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Improving Aerodynamic Efficiency Using Surface Augmentation

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Abstract—*Design of modern airplanes becomes complex and innovative as they are to be designed based on so many perspectives. Enhancing the aerodynamic parameters such as drag, lift, Side moments are at one hand and at the same time efforts are continuously laid to reduce the overall weight of the body. Aerodynamics plays an important role and it is all the way affected by the nature of flow like inviscid, laminar or turbulent. Scientists and researchers are continuously studying the importance of physics such as boundary layer separation, positive and negative pressure gradients, extent of wave region, stagnation and reattachment conditions. Out of the three types of drags such as skin friction, pressure/form and induced drag pressure drag has most impact comparably. Recent studies reveal that converting laminar into turbulent or increasing the intensity of turbulence reduces this form/pressure drag. Introduction of surface perturbations such as dimples effects this transition. Wingtip vortices take up responsibility of huge loss of lift. Wing tip vortex breakers are utilized to avoid them vortices to increase drag.*

Computational Fluid Dynamics (CFD) which gains momentum and popularity in the modern design industries replaces cost consuming, cumbersome proto-based experimental methods.

In this work CFD is initialized to understand and analyze the basic inherent, intricate behavior of aerodynamics to compare the presence of dimples, variation of wingtip configuration in a airplane wing to reduce drag and increase lift.

Keywords: *Form drag, CFD, Boundary Layer Separation.*

1. INTRODUCTION

In aircraft, Aerodynamic efficiency plays a predominant role in designing an aircraft. Now a day, fuel efficiency needs to be improved as there is huge production of nearly 44000 aircrafts in 2036. Due to a tough economic environment, efficiency is taking anincreasingly prominent role in aircraft design. In the past 30 years, major technological advancements have beenachieved in propulsion systems, structures, and electronics; however, there hasn't been a major technological breakthrough in aerodynamic geometry for a few decades. Airplane aerodynamics is constantly tweaked, but thegeneral layout of an airplane has hardly deviated from blueprints that were made with a slide rule.

The aerodynamic cross section of a body such as a wing that creates lift as it moves through air or fluid is called as an airfoil or airfoil. An airfoil –shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag.

1.1. Aerodynamic forces

The aerodynamic forces and moments on a body are due to two basic sources:

- ✓ Pressure distribution over the body surface
- ✓ Shear stress distribution over the body surface

1.2. Methodology

In order to improve aerodynamic efficiency of an aircraft, we have proposed ideas on surface augmentation

- ✓ Dimples
- ✓ Winglets

2. STUDY ON THE IMPACT OF PRESENCE OF DIMPLES

2. 1.Base case

Geometric model is generated in 'SOLIDWORKS' which is very popular modeling software. The generated model is exported to the further process in the form of. IGES as it is a third party format which can be taken in to any other tools. Extracting the fluid region is the next step in which all the surfaces which are in the contact of fluid are taken alone and all other surfaces are removed completely.

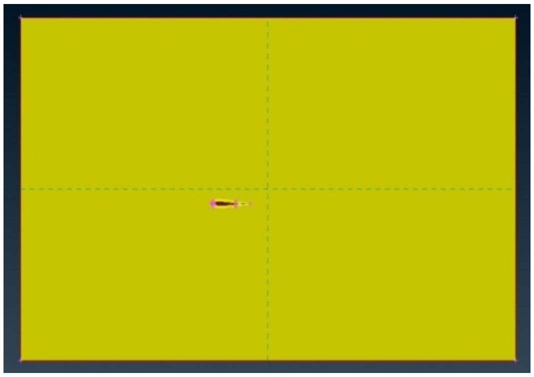

Fig. 1: CAD model and fluid domain

To keep the domain air /water tight some extra surfaces are created. This clean up is done in ANSA meshing tool which is very robust clean up tool. Extracted domain for vortex generation and finder assemblies are shown below.

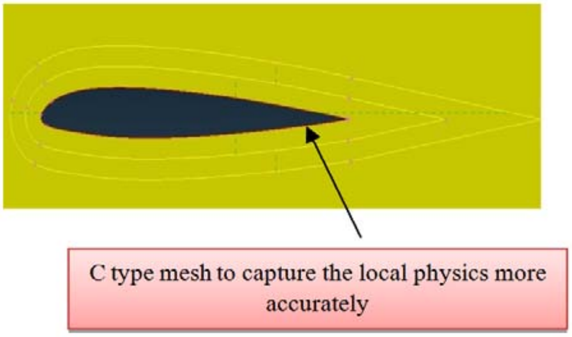

Fig. 2: CAD model zoomed view

Meshing

After cleaning up the geometry mesh is generated in ANSA tool itself. All the surfaces are discredited using tri surface element. As the geometry has some complicated and skewed surfaces tri surface elements are used to capture geometry. The following fig. shows the surface meshes.

