

AERODYNAMIC ANALYSIS OF RAMP TYPE VORTEX GENERATOR ON NACA 2215 AIRFOIL

Nilesh Nahar¹, Manoj Sharma², Amit Kumar Jha³, Rahul Joshi⁴

¹M.Tech student, Design of Mechanical Systems, Department of Mechanical Engineering, Swami Vivekanand College of Engineering, M.P.

²Assistant Professor & HOD, Department of Mechanical Engineering, Swami Vivekanand College of Engineering, M.P.

³Senior Manager, HAL, Bangalore

⁴Associate Professor, Department of Mechanical Engineering, Swami Vivekanand College of Engineering, M.P.

Abstract -

The project is on Aerodynamic Analysis of Ramp Type Vortex Generator on NACA 2215 Airfoil. Our goal is to design and analyze two models namely a ramp type vortex generator on a 3D airfoil (Wing) and normal wing without VG for Reynolds number value 68.47×10^5 . We analyzed it to determine whether VG giving an optimum performance in effectively postponing the wing stall angle. After that, we compared the analytical results accordingly. Designing was done by using Ansys Design modeler. NACA 2215 airfoil were chosen on which the vortex generators have been designed and modeled. The design will then be analyzed (CFD) by using ANSYS R20 software.

Key Words: NACA 2215, ANSYS, Reynolds number, Ramp Type Vortex Generator

1. INTRODUCTION

A vortex generator is an aerodynamic device consisting of a small blade usually attached to a lifting surface or airfoil (such as an aircraft wing) or a wind turbine rotor blade.

The vortex generators are installed quite close to the leading edge of the airfoil to ensure steady airflow over the trailing edge control surfaces to ensure the effectiveness of the trailing edge control surfaces.

1.1 Working of Vortex Generators

Vortex generators create strong tip vortices that bring in high energy air from the outer nozzle to mix with/replace slower moving air in the boundary layer. It reduces the effects of adverse pressure gradients and prevents separation.

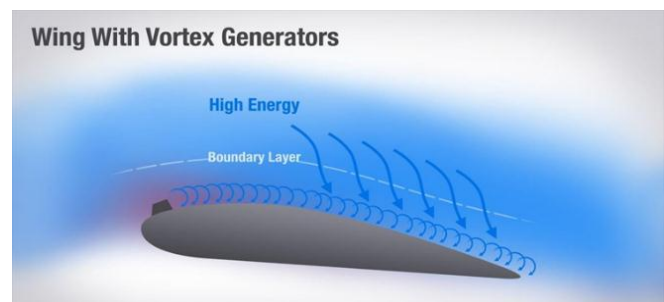


Fig 1.1: Wing with vortex generators

1.2 Boundary Layer Separation on An Airfoil with And Without VG's

All solid objects passing through a fluid acquire a fluid boundary layer around them, where viscous forces arise in the fluid layer near the surface of the solid. Boundary layers can be either laminar or turbulent. A reasonable judgment as to whether the boundary layer will be laminar or turbulent can be made by calculating the Reynolds number of the local flow conditions.

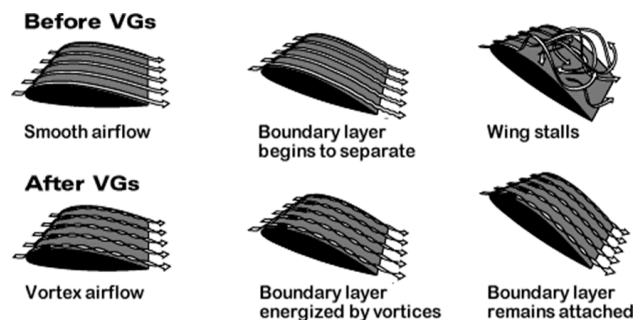


Fig 1.2: Flow before VG and After VG

1.3 Smart Vortex Generators

The VG creates a vortex that, by removing a portion of the slow-moving boundary layer in contact with the airfoil surface, delays local flow separation and aerodynamic stall, thereby improving the efficiency of wings and control

surfaces such as flaps, ailerons, rudders, and elevators. To achieve this, they are often placed on the exterior surfaces of vehicles or load-bearing surfaces. During steady cruise, most vortex generators create drag and must be retractable. Therefore, intelligent vortex generators need to be implemented. The intelligent vortex generator is based on the profile at launch and at low speeds. And they retract when cruising at high speed and altitude. Some concepts for an intelligent vortex generator have already been designed, constructed, and tested.

