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DRAG REDUCTION BY SUPPRESSION OF ROLL OVER VORTICES ON NACA 2424 WING

Subhadhanuraja.G[1], Sathish Kumar.K[2]

[1](PG scholar, Aeronautical Engineering, P.B.College of Engineering, Chennai, India, subhadhanu625@gmail.com)

[2](Assistant professor, Aeronautical Engineering, P.B.College of Engineering, Chennai, India, satz_aero@yahoo.com)

Abstract - *The objective of this project is to study and analyze the suppression mechanism of rollover vortices on airframes. Effect of rollover vortices on airframes causes major problems for many flying vehicles. Some of the problems are vibrations of wing, flow separation, increases induced drag, and decreased lift of wing. So it is important to suppress the rollover vortices on airframe. Lot of active techniques and methods are available which are very complex to design and difficult to implement. So it is necessary to develop some passive techniques which are easy to design and implement.*

The rollover vortices are difficult to determine directly. But it can be find indirectly by analyzing turbulence level in the flow. Vortices affect mostly on the wing. So NACA 2424 wing of span 0.6m and chord 0.15m is meshed and analyzed in commercial CFD software packages. Wedges, notches, slits and booms are the modifications done on the wing to suppress the vortices as taken from literatures

Keywords – *Vortices, NACA 2424 wing, Suppression, Slit, Turbulence*

I. INTRODUCTION

Vortexisaregion,inafluidmedium,inwhichtheflowismostlyrotatingonanaxisline,thevorticalflowthatoccurseitheronastraight-axisoracurved-axis.Vorticesareamajorcomponentofturbulentflow. Therearetwovorticeswhicharepredominant inwing.Oneiswingtipvortices,whichcanbeeliminatedbywinglets.Anotherisrollovervortices,whichiscontrolledbyactivetechnicslikeboundarylayersuction.Butthereare no passive techniquesavailabletoreducetherollovervortices. Theobjectiveofthisprojectistostudyandanalyzethesuppressionmechanismofrollovervorticesonairframes.Wingexperiencemorerollovervortices.Wingmodelwithlotofmodificationsisanalyzedbycomputationtopredictthepassivetechniquewhichsuppressestherollovervorticeseffectivelywhencomparedtothenormalwing.

II. DESIGN OF SUPPRESSORS

Typesofsuppressorsusedforanalysisarewedge1,wedge2,wedge3,wedge4,groove,notchandboom.Gambit2.4.6modelofthissuppressorsareshowninfigure.Suppressors areplacedat adistanceof0.11m,0.12m,0.13mfromthe leadingedgeofNACA2424aerofoilisnamedasposition1,position2andposition3respectively.Chordoftheaerofoilis0.15m.Dimensionsofsuppressorsareshowninthetable.Gambit2.4.6modelofaerofoilwithsuppressorsareshowninfigure1-8.

Table 1: Dimensions of Suppressors

Suppressor	Length (mm)	Height (mm)
Wedge 1	5	2
Wedge 2	5	2
Wedge 3	5	2
Wedge 4	5	2
Groove	2	2
Booms	2	2
Notches	5	2

