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Aerospace Structures - Conventional Aircraft Wing Box Structure Reinforcement (Idealization) – FEA methodology – [Aerospace Structural Reinforcement]

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Abstract: As an Aerospace Structures Engineer, the main apotheosis of this research was to reinforce a conventional wing box structure – idealization based using various FEA methodologies, along with various FEA packages used for modelling and reinforcing the structure which includes Strand 7, MSC Patran, and for performing the deformation on the mode of linear static analysis, determining post-buckling behaviour of the skin panel with respect to ribs and stringers supporting the skin subjected to pressurised loading, vibration analysis and Global Strength FEA with 'g' force on application of a point load on a single structural component. The wing box structure consists of the structural components such as front spar, rear spar, ribs, stringers, and the skin, which when integrated, and on reinforcement form the wing box structure of the wing of an aircraft. Here the wing box structure is taken as a whole to reinforce, and when performing the Structural Analysis the Front Spar is taken into consideration, which is a C- channel beam cross section, assumed to be as a Cantilever beam with a Point load application. The Solver is Linear Static – Structural analysis, to calculate the Bending Moment, Shear Force and deformation of the structural beam component on Strand 7, MSC Patran and Abaqus. Here as the beam element is taken into consideration for analysis, it will have 6 Degrees of freedom, whereas for the Skin, as it's a plate element, it will have 5 Degrees of Freedom, as they do not account for twisting stiffness normal to the plate surface, and the missing degree of freedom is called as 'Drilling Degree of Freedom'. Furthermore, the whole structural model is reinforced and a Global FEA analysis is done to check for the total deformation of the reinforced structure. Aircrafts and Rocket structures are capable of high-G manoeuvring, the reason which enables them to take tighter turns than the required target, and for this the structure needs to be strong enough to sustain these loads. When such a turn is entered, the structure is highly loaded by the inertia of the payload and the structural mass, and for this an 'Inertia Relief' solver is analysed, which is subjected to high '2g' to '6g' acceleration, which results in deformation of the structure, with a normal pressure force acting. The super structure is reinforced finally with the centre wing box structure and the fuselage along with the wings, after performing all these calculations. Sub-Space Iteration and Negative Eigenvalues including gravity force are taken into consideration.

Keywords: Strand 7, MSC Patran, Abaqus, Global FEA Structural analysis.

I. INTRODUCTION

The apotheosis of this area of research is in juxtaposition with respect to Aerospace Structures (Conventional Aircraft) Design Reinforcement and Finite Element Analysis Methodologies using various FEA tools such as Strand 7, MSC Patran, and Abaqus. Aerospace Structural Engineers are a part of the Aerospace Engineering Design team who provide the enclosure, airframe design and reinforcement, supporting and providing methods for various beam structural members, performing linear static structural analysis on various beam members (SSB, CB) with point loads or UDL assumptions taken into account to perform Global FEA on the entire reinforced structure or simply on a beam structure. Loads commonly acting on Aerospace structures, to be more precise on an aircraft, beam-column members are quite common in airplane structures. For example, the beams of externally braced wing and tail surfaces are typical examples, the air loads producing transverse beam loads and the struts producing axial beam loads. Boundary layer excitation over an aircraft wing, is a typical occurrence taking place due to external pressure continuous vibration/random pressure excitation. Buffeting is a high-frequency instability, caused by airflow separation or shock wave oscillations from one object striking another. It is caused by a sudden impulse of load increasing. It is a random forced vibration. Generally it affects the tail unit of the aircraft structure due to air flow downstream of the wing. Miscellaneous loads acting on an aircraft structure are ground loads: landing, towing, air loads: exerted on the structure during flight by the manoeuvres or by wind gusts (wind shear force), surface loads: acts on the surface of the structure - aerodynamic loads, body forces: acts over the volume of the structure generated by gravitational and inertia effect forces. Passenger aircrafts flying under steady flight, manoeuvre or gust conditions experience pressure distributions on the surface of the skin. The resultants of these pressures cause direct loads such as: bending, shear and torsion in all parts of the structure. A conventional aircraft of a fuselage, pair of wings and a tailplane.

