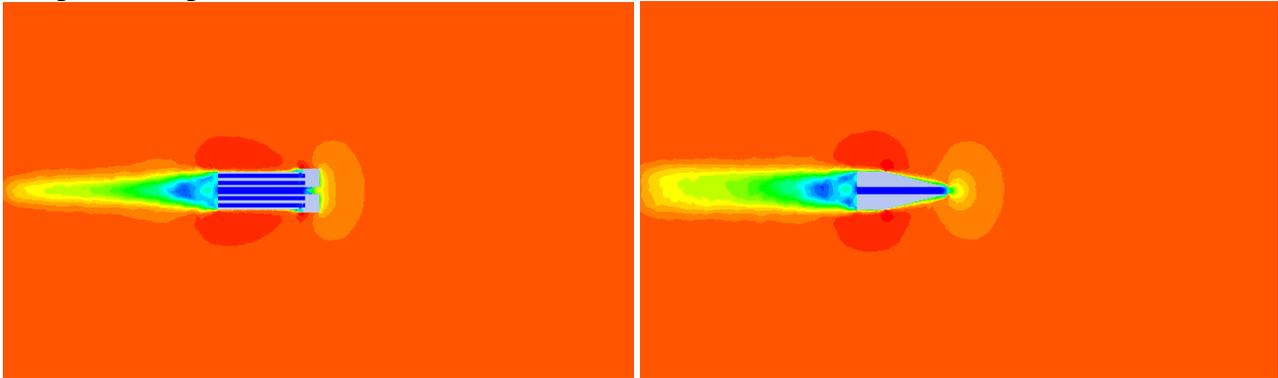
Simulation Result and Discussion

According to the numerical simulation result, the flow around the probe appears differently under different incoming Mach number.

If the Mach number is less than 1, the flow around probe is typical subsonic speed flow. From figure 3, the flow characteristic can be obtained. The air stream flow past the probe adhering the surface. There are no shock waves appearing. In this kind of subsonic speed flow field, the calibrate coefficient transform on account of the change of dynamic pressure.

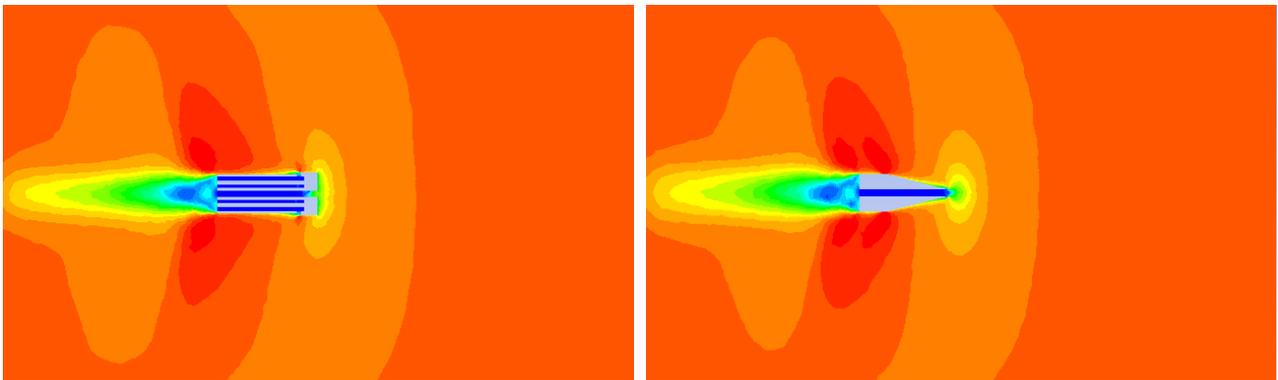
If the Mach number is close to 1, a disparate flow process appears. Shock waves form in front or wedge structure. All the five holes on wedge acquire pressure after shock wave. As what is shown in figure 4, the flow field distribution is caused by the weak shock wave around probe. In this kind of near-sonic speed flow field, the calibrate coefficient transform on account of both the change of dynamic pressure and shock wave.

If the Mach number is greater than 1, the shock waves become stronger and stronger. The shock wave develops to sharp-angled from. The strong shock waves will cause the pressure reducing, therefore the calibrate coefficient transform law is different from the other flow process. In this kind of supersonic speed flow field, the calibrate coefficient transform on account of shock wave.



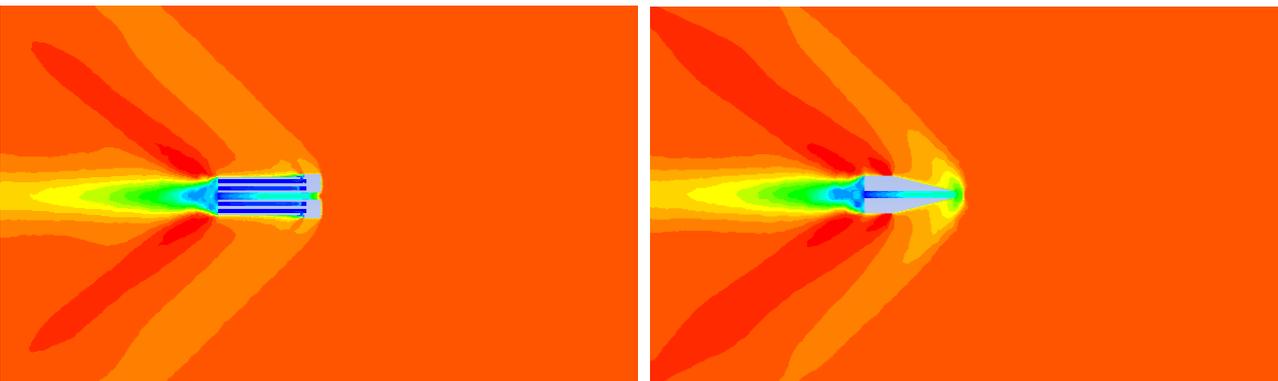
(Incoming flow Mach number 0.7)

