Design And Analysis Of Wing Fuselage Intersection For Fatigue And Self-Healing Technique

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Abstract-The drag which exists due to interaction of wing- fuselage section is called as Interference drag. High interference drag may lead to Fatigue which is progressive a failure mechanism and material degradation. The degradation or damage accumulation progresses until a finite crack is nucleated. The objective is to design a Fail-Safe Structural component and do the stress analysis and introducing carbon nano tubes in the structure for the self-healing process which is the modern technique to detect and heal the cracks. We have designed a Wing-Bracket attachment and done the analysis of wing-fuselage interaction using Ansys. We have represented Goodman diagram for Maraging steel and explained the methodology of Self-healing technique .The flow over the wing is accelerated such that aerodynamic interference between the wing and fuselage is critical in transonic flight regime, which may leads to structural failure

Keywords: — Aircraft, Fatigue, CATIA V5, Stress, strain, Airfoil, wing bracket, Interference drag, Ansys, Gambit

Introduction

The purpose of aerodynamic analysis of an airplane is to optimize aerodynamic performance. That is to maximize lift for a given amount of drag, and conversely to minimize drag for a given amount of lift. Shapes and contours of individual components and parts on aircraft affect the amount of total aircraft drag. Nevertheless, the total drag further rises when combining these parts into an airplane. This increment in drag is called interference drag [1]. The performance of the aircraft depends on the life span of the different components. At some number of cycles each and every component undergoes damage. Structure of an aircraft will resist different types of loads in different conditions. Weight also plays an important role in performance and life span of the aircraft. All of these investigations indicate that there is a possibility that the drag-rise characteristics can be improved by taking advantage of a favorable interference between two components and that the drag-divergence Mach number can be increased [2]. Aircraft structure damages due to the application of different cyclic loads at different segments of its Flight. The interference effects that occur for several wing-body geometries that are considered candidates for a design of an airplane intended to operate at low subsonic speeds at high altitude. Due to continuous applications of loads the structure degrades. This degradation of structure due to application of cyclic loads is called fatigue analysis. Each and every component of an aircraft undergoes fatigue damage. Now our next step is to select the component which undergoes fatigue damage. Fatigue is a type of fracture that occurs in materials that are subjected to changing or varying stresses over time. Fatigue occurs when a material is subjected to repeat loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the stress concentrators such as the surface, persistent slip bands (PSBs), and grain interfaces. Eventually a crack will reach a critical size, and the structure will suddenly fracture

The Advancement in technology made the structure of composite materials stronger than they actually needed to be, so when the damage occurs it will less likely to be catastrophic. This can be equally required for a composite material if the crack is detected that could heal itself, without the help of human interaction, These composite materials have made a good impact on automobiles and aircraft structures [3]. Crack formatted due to the heavy aerodynamic flow and gust loads areas which highly effected in aircraft structures are wings, control surfaces, and rudder

Wings: This are highly effected due to aerodynamic flow and fatigue, gust loads have a great impact on the wing structure. The first of these is the heating up and cooling down of the Aircraft surface during each supersonic flight which induces a thermal stress cycle contributing to the general Fatigue damage and critically affecting design at some locations. Same with the control surface and rudder

Different phases of the fatigue life

The fatigue life is usually split into a crack initiation period and a crack growth period:-

Crack initiation

This is the initial stage of the fatigue crack may be caused by surface scratches caused by handling, or tooling of the material. Cracks also generally originate from a geometrical discontinuity or metallurgical stress raiser like sites of inclusions.

Crack growth

This further increases the stress levels and the process continues, propagating the cracks across the grains or along the grain boundaries, slowly increasing the crack size. As the size of the crack increases the cross sectional area resisting the applied stress decreases and reaches a thresh hold level at which it is insufficient to resist the applied stress. Crack growth resistance when the crack penetrates into the material depends on the material as a bulk property. Crack growth is no longer a surface phenomenon. The crack continues to grow during this stage as a result of continuously applied stresses. Failure occurs when the material that has not been affected by the crack cannot withstand the applied stress.

