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Relationship between the riblet features and the turbulent boundary layer structure

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ABSTRACT:
Reducing the drag in wall-bounded flows can be donewith the passive flow control methodduring the function of bio-inspired riblet surfaces. This paperconcentrating on the importantrelationship between the riblet features and the turbulent boundary layer structurecausing from these surfaces in engineering purposes. The current experimental facilities, instrumentation (i.e. hotwire) and measurement techniques (i.e. velocity profile of a turbulent BL) have been utilized to measure the skin friction for two flat plates,one plat with a smooth surface and another with a riblet surface. Theinvestigational wind tunnel testing results show that the riblet surface can offerskin friction surface (C_f) value less than smooth surface.

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NOTATION

u_e: The velocity at the edge of a boundary layer	u_J **:** Friction velocity
u or u_{mean}: Measured velocity	J_w **:** Wall shear stress
C = 5	ρ : Air density
C_f : Skin friction coefficient	**BL:** Boundary layer
V: Kinematic Viscosity	**Y-position:** Distance of the probe from the plat
U+: Non-dimensional velocity from the wall	T_a**:** ambient temperature
y+: Non-dimensional distance from the wall	K: Von Karman Constant = 0.41

OBJECTIVES:
The main objectives of the present experiment are:
1- To obtain a better understanding of the principles of flow measurement using hot wire anemometry.
2- To carry out velocity measurement.
3- Analyse and discuss the results.

I. EXPERIMENTAL SETUP:

The experimental circumstanceinvolved of a flat plate (considered as a smooth surface), a ribleted plate, avertical wind tunnel, the sensing instrumentation, and data acquisition systems. The major goal of these experiments is to find out skinfrictioncoefficient(C_f) for the smooth andribleted surface.

•Wind Tunnel:
The experiment was carried out using the vertical blower wind tunnel, the dimensions of the test section were 150 mm × 50 mm. This tunnel additionally had a filter at inlet to eliminate dust and dirt elementsso thatreduce hot-wire contamination and breakage to be sure that the HWA is save.

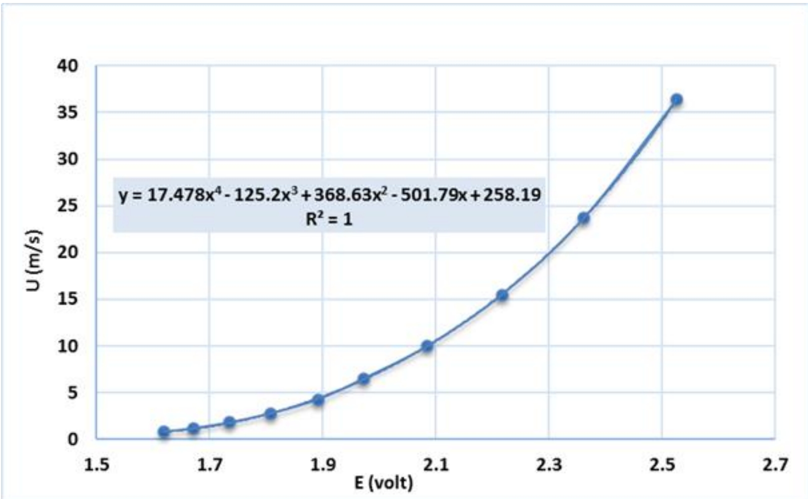
•Aluminium Plates Models:
Two Aluminium flat plates models have been used for the present experiment, one with a smooth surface and another with Serrate-Semi-Circular riblet surface, which is micro-cut directly an aluminium plate. Rough sandpaper has been placed near the nozzle outlet to artificially trip the both plates BL into turbulent.

•Hot Wire Anemometer:
The velocity profiles were measured by using a singlehot wire. The employedtheory is based on the cool down effect of the flow of a heated body. In experiments, the measurements of the streamwise velocity were conducted using a single hot wire with a 5µm tungsten filament heated by an electrical current.

•Hot Wire Calibration and Data Acquisition:
The automatic calibration of the crosswire probe used in the wake measurements was conducted using the StreamLine® calibrator with the StreamWarePro® application software.The supporting software allows for automatic calibration and re-calibrations of probes. Furthermore, all data have been collected using the StreamWarePro® application.

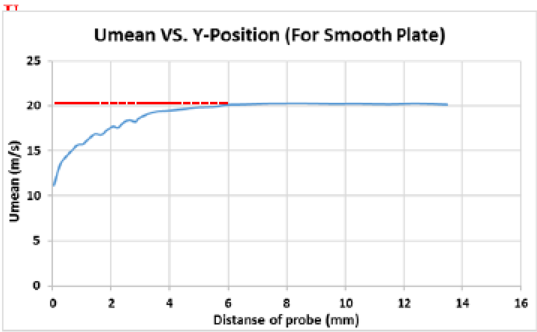
DISCUSSION OF EXPERIMENTAL RESULTS:

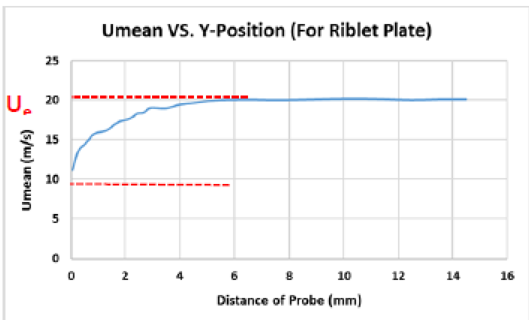
1- Determining the velocity at the edge of a boundary layer (U_e):



Graph (1): shows A typical single wire calibration curve

Atypical single wire calibration curve is swown in graph (1) **,**where this graph is build upon to the given data from the computor softweare during the experiment.This data is important to do the calibrating U_{mean} values for smooth and riblet plates.The calibration has been made by **Polynomail** method with the 4^{th} order ,because the order is usually between 3 or 5.Higher order can be use,but need more computational time.





