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FLOW SEPARATION CONTROL ON FLAPPED AIRFOIL

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Abstract*- The main subject of this work is the vortex generator control of flow separation on a deflected simple flap of a NACA 63A421 airfoil. The investigation was carried out using experimental and numerical methods. In the first step non-control case was solved by means of numerical simulation to determine the location of flow separation and airfoil boundary layer thickness. Information obtained from the numerical calculations was utilized for vortex generator (VG) design according to Godard, Stanislas , who dealt with vortex generator flow control on a bump and Lin . VGs were then applied to the flapped airfoil and their influence on flow was investigated using tuft filaments visualization technique. This experimental part was carried out in closed circuit wind tunnel of the Khulna university of Engineering & Technology (KUET)). All numerical simulations presented in this paper were calculated using commercial code Fluent.*

Keywords: Template, Double column, Times New Roman, References and Nomenclature (maximum 5 key words)

1. INTRODUCTION

The main subject of this work is the vortex generator control of flow separation on a deflected simple flap of a NACA 63A421 airfoil. The investigation was carried out using experimental and numerical methods. In the first step non-control case was solved by means of numerical simulation to determine the location of flow separation and airfoil boundary layer thickness. Information obtained from the numerical calculations was utilized for vortex generator (VG) design according to Godard, Stanislas [1], who dealt with vortex generator flow control on a bump and Lin [2]. VGs were then applied to the flapped airfoil and their influence on flow was investigated using tuft filaments visualization technique. This experimental part was carried out in open-circuit wind tunnel of the Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh. All numerical simulations presented in this paper were calculated using commercial code Fluent. The whole process is described in the following chapters.

2. VORTEX GENERATOR DESIGN

As it was mentioned above, firstly the numerical simulation of non-controlled case was performed. According to existing model of NACA 63A421 with simple flap, the 3-D geometry with flap deflection 45° at angle of attack $\alpha = 0°$ and subsequently computational structured mesh were created in program Gambit. Steady, three- dimensional, incompressible flow was solved. Turbulence was modeled by two- equation k-ω Shear-Stress Transport (SST) model. Inlet boundary conditions are in *Tab. 1* and correspond to the boundary conditions of the experiment. The symmetric conditions were set on the upper, bottom and both side faces of the computational domain; pressure outlet condition was set at the outlet of the domain. Second order upwind discretization scheme was selected with respect to the mesh used.

Results of the simulation provided information about location of flow separation, which occurred exactly on the flap edge. Location of the separation was a start parameter for vortex generator design. The design parameters of VG are defined in *Tab. 2* and correspond to the best result of [1] and to the data for rectangular vane VG in [2], which were also used for flow control on a bump. Because the position of VGs (ΔX_{VG}) is determined from flow separation location and also from height of vortex generator (h), which depends on boundary layer thickness (δ) and this thickness in turn depends on the position on surface, the iteration method was used to define vortex generator position and height. Consequently other parameters were computed.

Table-1

Free stream velocity v_∞ [m/s]	Turbulence intensity Tu [%]	Length scale L [m]	Reynolds number Re [-]
14.3	0.25	0.005	200 000

Table-2

		VGs	h/δ	ΔX_{VG}/h	e/h	L/h	Δz/h	β [°]
Godard 2006	CtR	Triangular vanes	0.37	57	2	2.5	6	18
Lin 2002	CtR	Rectangular vanes	0.2	10	4	-	9	25