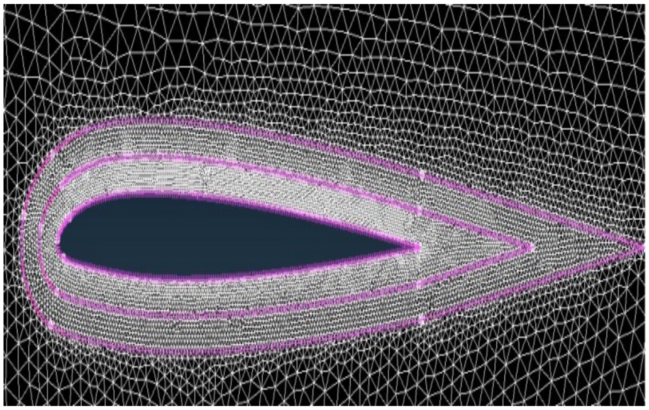

Fig. 3: Mesh on fluid domain

Table 1: Mesh details

Mesh	COUNT	QUALITY
TRIANGULAR- MESH	1262025	0.83

Solver setup

Ansys-fluent is used as the solver for this case.

- ✓ Fluid is assumed to be 2-D, turbulent, compressible in nature
- ✓ Turbulence is model byK-ε model,realizable
- ✓ Coupled algorithm is used to solve the problem
- ✓ Density based solver is used

Cell zone conditions

- ✓ The working fluid in the domain is air

Boundary conditions

For flow analysis,

- ✓ All other boundaries except wing body are assumed to be pressure far field with the mach number of 0.8
- ✓ Angle of attck is assumed to be 4 degrees

