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Letter to the Editors

Pressure measurements in a three-dimensional separated diffuser

Erica M. Cherry *, Christopher J. Elkins, John K. Eaton

Department of Mechanical Engineering, Stanford University, P.O. Box 17005, 94309 Stanford, CA, United States

Our previous measurements (Cherry, Elkins, and Eaton, 2008; henceforth CEE) on the velocity field in a three-dimensional diffuser are being widely used for CFD model validation (Cherry et al., 2008). The authors have received numerous requests for pressure data from these diffusers. In this paper, we present static pressure measurements for Diffuser 1 described by CEE.

Measurements were taken in the identical apparatus described in CEE except the working fluid was air. Compressed air from the lab supply passed through a Meriam (50-H10-4T) laminar flow element mass flow meter into the apparatus inlet and was exhausted to the atmosphere through the 2.54 cm diameter tube at the test section exit. Measurements were taken at a Reynolds number of 10,000 (based on the bulk inlet velocity and the inlet channel height) to match the Reynolds number of previous velocity measurements. Additional data were acquired at Reynolds numbers 20,000, and 30,000.

Thirty-four 0.5 mm diameter static pressure taps were installed in a row along the flat wall of the diffuser opposite of the wall sloped at 11.3° relative to the horizontal. The line of pressure taps was parallel to the flat side wall of the diffuser and intersected the diffuser's spanwise midpoint at the inlet. The reference pressure was defined as the pressure at $x = 0$ in the CEE coordinate system and was on the bottom wall of the rectangular channel inlet.

Pressure difference relative to the reference pressure was measured using a Setra Model 264 differential pressure transducer, calibrated using a slant tube manometer and connected to a 12 bit A-to-D converter in the lab computer. The pressure at each tap was averaged over 6000 samples acquired at 100 Hz after allowing the transducer output to settle for 2 min. Mass flow rate was measured using a second pressure transducer prior to each static pressure measurement.

Fig. 1 shows C_p, the dimensionless pressure recovery coefficient, plotted against the dimensionless axial coordinate. $C_p = \frac{P - P_{ref}}{\frac{1}{2}\rho u_{bulk}^2}$, where P_{ref} is the reference pressure, ρ is the air density, and u_{bulk} is the bulk velocity at the inlet of the diffuser. The data show a rapid rise in C_p near the inlet of the diffuser followed by a gradual reduction in the pressure gradient until the trend becomes nearly linear around $x/L = 0.7$. At this point, the reverse flow region has spread almost uniformly across the top expanding wall of diffuser. Reverse flow makes up 18.5% of the total flow area according to CEE. The pressure data also contain an inflection point around

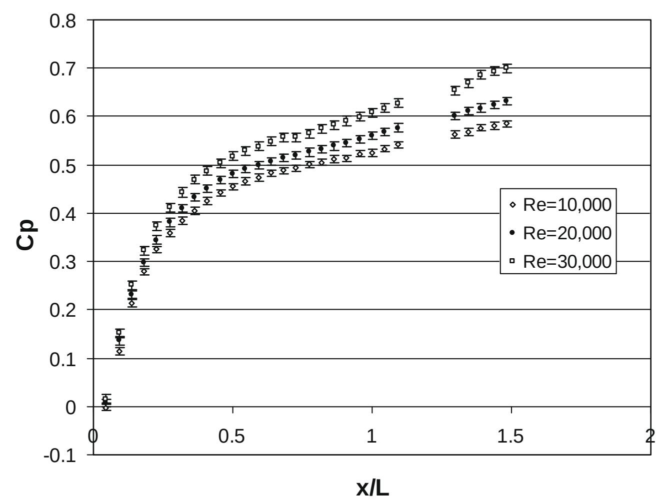

Fig. 1. Pressure recovery coefficients relative to the pressure on the bottom wall of the diffuser inlet. L = 15 cm, the length of Diffuser 1.

$x/L = 0.8$. Here, reverse flow occupies 18.7% of the total flow area. The pressure curve suffers no discontinuity or change of slope at $x/L = 0.53$, the position where the separation bubble leaps across the top expanding wall of Diffuser 1 as described in CEE.

The general shape of the pressure curve can be explained in terms of the blocked flow area. Near the inlet of the diffuser ($x/L < 0.2$), the flow area expands rapidly and the separation bubble is small, resulting in a large expansion of the potential flow area and a large pressure gradient. Farther downstream ($0.2 < x/L < 1$), the separation region grows rapidly and somewhat counteracts the growing cross-sectional area of the diffuser by reducing the area available for forward flow. This results in a more gentle pressure gradient. Downstream of the diffuser outlet ($x/L > 1$), the flow reattaches, increasing the forward flow area and recovering additional pressure. The dimensionless pressure recovery increases monotonically with Reynolds number but C_p curves obtained at different Reynolds numbers are similar in shape. This is consistent with the results of previous studies on pressure recovery in separated flows at varying Reynolds number (Song and Eaton, 2004; Sovran and Klomp, 1967).

The pressure data presented in this letter are publicly available and can be obtained by contacting the authors.

* Corresponding author. Tel.: +1 650 248 8248.
E-mail address: echerry@stanford.edu (E.M. Cherry).

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