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Comparative Analysis of Linear and Non Linear FEM Analysis of a Fuselage

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ABSTRACT

The term "stiffness" defines the fundamental difference between linear and nonlinear analysis. Stiffness is a property of a part or assembly that characterizes its response to the applied load. A number of factors affect stiffness like shape, material and part support.

When a structure deforms under a load its stiffness changes-

- If the change in stiffness is small enough then it is safe to assume that neither the shape nor material properties change at all during the deformation process. This assumption is the fundamental principle of linear analysis. Regardless of how much the model deforms, whether the load gets applied in one step or gradually, and no matter how high the stresses that develop in response to that load may be, the model retains its initial stiffness.
- On the other hand if structure deforms by large amount and the material reaches its failure limit, the material properties will change. non linear analysis is basically done when there are contact, nonlinear materials, or forces that push past the yield strength.

We will try to see this difference through FEM analysis of a fuselage section.

General Terms

Non linear analysis, fuselage, stringers, longerons

Keywords

FEM analysis, Fuselage, shear clip, catia, ansys

1. INTRODUCTION

Fuselage

Fuselage of a modern aircraft is a stiffened shell commonly referred to as semi-monocoque construction. In order to support the skin, it is necessary to provide stiffening members like frames, bulkheads, stringers and longerons.

Fuselage as a beam member contains longitudinal elements (longerons and stringers) and transverse elements (frames and bulkheads) and its external skin.

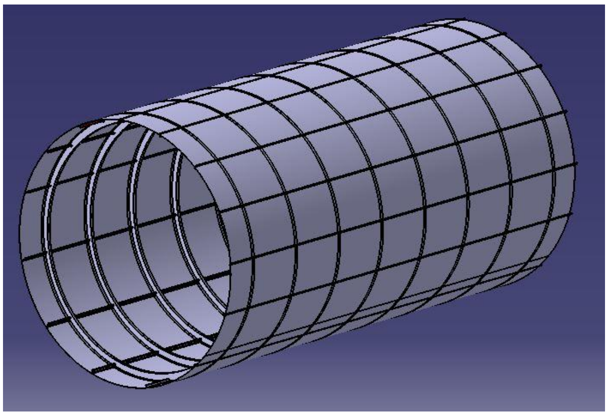

Figure 1 Section of a Fuselage

Skin

It carries the shear from the applied external transverse and torsional forces and cabin pressure. Buckling of skin is not an important factor in limiting the ultimate strength of the structural system.

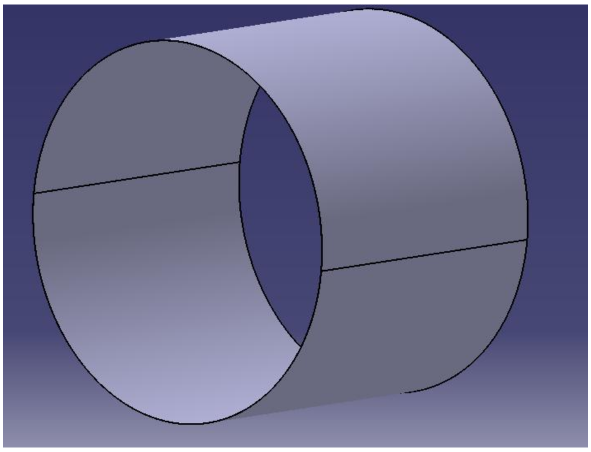

Figure 2 Skin

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Stringers

In addition to stabilizing the external skin, it also carry axial loads by bending moment. Longitudinal stringers provide efficient resistance to compressive stresses.

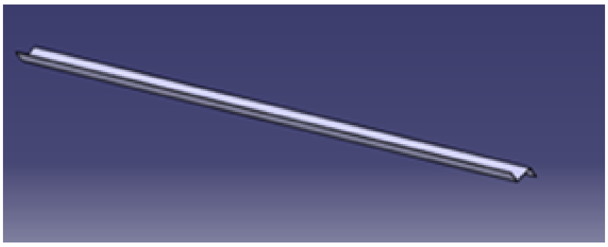

Figure 3 Stringers can be of any shape, in this paper a Z section stringer is chosen

Longerons

They carry the major portion of the fuselage bending moment, loaded by axial forces resulting from the bending moment. They are thicker in width but extends same in length.