The fuselage carries crew, payload, passengers, cargo, weapons, or fuel. The wings provide lift and the tailplane contributes to directional control. The fuselage is subjected to large concentrated forces such as wing reactions, landing gear reactions, empennage reactions, and should also withstand internal pressures, and to handle these loads efficiently, the fuselage forms circular cross-section beam member or a combination of circular beam elements. The fuselage structure is essentially a single cell thin walled tube with many transverse frames or rings and longitudinal stringers to provide a combined structure which can absorb and transmit the many concentrated and distributed applied forces.

The fuselage structure is essentially a beam structure subjected to bending, torsional and axial forces, consisting of transverse frames and longitudinal stringers. It is a common practice to use the simplified beam theory in calculating the stresses in the skin and stringers of a fuselage structure. Shear force acting on the wing structure is transmitted using the ribs that form the wing structure.

The dead weight of all the payload and fixed equipment inside the fuselage is be carried to the frames and transmitted to the fuselage shell structure. Since the dead weight must be multiplied by the design acceleration factors, these internal loads become quite large in magnitude.

Aircraft structures are complex and the structural subsystem of an aircraft has multiple components that form the wing, fuselage and empennage, which consists of various structural members such as Spars(main load –bearing members in the wing),Wing skin(carries chordwise and spanwise pressure distribution to the ribs and spars) Ribs(forms the wing-box structure that resists wing twist|/torsional force, Stringers(Keeps the skin from bending), fuselage frames/bulkheads(provides support to internal structure and maintains fuselage shape) and longerons(longitudinal fuselage beams).

The focus is therefore emphasized, on the fuselage and wing structural reinforcement, on integration of the stringers, spars, ribs, circular frames, keel beams using the FEA tool – MSC Patran,Wing structural reinforcement – Strand 7,and performing Linear structural analysis of the stringer using MSC Patran and Abaqus(assumed as Cantilever beam C-channel with point load application), Bulkhead structural component structural analysis using MSC Patran to check for deformation on application of loads (C- channel cross-section beam free in 3d space).

WING BOX STRUCTURE AND CENTRE FUSELAGE STRUCTURE REINFORCEMENT – MSC PATRAN FEA TOOL – COMBINATION OF BEAM AND SHELL ELEMENTS

At first the structure was idealized and then superimposed on the FEA tool using different element properties – beam and shell, with material Al2024 for the whole superstructure. For the purpose of elucidation, an Aerospace Structures Engineer needs to first surmise the type of element to be designated.

In this case, it's a Hybrid element type- beam and shell element type. The shape of the element undergoes a stage known as Facetization, depending on the accuracy of the mesh controls assigned, the smaller the number, more accurate is the Beam Element Facetization.Below are the figures of the Aircraft Centre fuselage and wing box structure superstructure reinforcement.