Graph (2):shows U_{mean} VS. Y-position for smooth plat

Graph(3):shows U_{mean} VS. Y-position for riblet plat

Graph(2)and(3) illustrate the interpolated calibrated values for the measured velocity **U_{mean}** for smooth and riblet plats, also show the velocity at the edge of a boundary layer **U_e**, whereit is clear from the graphs that after certain distance of the probe from the wall of the plat there is no effect of the boundary layer where **U_{mean}** = **U_e**, which in this case there is no effect for the probe movements forward from the both plats.**$U_{e\ Riblet}$= 20.0301 m/s and$U_{e\ Smooth}$= 20.111 m/s**

2- the velocity profile of a turbulent boundary layer &skin friction coefficient (C_f):

For a two dimensional turbulent boundary layer developed with zero pressure gradient, the boundary layer profile in the logarithmic region has been calculated by the law of the wall:

$$\frac{u}{u_J} = \frac{1}{k} Ln\left(\frac{yu_J}{v}\right) + C$$

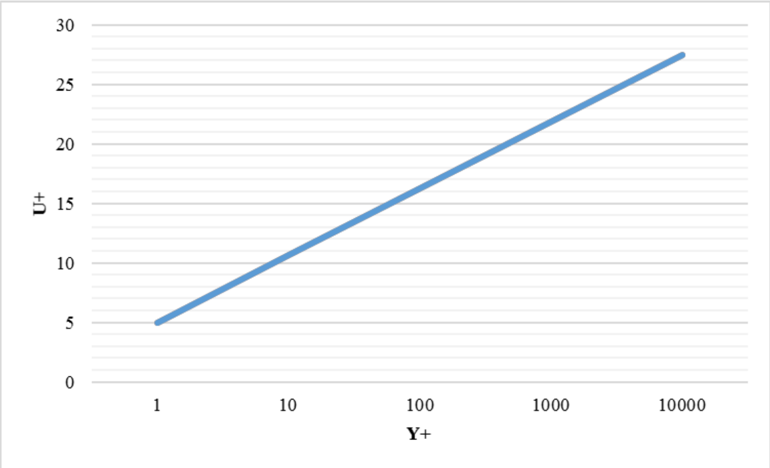
Where the non-dimensional velocity $U^+$and distance $y^+$from the wall are: $U^+ = \frac{u}{u_J}, y^+ = \frac{yu_J}{v},$

the velocity profile has been drawn after assuming (y^+) values as the following:

y^+	1	10	100	1000	10,000
u^+	5	10.616	16.232	21.848	27.464

Sample calculation for determining the velocity profile:$u^+ = \frac{1}{0.41} Ln(1) + 5 = 5$

The experiment has been done under room temperature,and it was **T_a** =20°C
That mean:
ρ = 1.2063 kg/m^3
v = 1.5064 m^2/s



Graph(4): shows the velocity profile of a turbulent boundary layer

Determining C_f for Ribletand smooth Plates:

(Smooth Plate) :at the beginning friction velocity(u_J)has been determined by using the velocity profile and the law of the wall, after many **iterations**the ideal u_J=1.0397 m/s

Then wall shear stress (J_w) has been calculated from this equation$J_w = u_J^2 \rho$

Where J_w= (1.0397^2 * 1.2063) =1.30398 kg/ms^2 or pa, $C_f = \frac{J_w}{0.5\rho u_e^2}$, u_e = 20.111 m/s **(see graph2)**

C_f=0.00534

(Riblet Plate): Same procedure as followed for the smooth plat has been followed to determine $C_f$for the riblet Plate with u_e =20.0301 m/s **(see graph3),** where the skin friction coefficient for the smooth platis C_f = 0.00528830.

II. CONCLUSIONS:

The skin friction coefficient C_f was calculated for smooth and riblet flat plates by using the velocity profile for turbulent boundary layer and the law of the wall, to determine the effect of the riblet technology on skin friction coefficient. The results show that C_f riblet <C_f smooth. It is clear from the drag force law, the direct correlation between the drag force and the skin friction coefficient. As the results of the experiment showed that theC_f riblet <C_f,then surly the riblet surface lead to reduce the drag effect on ribleted body.

Experimental facilities, equipment and measurement procedures have been used in the present experiment. Newly devisedmeasurements of good quality, using hot-wire (single -wire probes), has been employed to measure critically, and then to enhance the experimental precision of, the determination of the surface shear and skin friction. However, there are possible sources of error such as human error, software error, damage in the probe and calibration error.

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