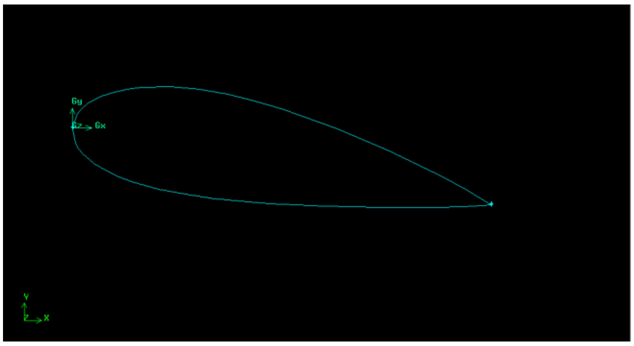


Figure 1: NACA 2424 aerofoil

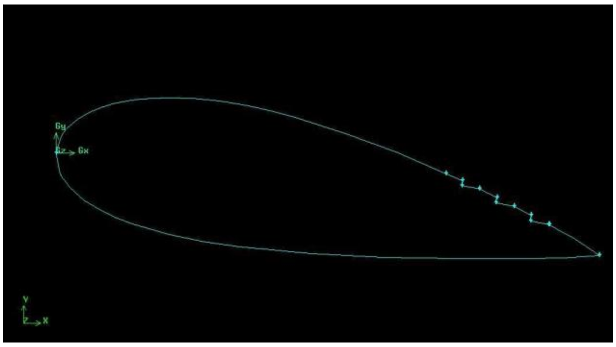


Figure 2: NACA 2424 aerofoil with Wedge 1

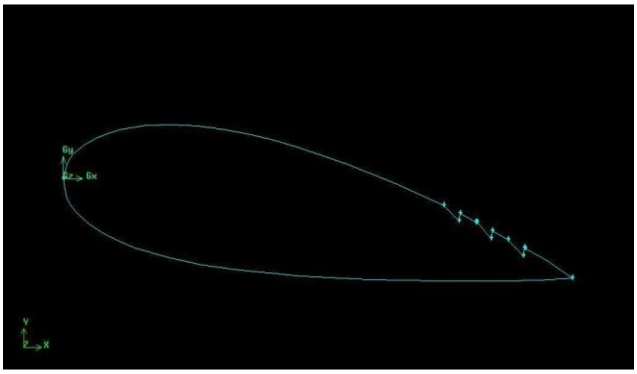


Figure 3: NACA 2424 aerofoil with Wedge 2

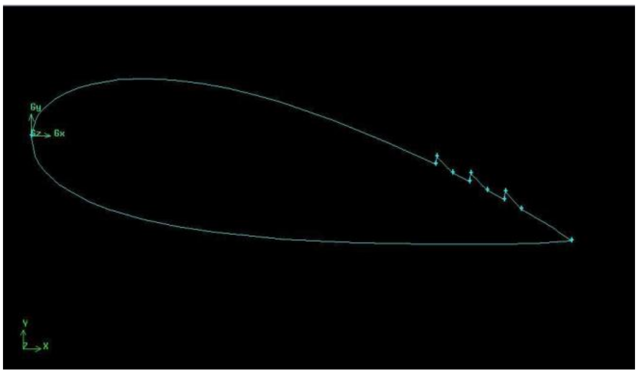


Figure 4: NACA 2424 aerofoil with Wedge 3

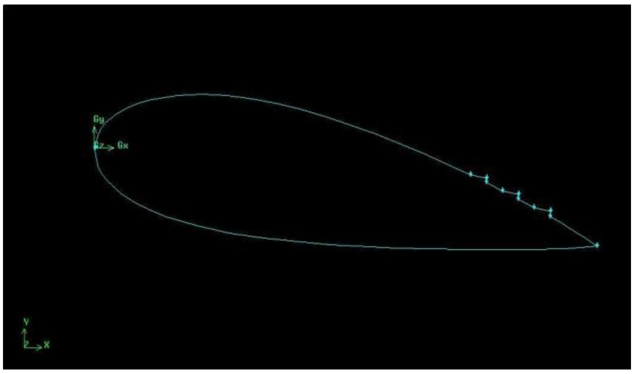


Figure 5: NACA 2424 aerofoil with Wedge 4

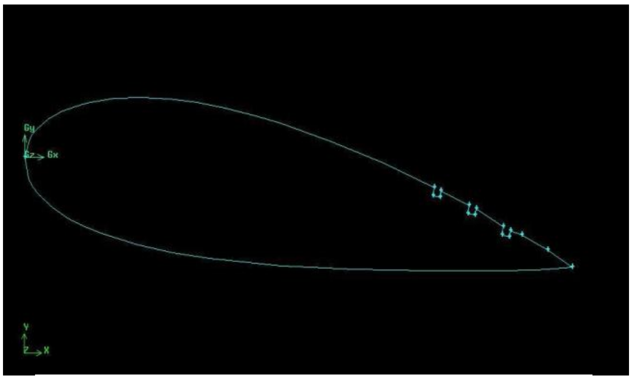


Figure 6: NACA 2424 aerofoil with Grooves

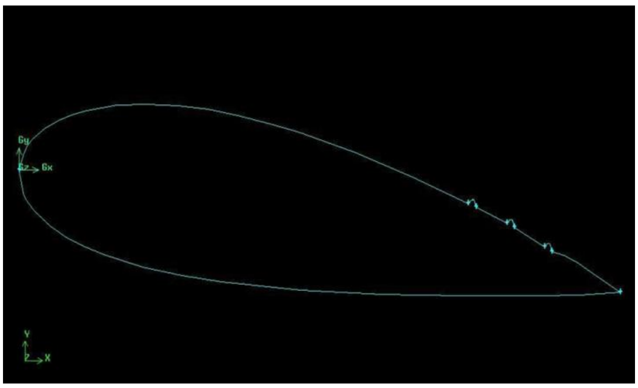


Figure 7: NACA 2424 aerofoil with Booms

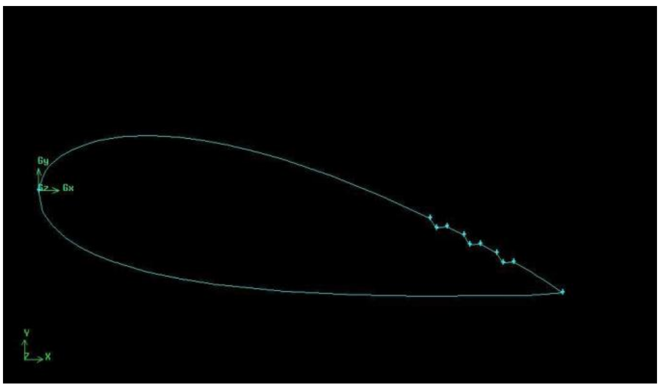
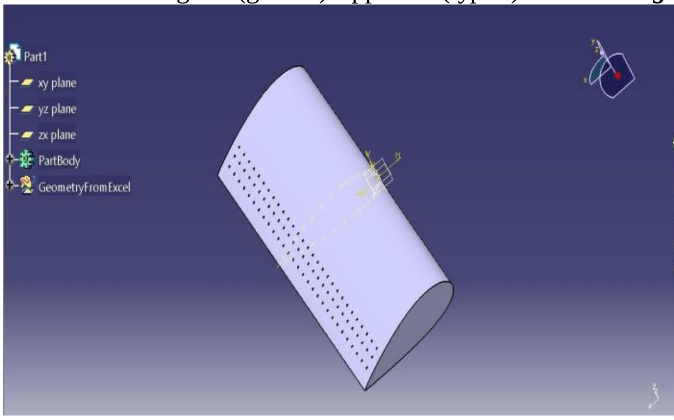