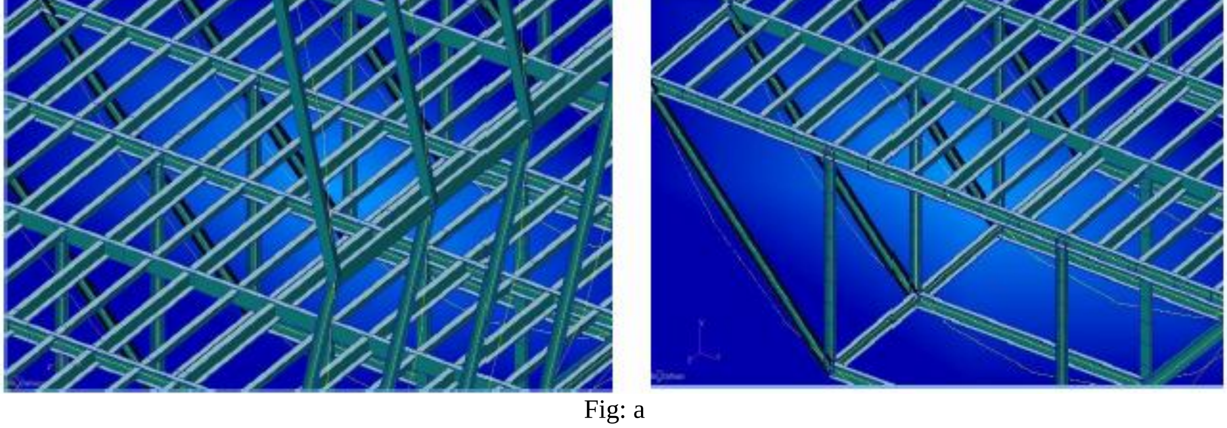

Fig: a

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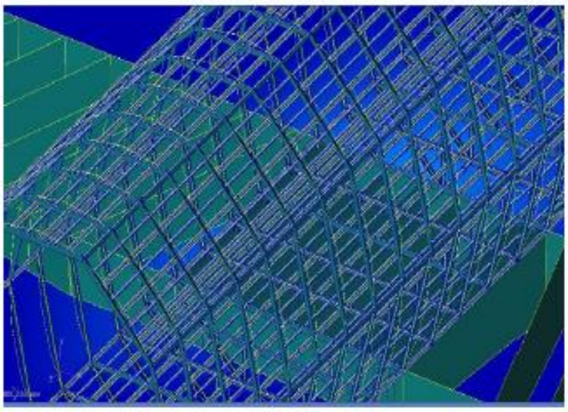
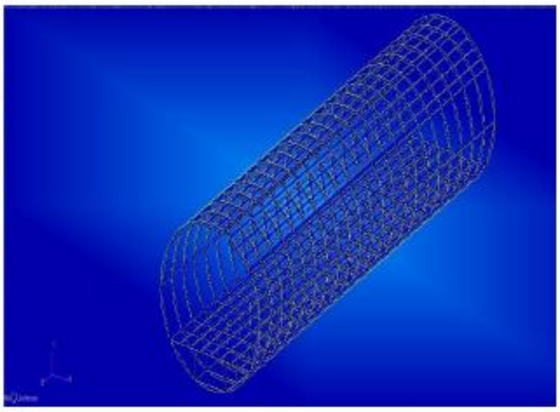

