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BOUNDARY LAYER SEPARATION IN DIFFUSER

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Summary: *Boundary layer separation in diffuser is studied experimentally using time resolved PIV technique. Space and time velocity field correlations are studied in context of mean pressure distribution.*

1. Introduction

Separation of a boundary layer is a very important phenomenon occurring frequently in many practical situations. Classical concept based on mean flow picture fails in explaining basic physical mechanisms involved. More physical dynamical approach is under intensive development (see e.g. Simpson, 1996), but relevant experimental data is still missing.

2. Experimental setup

The existing blow-down wind tunnel was used. One-sided diffuser with angle 15.5 deg. Mean flow velocity in the diffuser inlet was 7.8 m/s, turbulent boundary layer. In Fig. 1 the schema of experimental setup is shown. The coordinate system was defined with the x axis in the input flow direction on the wall and y axis is perpendicular to the wall. Origin of the coordinates is in the beginning of the diffuser, the cross-section here is 100 x 100 mm^2. Downstream of this section, the upper wall is inclined, while the bottom plane wall is used to study the boundary layer separation. To prevent separation from the upper wall, this is permeable and sucked out. The mean flow velocity outside boundary layer at $x = 0$ was 7.8 m/s, the boundary layer was of turbulent nature, about 5 mm thick. The suction velocity along the upper wall could be estimated to 3 m/s. The situation is described in details in Uruba (2008).

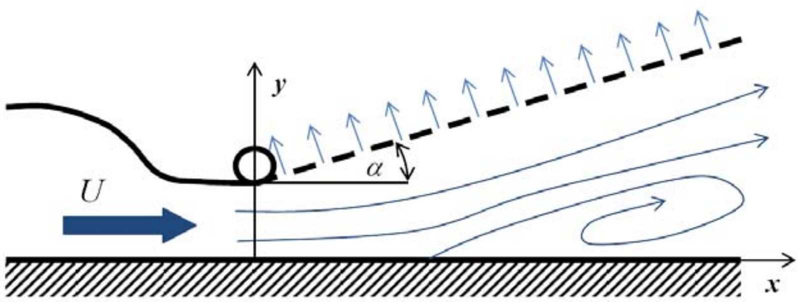

Fig. 1 – Experimental setup

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Standard configuration of time resolved PIV was used, particles were generated using fog SAFEX generator, introduced to the inlet of the blow-down facility.

3. Results

Origin of the coordinate system corresponds to beginning of the diffuser in x direction, $y = 0$ corresponds to the wall. Mean pressure gradient along x-axis is 48,3 Pa/m in region for $x < 400$ mm, then the pressure is influenced by separation, for $x > 500$ mm we get the gradient 2,3 Pa/m only. The situation is shown in Fig. 2, the mean pressure have been measured on the wall, relative to atmospheric pressure on the diffuser outlet.