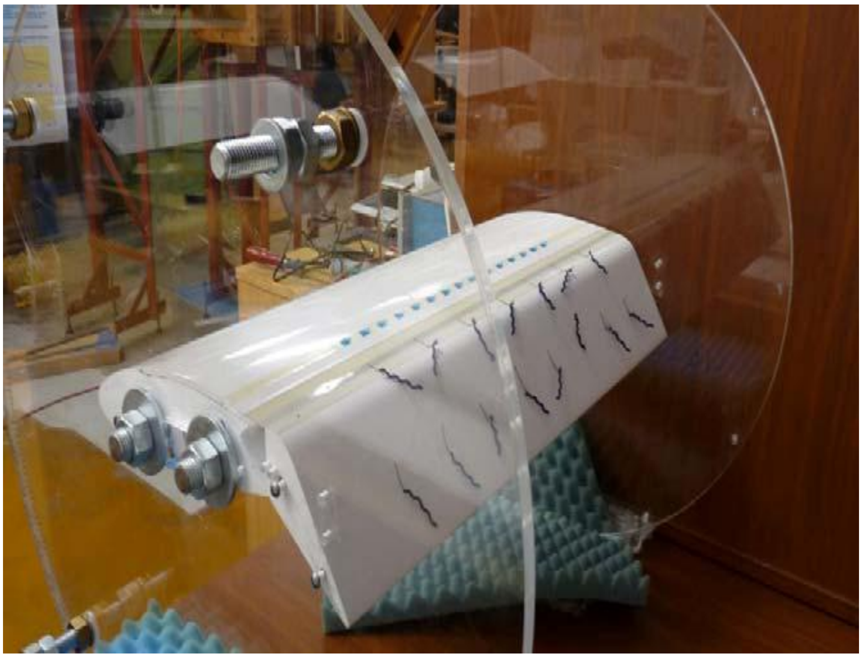

Figure: 1 Position of VGs on NACA 63A421 airfoil

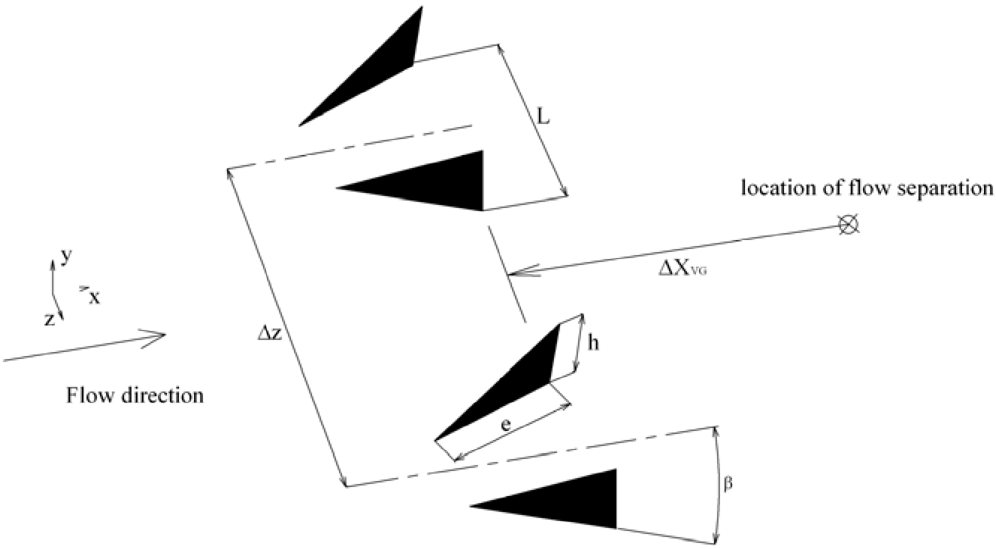

Figure: 2 VGs design and its relative position

3. EXPERIMENTAL PROCEDURE

Triangular and rectangular vane vortex generators were made of plastic sheet and stuck to the airfoil surface in specific locations, as shown on *Fig. 1*. Relative position of vortex generators was set such to produce counter-rotating (CtR) vortices, see *Fig. 2*. The flap was covered by tufts. Due to the length of flap, only two rows were made with specific spacing along tuft length. The distance between tufts in each row depends on tuft length likewise. The measurement was carried out in open-circuit wind tunnel at the same conditions as numerical computation. The investigation was performed for two flap deflections 45°, 20° at angle of attack ranging from -5 to 15 deg. Triangular and rectangular VGs designed according to *Tab. 2* and VGs of the same shape but twice larger were used. All measurements were performed for different spacing between VGs. The digital camera recorded measurement process.

4. RESULTS

The evaluation of pictures and videos shows no effect of any VGs on flow separation for 45 deg flap deflection at all angles of attack. The separation is so strong, that even twice magnified vortex generators do not cause any improvement. Flow separation suppression was achieved in case of 20deg flap deflection at zero angle of attack when twice larger rectangular vane VGs were applied, see *Fig 3, 4*. The spacing among VGs was the smallest possible. The flow separation on airfoil without flap deflection does not appear at any angle of attack, except angle of attack of 15 deg, where the separation starts approximately in the middle of the chord, thus upstream of vortex generators. Notwithstanding the improvement was reached with triangular VGs of twice larger size at the spacing equal to 9, see *Fig. 5, 6*. Generally, results reflect importance of the spacing between vortex generators.