1.4 Shape Memory Alloys

A shape memory alloy is an alloy that can be deformed when cold but returns to its pre-deformed ("remembered") shape when heated.

SMA's can be used as intelligent vortex generators; they change shapes due to changes in atmospheric temperature at different altitudes.

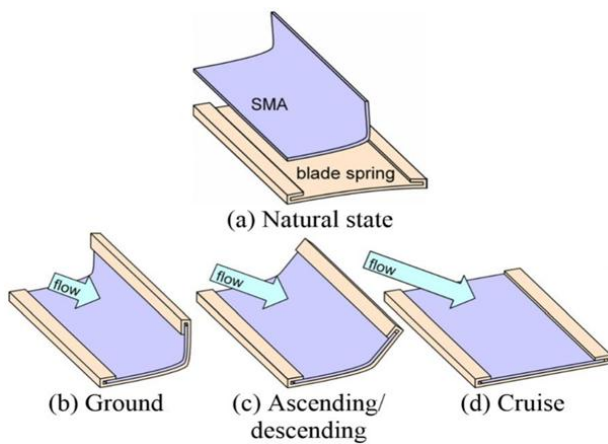


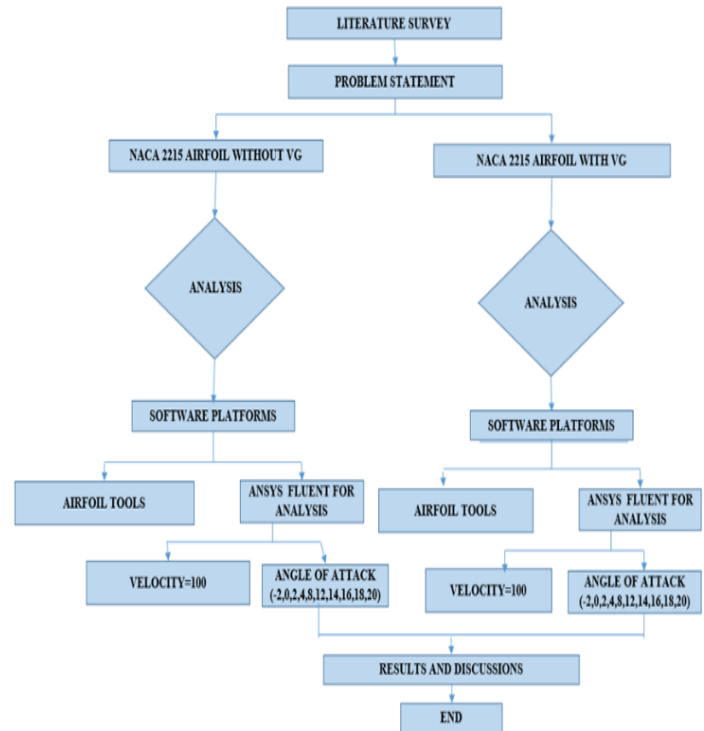
Fig 1.3: Example structure of shape memory alloy

1.5 Pneumatic actuators

Pneumatic actuators are mechanical devices that use compressed air acting on a piston inside a cylinder to move a load along a linear path. Unlike their hydraulic alternatives, the operating fluid in the pneumatic drive is only air, so leaks do not drip and pollute the surrounding spaces.

These pneumatic actuators are used to control vortex generators. Pneumatic actuators can be controlled by an altimeter for height measurement and a speedometer for retracting and extending by measuring height and speed.