Fig a-b – Beam reinforcement of Centre Fuselage

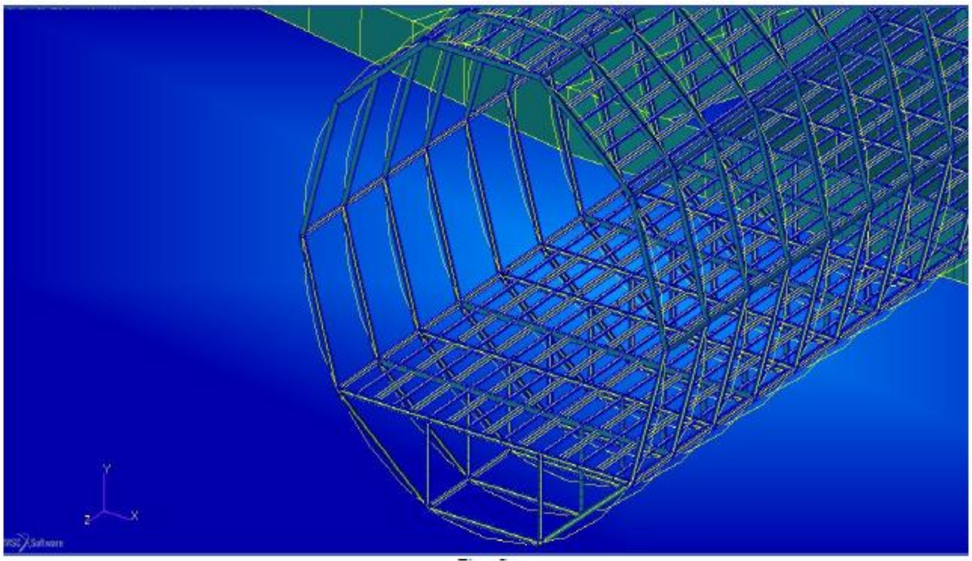

Fig: C

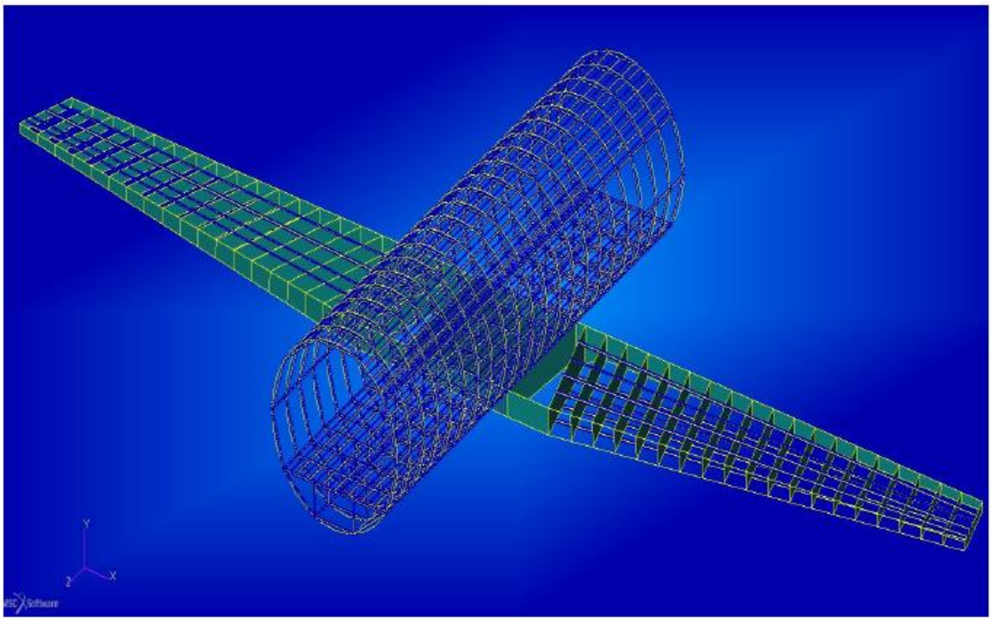

Fig:D

Fig c- d Wing box Structure and Centre fuselage Structure reinforcement

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IDEALIZED WING BOX STRUCTURE – STRAND 7 FEA TOOL – HYBRID ELEMENT – BEAM AND SHELL

In this methodology, it's taken into consideration the same element type used for the structural reinforcement as previous, the only differenece is in the FEA tool used, instead of 'MSC Patran',an another FEA tool 'Strand 7' is being used for the structural reinforcement, by taking two wing box structures into consideration 1) Commercial Passenger aircraft wing box structure 2) Fighter Aircraft wing box structure

