Modelling and Analysis of Aircraft Wind Shield made of PVB and PMMA Material

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ABSTRACT

The windscreen is the part of a car, bus, motorcycle, or tram that faces forward. An airplane's windscreen is an essential part, and the effectiveness of one of its most important features depends on it. Some of the key characteristics of a windscreen are visibility through the canopy, structure stiffness, impact resistance, dependability of the internal mechanics, and construction lightness. The most common material for windshields on light trainer aircraft is glass. It is suggested that the glass be replaced by a light trainer in the current development. Two other materials—polymethyl methacrylate (PMMA) and polyvinyl butyl (PVB) for windshields—were considered in the current experiment. The windshield was turned into a 3D model using Pro/Engineer software. Dynamic analysis utilizing Computational Fluid Dynamics (CFD), the Fluid-Solid-Interaction (FSI) approach, and ANSYS was carried out to evaluate fluid pressure, stress distribution, and deformation in windshield with various air speeds. Analysis is conducted on all three materials at various air speeds of 900, 800, 600, and 400 km/hr. In this thesis, the pressure, velocity, stress, and deformation are calculated for various materials and speeds using the FSI analysis.

Keywords— CFD, PMMA,PVB,FSI Technique, wind shield, ANSYS.

#  INTRODUCTION

The front window of an airplane, automobile, bus, motorcycle, or tram is its windshield (in North America) or windscreen (in Commonwealth nations). The majority of modern windshields are constructed of laminated safety glass, a type of treated glass, which is bonded into the window frame and made of two (usually curved) sheets of glass with a plastic layer fused between them for protection. Windshields on motorcycles are frequently made of high-impact acrylic plastic. Windshields provide a front window with an aerodynamic design while protecting the car's occupants from the wind and flying debris including dust, insects, and rocks. On the outside of the screen, a UV coating might be placed to block harmful ultraviolet rays. This is normally not necessary, though, as the majority of car windshields are made of laminated safety glass. The majority of UV-B is absorbed by the glass, and the remaining UV-B and most UV-A are absorbed by the PVB bonding layer. On motorcycles, its primary purpose is to partially — compared to a car — protect the rider from the wind. In sports and racing bikes, the windshield's primary purpose is to lessen drag when the rider achieves the best aerodynamic configuration with his or her body working in concert with the vehicle. It does not protect the rider from the wind when sitting upright. To compare and assess fluid pressure, stress distribution, and deformation in wind shields for all 4 materials, computational fluid dynamics (CFD) and fluid-solid interaction (FSI) methods are used with varying air speeds. Applying air speeds of 900, 800, 600, 555, and 400 km/hr to the windshield during fluid analysis yields pressure readings, which are used to calculate pressures during stress analysis.

# MATERIALS AND METHODS

Dynamic analysis utilizing Computational Fluid Dynamics (CFD), the Fluid-Solid-Interaction (FSI) approach, and ANSYS was carried out to evaluate fluid pressure, stress distribution, and deformation in windshield with various air speeds. Analysis is conducted on all three materials at various air speeds of 900, 800, 600, and 400 km/hr. Two alternative materials—polymethyl methacrylate and polyvinyl butyl for windshields—were considered in the current experiment. Using Pro/Engineer software, a 3D model of the windshield was created.

 Table 1: ANSYS Parameters

|  |  |  |
| --- | --- | --- |
| Speed (km/hr) | Velocity (m/s) | materials |
| 900 | 250 | **Glass,** |
| 800 | 222.22 | **polymethyl** |
| 600 | 166.66 | **methacrylate &** |
| 400 | 111.11 | **Poly vinyl butyl** |

Fluid-structure interaction (FSI) is a method of connecting the laws that govern fluid dynamics and structural mechanics. A deformable or moving structure interacts with an external or internal fluid flow, which may be steady or oscillatory, to produce this phenomenon. When a fluid flow interacts with a structure, stresses and strains are exerted to the solid, which can result in deformations. These deformations can be quite large to extremely little, depending on the flow's pressure, velocity, and material composition. If the structure's deformations are relatively small and the time fluctuations are also fairly gradual, the behavior of the fluid won't be much affected by the deformation, thus we just need to be concerned about the ensuing stresses in the solid components. However, if the time fluctuations are quick—greater than a few cycles per second—even slight structural deformations will result in pressure waves in the fluid. Structures vibrating as a result of these pressure waves produce sound. As opposed to fluid-structure interactions, such problems can be addressed as acoustic problems. The use of a bidirectionally coupled multiphysics study is required to address the problem since significant structural deformation will alter the fluid's velocity and pressure fields. Fluid flow and pressure have an effect on the fields of both flow and pressure as well as the structural deformations.

# RESULTS AND DISCUSSIONS

As seen in the fig.1 and 2, finite element analysis (FEA) represents an actual project as a "mesh" made up of a number of little, connected, regularly formed tetrahedrons. After which enormous arrays of simultaneous equations are built up and solved. The results are more precise as the mesh is finer, but more processing power is needed. The input parameters cannot be used directly in CFD. As a result, boundary conditions for air entry and air outflow must be established.