2 METHODOLOGIES



3 CFD MODELLING

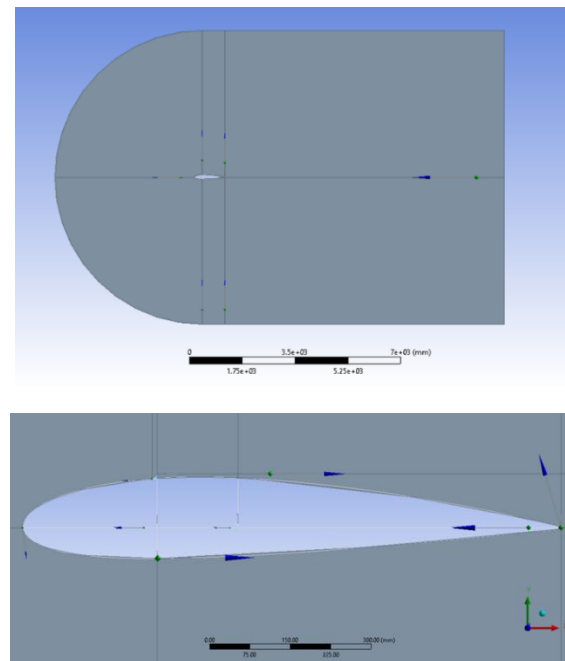


Fig 3.1: Flow Domain

The Airfoil design is imported into Workbench Mesh. The domain is created in geometry using the "draw and create" option. A network is created within a network. The mesh size is varied until the desired Skewness, aspect ratio & orthogonal quality is achieved.

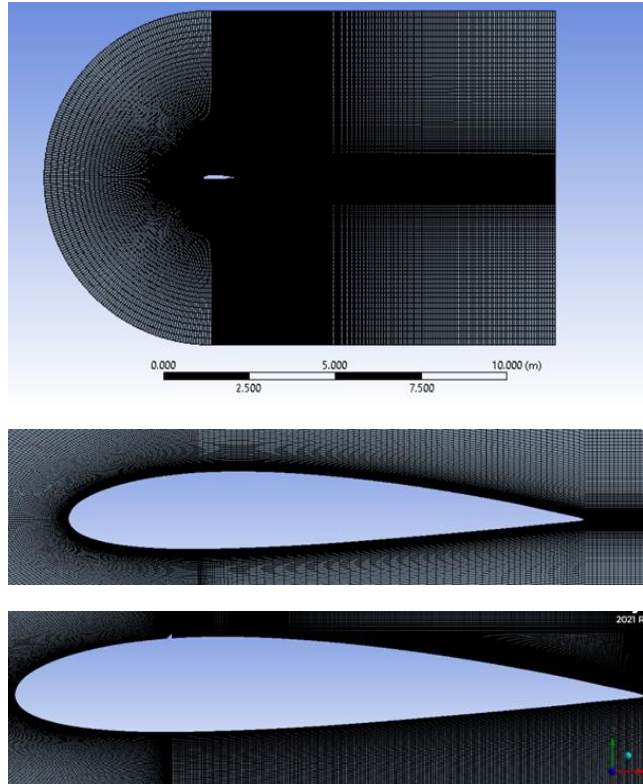


Fig 3.2: Mesh of the flow domain with & without VG

4 RESULTS AND DISCUSSION

This subsection combines the Computational Fluid Dynamic analysis results of a complete analysis of the NACA 2215 airfoil with VG configurations. CFD analysis of the problem, two-dimensional structured mesh with RANS model and S-A turbulence.

The aim of the project is to study the aerodynamics flow behavior around the wing with VG at specified heights of 3 mm and to improve the aerodynamics.

