Application of Ru(Ⅱ)-Complex-Based PSP Measurement To Engineering Problems

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1. Introduction

There are many aerodynamic phenomena that are not fully understood but are still important from engineering point of view. One example of these phenomena is under–expanded supersonic jet impinging on a flat plate. Although the complicated flow field had been investigated by using pressure taps and Shadowgraph images in the past studies [(1)], these methods did not provide enough information of the flow structures. In that sense, the PSP measurement is efficiency as it can provide surface pressure distributions on the flat plate.

Another example that has potential needs for PSP-based measurement is aerodynamic force measurement in the wind tunnel. Traditionally, aerodynamic forces on a model are measured by the balance method. However, it is very expensive and time-consuming for the balance method. In the past study [(2)], feasibility of the PSP measurement based on Ruthenium (Ⅱ) complex in the ISAS transonic wind tunnel was demonstrated using a simple delta wing model.

The objectives of present study is to reveal the flow structure of the supersonic jet impinging on a flat plate and to measure aerodynamic forces on a complicated configuration model using the current PSP measurement system based on Ruthenium (Ⅱ) complex.

2.Experiment Equipments Using Blue LED and Ruthenium Complex(Ⅱ)

PSP-based experiments are less expensive than conventional experiments with pressure taps. However, typical PSP measurement system is still expensive as it uses UV Lamps or Laser light systems as excitation light sources. Therefore, the inexpensive PSP measurement system based on the combination of Blue LED light sources and Ruthenium(Ⅱ) dye [(3)] is used.

The experiment of the under-expanded supersonic jet impinging on a flat plate is carried out in a small induction-type wind tunnel (Fig. 1). The distance and the angle of the flat plate and the ratio of the nozzle exit pressure to the ambient pressure can be varied. The conical nozzle designed for Mach number of 2.2 is used.

The experiment in a large transonic wind tunnel is conducted using the same PSP system. The Blue LED and the CCD camera are placed in the dark room to intercept lights from outside. The PSP images from both the upper and lower sides of the model are measured for computation of the forces on the model.

3. Under-Expanded Supersonic Jet Impinging on a Flat Plate

Flow field created by a supersonic jet impinging on the flat plate appears in a wide variety of industrial applications. [(1)] As shown in the Fig. 3, the flow structures on the flat plate were classified into four types according to the pressure ratios (PR), the plate-angles (θ) and the nozzle-plate distances (L/d) using Schlieren method in the past study [(4)] so that the flow structures on the flat plate can be predicted easily. However, the information from Schlieren images are not enough for discussion of the flow fields in detail. Therefore, the current PSP measurement system is applied to the supersonic jet impinging on the flat plate to obtain pressure distributions on the plate. Figure 4 shows one example of the captured pressure images on the plate and the pressure plots obtained from the PSP image along the centerline compared with the corresponding Schlieren image. The PSP measurement captured the crescent-shaped pressure peak on the flat plate, which helps understanding of flow structure of the jet impinging on the flat plate.

4. Transonic Flow Fields over Space-Shuttle-Type Configuration

In the past study [(2)], feasibility of the current PSP measurement system in the ISAS transonic wind tunnel was demonstrated using a simple delta wing model. In the present study, the current PSP measurement system based on Ruthenium (Ⅱ) complex is applied to a complicated configuration model like space-shuttle with two wings and two main tail wings in the transonic wind tunnel. To cover the entire surfaces, the PSP images are captured from four directions, i.e., top, bottom, left, and right. Then the pressure and temperature images are mapped onto the model that is measured by three-dimensional configuration measurement equipment to compute aerodynamic forces on the model by integrating surface pressure distributions.

Figure 5 shows pressure and temperature images on the model. Flow features such as the shock wave on the wings are successfully captured. Figure 6 shows the mapped pressure and temperature images on the model surfaces and the computed lift coefficient distribution against angle of attack compared with the balance data. The graph shows the aerodynamic force computed by the current PSP measurement system agreed well with the balance data.

These results i[illegible] hat the current PSP measurement sy[illegible] applicable to real-world engineering prob[illegible] g complicated models.

5. Conclusion

An inexpen[illegible] measurement system based on the Blu[illegible] nd the Ruthenium (II) complex has be[illegible] ed to two engineering problems. First[illegible] ent PSP measurement system was used[illegible] flow structures created by the under-exp[illegible] personic jets impinging on the flat plate.[illegible] erodynamic forces on a complicated [illegible] tion model like space-shuttle ar[illegible] ed by using the current PSP measureme[illegible] n and are well agreed with the balance[illegible] These results confirmed that now the cur[illegible] measurement system is applicable to rea[illegible] neering problems.

