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Pressure Measurements of the Flow over a Rearview Side Mirror

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Abstract: The flow fields over a rearview side mirror were examined experimentally in a wind tunnel. Velocity and pressure measurements were carried out by a constant-temperature hot wire anemometer and a micro-manometer, respectively. The Reynolds number based on the free stream velocity of the air and the width of the mirror was varied from $9.5x10^4$ to $1.3x10^5$. The results showed that the static pressures are showed different distribution over the rearview side mirror and took smaller values at the separation points of the boundary layer from the mirror surface.

Index Terms: Side mirror, pressure coefficient, wind tunnel, flow separation

I. INTRODUCTION

The fluctuating pressures over the vehicle rearview side mirror cause are the primary source of aerodynamic noise and vibration as strong flow separation occurs here due to complex geometry. Aerodynamic noise and vibration adversely affects occupant's comfort, vision and safety. Therefore, there have been several previous investigations on the side mirrors such as, Su and Yu [1] applied a parallel large eddy simulation with unstructured meshes to turbulent flow around car side mirror. Li and Yang [2] studied on the transient flow over generic rear view mirror with different turbulent models, Reynolds numbers and model yawing angles. Pressure measurements on an automobile side rear view mirror were carried out by Jaitlee et al. [3]. Wang et al. [4] investigated the aerodynamic noise radiation from a side view mirror in the high-speed airflow which was calculated by the combination of unsteady incompressible fluid flow analysis and acoustic analysis. The flow and aerodynamic noise of a generic side mirror in high-speed was evaluated using numerical simulation and experiment by Xiaohui et al. [5]. Ask and Davidson [6] carried out a numerical investigation of the flow past a generic side mirror and its impact on sound generation. Surface flow and wake structure of a rear view mirror of the passenger car was investigated by Kim et al. [7]. Yu and Liu [8] performed a numerical analysis on the relationship between aerodynamic drag coefficient and 3D molding of rear view mirror. Measurements of Aeroacoustic noise and pressure fluctuation generated by a door mirror model placed on a flat plate were carried out by Kato et al. [9].

The primarily objectives of this paper is to investigate the aerodynamic pressures on the mirror surface vary with local geometry and free stream velocity. The experiments were carried out at the free stream velocity (U) of 30 and 40 m/s.

II. EXPERIMENTAL PROCEDURE AND EQUIPMENT

Experiments were performed in an open-type wind tunnel that was designed and contracted in the laboratories of the Department of Mechanical Engineering of the Uludag University. Maximum flow speed was 40 m/s, and under uniform flow conditions, the longitudinal free stream turbulence intensity was less than 0.9%. A 22kW centrifugal blower is located at the upstream followed by a diffuser a header containing a honeycomb and five screens, and then a nozzle, as shown in Fig. 1. The nozzle leads to the test section, which is a rectangular duct 2 m long, 0.7 m wide and 0.3 m height. The side surface of the test section was made of plexiglass to provide full visibility of the flow area.

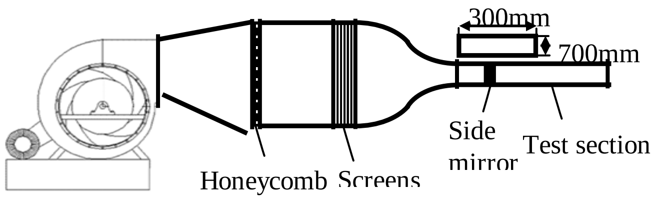

Fig. 1. Wind tunnel and test section

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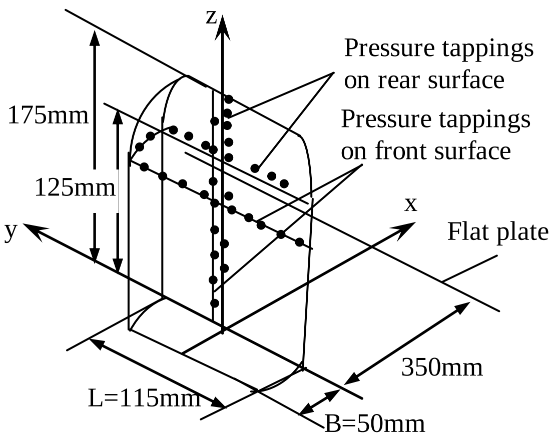
DANTEC digital constant temperature anemometer along with model 55P11 probes and a calibration device were used for velocity measurements. The calibration device, in that the flow was generated by a compressor, was used to correct and rapid experiment results. All measurement was obtained at a sampling frequency of 2500 Hz and low-pass filter frequency of 1250 Hz. The static pressures of the flow surface were recorded by a micro-manometer.