Select faces → right click → create named section → enter name → air inlet Select faces → right click

→ create named section → enter name → air outlet

* 1. **Fig. 1 Air Inlet Fig. 2 Air outlet**

Update project>setup>edit>model>select>energy equation (on)>ok

Materials> Materials > new >create or edit >specify fluid material or specify properties > ok

Select fluid

Boundary conditions>inlet>enter required inlet values Inlet air Velocity

Table 2. Boundary Conditions

|  |  |
| --- | --- |
| Speed (km/hr) | Velocity (m/s) |
| 900 | 250 |
| 800 | 222.22 |
| 600 | 166.66 |
| 400 | 111.11 |

Pressure=101325Pa Temperature=313K

Solution > Solution Initialization > Hybrid Initialization >done

Run calculations > no of iterations = 100> calculate > calculation complete>ok

 **Results**>edit>select contours>ok>select location (inlet, outlet, wall.etc)>select pressure>apply

**3.1 Pressure Counter:**

The highest static pressure is located in the corner areas of the border of the inlet, and the minimum static pressure is located at the boundary of the outflow, as shown by the contour map above. The highest static pressure is 7.51e+02Pa, while the minimum static pressure is 3.75e+01Pa, as seen by the contour map above.

**3.2 Velocity Magnitude:**

The wind shield's greatest velocity magnitude is in the boundary's inside and minimum velocity magnitude is outside, according to the contour map shown above. The greatest velocity is 2.51e+02m/s, and the minimum velocity is 1.28e+01m/s, as seen by the contour figure above.

|  |  |
| --- | --- |
|  Fig 3: Pressure Counter | Fig 4. Velocity Magnitude |

**3.3 Deformation:**

This technique creates the distortion of the wind shield brought on by opposing air forces, which is essential for the wind shield's precise operation in challenging conditions. The wind shield has been observed to have undergone substantial deformation. When the applied loads, namely velocity and pressure, are imported and put on the wind shield, the maximum deformation value is 2.5173e-5. The greatest stress value at one side of the wind shield's edge when the loads, pressure and velocity, are applied is 0.0082824MPa, while the minimum stress value is 0.00012595MPa. The greatest strain value at one edge of the wind shield is 1.2947e-7, and the minimum strain is 2.7565e-9 when the stresses, such as pressure and velocity, are applied.

|  |  |
| --- | --- |
| Fig 5. Deformation in Glass Material | Fig 6. Deformation in Polymethyl Methacrylate (PMMA)  |
|  Fig 7. Maximum stress |  Fig 8. Maximum strain |
| Fig 9. Deformation in Poly Vinyl Butyl material(PVB) |  Fig 10.Pressure Contour  |

Table 3. CFD Result Table

|  |  |  |
| --- | --- | --- |
| **Speed km/hr** | **Pressure(Pa)** | **Velocity(m/s)** |
| 900 | 7.51e+02 | 2.51e+02 |
| 800 | 6.07e+02 | 2.23e+02 |
| 600 | 3.54e+02 | 1.67e+02 |
| 400 | 1.66e+02 | 1.12e+02 |

Table 4. Structural analysis table with stress and strain values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Speed km/hr** | **Material** | **Deformation Values in mm** | **Stress values in mpa** | **Strain values in mpa** |
| 900 | Glass material | 2.5173e-5 | 0.0082824 | 1.2947e-7 |
| PMMA | 3.7746e-6 | 0.0082039 | 2.2197e-8 |
| PVB | 0.000533 | 0.0082324 | 3.1699e-6 |
| 800 |  Glass material | 2.0156e-5 | 0.0066598 | 1.041e-7 |
| PMMA | 3.0223e-6 | 0.0066007 | 1.7859e-8 |
| PVB | 0.00042677 | 0.0066238 | 2.5505e-6 |
| 600 | Glass material | 1.1825e-5 | 0.0039146 | 6.1193e-8 |
| PMMA | 1.7731e-6 | 0.0038801 | 1.0498e-8 |
| PVB | 0.00025038 | 0.0038937 | 1.4993e-6 |
| 400 | Glass material | 5.6415e-6 | 0.0018608 | 2.9088e-8 |
| PMMA | 8.4594e-7 | 0.0018433 | 4.9874e-9 |
| PVB | 0.00011945 | 0.0018498 | 7.1224e-7 |

* 1. **Pressure Plot**

Figure 11 above depicts a plot between maximum pressure and velocity using the FSI technique. The graphic shows the fluctuation in the maximum static pressure. Speed increases result in a rise in maximum static pressure.

8.00E+02

7.00E+02

6.00E+02

5.00E+02

4.00E+02

3.00E+02

2.00E+02

1.00E+02

0.00E+00

900

800

600

400

**speed (km/hr)**

Fig 11. Pressure plots at various speeds (Pressure vs Speed)

* 1. **Velocity Plots:**

**deformation(mm)**

Figure 12 above depicts a plot between maximum velocity and speeds using the FSI technique. The graphic shows the fluctuation in maximum velocity. Speed increases result in an increase in maximum velocity.

3.00E+02

2.50E+02

2.00E+02

1.50E+02

1.00E+02

5.00E+01

0.00E+00

900

800

600

400

**speed (km/hr)**

Fig 12.Velocity Plots (Velocity vs Speed)

**IV. CONCLUSION**

In this work, a windscreen for a light trainer aircraft is investigated using computational fluid dynamics (CFD) and a fluid-solid interaction (FSI) technique at various air speeds using ANSYS in order to evaluate fluid pressure, stress distribution, and deformation. The windshield's 3D model was made with the help of the Pro-E Wildfire 5.0 program. The three materials that were considered to evaluate the deformation and stress at various speeds of 900, 800, 600, and 400 km/hr were glass, poly methyl methacrylate, and poly vinyl butyl. According to the results of the CFD research, pressure and velocity increase as air speed increases. We can observe from the CFD analysis that as speed is raised, velocity also does so while pressure declines. As we can see from the static analysis, the stress values are decreased by reducing the speeds, and the various pressure values are collected from the CFD study. The stress value of poly methyl methacrylate material is lower than that of glass and poly vinyl butyl. Therefore, we may conclude that poly methyl methacrylate is a superior material for wind shields.

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