Safe-life design

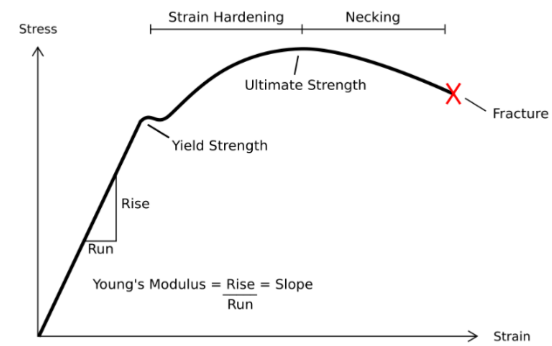
Safe-life design is based on the assumption that the part is initially flaw-free and has a fine life in which to develop a critical crack size.

Fail-safe design

The fail-safe design philosophy assumes that fatigue cracks will be detected and repaired before they lead to failure.

Mean Stress Consideration

The standard S-N Curve used for fatigue calculations is based on pure alternating load. Mean stress for this test is zero. Mean stress would be present for all the loading conditions other than pure alternating. It is also generated due to processes like rolling or heat treatment, bolt pre-stresses or constant loading applications.



Strain-Life Approach (E - N)

Strain life approach is also known as Crack Initiation approach. This method calculates crack initiation life. It is considered for plastic strain and recommended to Low Cycle fatigue.

In the High Cycle fatigue region, stress and strain levels are low and they are linearly related. Traditionally, the magnitude of the observed cyclic stresses were observed to be less than the tensile elastic limit and the lives long (i.e., greater than about 10^5 cycles). This pattern of behavior has become known as high-cycle fatigue.

Wing fuselage configuration

Wing-Fuselage junction flow occurs when the boundary layer on a fuselage encounters an obstacle placed on its surface5. The result is an interrupted boundary layer causing changes in pressure gradient at the intersection area, which leads to three dimensional separations with horseshoe vortices wrapping around the wing surface.

The wing located slightly higher than the mid-fuselage. The fuselage maintains its shape, only with the wing placed through its body. The middle section of the wing is fully covered by the fuselage.

The wing positioned partly above the fuselage. The fairing is designed to partially cover the top, back section of the wing to alleviate the effects from sharp conjunction between aft wing and fuselage. The fairings extend from fuselage to the wing to help minimize separation, and wing-fuselage interference effects.

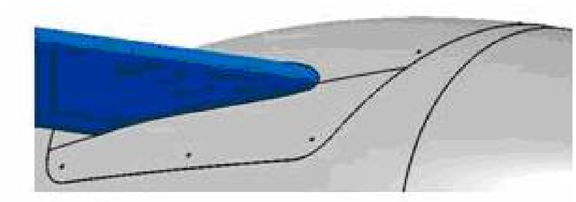


Fig. wing-fuselage geometry

Modeling of Wing-Bracket Interaction

For designing an airfoil key points are mandatory. We have chosen NACA 2412 airfoil. NACA 2412 airfoil is a semi-symmetric and has maximum lift values around 1.93.