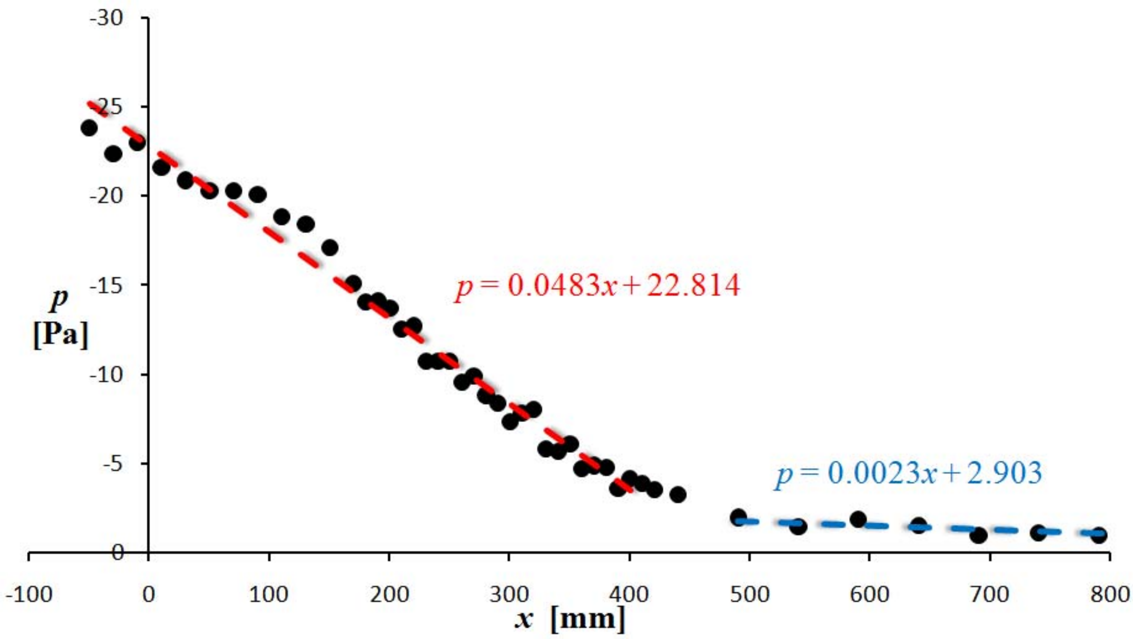

Fig. 2 – Mean pressure distribution along the diffuser

The evaluated regression equations in Fig. 2 suppose position x in [mm].

For steady free-stream separating turbulent boundary layers, a set of quantitative definitions on the detachment state near the wall has been proposed, with the definitions based on the fraction of time that the flow moves downstream, the forward-flow-fraction (*FFF*) coefficient has been defined e.g. in Uruba et al. (2007).

Simpson (1996) defined several points in the separation region. The Incipient Detachment (ID) occurs with instantaneous backflow close to the wall is 1% of the time, that is *FFF* = 0,99; Intermittent Transitory Detachment (ITD) is for *FFF* = 0,80; Transitory Detachment (TD) is for *FFF* = 0,50 and Detachment (D) occurs where the time-averaged wall shearing stress or U velocity component close to the wall is 0. Simpson states that TD and D are at the same location according to available data, in our case it is not fully true. Position x of the above defined points are shown in following table:

point	ID	ITD	TD	D
x [mm]	512	557	610	626

The distributions of mean velocity U component (nondimenzioned by its value in inlet Uin) and FFF is shown in Fig. 3.

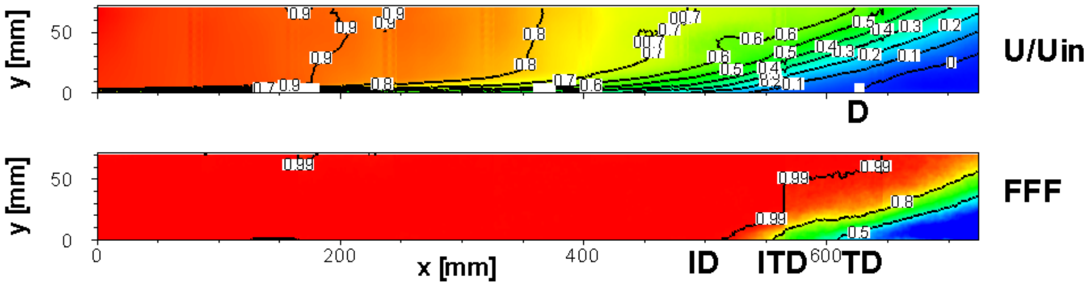

Fig. 3 – Distributions of nondimensional mean longitudinal velocity component and forward-flow-fraction coefficient

In Fig. 3 the flow development overview is shown from the beginning of the diffuser, flow deceleration along x-axis and the boundary layer thickening is obvious. The points are located there, however closer view to separation region would be more instructive – see Fig. 4.

