Measuring Unsteady Flow With Bi-directional Holographic Interferometry

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Abstract：

To measure unsteady flow fields, we can follow three steps -- obtain the refractive indices in several directions, extract the chromatography data and reconstruct the flow field by chromatography algorithm [1]. The first way to scan refractive index distribution is rotating the model or optical path until all directions have been examined. But it is difficult to duplicate all the parameters of flows completely, especially for unsteady ones. Aligning several optical paths can solve the problem. There are several techniques can be used, like the diffuse reflection holography and diffraction interference with small observation angle, the F-P with high cost and small field of view. The image plane hologram interference was selected due to many advantages, such as larger observation angle and field, produce hologram fringes with high resolution and contrast focused on the image plane, with the characteristic of eliminating the errors caused by optical components.In this paper, we visualize flow fields with off-axis image plane holographic interferometry in two perpendicular directions. Computational flow imagine (CFI) is used to simulate flow visualization, and the photographs from test are ompared with images from simulation for validation. This bi-directional investigation is the foundation of three-dimensional visualization for unsteady flows, which requires at least six optical paths aligned.

The bi-directional holographic interferometry adds another vertical optical path to the off-axis horizontal optical path. The conventional setup is shown in Fig. 1. The ruby laser beam is separated by a beam splitter, one passes through the test section after been expanded (known as the scene beam), and the other one named as the reference beam is expanded just before intersection with the scene beam at the hologram plane. We can adjust the intensity proportion, angle and optical path difference of the two beams to improve the quality of holograms [2].

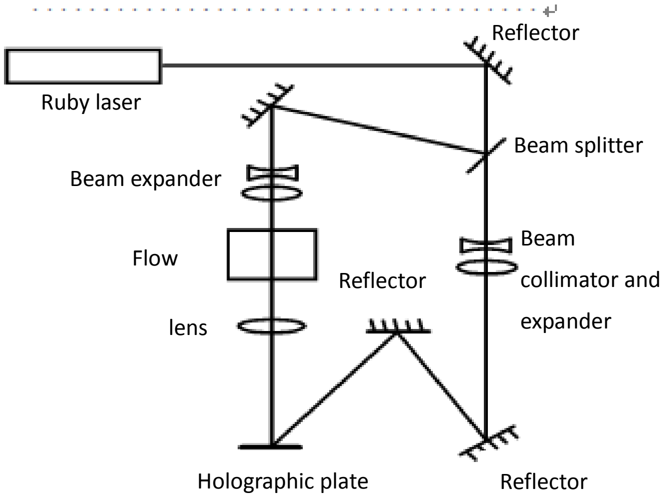
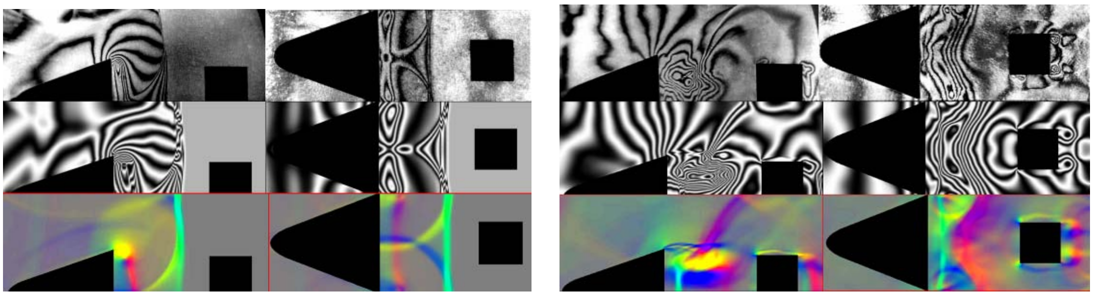


Fig. 1. Setup of holographic interferometry

The testing model is the combination of a cube with 12 mm on each side and a blunt semi-cone with height of 30 mm, radius of 14.2 mm on the bottom.

CFI simulation is carried out under similar conditions as that of tests. As shown in Fig. 2, the test holograms are shownin the first row of each group, while simulated interference and color schlieren images are shown in the second and the third row, respectively. Photographs in the first column are for the horizontal optical path, and the second for the vertical one.



a） V=488m/s， ⊿t=0us　　b V=501m/s， ⊿t=80us

Fig. 2. Results of Test and simulation

Although obtained from different methods, the structures of shocks are basically consistent with each other. When the normal shock wave leaves the semi-cone, the shocks around the front surface of model go weaker, as shown in color schlieren simulation and test holograms.

There are some differences between results from measurement and calculation. For example, the capture time is not precisely matched, that's because in calculation, the Mach number and temperature are specified, whereas in test, value drifts are unavoidable. The difference between diaphragms and the missing accuracy of machining and assembly of models contribute to this mismatch too. The simulated normal and reflected shock waves seem thicker than that of test, due to dissipation error and lack of samples in simulation. On the whole, the test and simulation results agree well in our investigation.

The bi-directional holographic interferometry is used to investigate unsteady flow fields. We add a vertical optical path to the conventional holographic interferometry, so two holograms are recorded in one run. The holograms or thephotographs reproduced by white light are qualified to reconstruct the three-dimensional flow field, and also provide more verification to help the improvementof CFI method.

From the comparison of the sequence of holograms by test and CFI simulation, the normal shock wave, vortex and reflected wave are mostly the same, despite some details vary.

Bi-directional holographic interferometry is a foundational method to investigate non-steady flow fields in three dimensions. To reconstruct 3D flows, at least six optical paths should be placed around the flow. So the shock tube has to be s,assembled vertically to place models and components of all the six optical paths. Besides, how to analyze multi-directional holograms and reconstruct three-dimensional flow fields accurately is still in our study.

References

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