Frames

It primarily serve to maintain the shape of the fuselage and to reduce the column length of the stringers to prevent general instability of the structure. Frame loads are generally small and often tend to balance each other and as a result, frames are generally of light construction.

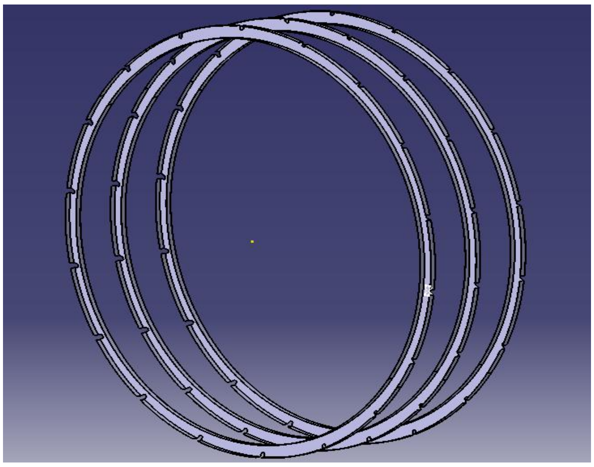

Figure 4 Three adjacent Frames

Bulkhead

They are provided at points of introduction of concentrated forces such as those from the wings, tail surfaces and landing gear. Unlike frames, the bulkhead structure is quite substantial and serve to distribute the applied load into the fuselage skin. Their construction is similar to stringers, just they are very much thicker than frame members.

Shear-clip

They join stringers to the frame and allows the load path from skin>stringers>shear-clip>frame.

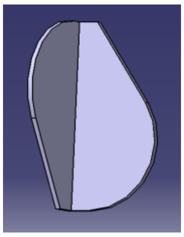

Figure 5 Shear clip

2. MATERIAL USED

Table 1, Mechanical Properties of AL 7075

Density	2.81 g/cm³
Elastic Modulus (young's modulus)	72 GPa
Tensile Strength: Yield (Proof)	510 MPa
Tensile Strength: Ultimate (UTS)	580 MPa
Strength to Weight Ratio	207 kN-m/kg
Shear Strength	331 MPa

3. DESIGN METHODOLOGY

First made a fuselage section of size comparable to a passenger aircraft with three frames, just to lower the analysis time

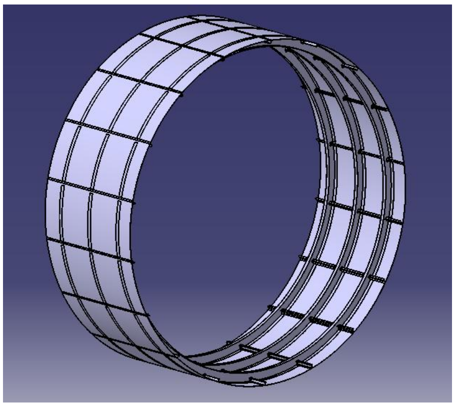

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Figure 6 A small section of a fuselage

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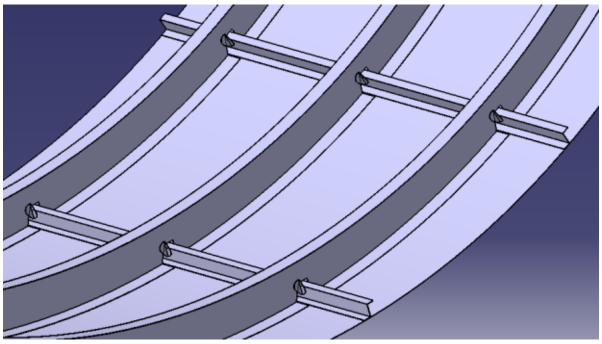

Figure 7 Enlarged view

Then extracted the midsection of all the parts. This is done in order to do 1-D analysis. Doing a 3D analysis considerably increases the time.