Figure 8: NACA 2424 aerofoil with Notches

n 1st type, at pos ssers each of spacing of 20mm and thickness of 2mm. Chord of the wing is 0.15m. Span of the wing is 0.6m.CATIA V5R18 model of wing with (groove) suppresser (type i) is shown in F*igure 9.* In2nd type,atposition1,position2and position3thereisonlyonesuppresseralongthewholespan(0.6m)ofthewing.Chordofthewingis0.15m.Spanofthewingis0.6mCATIAV5 R18modelofwingwith(groove)suppresser(typeii)isshownin***Figure10.***



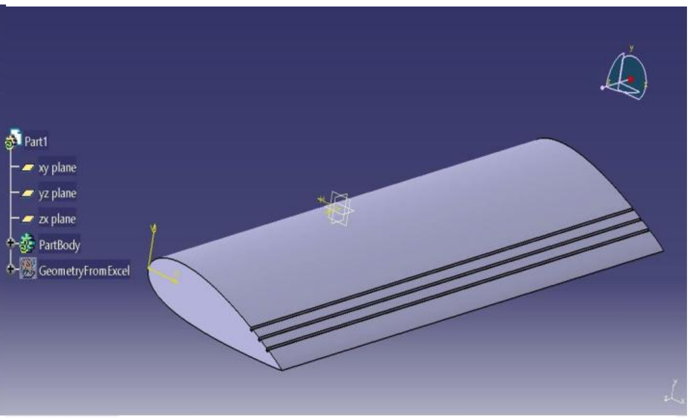


Figure 9: NACA 2424 wing with 1st type suppressor

Figure 10: NACA 2424 wing with 2nd type suppressor

III. COMPUTATIONAL WORKS

DESIGNING OF WING WITH SUPPRESSER IN CATIA V5R18:

BeforemodelthewinginCATIAV5R18firstcreatetheMS-Excelfilewithco-ordinatesofNACA2424andthenopenCATIAV5R18partdesignandthenrunmacrosintheMS-Excel.NowthepointsareimportedinCATIAV5R18.Thenconnectallpointsbyspline.Extrudethesplinewithmirrorextentof300mmusing pad.Thenmodelthesuppresserandusingpocketoptionsubtractthesuppresserfromaerofoil.Nowsavethefileas .igs or.stpfileto open intheICEMCFD14.5. Alsosaveitas.part.

MESHING OF WING

In ICEM CFD software import the wing model which is designed in CATIA V5R18 by import geometry command. After import draw the vortex of the domain by using explicit coordinates in create point of the geometry. Then connect the points and draw line using from points option of create/modify geometry of geometry. Then create face by connecting line using simple surface option from create/modify surface of geometry. Then create body by taking two points as references using material point option in create body of geometry. Now model of wing with domain is done.After model, define global factor of 1 in global mess size in global mess setup. Then define mess size for aerofoil as 5, inlet and sides as 100, to get more accuracy define exit as 50 and body(air) as 100 in part mesh setup in mess. Now compute the mess by using volume mess option in compute mess. In order to smoothen the mess go to surface mess setup and give quality check and give smooth mess in edit mess menu. Then select solver as fluent v6 in solver setup of output. Then give boundary condition in boundary condition option in output as follows

1. Inlet - velocity inlet
2. Exit - pressure exit
3. Sides of the domain - wall
4. Aerofoil - wall
5. Body - fluid

After define the boundary condition, the file is exported to analysis in fluent using write input option in output menu. The messed model of the NACA 2424 wing is shown in ***Figure 11***.

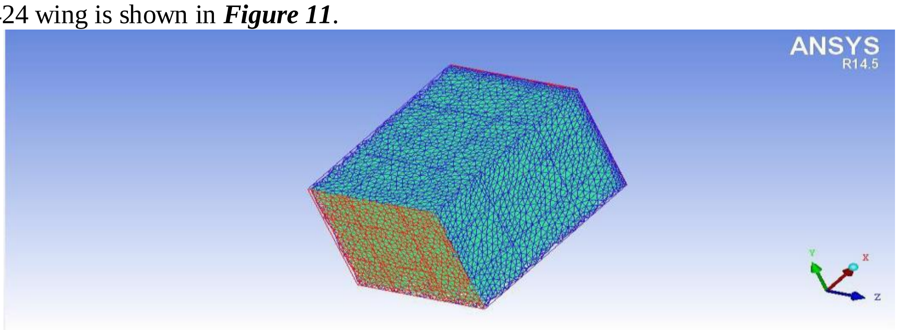


Figure11:MeshedmodelofNACA2424wingwithinthedomain

IV. RESULTS AND DISCUSSIONS

The vortex is difficult to measure directly by simulation but can measure indirectly by measuring turbulent intensity and turbulent kinetic energy of the flow through simulation. So the NACA 2424 aerofoil with suppressers (wedge 1, wedge 2, wedge 3, wedge 4, groove, notch, booms) and without suppressers are analyzed in fluent14.5 and its results are tabulated.Variation of lift, drag, location where turbulent kinetic energy reaches 0.2% behind aerofoil from leading edge and location where turbulent intensity reaches 0.2% behind aerofoil from leading edge with different suppressers are potted in the figure 12-15 at free stream velocity of 200m/s and 300m/s**.**The NACA 2424 wing with suppressers (wedge 1, wedge 2, wedge 3, wedge 4, groove, notch, booms) and without suppressers of type i and type ii are analyzed in fluent 14.5 and its results are tabulated in table 2 and 3.

