ON THE SPATIAL DEVELOPMENT OF A WALL JET GENERATED BY DBD ACTUATOR

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Abstract
It will be presented a definition of wall jet created by plasma DBD actuator. Some aspects of this phenomenon will be shown on practical examples gained from experimental PIV measurements.

1) Introduction

A wall jet flow is in the center of interest for many research group because this belongs to the fundamental problem of turbulence due to its character. The inner layer of that wall jet is very similar to the turbulence boundary layer, while the outer layer resembles a free jet [1]. The interaction of large turbulence scales in the outer layer with smaller scales in the inner layer creates a complicated flow field and determines the development of the wall jet. There are many practical application of the wall jet. For example, they can be used as defrosters in automobiles or in aero turbines for cooling of combustion chamber walls and the leading stages. One of the common definition describes the plane wall jet in still air as a shear flow directed along a wall where, by virtue of the initially supplied momentum, at any station, the streamwise velocity over some region within the shear flow exceeds that in the external flow. However, a wall jet generated by DBD actuators has some different features; the main difference is a way, how the initially supplied momentum is excited. In case of plasma discharge actuator, the body force is created due to electric wind (charged ions transfer their momentum to neutral molecules by precipitations). This situation is schematically sketched in Fig. 1.

This article builds on previous work of author [2]. In spite of the fact that a train of vortices appears after low-frequency amplitude modulation (AM) of inlet voltage signal, experimentally obtained results mentioned here will be related only with mean flow field of the wall jet. It will be presented here the velocities development along wall jet as well as the jet thickness. The knowledge of the layer thickness is crucial due to determination of Reynolds number.

2) Experimental setup

It was presented in [2], where detailed information about DBD geometry and its power source can be found.

3) Result

Conventional wall jet Reynolds number is defined as $Re=U_0*b/\nu$ where U_0 is inlet velocity and b is orifice height. But there is no inlet velocity and not at all orifice in DBD geometry. Reynolds number of plasma wall jet is defined so that U_0 represents maximal velocity in velocity profile far from wire electrode and b is height of the jet at the same place. The jet boundary is defined as existence of 50 % max. velocity value. Reynolds numbers alternate in dependency on frequency of AM and duty cycle. For our examined cases of AM - 10Hz_30%, 10Hz_70%, 20Hz_80% and 60Hz_30% - Re numbers are 697, 708, 602 and 808.

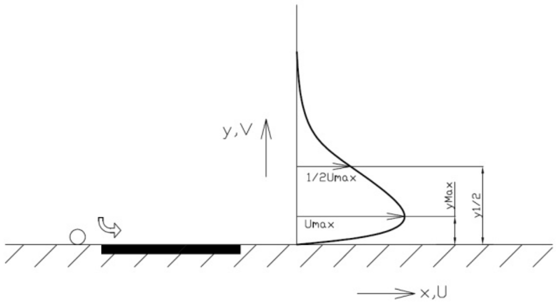

Fig.1. Wall jet generated by plasma DBD actuator

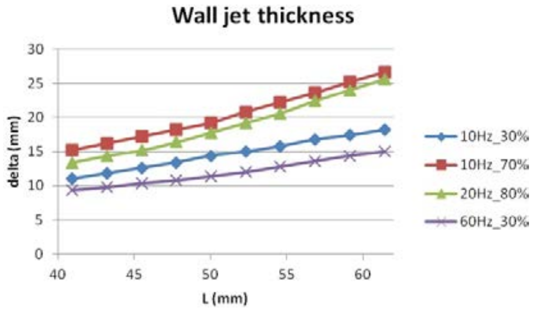

Fig. 2. Spatial development of wall jet

A reason for the acquisition of these values has to be found in dependencies on DC and frequency. Max. velocity of mean flow field is decreasing with duty cycle. DC of 10% generates velocity more than two times bigger than DC of 90%. The velocity is also varying with changing frequency of AM. The most powerful frequencies start on 40Hz and this effect fades by 80Hz when plasma discharge start to be similar to continuously discharge. Unfortunately, the Reynolds number is dependent on both the velocity magnitude and the thickness of the jet, so it cannot be watched just the absolute value of Re, but also increases from individual parameter. However the main goal was to observe a development of mean wall jet in area from appr. 40mm from wire electrode to 60mm. The velocities in velocity profile are decreasing with distance from electrode. The most rapid decrease is concerned with bigger AM frequency. On the other hand, bigger value of DC causes very slowly decrease, because from the beginning the jet is with smaller velocities but with a more thicker shape.

Fig. 2 shows increase of wall jet thickness with distance from electrode. Here it is practically reversely. The cases with big DC (70 and 80%) dispose a more robust wall jet but at a lower velocity. A shape factor for wall jet is often used. This factor is defined as rate of maximal velocity position to position of half-magnitude ($y_{Max}/y_{1/2}$) and for conventional cases takes the value between 0,13 and 0,17. Values of plasma wall jet are from 0,3 to 0,5, which implies that the plasma wall jet is not held tight to surface (unlike normal synthetic jet). This shape factor is quite constant (or oscillates around a distinct value) for all cases except 60Hz_30%. Here it was observe a rapid decrease of 25%, which could indicate that the shape of wall jet is developed later for higher frequencies of AM. Notice that for symmetrical velocity profile, the shape factor is equal to 2/3. An investigation of other configurations will be performed next time.

4) Acknowledgement

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5) References

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