The side mirror with pressure tappings of 0.5 mm diameter was placed 1000 mm downstream of the nozzle exit on a flat plate.

(a) Experimental set up of the side m irror



(b) The mirror dimensions and pressure tappings

Fig. 2. Experimental set up of the side mirror and pressure tappings.

Fig. 2 shows the dimensions of the mirror and the locations of the tappings. The mean static pressure measurements of the front surface of the mirror were performed at 13 equally interval location in spanwise and pitchwise directions, while the measurements of the rear surface were carried out at 7 point in the spanwise y-locations and pithwise z-locations. The length (L), height (H) and width (B) of the mirror was 115, 175 and 50 mm.

Pressure coefficient which is used to represent static pressure measurements is derived by $C_P=(P-P_0)/0.5\rho U^2$, where

P: static pressure measured at pressure tappings

U: free stream velocity

P_0: static pressure of free stream.

The overall uncertainty in the Reynolds number and pressure coefficient was estimated to be nearly ±2.3% and ±4.8% respectively, using the Kline and McClintock [10] uncertainty estimation method.

III. RESULTS AND DISCUSSION

Free stream velocity was set to 30 and 40 m/s, resulting, respectively, in a Reynolds number, Re, of $9.5x10^4$ and $1.3x10^5$ based on width B of the mirror.

Fig. 3 shows the static pressure distributions in spanwise direction on the front surface of the side mirror at Re of $9.5x10^4$ and $1.3x10^5$ which were carried out at z/B=2.5. The maximum values of C_p were obtained at y/B=0 as nearly 0.95. The pressure coefficients took minimum values at nearly y/B=0.8 because of the boundary layer separation on the mirror. The static pressure showed a symmetric distribution around y/B=0, similar to Wang et al. [4] findings. The distributions of mean pressure coefficient at both Reynolds number are basically the same, except smaller values were found at higher Reynolds number.

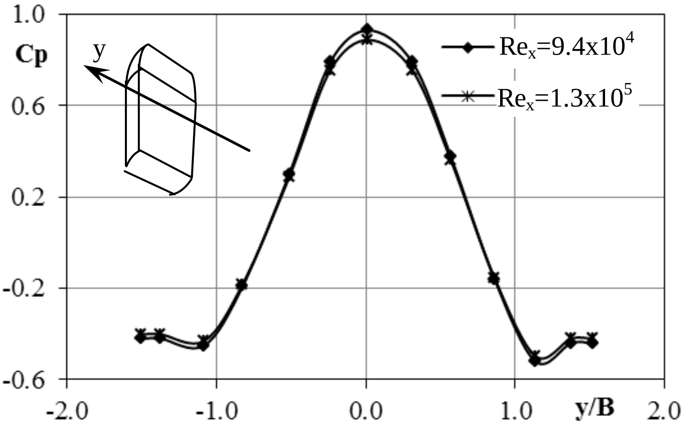


Fig. 3. Static pressure coefficients in spanwise direction with y/B on the front surface of the mirror.

The pressure coefficients in pitchwise direction on the front surface of the side mirror at Re of 9.5x10^4 and 1.3x10^5 is presented in Fig. 4. The mean pressure coefficient curves showed similar trends. The C_p values decreased in the pitch wise direction and smaller values were found at higher Reynolds number, similar to Kim et al. [7].