Table 2: Fluent 14.5 result of NACA 2424 wing with and without suppressers type i with free stream velocity of 300m/s

Model	**Lift (N)**	**Drag(N)**	**Location whereturbulent kinetic energy reaches 0.1(m/s)2 behind mid plane of wing from leading edge**	**Location where turbulent intensity reaches 5% behind mid plane of wing from leading edge**
normal	391.6108	3974.8814	306.8182	503.8462
Booms	573.2120	3970.5400	297.4138	515.0000
Notch	394.7139	4005.7460	272.7273	473.0769
groove	565.1980	3972.4547	188.6598	277.8689
wedge1	574.8750	4059.0337	276.9231	586.3636
wedge2	574.6561	4060.3037	280.4348	492.1875
wedge 3	373.0474	3655.6434	220.5882	414.1304
wedge 4	575.2440	6500.6605	306.1224	491.2500

Table 3: Fluent 14.5 result of NACA 2424 wing with and without suppressers type ii with free stream velocity of 300m/s

Mod el	**Lift(N)**	**Drag(N)**	**Location where turbulentkineticenergy reaches5%behindmidplaneofwingfromle adingedge(mm)**	**Location whereturbulentintensityreaches5%behindmidplaneofwing fromleadingedge(mm)**
nor mal	171.761	1748.720	267.647	512.069
boo ms	248.280	1406.267	221.154	377.148
notc h	254.565	1564.520	297.940	516.667
groo	166.250	1670.440	160.714	221.134
wed ge1	252.055	1693.178	277.174	468.293
wed ge2	289.581	1634.697	403.846	807.692
wed ge3	250.885	1330.068	192.568	320.833
wed ge4	133.039	255.245	278.800	422.727