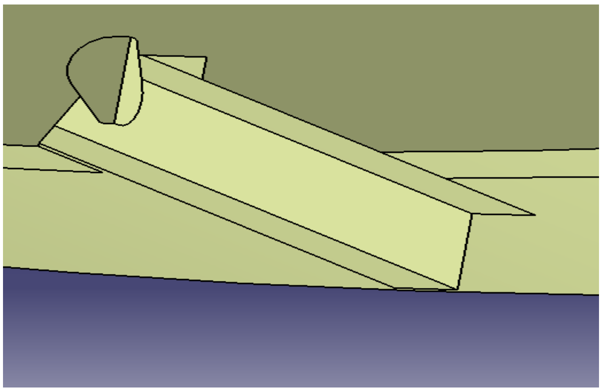

Figure 8 Joining arrangement of stringer and frame with help of shear clip

4. FEM ANALYSIS

Imported the catia part to ANSYS for structural analysis and did the 2-D meshing of fuselage.

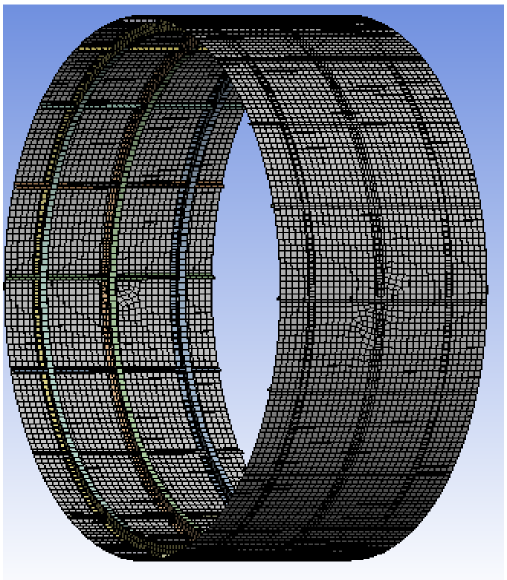

Figure 9 Meshed model of the fuselage section

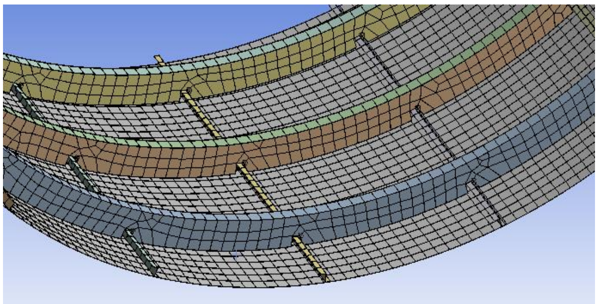

Figure 10 Enlarged meshed model

4.1 Applying load and constraints

Applied the motion constraint at the ends (where it is connected to other part of the frame) and pressure differential of 0.075 MPa.