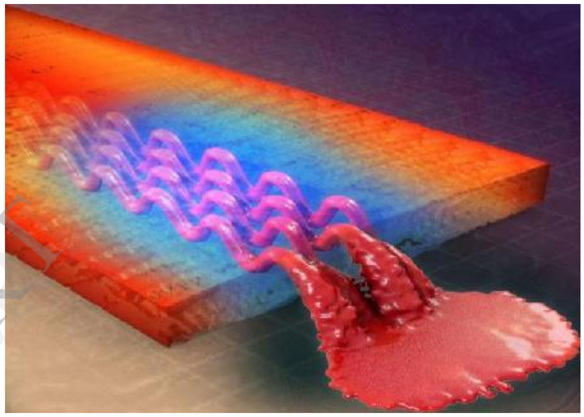
How self-healing works

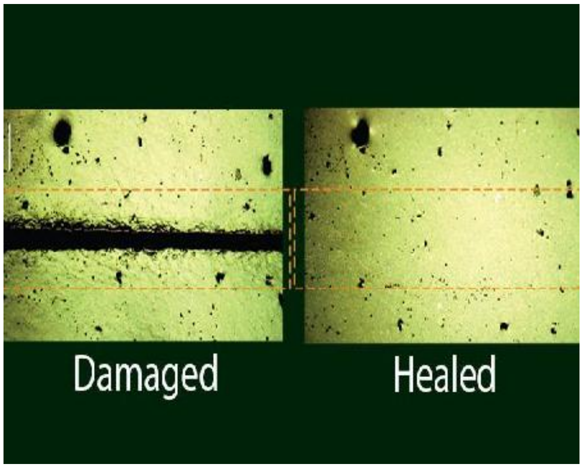
Carbon nanotubes are allotropes of carbon with a cylindrical nanostructures. These cylindrical carbon molecules have unusual properties like thermal conductivity and mechanical and electrical properties. By implanting a polymer with electrically conductive carbon nanotubes, and then monitoring of the structure's which are electrically resistive, Once a crack is identified, then we can send a short electric charge to the area in order to heat up the carbon nanotubes and in turn melt an embedded healing agent that will flow into and seal the crack with a 70 percent recovery in strength

A structure from common epoxy, this kind is used to manufacture everything from the lightweight frames of fighter jet wings to countless devices and components used in manufacturing but they added enough of multiwalled carbon nanotubes to comprise 1 percent of the structure's total weight. They mechanically mix some liquid poxy to ensure the carbon nanotubes were properly dispersed throughout the structure as it dried in a mold.

When the composite structure are introduced with a series of wires in the form of a grid, which can be used to measure electrically resistive and also apply control voltages to the structure. By giving a small amount of electricity through the carbon nanotubes, the research team could be able to measure the electrical resistance between any two points on the wire grid. Then they create a tiny crack in the structure, and measured the electrical resistance in between two nearest grid points.

Hence the electrical current has to travel around the crack to get from one point to another, the electrical resistance. As longer as the crack grew, electrical resistance between the two points increased.



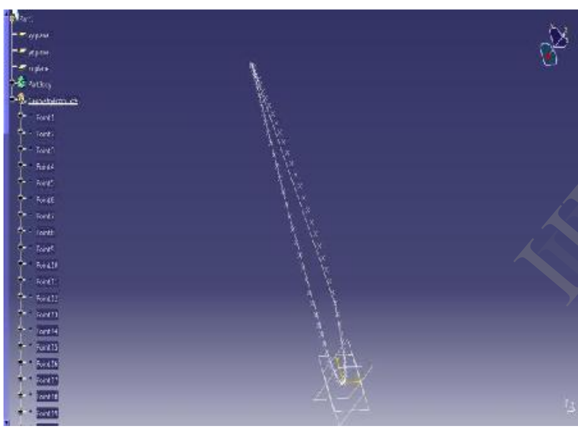


Self-healing agents

Development of submicron capsules and nano capsules filled with healing agent will allow for the incorporation of healing functionality in composites with interstitial spacing smaller than capsules prepared using previous methods. Submicron capsules and particles have been prepared previously for encapsulation of inorganic particles such as magnetite in polystyrene [6], pressure sensitive adhesives [7], and melamine-formaldehyde capsules containing cyclohexane and n-octadecane [8].

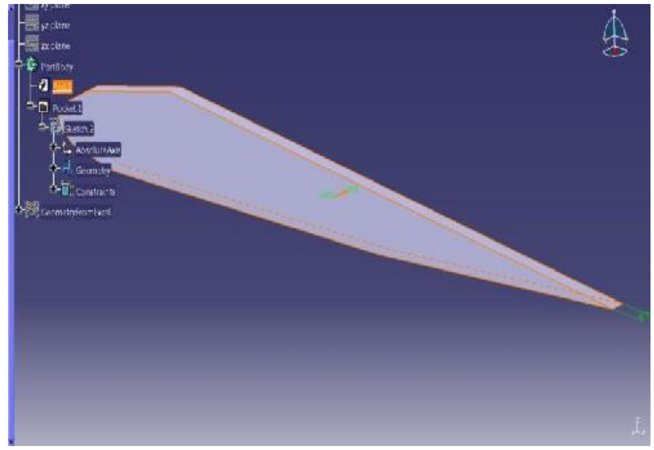
The process of in situ polymerization has been used to produce microcapsules as described in the previous works of Brown et al. [5], Ni et al. [7], and Alexandridrou et al. [11]. The addition of particulate fillers, such as capsules, to an epoxy resin can have a significant influence on the mechanical properties of a material.