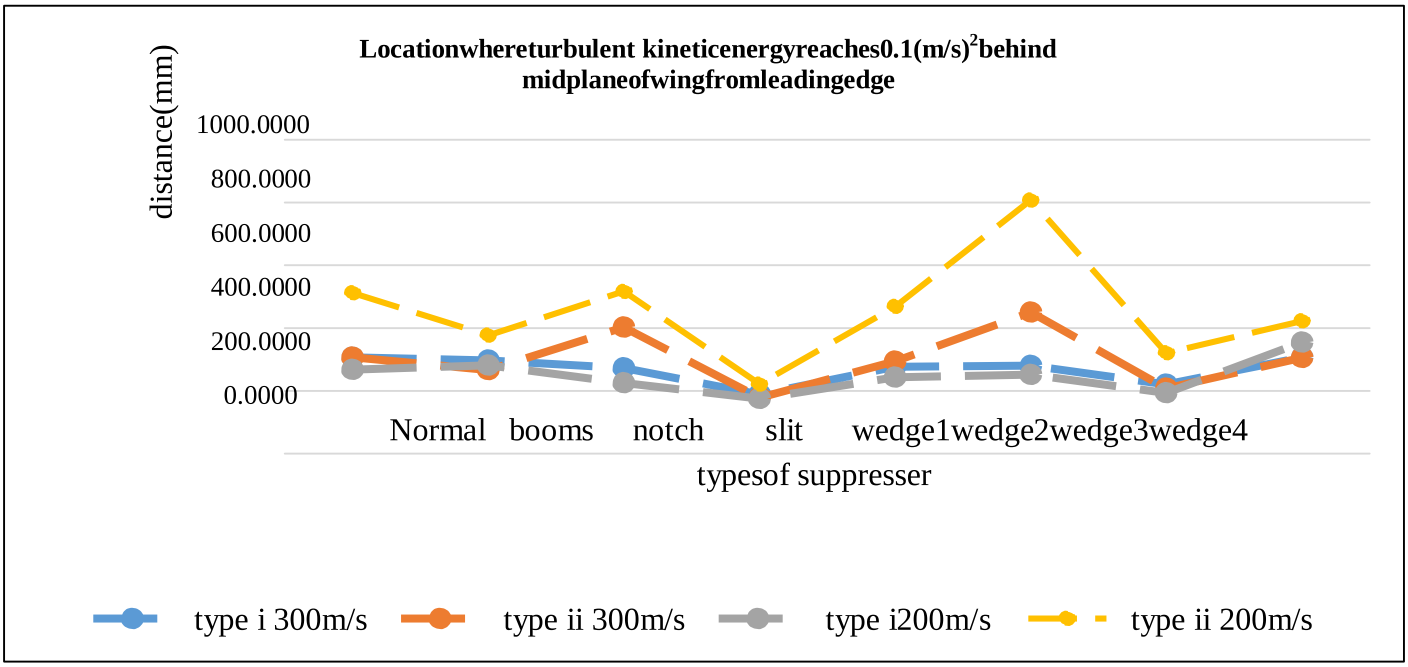


Figure 12: Variation of location where turbulent kinetic energy reaches 0.1(m/s)^2 behind the wing from leading edge with different types of suppressers

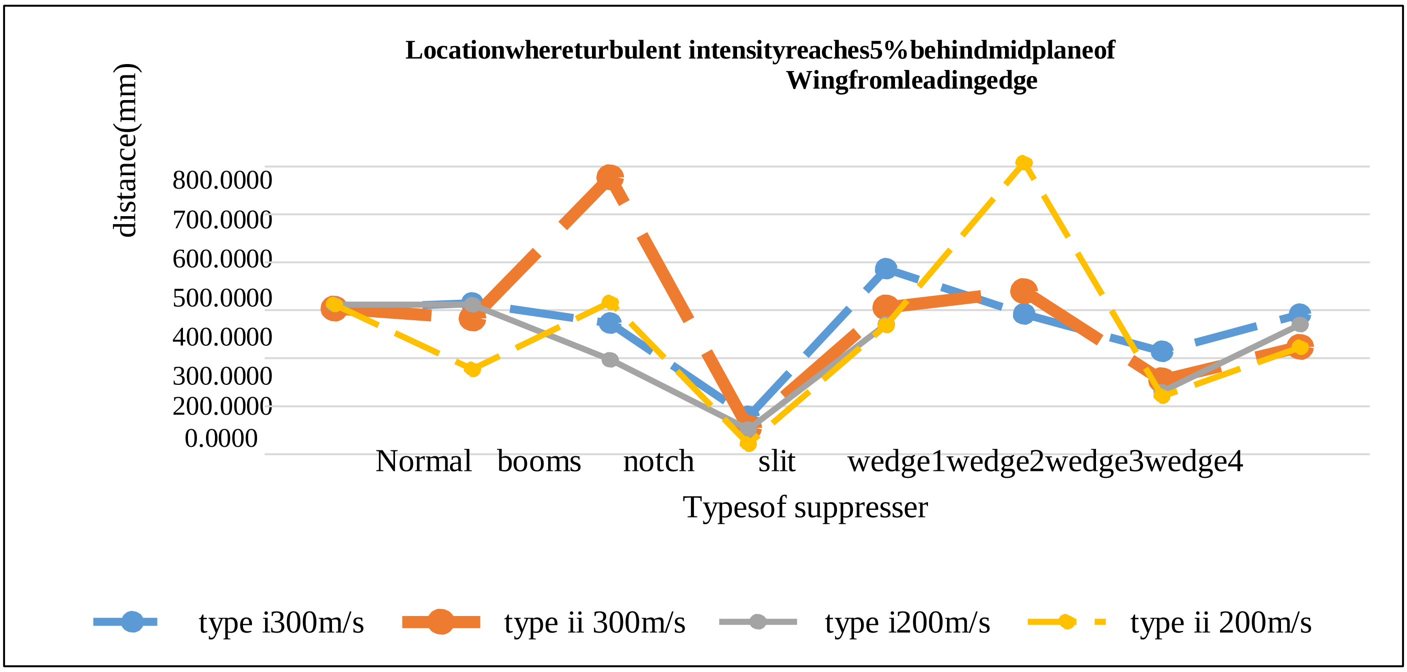


Figure13:Variationoflocationwhereturbulentintensityreaches5%behindwingfromleadingedgewithdifferenttypesofsuppressers