Figure 3. Mach number distribution around Probe



(Incoming flow Mach number 1.0)

Figure 4. Mach number distribution around Probe



(Incoming flow Mach number 1.5)

Figure 5. Mach number distribution around Probe

Calibrate coefficient A_w and A_p are selected to describe the flow field in this article.

$$A_w = \left(\frac{P_{2A} + P_{2B}}{2P_{*\infty}} \right)_{\alpha=0} \quad (1)$$

$$A_p = \frac{P_{3A} + P_{3B} - P_{\infty}}{2P_{*\infty}} \quad (2)$$

In order to acquire calibration curve, the total pressure, static pressure and Mach number of incoming flow is measured. The five holes on complex probe collect the pressure around wedge.

Based on the data mentioned above, the calibration curve which uses Mach number as independent variable is drawn and the calibrate coefficient is confirmed by least square method.

The numerical simulation result a shows that the calibrate coefficient has disparate transformation law in subsonic speed flow process, near-sonic speed flow process and supersonic speed flow process. The calibrate coefficient A_w rapidly decreases in both subsonic speed and supersonic speed condition. In near-sonic speed, the calibrate coefficient A_w is steady. The calibrate coefficient A_p rapidly increases in subsonic speed and near-sonic speed condition. In supersonic speed condition, the calibrate coefficient A_p rapidly decreases.

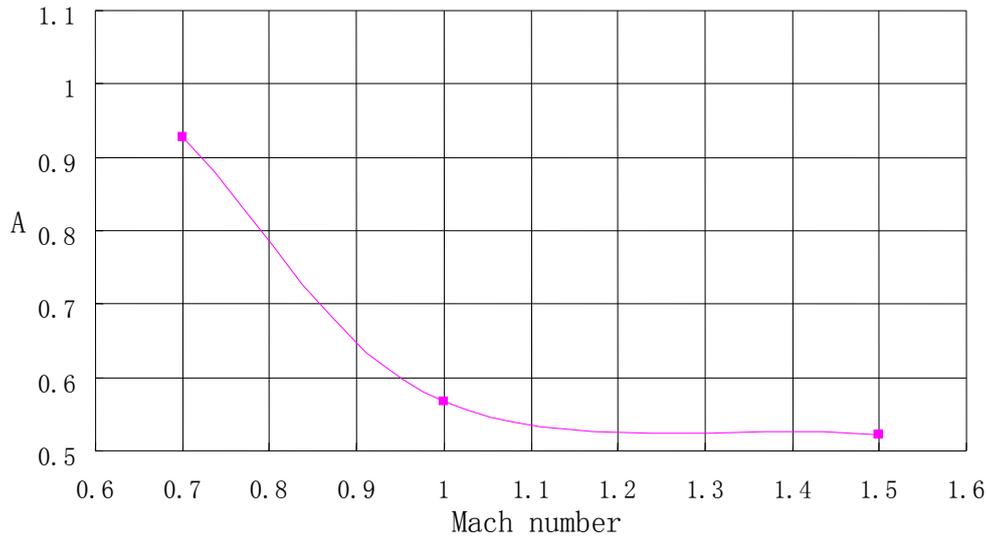


Figure 6. The variation trend of A_w

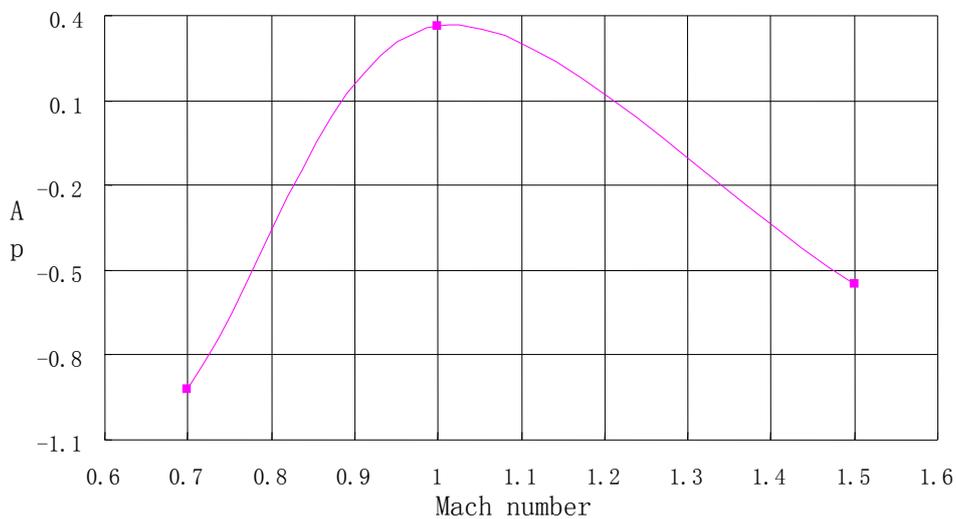


Figure 7. The variation trend of A_p

Conclusion

1. The flow field around the complex probe is disparate in subsonic speed flow field, near-sonic speed flow field and supersonic speed flow field. The influence of shock wave becomes stronger with the increasing of incoming Mach number.

2. The calibrate coefficient A_w rapidly decreases in both subsonic speed and supersonic speed condition. In near-sonic speed, the calibrate coefficient A_w is steady.

3. The calibrate coefficient A_p rapidly increases in subsonic speed and near-sonic speed condition. In supersonic speed condition, the calibrate coefficient A_p rapidly decreases.

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