4.1 Pressure Contours of NACA 2215 Airfoil Without VG

Pressure Contours of NACA2215 Airfoil without VG at various AoA shown below

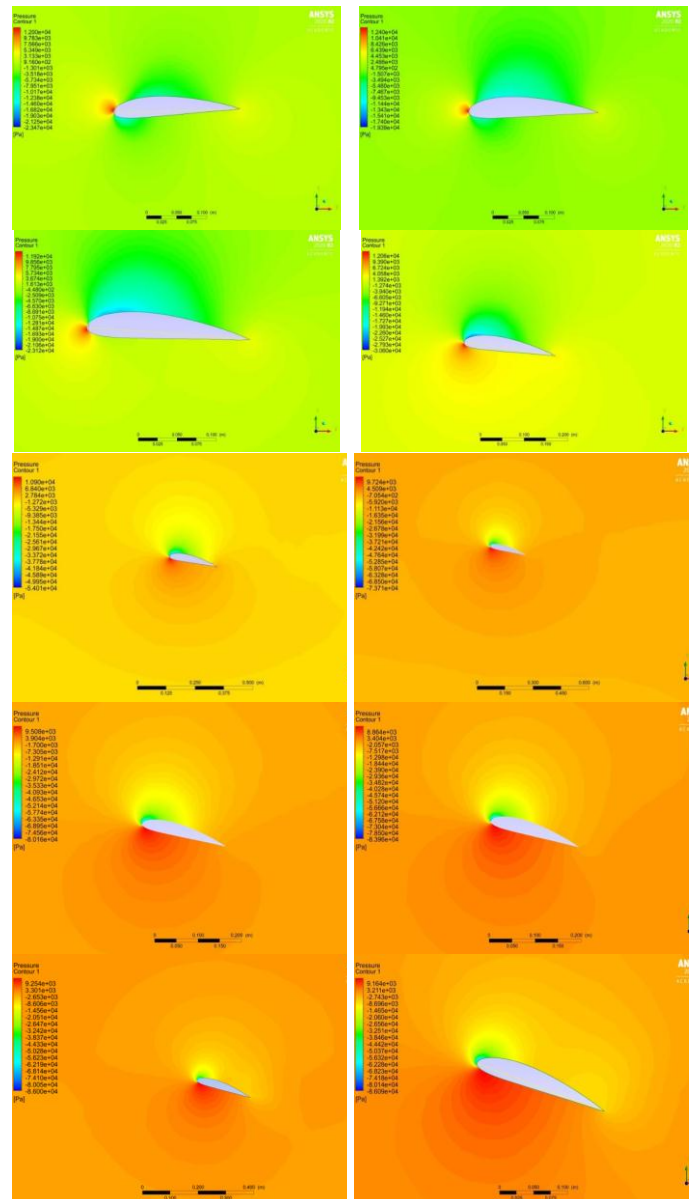
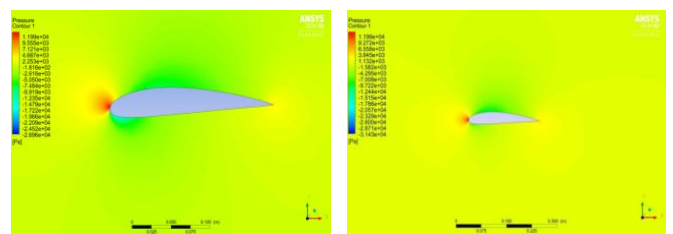


Fig 4.1: Pressure Contours of wing without VG at various angles of attack (-2,0,2,4,8,12,14,16,18,20)