CFD results

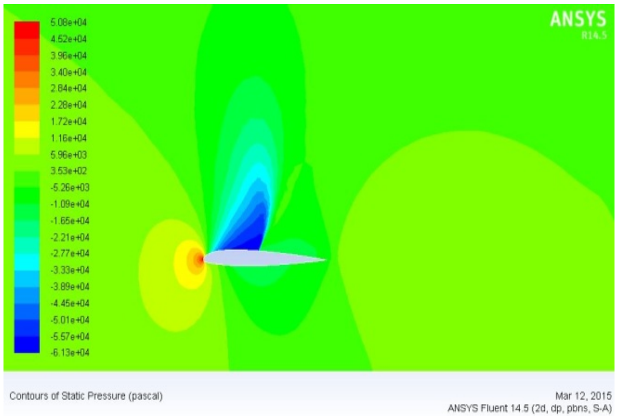

Fig. 4: Static Pressure contour at mid plane

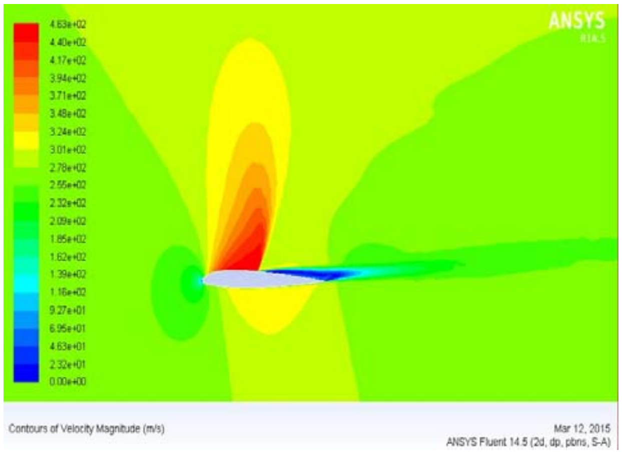

Fig. 5: Velocity contour at mid plane

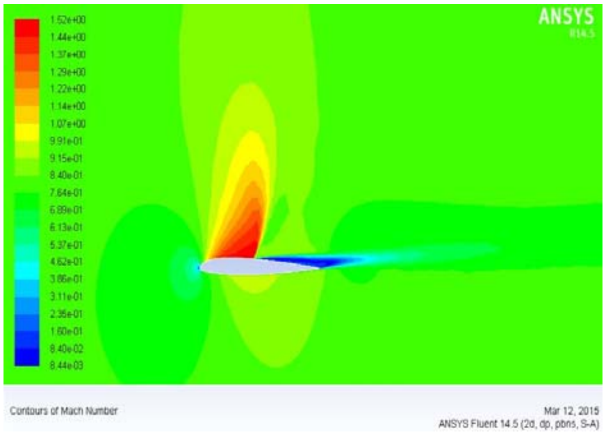

Fig. 6: Contours of mach number

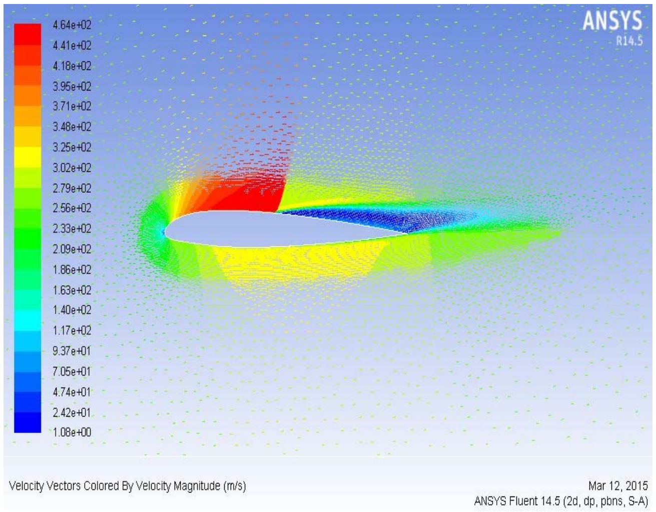

Fig. 7:Velocity vector indicating flow seperation and wake region

2.2. Modified case –with dimples

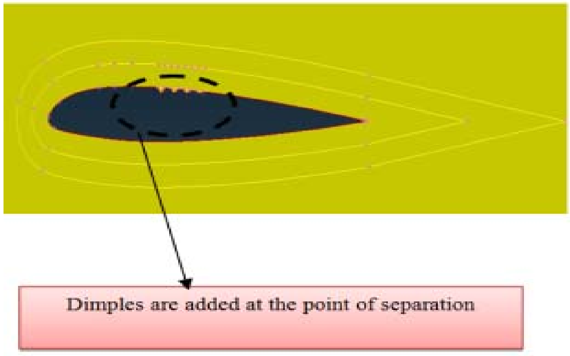
Dimples are added at the point of separation