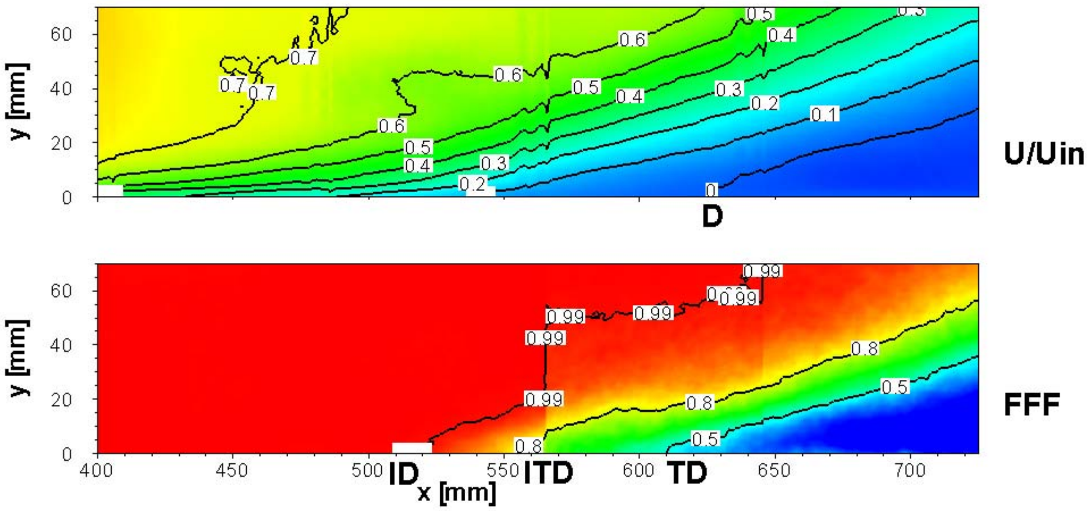

Fig. 4 – Close-up to the separation region, quantities correspond to Fig. 3

From Fig. 3 and 4 the basic information on dynamical behavior of separation process is distinct. The instantaneous position of the separation point indicated by back-flow could range from ID point further downstream. It is clear that the separation activity starts upstream the “detachment point” D. On the other hand it continues downstream the D or TD point, while forward flow could be indicated here.

In this context it could be stated, that the term “separation point” is misleading, term “separation region” is more appropriate.

An interesting question is connection of the pressure distribution with separation process. In Fig. 2 the typical behavior of the mean pressure is shown, consisting of two linear parts. The steeper part for $x < 400$ mm belongs to fully attached boundary layer, while the gradual part for $x > 500$ mm is characterized by any separation activity, between the regions, there is a transitional region. Detailed relation between the pressure and points location is shown in Fig. 5.

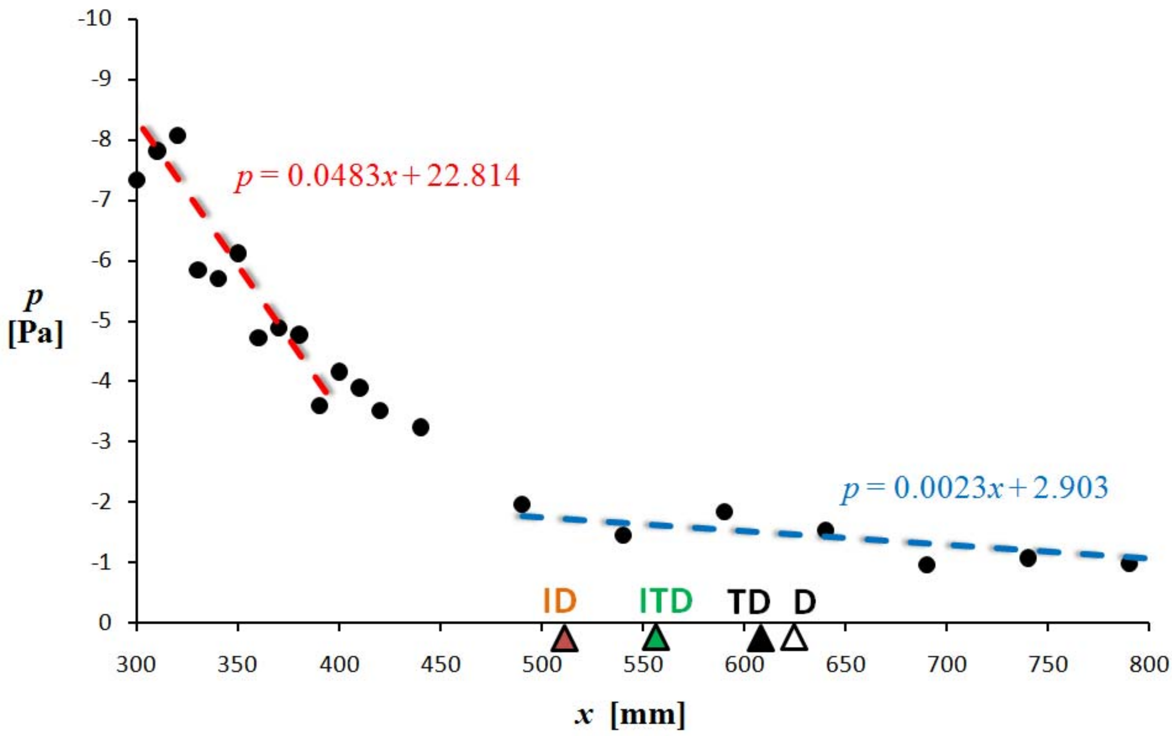

Fig. 5 – Mean pressure distribution in the separation region

4. Conclusion

A boundary layer separation is definitely highly dynamical process, which could not be fully described by classical theories based on time-mean concepts. Separation activity starts in far upstream the "detachment point" D. The new dynamical approach is needed.

5. Acknowledgement

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6. References

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