Importing key points into CATIA using EXCEL sheet



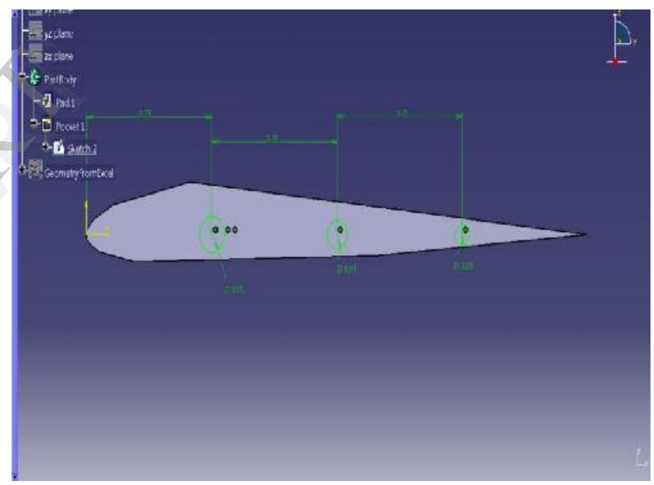
Extruding key points

Next exit the work bench and use PAD option to add material along perpendicular direction (EXTRUDE). Thickness of the airfoil we have chosen here is 0.2mm.



Giving Holes

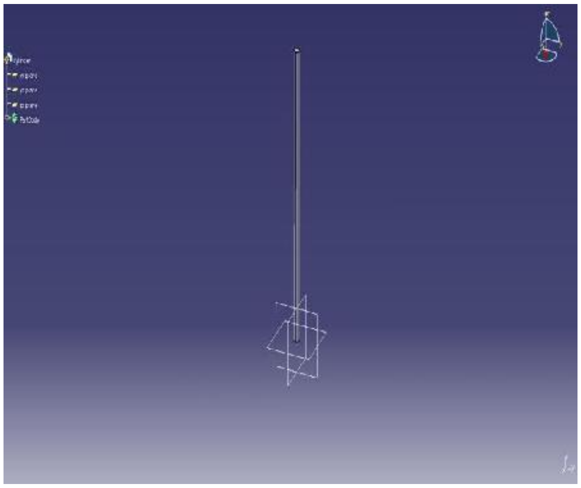
In sketcher, using circle and constraints three circles are drawn on airfoil. Distance between holes is maintained 0.25mm. Hole diameter are 0.05mm, 0.04mm, 0.03mm respectively.



Modeling of Stringers

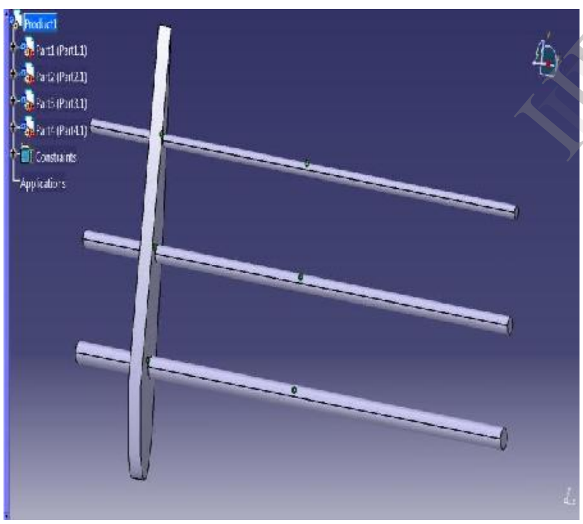
In this section we first draw circle with 0.05mm diameter. By using PAD option in part design we extrude these circles to a length 1.75mm cylinder. These cylinders represent stringers in actual aircraft.