Fig. 8: CAD model with dimples

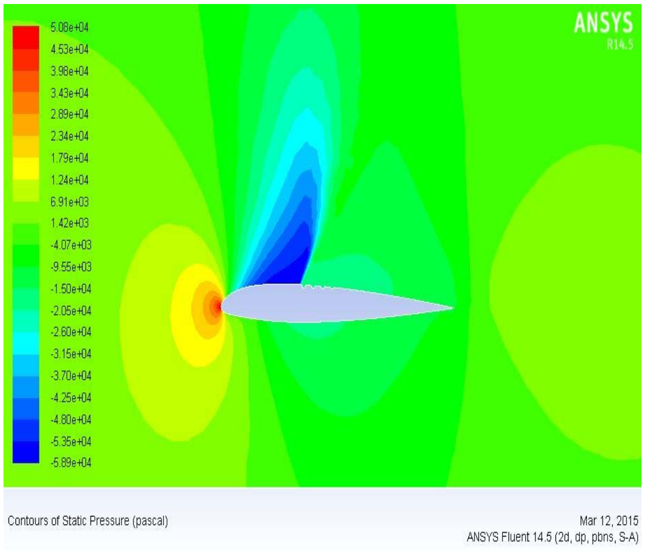

Fig. 9.Contours of static pressure

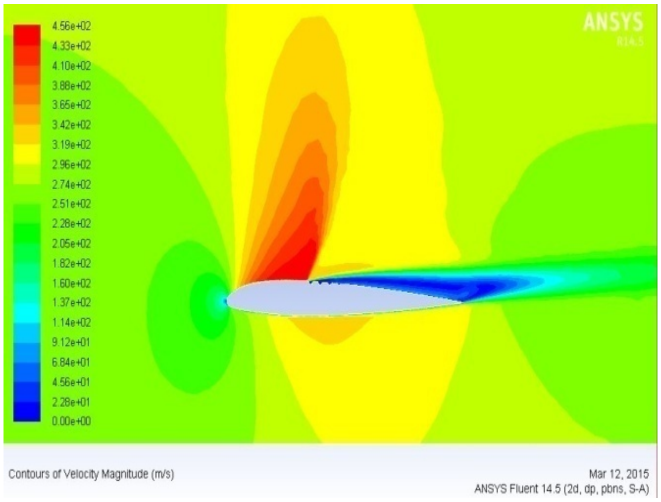

Fig. 10: Contours of velocity

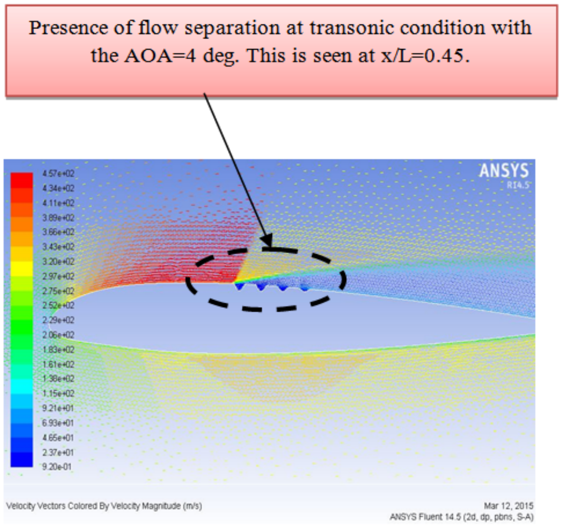
Presence of flow separation at transonic condition with the AOA=4 deg. This is seen at x/L=0.45.

Fig. 11.Velocity vector plot

2.3 Results and discussions

From the plots and values there is no considerable change in the value of Cd as air foil is a body which has good closureness with stream lined body.At a mach number 0.8 which is transonic and at an AOA of 4 there is recirculation and presence of wake region is found .It has been observed that dimples play a major role in reduction of drag for bluff bodies and very less significance is pronounced in streamlined bodies.On the other hand ,it increases the Cl value to certain extent as it increases the localised static pressure value that can be seen from static pressure plot.