4.2 Pressure Contours of NACA 2215 Airfoil of 3mm VG heights



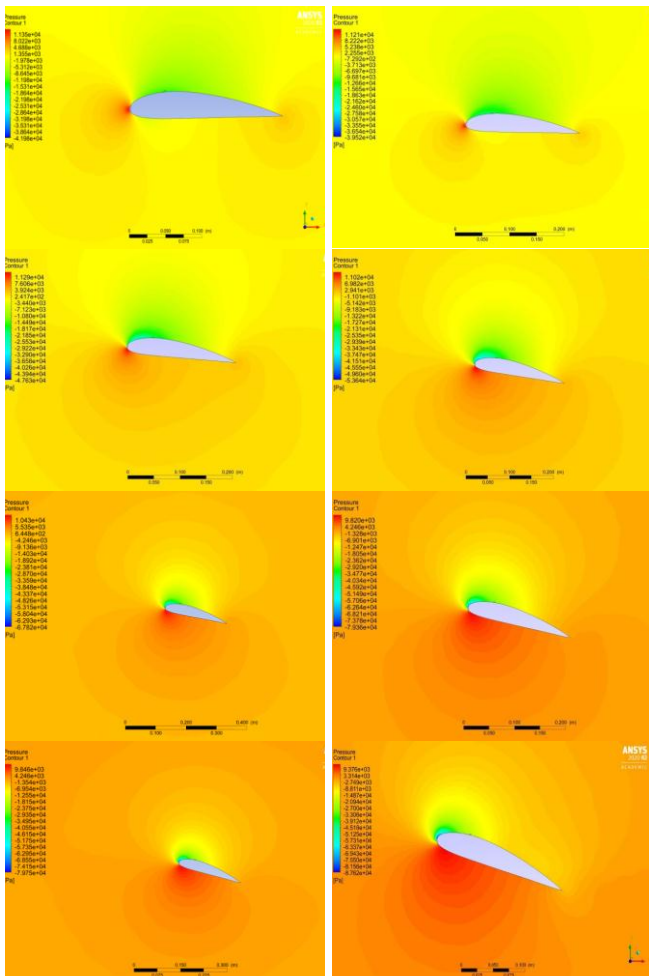


Fig 4.2: Pressure Contours of wing with VG of height 3mm at various angles of attack (-2,0,2,4,8,12,14,16,18,20)

4.3 Lift and Drag Characteristics

The lift and drag characteristics of NACA 2215 airfoil with vg 0.3 mm height at different angle of attack (-2, 0, 2, 4, 8, 12,20) along with Reynolds number (68.47×10^5) are three parameters considered in this case study and the simulation is performed for each height of Re and vg. The results obtained from these parameters are shown below in the table column in terms of C_l and C_d .

$$Re = 68.47 \times 10^5$$

α (deg)	NACA2215 Airfoil without vg			NACA2215 Airfoil with 3mm vg		
	C_l	C_d	C_l/C_d	C_l	C_d	C_l/C_d
-2	0.117	0.027	4.33	0.115	0.019	6.05
0	0.31	0.027	11.48	0.304	0.027	11.25
2	0.48	0.045	10.66	0.505	0.05	10.1
4	0.71	0.088	8.068	0.71	0.087	8.16
8	1.1	0.203	5.418	1.08	0.2	5.4
12	1.45	0.37	3.918	1.42	0.36	3.94
14	1.41	0.41	3.439	1.56	0.45	3.46
16	1.36	0.45	3.022	1.65	0.54	3.05
18	1.3	0.54	2.407	1.54	0.62	2.48
20	1.23	0.61	2.016	1.51	0.69	2.18

Table 4.1 Lift and Drag characteristics at $Re = 68.47 \times 10^5$

5 CONCLUSIONS

With the help of Ansys-Fluent CFD software, CFD analysis of aerodynamic performance of a NACA2215 Airfoil with ramped vortex generator at various angles of attack -2, 0, 2, 4, 8, 12, 20 degrees with a Reynolds number of 68.47×10^5 using the Spalart-Almaras turbulence model has been done. The results shows that successful delay of flow separation on the NACA 2215 Airfoil with a ramp-type vortex generator as a passive control technique, but not only that it is a pond post. angle of attack but also increased the C_l (max) of the NACA 2215 airfoil. For $Re = 68.47 \times 10^5$ ($V = 100$ m/s) the VG ramp of 3 mm is shown to be effective in delaying the stall angle by 4 degrees and increasing the C_l (max) = 1.65.

It can be seen from above that with a 3mm ramp, vg is very effective in delaying the angle of attack of a normal NACA2215 Airfoil. Although the value of C_d is slightly higher than that of a normal wing at a higher angle of attack, the C_l/C_d ratio is higher than that of a normal NACA 2215 wing.

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