EFFECT OF VORTEX GENERATORS ON THE VERTICAL TAIL OF SARAS PT1N AIRCRAFT

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ABSTRACT

The effect of Vortex Generators placed on the vertical tail of an aircraft have on the aerodynamic forces and moments has been studied by computational fluid dynamic (CFD) analysis. Steady flow simulations have been carried out over SARAS PT1N aircraft by using Reynolds averaged Navier-Stokes (RANS) solver with Spalart-Allmaras turbulence model at Mach number 0.24, Reynolds number 8.0 million and angle of attack α = 7º. These simulations are performed using an open source CFD solver SU2 software suite. The results are presented in the form of overall forces, moments and hinge moment coefficients. The computational hinge moment coefficients with and without vortex generators are compared for different rudder deflection angles.

Keywords: SARAS PT1N aircraft, Side-slip angle, Rudder deflection, Vortex generators, SU2 solver

INTRODUCTION

Vortex Generators are widely used devices on aircraft wings, wind turbine blades, racing cars etc. to enhance the performance of the vehicle by delaying the flow separation [1]. Vortex generators are the vanes on the suction surface of the wings which delay the flow separation at high angles of attack by extracting momentum transfer from free stream to the fluid layer near the surface, where flow susceptible to the separation. In order to model such a flows involving wide range of scales, grid generation is the challenging task. Where we need to resolve the scales from size of the vortex generators to the size of the aircraft in the same simulation. The main objective of the current work is to study the effect of vortex generators on the vertical tail of the SARAS PT1N aircraft, on aerodynamic forces and moments at different rudder deflection angles by computational fluid dynamics analysis. Also to study in detail the flow physics involved, which can help us to have a better understanding of the mechanism responsible for effectiveness of the rudder performance. Following sections briefly describe about the solver used, grid generation, results and finally the conclusion.

SU2 SOLVER

The SU2 solver is an open source Unstructured grid solver developed by Aerospace Design Lab in the Department of Aeronautics and Astronautics at Stanford University. The software is built with C++ tools for solving PDEs, primarily optimization and CFD problems. For fluid flow analysis it uses finite volume discretization (FVM) method for discretizing PDEs. The convective fluxes are discretized using Roe scheme

With second order limiter method and for time integration, the first order accurate Euler implicit method is used [2]. The SU2, CFD solver has been extensively validated for compressible viscous turbulent flows over wide range of Mach numbers [3]. In this work, the RANS capability of the SU2 CFD solver has been used along with Spalart-Allmaras turbulence model for simulating SARAS PT1N aircraft with and without vortex generators on the vertical tail.

GRID GENERATION

For all the present computations unstructured tetra-hedral grid around the SARAS PT1N configuration were used. The aircraft geometry and the vortex generators on the vertical tail are shown in figure 1. The commercial software package Point wise V18.0R3 [4] was used for generating the grids. The far field is considered in the form of a co-axial (with longitudinal axis of aircraft) cylinder of 134 meter in diameter and 425 meter in length respectively. The dimensions along the direction of flow is 150 meters

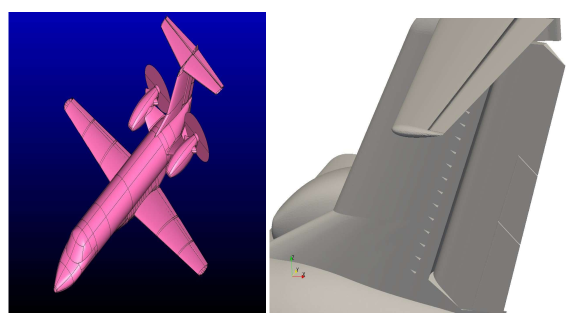

FIGURE 1: SARAS PT1N GEOMETRY (LEFT) AND VERTICAL TAIL SHOWING VORTEX GENERATORS (RIGHT)

On upstream from the nose of the aircraft and 260 meters on downstream of the aircraft tail respectively is considered. Nearly about 64 million tetrahedral cells were created with cell growth rate of 1.3 and 34 prism layers of cells are placed in the wall normal direction. The grid points are clustered properly near the leading, trailing edges, normal direction to the surface in the boundary layer and near the tip of the main wing, tail wing, and vertical tail and especially on the vortex generators, as the length scales from vortex generators size to aircraft size needs to be resolved properly. The surface grids with and without vortex generators are shown in figure 2.