Table 3: Data of lift and drag coefficients

MODEL	Cd	Cl
BASE	0.046035	0.31143
WITH DIMPLES	0.045583	0.32811

- ✓ Thus the aerodynamic efficiency**(L/D) is increased by 6.4 %**

3. STUDY ON THE IMPACT OF PRESENCE OF WING TIPS

3. 1.Base model

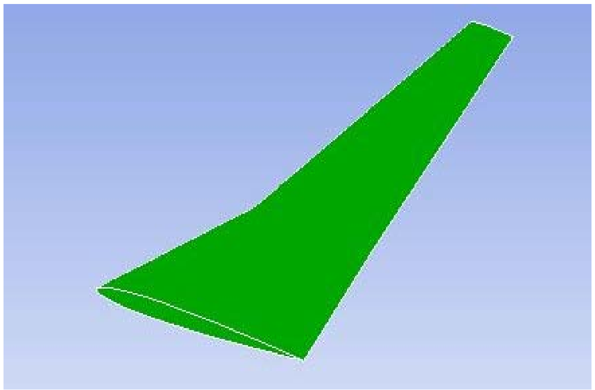

Fig. 12: CAD model of base wing

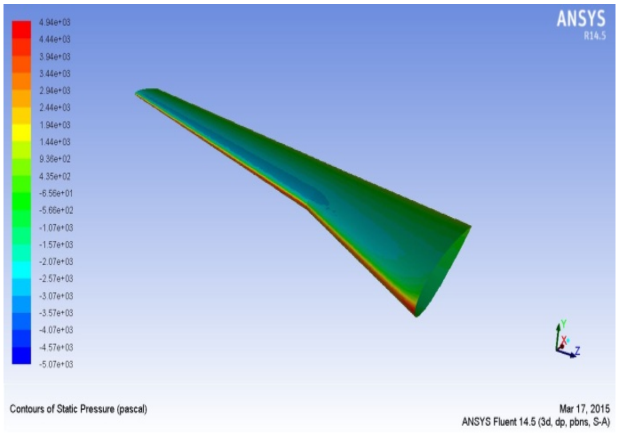

Fig. 13: Contours of static pressure –base wing

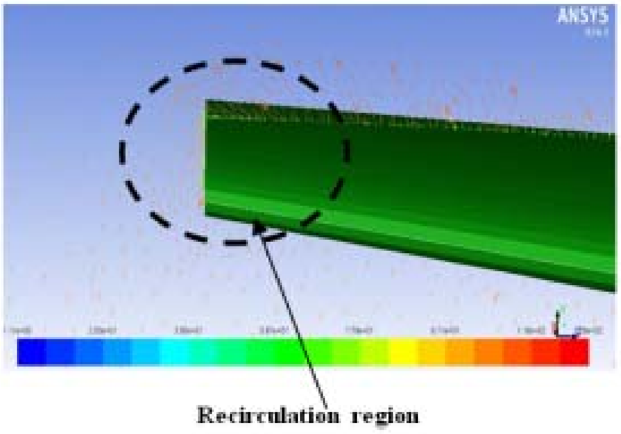

Fig. 14: Contours of velocity-base wing

3. 2.Modified model with wing lets

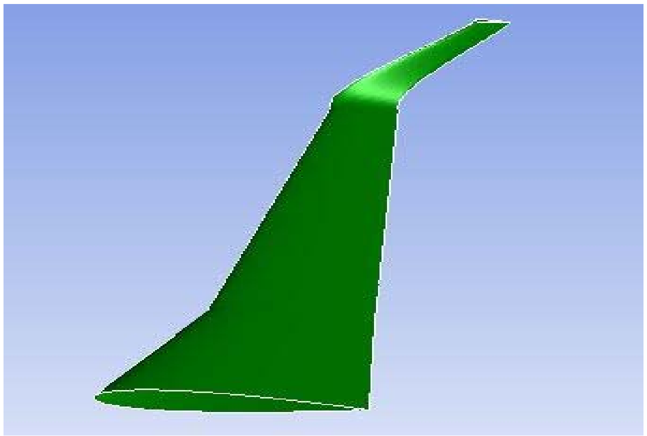

Fig. 15:CAD model of wing with winglet

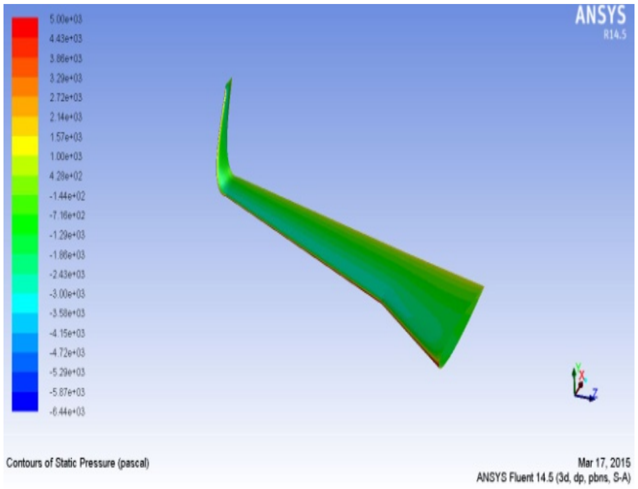

Fig. 16: Contours of static pressure-wing modification 1

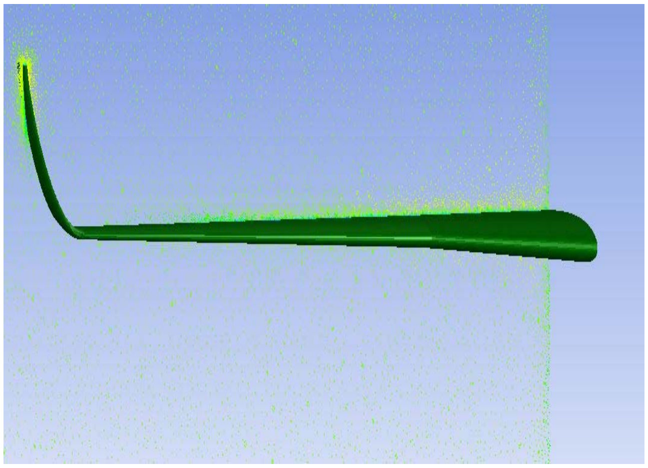

Fig. 17.Contours of velocity- wing modification 1

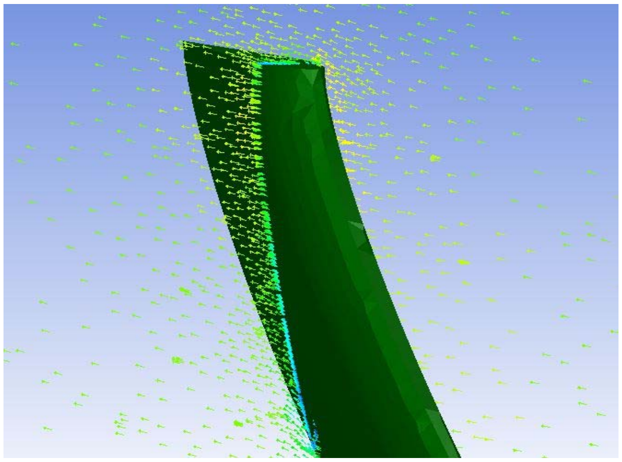

Fig. 18: Exaggerated view of velocity

3.3.Modified model with 'c'shaped wing lets

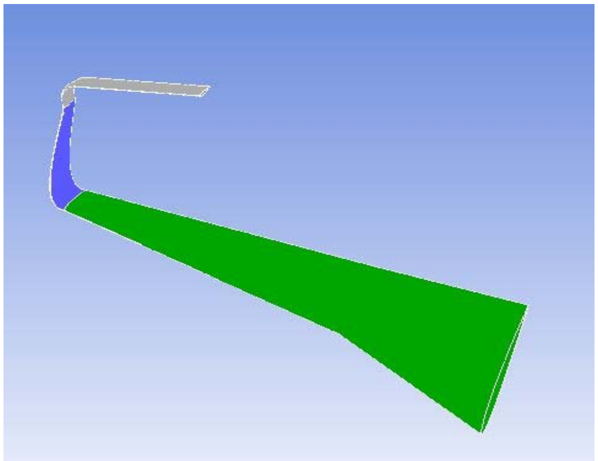

Fig. 19: CAD model of wing with c-type winglets

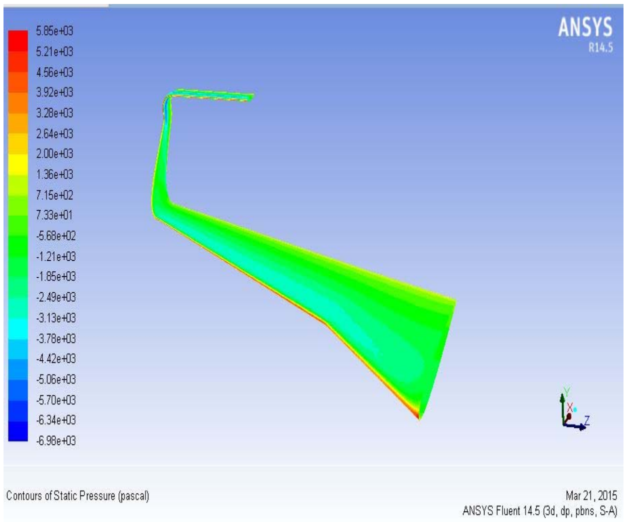