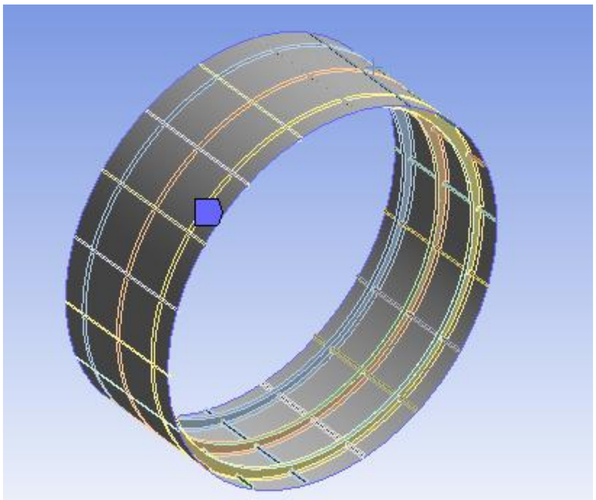

Figure 11 Applying position constraint

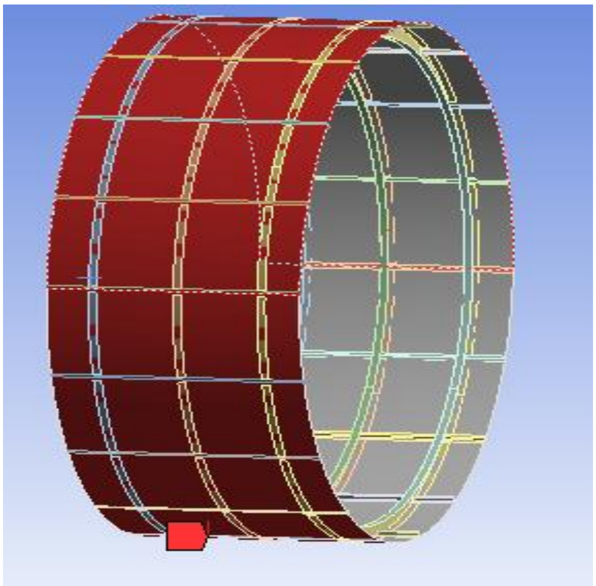

Figure 12 Applying load

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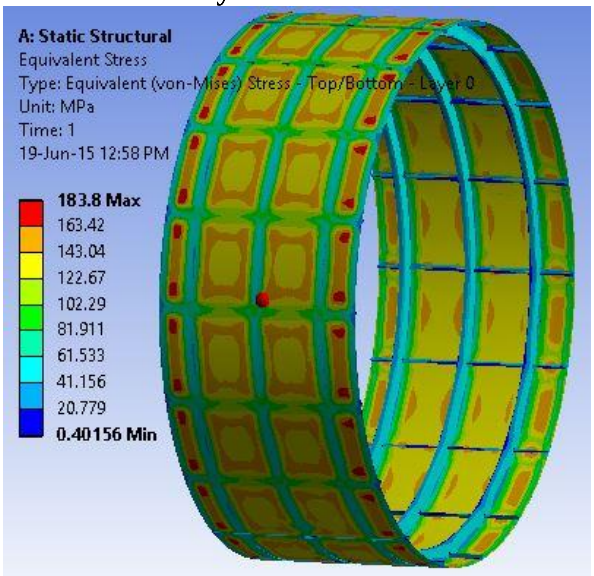
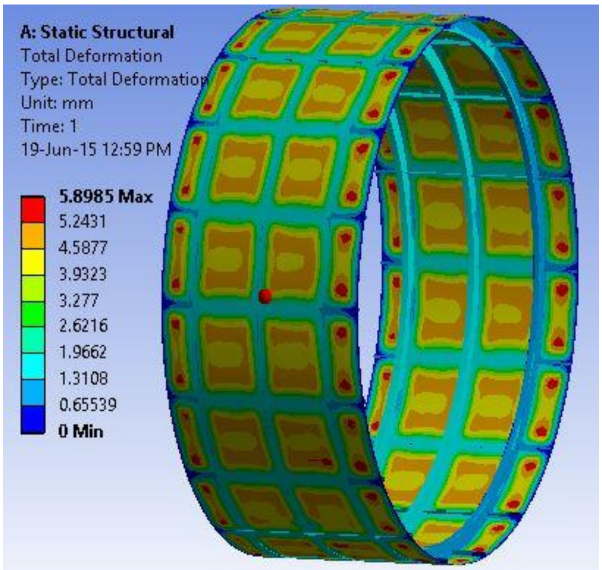
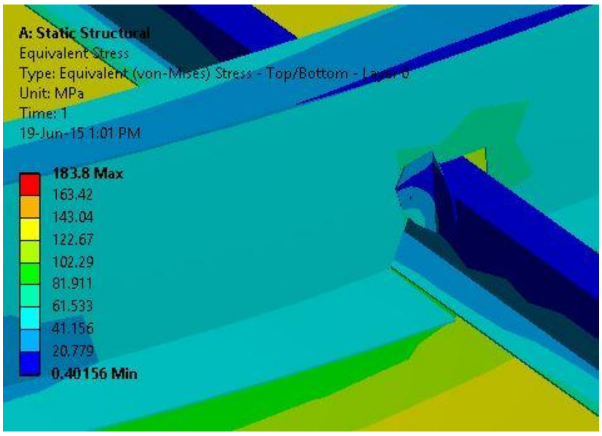
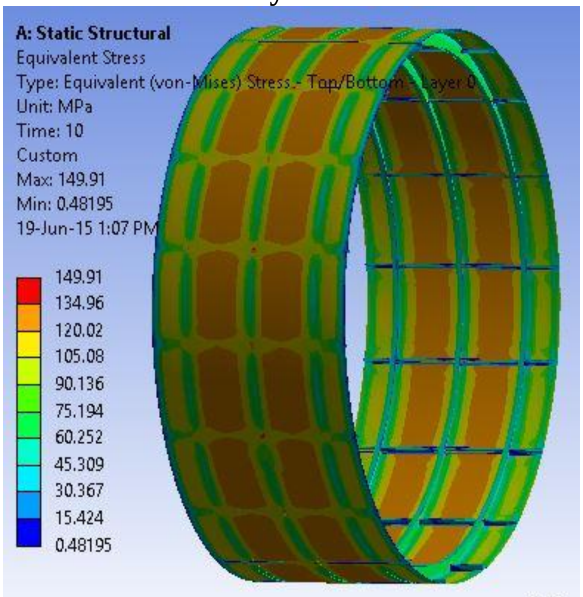
4.2 Linear analysis