Assembling of stringers with NACA 2412

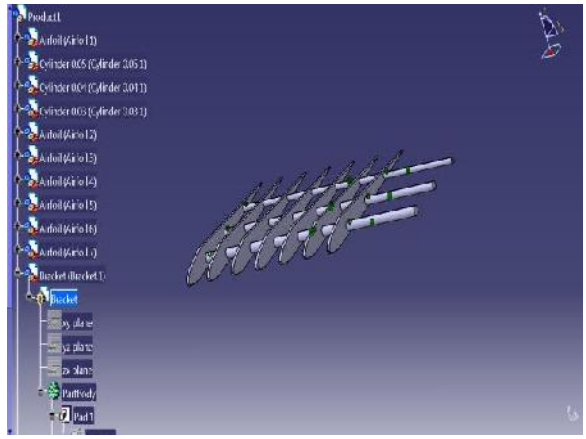


Airfoils

To combine the parts we use assembly work bench. We insert each part one by one. Initially we inserted 0.05 mm cylinder using "Insert existing part with position". By using coincidence command gave coincidence between the airfoil 0.05mm hole and cylinder

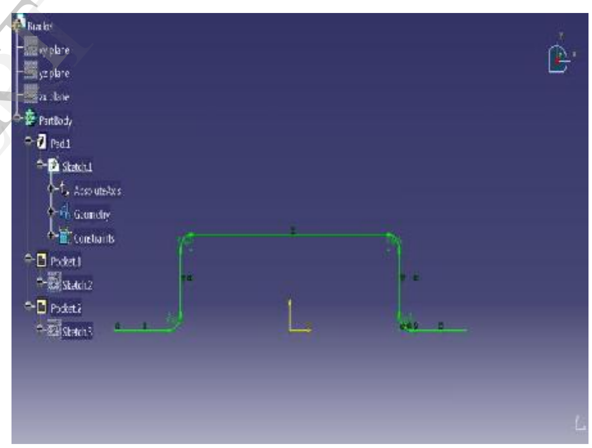


But to support the length of the rod we have created 7 respective number of similar airfoils. In this select the distance between the airfoils with respect to the length and number of such airfoils required such that cylinders are equally balanced

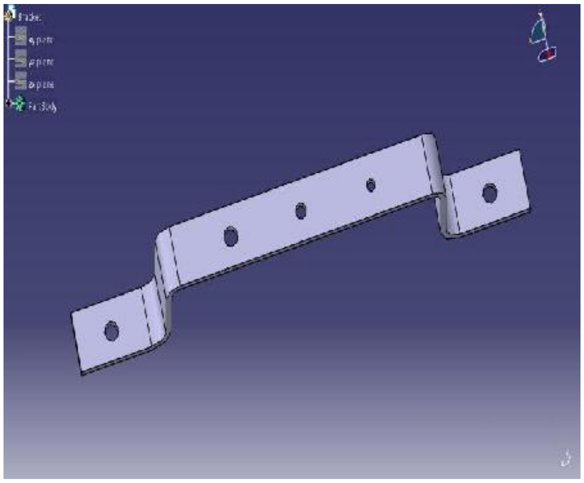


Sketch of Bracket

Dimensions of the bracket are taken in such a way that the length of airfoil must be equal to middle part of bracket. Middle length of bracket is exactly equal to airfoil length. Thickness of the bracket is 0.02mm. Fillet is same in four corners having a radius of 0.015mm. The distance between holes is 0.20, 0.25, and 0.25.

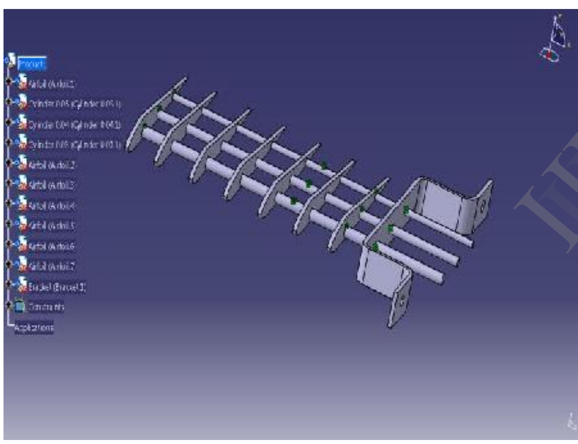


Then holes are made on both ends using pocket tool.



Assembly of Airfoil and Bracket

For assembling we insert individual parts of "multiple airfoils with cylinders" and "bracket" using "existing component with positioning". The final model of wing and fuselage interaction through bracket



Analysis

The aim of a fatigue analysis is to determine if a part will survive the large number of load cycles experienced in its lifetime. A fatigue analysis will determine the durability or the fatigue life of a part.