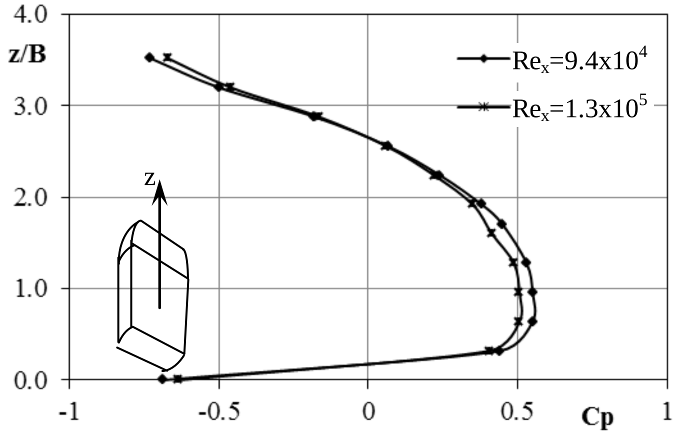


Fig. 4. Static pressure coefficients in pitchwise direction with z/B on the front surface of the mirror.

The distributions of the mean static coefficients at rear surface of the mirror at z/B=2.5 for different Reynolds number were given in Fig. 5. The C_p values with y/B were found as around -0.45 and showed same trends at all Reynolds number, like Li and Yang results [2].

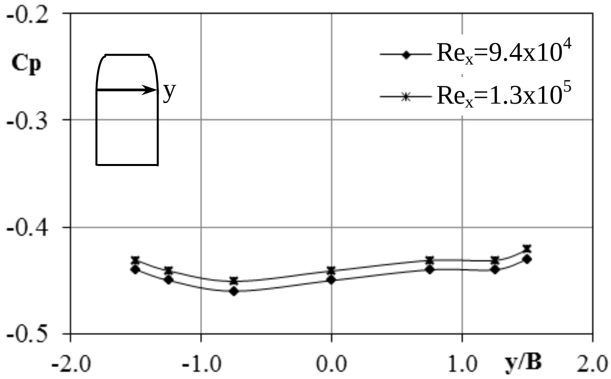


Fig. 5. Static pressure coefficients in spanwise direction with y/B on rear surface of the mirror.

Fig. 6 presents the static pressures at the rear surface of the mirror along vertical line for Reynolds number of 9.5x10^4 and 1.3x10^5. The curves of C_p were almost identical for both Reynolds numbers. The weak peak of C_p were obtained at nearly z/B=1.4 where the rear stagnation point, like Li and Yang results [2].

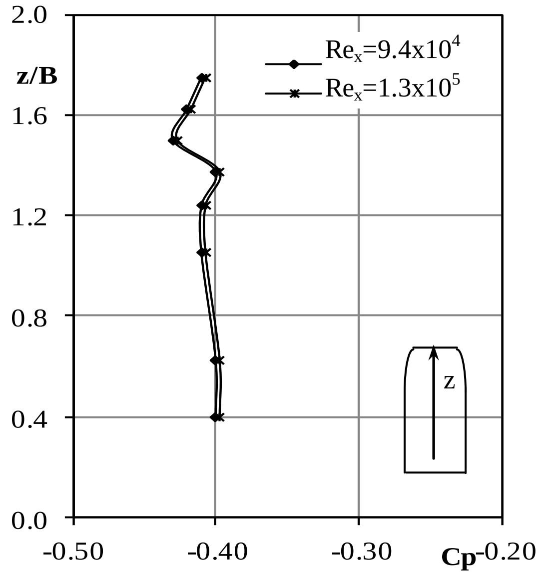


Fig. 6. Static pressure coffecients in pitchwise direction with z/B on rear surface of the mirror.

IV. CONCLUSION

The following conclusions have been drawn from the work presented here:

- The static pressures are not uniformly distributed over the rearview side mirror.
- The pressure coefficients took minimum values at the separation points of the boundary layer from the mirror surface.
- The static pressures of the front surface of the side mirror took smaller values at higher Reynolds number.
- The highest pressure coefficient of the side mirror was found at the central bottom section of the mirror surface.
- There are no significant effects of Reynolds number on surface mean pressure coefficients at the rear surface of the mirror.

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