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# ENIGMA OF SUBMERGED FENCE SKIN FRICTION SENSOR

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**Abstract:** *The problem with existing principles of skin friction measurements are the disturbances caused by the components of the sensor protruding above the surface, however small they are. Also the hot film versions were demonstrated to change the character of the flow. Author has eliminated these adverse influences in his original version of the sensor with the fence submerged slightly below the surface. Recent detailed investigations revealed the pressure difference output to be dependent on creation of miniature recirculation regions. An attempt to facilitate the recirculation, quite surprisingly, has led to total disappearance of a useful output signal.*

**Keywords:** ***skin friction, surface shear stress***

## 1. Introduction

All known principles of skin friction measurements have the disadvantage of acting upon and changing the investigated flowfield. In the case of the Coanda-effect attachment to a strongly curved wall even a very small object placed on the surface can cause premature transition into turbulence. Also, the heat from a hot film sensor was demonstrated (Tesař 1998) to be able to separate the curved wall-jet from its attachment wall.

The solution was found in the "split-cylinder" sensor (Tesař 1973, 1974). It resembles the well-known fence method, based on measuring the pressure difference between the front and rear side of an obstacle (fence) protruding from the surface. In the "split-cylinder" case the fence does not protrude but its top is below the surrounding surface — a unique principle causing absolutely no disturbance. It was recently found to be a promising potential component - combined with the high frequency small-scale fluidic oscillators, described by Tesař, 2012 - for microfluidic devices suppressing turbulent drag by blowing away from wall the hairpin vortices.

One of the problems with the submerged fence is lack of understanding of its working mechanism. In some way the sensing has to be associated with the standing vortical structures that form in the entrances of the sensing slits. To get more insight it was decided to perform flowfield computations. In the standard case corresponding to earlier experiments - with the width b = 0.25 mm and 0.05 mm thick fence, positioned vertically with its top edge at h = - 0.05 mm - the computations have revealed as the characteristic feature of the flowfield the two co-rotating, non-communicating vortices – as shown in Fig. 1 by the computed pathlines. The dependence of the generated pressure difference between the output channels A and B on the skin friction is presented in Fig. 2 and shows values that may be reasonably measured by a micromanometer.

In an attempt to produce higher pressure differences, the top of the fence was moved downwards. The idea was to provide more space for the vortical motion and thus perhaps generate more asymmetry between the front and rear sides of the fence. The pathlines in Fig. 3 are indeed in correspondence with these expectations — but brought a total surprise: the pressure difference became constant (in Fig. 4 it is presented by way of pressure coefficient). Thus, instead of the expected improvement, the sensor in this configuration became useless.

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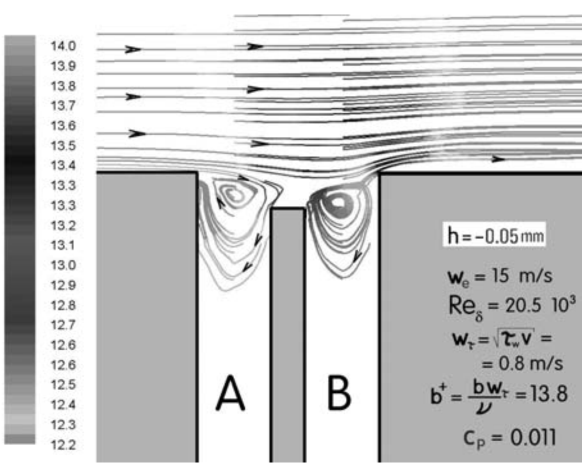


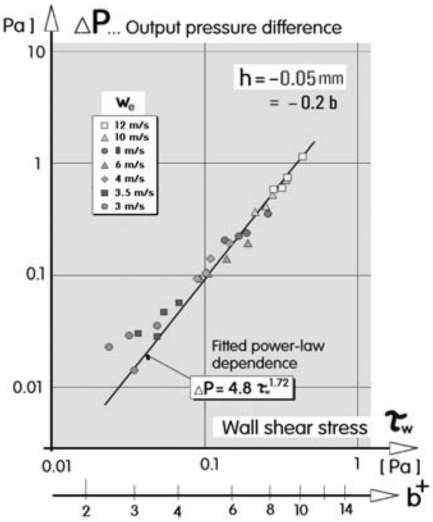
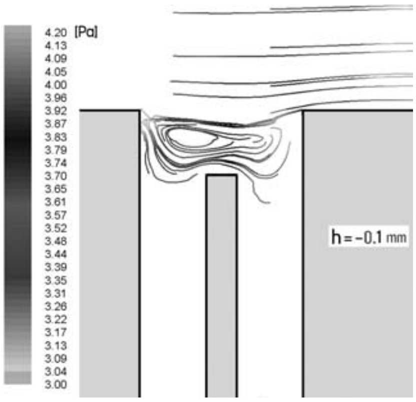




*Fig. 1 (Left) Typically for the configurations generating the reasonable pressure signal, also in the* $h = -0.2\ b$ *case presented here, the computed pathlines show two separate vortices in the sensor entrances.*

*Fig. 2 (Right) Dependence for sensor configuration from Fig. 1 of output pressure difference* $\Delta P$ *on the shear stress* $\tau_w$*. The auxiliary scale below indicates very small magnitude of the sensor entrance width* $b$ *evaluated in the friction co-ordinates. The velocity* $w_e$ *is the boundary condition above the boundary layer.*



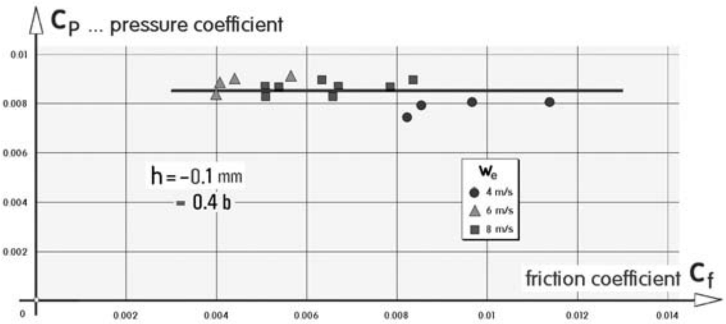




*Fig. 3 (Left) Typical computed pathlines for the fence moved downwards to* $h = -0.4\ b$*. The two vortical motions merge into a single larger vortex.*

*Fig. 4 (Right) Contrary to the expectations, in the configuration from Fig. 3 the output pressure (here presented in terms of pressure coefficient* $c_P$*) is constant irrespective of variations of the wall shear stress (characterised by the friction coefficient).*

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