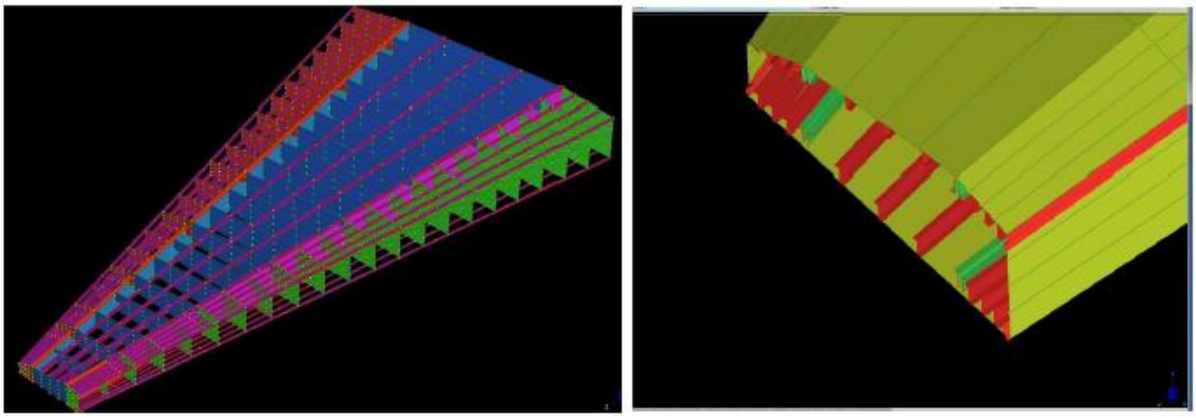

Fig a1 – Commercial Passenger aircraft wing box structure reinforcement

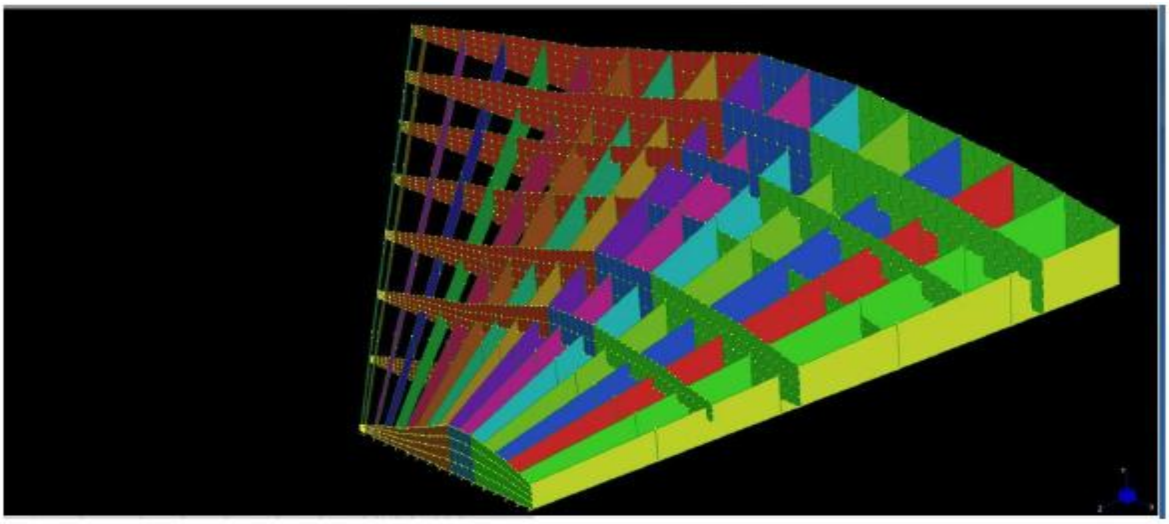

Fig b1 – Fighter aircraft Delta Wing box structure

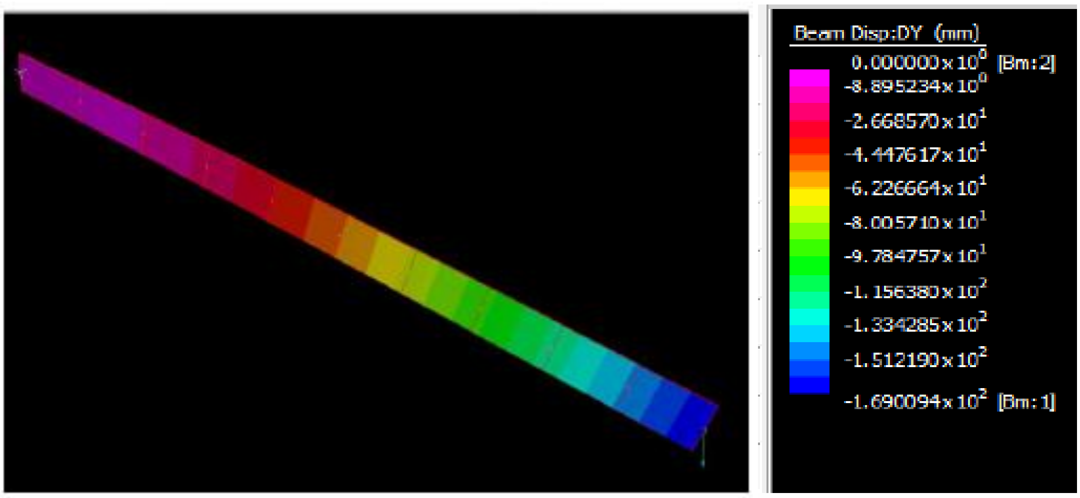

Fig 1 – Strand 7 Beam deflection result

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Fig 2 – MSC Patran Beam Deflection result