Preference>Structural

Pre-Processor

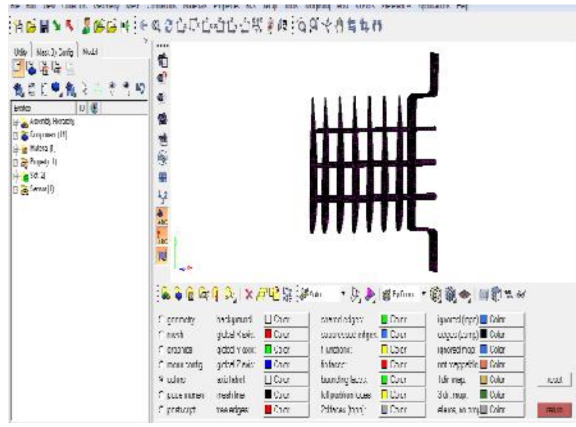
Preprocessor>Element type>Add>Solid>20 node 95
Preprocessor>Material Props>Material Models>Structural>Linear>Elastic>Isotropic

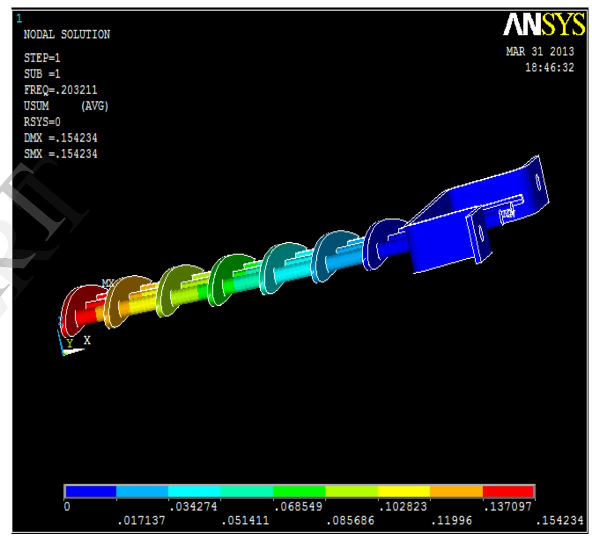
EX=2.1.e5

PRXY=0.3

Preprocessor>Material Props>Material Models>Structural>Density>8.1e-6

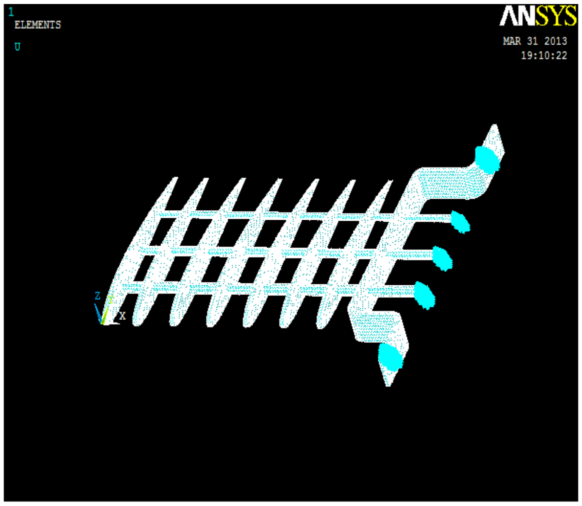
Meshing was done in hyper mesh.



