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Backward-Facing Step Measurements at Different Reynolds Numbers Using Acoustic Doppler Velocimetry

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Abstract : The flow over a backward-facing step is characterized by the presence of flow separation, recirculation and reattachment, for a simple geometry. This type of fluid behaviour takes place in many practical engineering applications, hence the reason for being investigated. Historically, fluid flows over a backward-facing step have been examined in many experiments using a variety of measuring techniques such as laser Doppler velocimetry (LDV), hot-wire anemometry, particle image velocimetry or hot-film sensors. However, some of these techniques cannot conveniently be used in separated flows or are too complicated and expensive. In this work, the applicability of the acoustic Doppler velocimetry (ADV) technique is investigated to such type of flows, at various Reynolds numbers corresponding to different flow regimes. The use of this measuring technique in separated flows is very difficult to find in literature. Besides, most of the situations where the Reynolds number effect is evaluated in separated flows are in numerical modelling. The ADV technique has the advantage in providing nearly non-invasive measurements, which is important in resolving turbulence. The ADV Nortek Vectrino+ was used to characterize the flow, in a recirculating laboratory flume, at various Reynolds Numbers (Reh = 3738, 5452, 7908 and 17388) based on the step height (h), in order to capture different flow regimes, and the results compared to those obtained using other measuring techniques. To compare results with other researchers, the step height, expansion ratio and the positions upstream and downstream the step were reproduced. The post-processing of the AVD records was performed using a customized numerical code, which implements several filtering techniques. Subsequently, the Vectrino noise level was evaluated by computing the power spectral density for the stream-wise horizontal velocity component. The normalized mean stream-wise velocity profiles, skin-friction coefficients and reattachment lengths were obtained for each Reh. Turbulent kinetic energy, Reynolds shear stresses and normal Reynolds stresses were determined for Reh = 7908. An uncertainty analysis was carried out, for the measured variables, using the moving block bootstrap technique. Low noise levels were obtained after implementing the post-processing techniques, showing their effectiveness. Besides, the errors obtained in the uncertainty analysis were relatively low, in general. For Reh = 7908, the normalized mean stream-wise velocity and turbulence profiles were compared directly with those acquired by other researchers using the LDV technique and a good agreement was found. The ADV technique proved to be able to characterize the flow properly over a backward-facing step, although additional caution should be taken for measurements very close to the bottom. The ADV measurements showed reliable results regarding: a) the stream-wise velocity profiles; b) the turbulent shear stress; c) the reattachment length; d) the identification of the transition from transitional to turbulent flows. Despite being a relatively inexpensive technique, acoustic Doppler velocimetry can be used with confidence in separated flows and thus very useful for numerical model validation. However, it is very important to perform adequate post-processing of the acquired data, to obtain low noise levels, thus decreasing the uncertainty.

Keywords : ADV, experimental data, multiple Reynolds number, post-processing
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