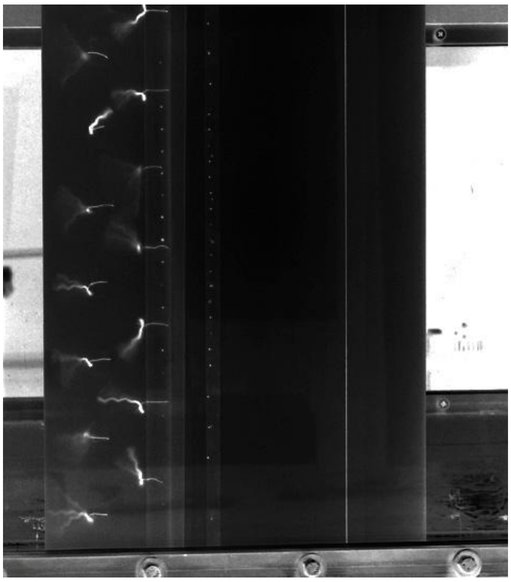

Figure: 3 Non-controlled case, 20^0 deflected flap, $\alpha = 0°$

Different type of flow control is probably necessary to use for reducing or avoiding as strong separation as the one that occurred on 45deg deflected flap. This work is the first step in the research oriented on utilization of vortex generators as a mean of control of flow separation on deflected flap. So the future study should focus on forces, pressure distribution measurement, numerical simulations and its verification especially.

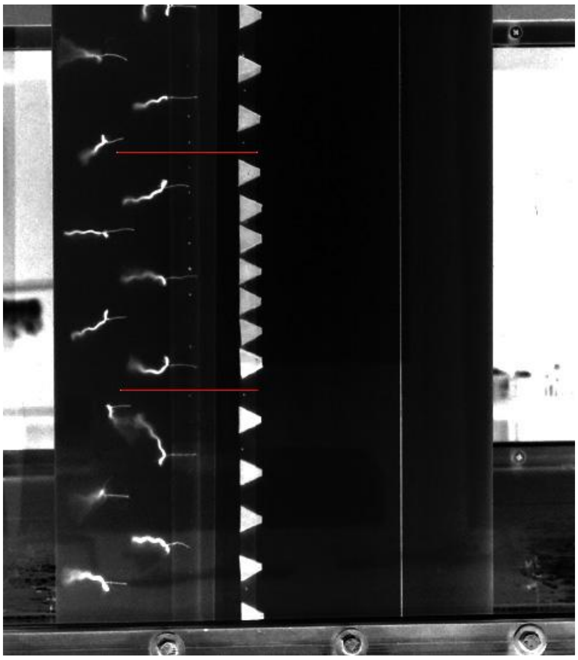

Figure: 4 Rectangular VG (h=3mm, Δz=16mm, red lines area), 20^0 deflected flap, $\alpha = 0°$

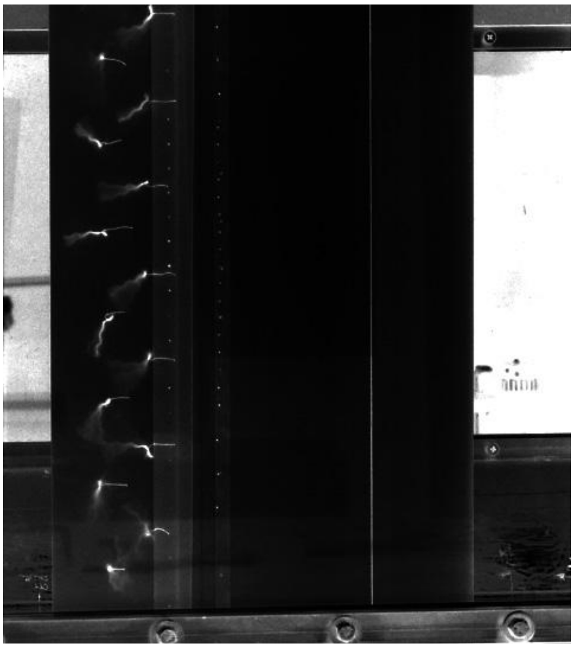

Figure: 5 Non-controlled case, 0deg deflected flap, α =15°

Figure: 6 triangular VG (h=3mm, Δz=9mm) 0^0 deflected flap, α = 15°

5. CONCLUSION

From this investigation it has been observed that the flow separation can be delayed by attaching vortex generator and significant changes of lift to drag ratio which improved the aerodynamic character of wing.

6. REFERENCES

[1] Godard G., Stanislas M.: Control of a decelerating boundary layer. Part 1: Optimization of passive vortex generator, Aerospace *Science and Technology 10, 2006, pp. 181-191*

[2] Lin J.C.: Review of research on low-profile vortex generators to control boundary-layer separation, *Progress in Aerospace Science 38, 2002, pp. 389-420.*