Fig. 20: Contours of static pressure-wing modification 2

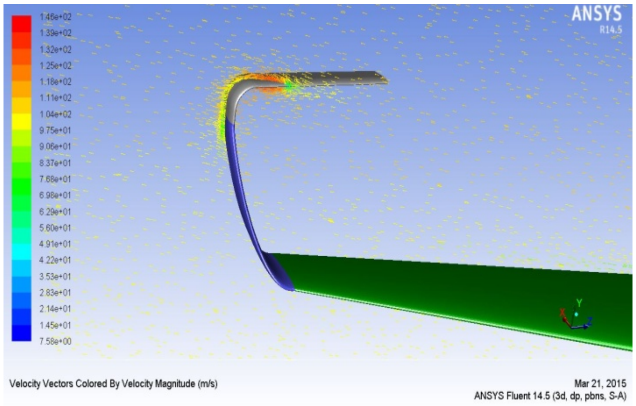

Fig. 21: Contours of velocity- wing modification 2

3.4.Results and disscusions

From the static pressure plots it is observed that is model with winglet has high suction pressure in turn generates more lift.

From the velocity vector plots of the base model there is clear recirculation region in the near vicinity of wing tip , this recirculation region induces pressure equilibrium this physics leads to reduction of lift but in the case of model with winglet the recirculation absent.

Table 3: Data of lift and drag coefficients

MODEL	Cd	Cl
BASE WING	0.0331	0.223
MODIFICATION 1	0.0338	0.243
MODIFICATION 2	0.0422	0.4

- ✓ By comparing the base wing with that of the wing having winglets,the aerodynamic efficiency**(L/D) is increased by 6.71 %**
- ✓ While comparing the wing having normal winglets with that of the wing having c-type winglets,the aerodynamic efficiency **(L/D) is increased by 31.84 %**

4. ACKNOWLEDGEMENTS

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