FromthesimulationworkcarriedoutonNACA2424wingwithsuppressersandwithoutsuppresser,itisconcludedthattheturbulent kineticenergyandturbulentintensitysuppresses earlyforawing withgroovethananyothersuppresser.While using groove of 0.02m*0.02m along the span of upper surface of the wing, it is found that vortices are suppressed earlier than the wing with other modifications. At 200m/s on the normal wing, vortices are suppressed at a distance of 0.512m from the leading edge. But while using groove on the wing, vortices are suppressed earlier at a distance of 0.252m from the leading edge of wing. Vortices suppressed 50.78% earlier in the wing with groove than the normal wing.

COMPARISON OF NORMAL WING AND WING WITH GROOVES:

Wing with slit is more effective than other modification. So slit alone is taken and compared with normal wing for different velocities and for different angle of attacks. And the result is tabulated below.

Table 4: Variation of location where turbulent intensity reaches 5 % behind wing from leading edge with variation in angle of attack

Angle of attack	**Location where turbulent intensity reaches 5% behind mid plane of normal wing from leading edge(mm)**	Win **Location where turbulent intensity reaches 5% behind mid plane of wing with grooves from leading edge** (mm)
-4	345.9677	304.3243
-2	265.263	193.548
0	200.9433	185.762
2	208.564	195.283
4	217.2413	199.7073
6	220.4819	202.5
8	281.5789	205.102
10	357.69	222.6562

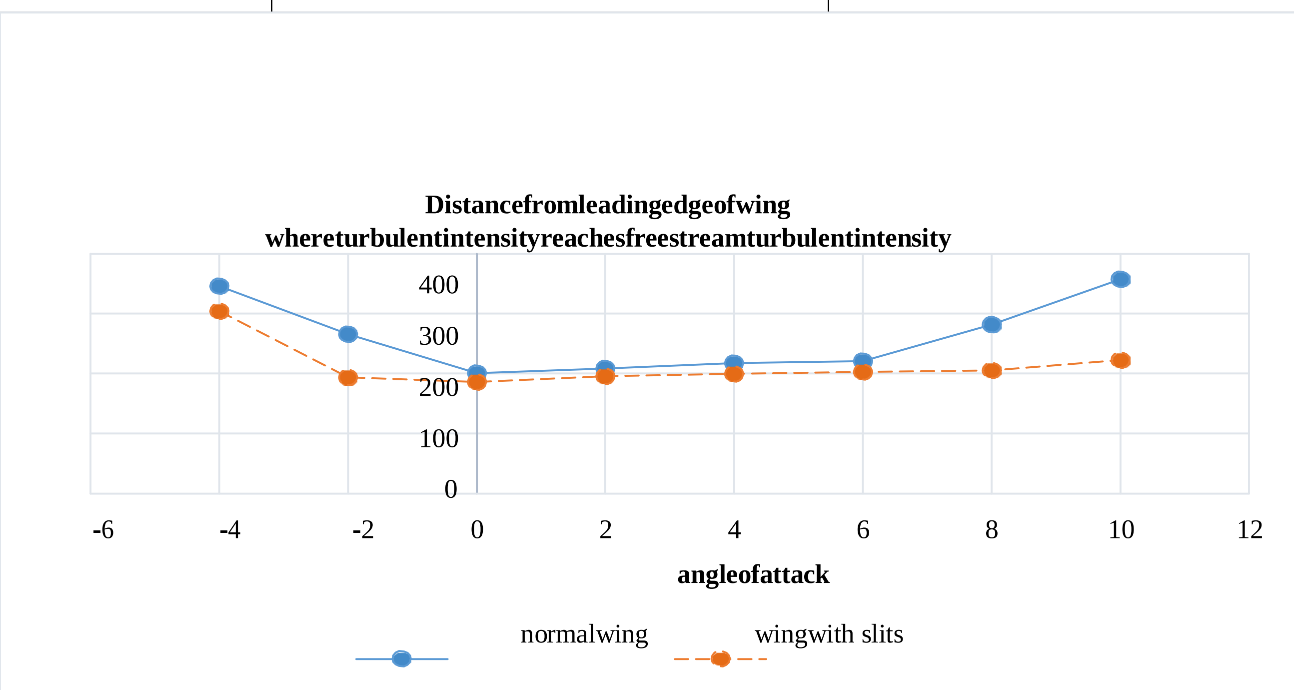


Figure14: Variation of location where turbulent intensity reaches 5 % behind wing from leading edge with variation in angle of attack