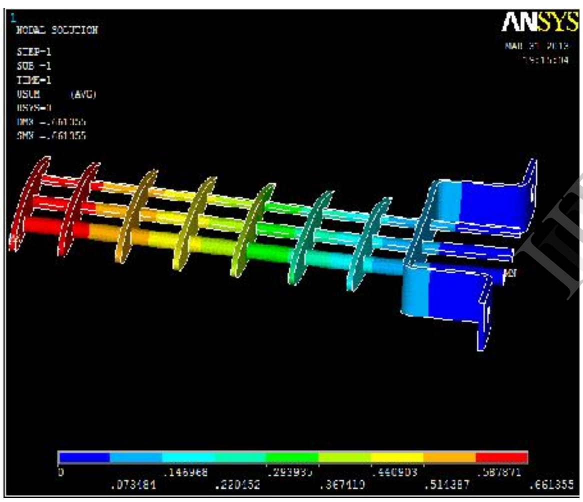


Fatigue Analysis Maraging Steel Solution

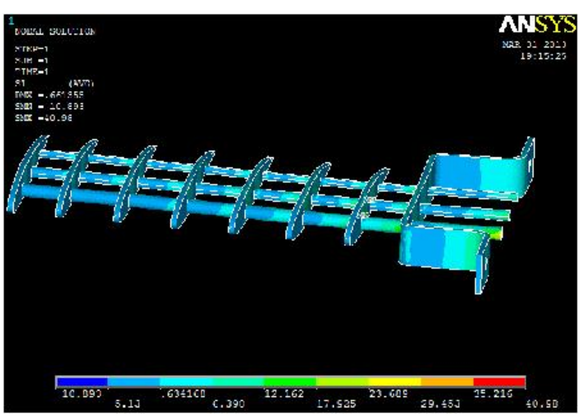
Solution>Analysis Type>New Analysis>Static
Solution>Analysis Type>Sol'n Controls>Basic>Check Prestress effects
Solution>Define Loads>Apply>Structural>Displacements>On nodes>
Pick bracket holes and cylinders edges and select All DOF



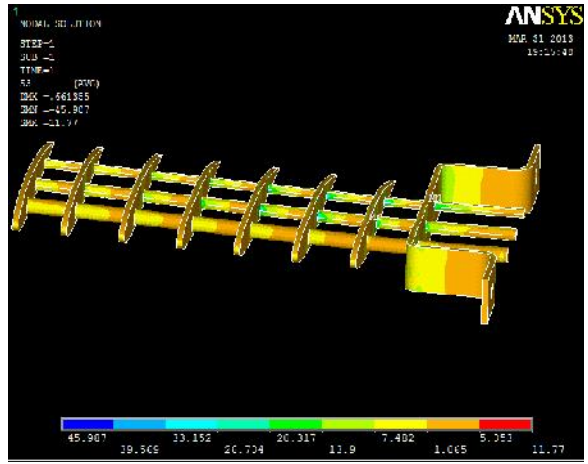
Solution>Define Loads>Apply>Structural>Pressure>On nodes>
Pick all the leading edges of the airfoil and provide pressure value as 1MPa



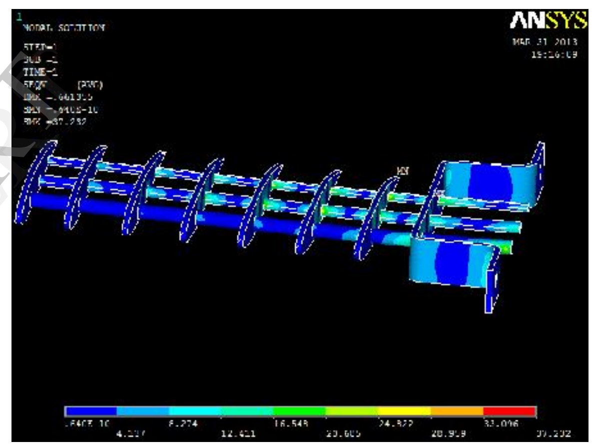
General Postproc>Plot Results>Contour Plot>Nodal Solution>Stress>1st Principal Stress



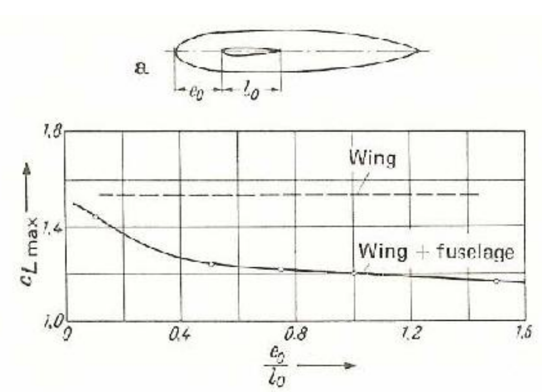
General Postproc>Plot Results>Contour Plot>Nodal Solution>Stress>3rd Principal Stress

