A new non-contact optical method for wall skin friction measurement was proposed by researchers from Beihang University

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Summary How to get accurate measurement of the wall skin friction caused by the bounded flow is always a critical and practical problem for aerodynamicists. In 2014, 57(7) issue of Science China Physics Mechanics & Astronomy, a paper entitled “Accurate measurement of wall skin friction by single-pixel ensemble correlation” proposed a new non-contact optical method which extends the traditional Particle Image Velocimetry to the field of friction measurement. It has been proved that this technique enhances the skin friction measurement accuracy to about one order, thus provide a promising tool for aerodynamicists.

The skin friction caused by fluids flowing over a steady wall contributes a lot to the total drag on that wall, so that it directly determines the aerodynamic performance of high-speed vehicles. Most of flow control techniques aiming at drag reduction will take the strategy of reducing the skin friction. However, the accurate determination of surface skin friction is still a big challenge for fluid mechanics community. Dr. Pan Chong and his group from Fluid Mechanics Key Laboratory of Ministry of Education, Institute of Fluid Mechanics, Beihang University set out to tackle this problem via non-contact optical method. Their work, entitled “Accurate measurement of wall skin friction by single-pixel ensemble correlation”, was published in SCIENCE CHINA Physics, Mechanics & Astronomy. 2014, Vol 57(7).

Theoretically, the wall skin friction can be calculated by the velocity gradient very close to the wall. But traditional hot wire velocity measurement technique lacks credibility and stability when used in the vicinity of the wall. While the non-contact Particle Image Velocimetry (PIV) are limited by their spatial resolution due to the adopted window correlation algorithm. Therefore, the problem becomes how to enhance both the spatial resolution and the accuracy of the near-wall velocity measurement if optical method is used. In their recent work, the researchers used a new method of single pixel ensemble correlation to replace the traditional window correlation in PIV. It was shown that this method can resolve the velocity profile at the level of single pixel of the image CCD. Based on this findings, the researchers developed a new non-contact optical method to measurement the wall skin friction.

To estimate the accuracy of the proposed technique, synthetic method (see Fig.1) was used to examine the effect of the potential parameters onto the measurement uncertainty. It was shown that among all the possible factors, the effective particle number is the dominant one which critically determines the accuracy behavior. The straight optimizing strategy is to increase the effective particle number as large as possible. And the recommended particle diameter on the image CCD plane is 3~4 pixels. After comparing with traditional PIV-based method, the
researchers concluded that the single-pixel-ensemble-correlation method reduces the error of the skin friction measurement to about one order (see Fig.2). And its advantages also lies in the fact that a quick global flow-field diagnose can be implemented because of the field measurement feature, this is attracting to engineers since the skin friction distribution along a model surface can be simultaneously obtained in one measurement.

Figure 1 One snapshot of synthetic particle image in a steady near-wall flow field

Figure 2 Dependence of ensemble size $N_f$ on the relative error of wall skin friction coefficient $|e_{c_f}|$ in both the single-pixel ensemble correlation (SPEC) case and the window correlation (WC) case