6. References

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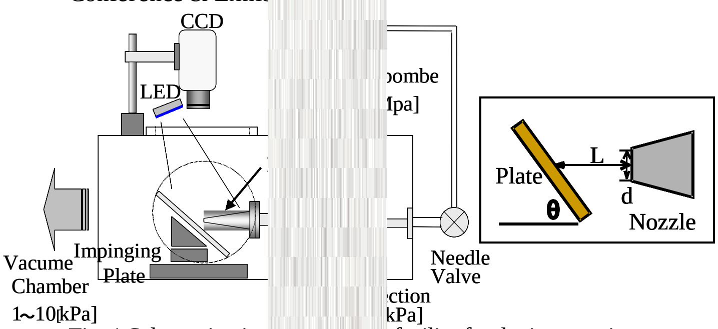

Fig. 1 Schematic pictu[illegible] facility for the jet experiment

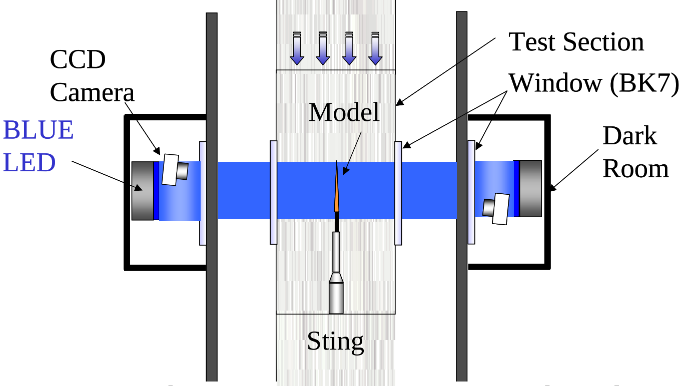

Fig. 2 Schematic pi[illegible] transonic wind tunnel test.

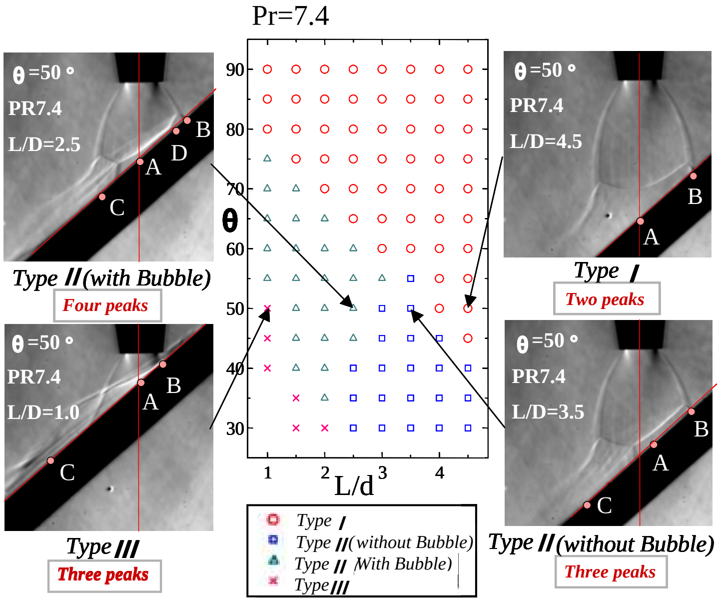

Fig. 3 Classification of the flow patterns.

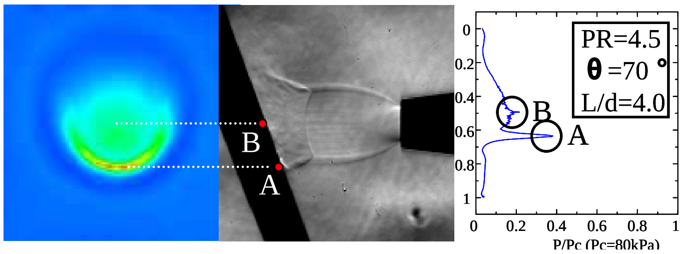

Fig. 4 An example of the measured PSP image and the pressure distribution along the symmetric plane (also with the Schlieren image).

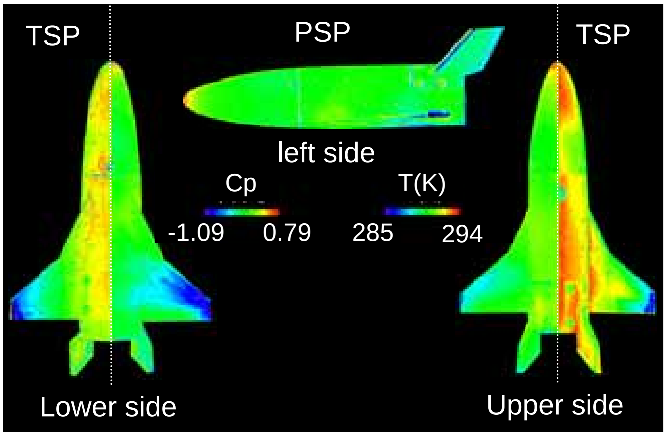

Fig. 5 Flow field over the Shuttle model (M=0.9, α=0 °).

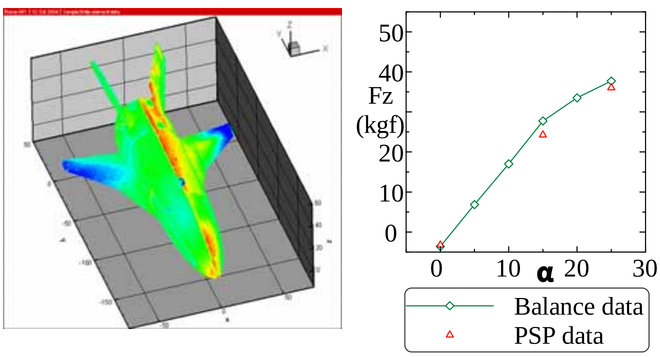

Fig. 6 Mapped data and Cl- α characteristics at M=0.9.