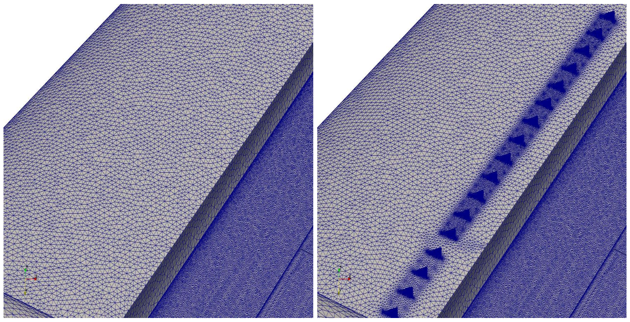

FIGURE 2: SARAS VERTICAL TAIL SHOWING SURFACE GRID WITHOUT (LEFT) AND WITH VORTEX GENERATORS (RIGHT)

RESULTS AND DISCUSSIONS

The present computations are performed at Mach number 0.24, Reynolds number 8.0 million, Side-slip angle $\beta = 0^o$ and angle of attack $\alpha = 7^o$, to study the effect of vortex generators. The results are discussed in detail below.

The simulations have been carried out for the above given aerodynamic parameters, without and with vortex generators on the vertical tail at different rudder deflection angles from 0^o to 30^o in steps of 10^os. The streamline contours at 20^o rudder angle deflection is shown in figure 3, for without (top) and with vortex generators (bottom). From the tabulated overall forces and moments and the streamline contours, it has been observed that there is no major difference in the overall forces and moments with the inclusion of vortex generators on the vertical tail. To understand in detail the effect of vortex generators on

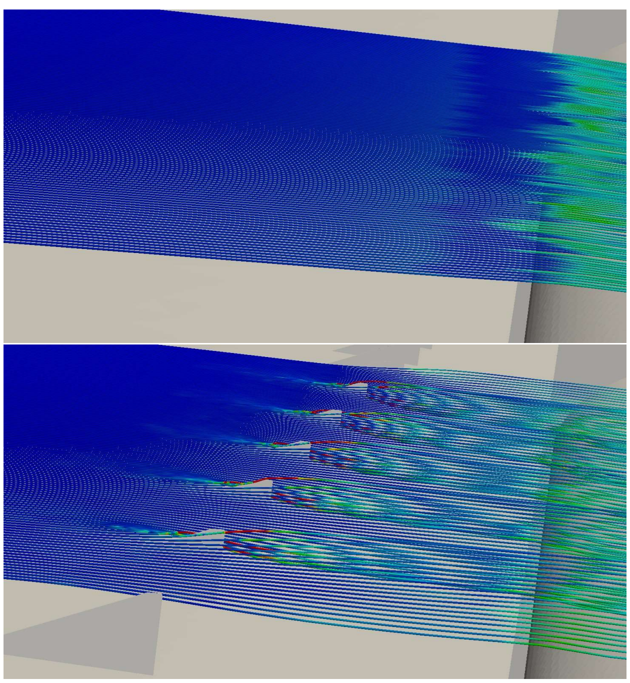

FIGURE 3: STREAMLINE CONTOUR FOR 20^O RUDDER ANGLE DEFLECTION - WITHOUT (TOP) & WITH VORTEX GENERATORS (BOTTOM)

The flow near the rudder, which modifies the hinge-moments, the sectional surface pressure distribution at different planes on the vertical tail has been extracted for comparing configurations with and without vortex generators for different rudder deflection angles, it has been observed that at zero degree rudder deflection angle very slight difference is seen between with and without vortex generators. With increase in deflection angle the difference are clearly visible as shown in figure 4, the contours of positive C_p move slightly forward in the gap region, due to the presence of the vortex generator. Another effect is the slight reduction of negative C_p at the trailing edge of the rudder on the suction side. These explains the reduction in hinge-moments seen in table 1. The rudder hinge moments about rudder hinge line estimated at different rudder deflection angles are plotted in figure 5. Table 1 shows the hinge moment data for different rudder deflection angles with estimated percentage differences with and without vortex generators. It should be noted that the calculated.

