# LOCAL FRICTION COEFFICIENT VARYING IN TIME IN THE BOUNDARY LAYER INDUCED BY WAKES

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Summary: The measurements of the boundary layer on the flat plate induced by wakes were made at the subsonic wind tunnel. The phase averaging of the velocity signal was accomplished in one period of time T of the oncoming disturbing wake generated by the single rode in the up and down motion situated upstream to the plate. The local friction coefficient $C_f$ in the period time T was determined using the phase averaged velocity profile across the boundary layer. The measurements were made for different angle of incidence of the plate.

1. **Introduction** The interaction of wakes and boundary layer is the rather complex phenomenon often encountered in the different energy equipment and especially in turbomachinery [1]. The aim of the investigation presented in this paper is to determine the phase averaged characteristics of the boundary like $\delta$, $\delta^*$ , $\delta^{**}$, H and $C_f$ on a plate as a function of one period of the disturbance $\tau$ i.e. oncoming wake generated by a rode moved up and down. The measurements of time averaged characteristics of boundary layer induced by wakes were presented in [2].
Also the velocity distribution in different time of the period was measured. The results of the measurement can be used for validation of numerical codes simulating the flow around the blades in turbomachinery.

2. **Experimental rig** The investigation was carried out in the subsonic wind-tunnel of small turbulence level at the Institute of Fluid-Flow Machinery in Gdańsk. The flow with wakes is generated by means of single rod in up and down motion of 4 Hz. The flat plate of dimensions: 0.7 m long, 0.6 m wide and 0.012 m thick was used for the cold boundary layer investigations. The measurements were carried out for the oncoming velocity $U_o$=15 m/s and for different angle of inclination of the plate $\alpha$ = 0 to 2.5°. The velocity fluctuations across boundary layer are measured by means of the single hot-wire probe. The special electronic device was used to accomplish the phase (group) averaging of the velocity signal in the boundary layer.
First the measurement of the boundary layer without outside flow disturbances were carried out. Next the measurement of boundary with oncoming wakes were made.

3. **Results of measurements** The local shear coefficient $C_f$ was find out by means of the velocity gradient in the boundary layer after the phase averaged velocity was determined. Fig.1 shows the $C_f$ coefficient for the $U_o$=15 m/s at x=165 mm and for three different Re= (1.68, 368 and 6.57)$\cdot 10^5$. In Fig. 2 the $C_f$ as the function of Re and the disturbances period $\tau$ is shown. As expected, the decreasing tendency of the $C_f$ coefficent versus Re is clearly shown. In the region of wakes the increase of the $C_f$ of about 75% is also shown. Furthermore the time shift of the wake can be observed in the Fig.1. In Fig. 2 the time variation of the $C_f$ is seen as the double loop, each connected with the first and second wake, appropriately.

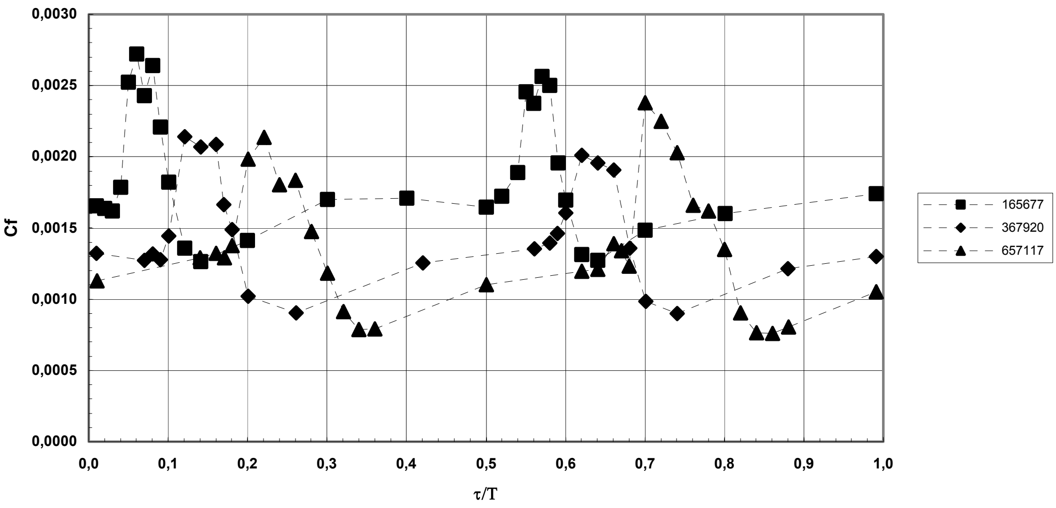


Fig. 1 Variation of $C_f$ in period time $\tau$ for three different Reynolds numbers for the incidence angle $\alpha = 0.44\,°$

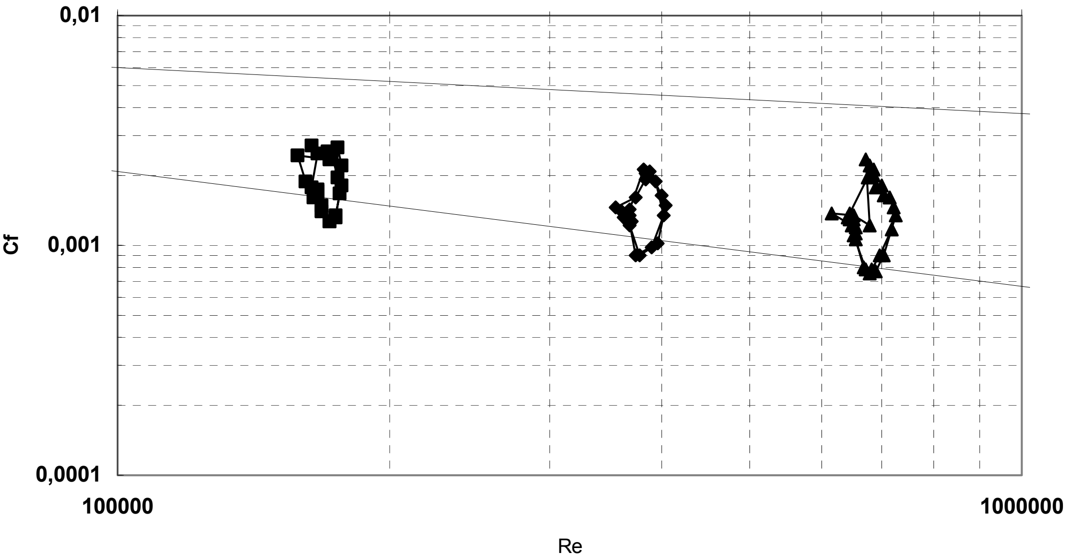


Fig. 2 Variation of $C_f$=f(Re) in period time $\tau$ for three different Reynolds numbers

## 4. Conclusions

The results of the measurements of the $C_f$ coefficient as a function of the time period of disturbance generated by the rode show great changes which lie between the laminar and turbulent lines. The same great changes are also shown for other characteristics of boundary layer induced by wakes. This measurements can be used for validation of the time-averaged calculation of the code based on the Reynolds assumption.

**References:**

[1] Mayle, R.E., 1991, The role of laminar-turbulent transition in gas turbine engines.J. Turbomachinery, Vol. 113, pp.509-537

[2] Wiercinski, Z., 1999, Laminar-turbulent transition in the boundary layer induce by wakes, Bull. IFFM, No.499/1450/99