FromthegraphitisobservedthatForbothnormalwingandwingwithgroovestheturbulentintensitydecreasesuptozeroangleofattackandthen itremainsconstantup tocertainvelocity,andthenitincreaseswhenincreasingtheangleofattack.Whilecomparingthe normalwingandwingwithgrooves, itis foundthatturbulent intensityreachesfreestreamturbulence intensityshorterinthewingwithgroovesthanthenormalwing

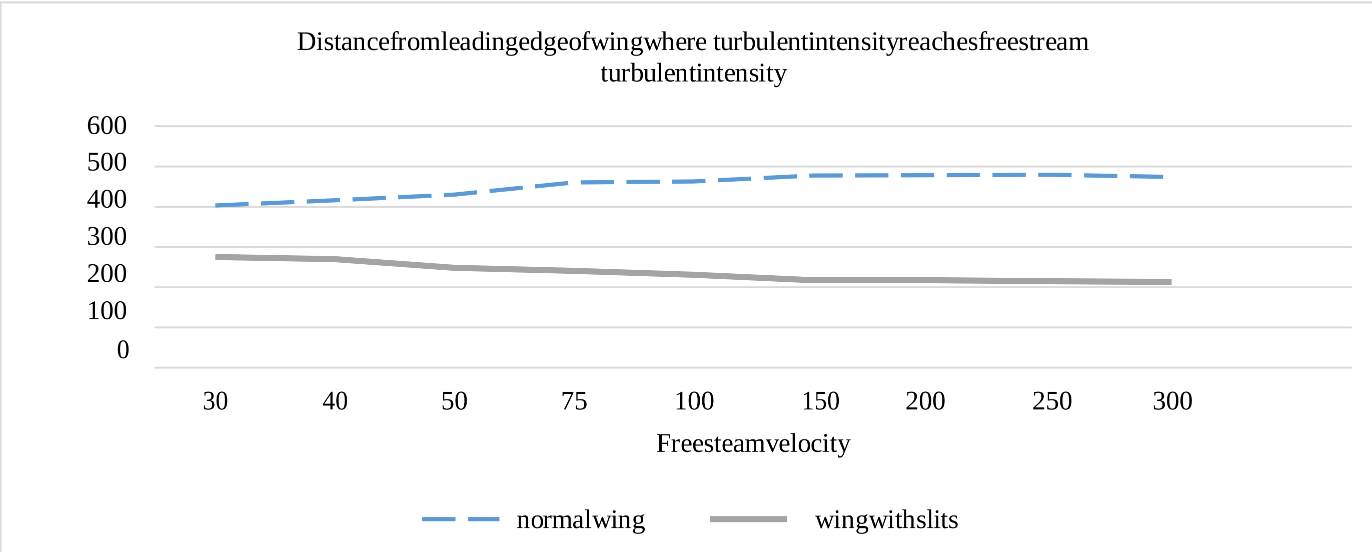


Figure 15: Variation of location where turbulent intensity reaches 5 % behind wing from leading edge with variation in free stream velocity

From the figure it is observed that for a normal wing turbulent intensity increases with increasing free stream velocity up to 200m/s and then it becomes nearly constant.For a wing with grooves turbulent intensity decreases with increasing free stream velocity up to 200m/s and then it becomes nearlyconstant.While comparing normal wing and a wing with grooves the turbulent kinetic energy is less for a wing with grooves, So it suppress more vortices. Thus effectiveness of using slit increases with increasing free stream velocity up to 200m/s.

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