Hinge moments are very sensitive to the location of the hinge-line, especially the co-ordinate of the lower point. The changes in hinge-moments with configurations, or the delta effects, however are robust and these can be used to estimate the effect of various design modifications.

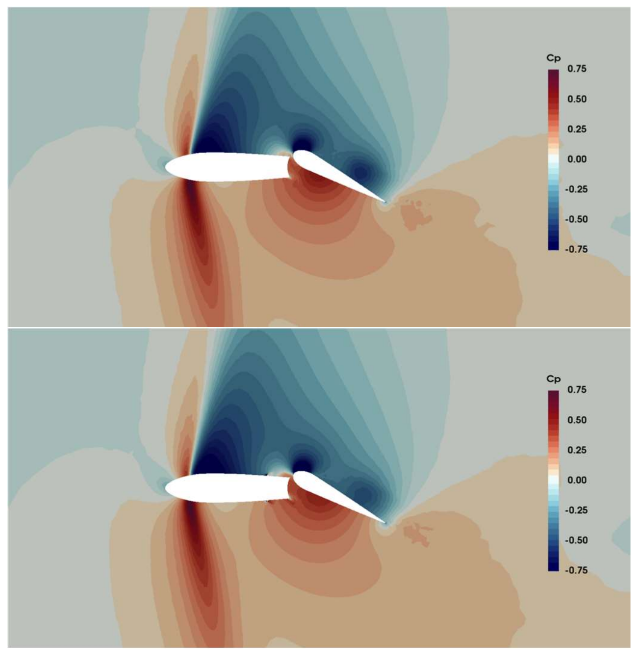

FIGURE 4: C_P CONTOURS FOR 30^O RUDDER DEFLECTION AT A SECTION NEAR TIP, WITHOUT & WITH VORTEX GENERATORS

Rudder Deflection (Degree)	Percentage Decrease (%)
0	–
10	29
20	25
30	8

TABLE 1: HINGE MOMENT COEFFICIENT:

CONCLUSION

CFD studies of steady flow over SARAS PT1N aircraft with and without vortex generators on the vertical tail have been carried out at different rudder deflection angles using RANS capability of the open source SU2 code. From simulation results it has been observed that there is no major difference in the overall forces and moments. Further, detailed analysis of the flow field of various rudder angle deflections, has led to insights into the reason for their effectiveness. These simulations have also demonstrated the capability of the simulation and computation methodology.

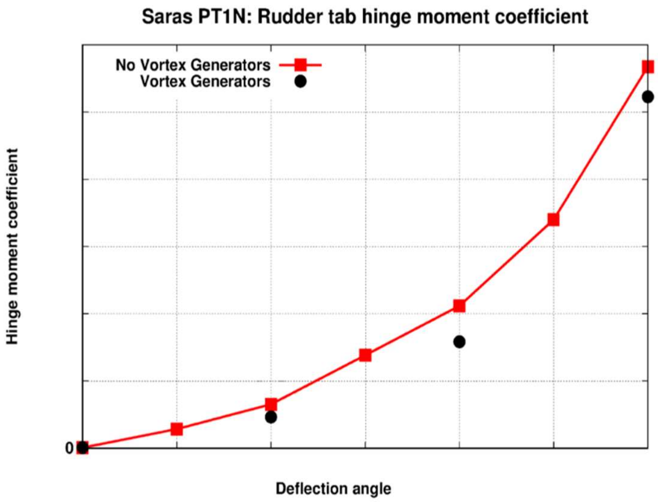

FIGURE 5: HINGE MOMENT COEFFICIENT AT DIFFERENT RUDDER DEFLECTION ANGLES

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