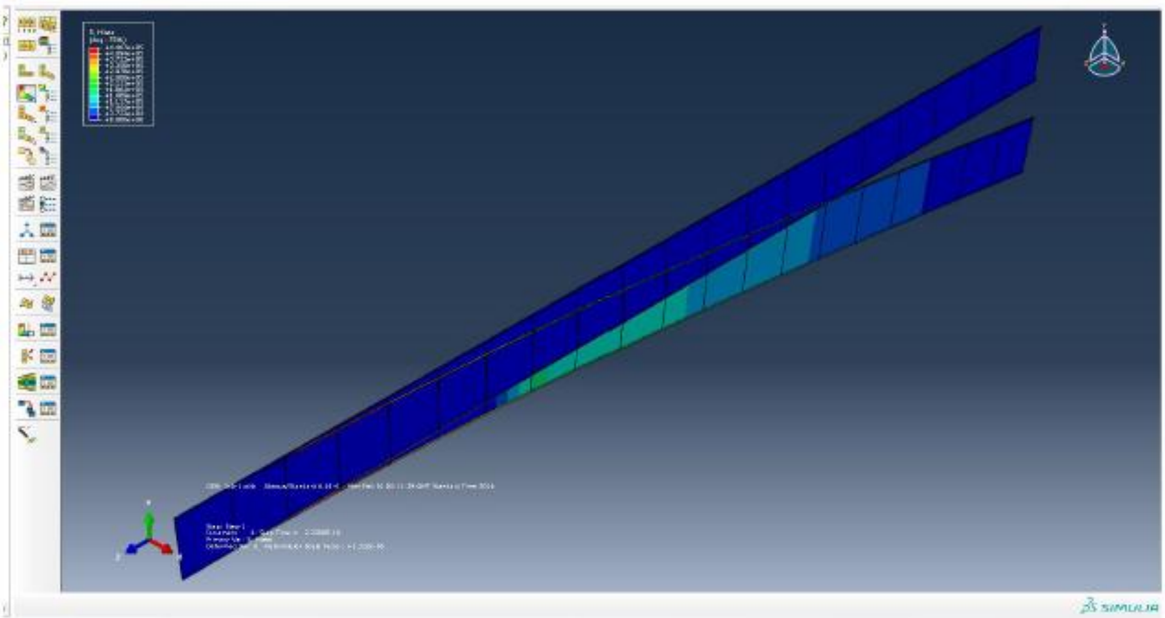

Fig 3 – Abaqus – Beam Deflection result

Displacement results

FEA Tool	Element type	Beam type – C channel	Load Applied(kN)	Results (mm)
Strand 7	Beam element	Cantilever beam	-2	-1.69
MSC Patran	Beam element	Cantilever beam	-2	-1.68
Abaqus	Beam element	Cantilever beam	-2	-1.62

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CONCLUSION

1. Wing box structure and Centre Fuselage structure reinforcement – The tool MSC Patran was chosen for the purpose of the structural reinforcement, as it's highly capable to attain a high degree of accuracy when applying the material properties and also for reinforcement purposes. The tool is capable to mesh and align the beam reinforcement as per the requirement, and is also capable to produce results on application of the load applied for solvers such as deformation-linear static, vibration analysis, and many other results with respect to structural analysis.

2. Beam deformation on application of the load – The results were tested and compared with respect to various FEA tools such as Strand 7,MSC Patran and Abaqus to check for variation on results that were obtained. On the platform of accuracy, almost all the three tools did provide results in terms of accuracy, but not precisely. Results obtained did match the hand calculation for the bending moment, and slightly vary in terms of very minute levels, which is acceptable. It proves that the structure is strong enough to withstand the load, in comparison with respect to Ultimate and Limit load.

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