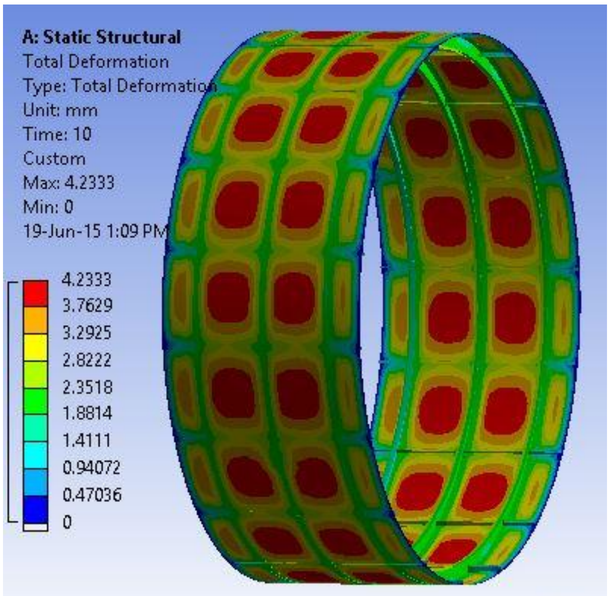






4.3 Non linear analysis





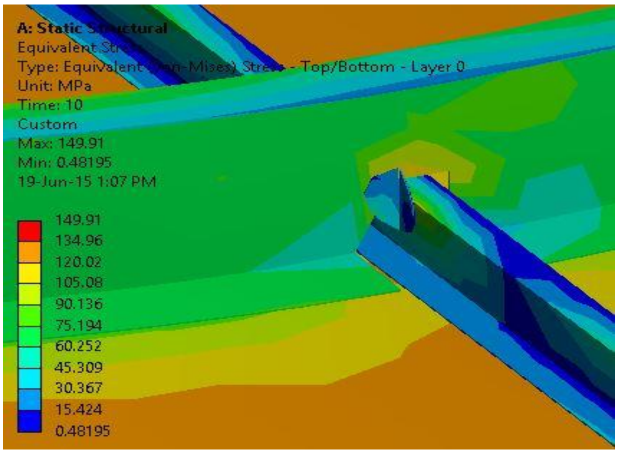


Table 2: Comparative stress and deflection analysis

	Stress (MPa)	Deflection (mm)
Linear	183.8	5.898
Non linear	149.91	4.233

5. CONCLUSION

We found that linear stress comes out to be 183.8 MPa which is greater than non linear stress of 149.91Mpa. The non linear stress is much more closer than actual value and find its implication in further weight reduction and optimization.

Finite element analysis (FEA) is now more commonly used in design engineering. CAD software also now comes with built-in FEA capabilities.

6. ACKNOWLEDGMENTS

I would like to express a deep sense of gratitude to my colleagues and friends, without them it would not be possible to pursue my research work in this manner. I also would like to thank my parents for their support. Finally, I express my indebtedness to all who have directly or indirectly contributed to the successful completion of my research work.

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