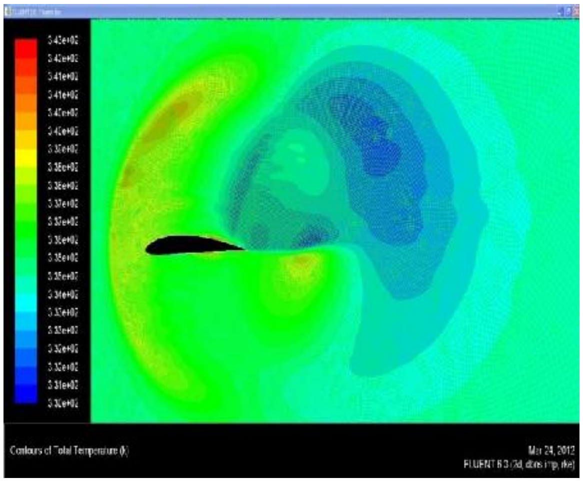


General Postproc>Plot Results>Contour Plot>Nodal Solution>Stress>VonMises stress



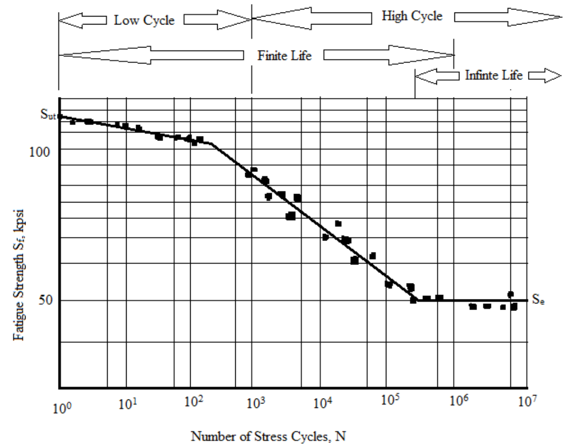
Variation of CL_{MAX} With Chord Length



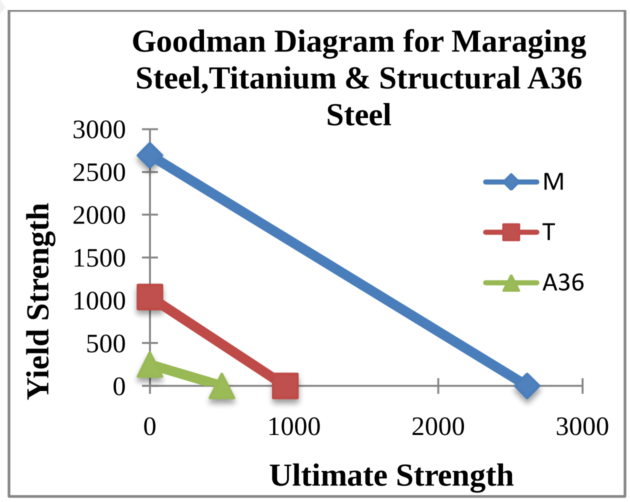


The figure shows effect on dynamic temperature the formation of shockwave leads to rise in temperature and total temperature also increases.
Interference drag comes from the intersection of airstreams that creates eddy currents, turbulence, or restricts smooth airflow. For example, the intersection of the wing and the fuselage at the wing root has significant interference drag. Air flowing around the fuselage collides with air flowing over the wing, merging into a current of air different from the two original currents. The most interference drag is observed when two surfaces meet at perpendicular angles. Fairings are used to reduce this tendency. If a jet fighter carries two identical wing tanks, the overall drag is greater than the sum of the individual tanks because both of these create and generate interference drag. Fairings and distance between lifting surfaces and external components (such as radar antennas hung from wings) reduce interference drag.

RESULTS



This is the main graph which determines the fatigue life of the component. Our component is in high cycle region then we consider stress-life approach. Our wing-bracket interaction model is in high cycle region so we considered stress-life approach which in turn tells that our component is in infinite life region.



CONCLUSION

The wing-fuselage configuration shows flow separation in front of the non-filleted junction with v-shape wing downwash on the fuselage after section. This certainly lowers lifting capability and increases drag due to separation. It is also highly beneficial for studying different characteristics of wing-body geometries. Effective arrangement of Carbon nanotubes in the aircraft structures should be in square grid cross-section, hence it reduces the diameter of the carbon nanotube and the healing agents are implanted in geometric points of the square grid. The carbon nanotubes are helping in increase the lifetime, safety, and cost effectiveness of structures. There is also evidence that carbon nanotubes play a passive role in suppressing the rate at which micro cracks grow in structures.

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