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Finite Element Analysis of Skin-Stringer Panel for Typical Fuselage Structure

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***Abstract* - Aircraft main components such as wings, fuselage, horizontal and vertical stabilizer, elevators, flaps, rudders, and spoiler structures are covered by panels which constitute the aircraft skin. The aircraft skin consists of different types of panels where curved and flat panels are more often used. The main purpose of this paper is to represent the Finite Element analysis on one of the skin stringer panels of the fuselage and its behaviour when it is subjected to uniaxial loading. The curved panel is considered for this analysis, and its behaviour with different types of stringers which are L section, Z section and inverted hat section made of metallic material is studied. The buckling analysis is carried out individually for different stringers with three different finite element approaches which are 1D, 2D and 2D with proper idealization of rivets. After the analysis of all the three types of stringers, comparison is carried out among them to infer which is the most suitable stringer for the curved panel when subjected to uniaxial loading. This study can lead to further analysis of the panel constructed of a composite material.**

Keywords – Aircraft skin, stringer, fuselage, curved panel, finite element analysis

I. INTRODUCTION

Panels are majorly found in all most all external parts of aircraft such as wing, fuselage, vertical stabilizer, horizontal stabilizer, etc. Wing mainly consist of rib, stringers, spars, where all this is covered by a flat panel or the curved panel. Flat panel can be seen most of the time on the top and bottom surface of the wing which covers the inner structure and gives suitable surface for the aerodynamics. Flat panels can also be seen in wings main components such as flaps, spoilers, Ailerons, elevators, rudders in the stabilizers.

II. LITERATURE SURVEY

According to a study by Sridhar Chintapalli *et al*. the ability of the panel to resist the compressive load is verified via a study on stability of the structure by computing the critical buckling load of the stiffened panel whereas the ability to resist the tensile loading is assessed through damage tolerance analysis of the lower wing panels. The design methodology of the panel subjected to compression includes analysing general and local failure modes or global and local mode shapes as well as the panel beam column analysis that are common in aerospace compression structures. Linear Elastic Fracture Mechanics theory is applied for the design of the tension panels where the Boundary Element Method is used to perform numerical crack growth analysis [1].

As studied by Amandeep Singh Sivia *et al*, the design & analysis of skin-stringer panel is an important part of the design process. The lift generated by the wing opposes the weight of the aircraft and thus generates bending. Depending on their location and type of stringers, stiffened panels are mainly loaded in compression and tension. Upper skin-stringer panels are typically subjected to compressive load while the lower panels subjected to tensile loads. The ability to resist the compressive loads is analysed through a stability study to compute the critical buckling load [2].

According to a study done by Sreenivasa R *et al* the selection of suitable materials in the construction of aircrafts is a complex process and is basically a trade-off amongst various conflicting requirement such as high strength to weight ratio, lower density, better fatigue related properties and easy manufacturability and processing. The material used in various parts of vehicle structures generally are selected by different criteria. The material used in the fuselage structure is Aluminium alloy 2024-T351 [3].

The static analysis can be made by different ways such that different conceptual designs that included as frames spacing was smaller compared to stringers spacing, frames spacing was larger compared to stringers spacing, frames and stringers spacing was approximately equal [4] and laminate constructions for stiffened fuselage panels in aircraft design [5]. The researchers also made analysis related to predicting the service durability of aerospace components [6], residual strength pressure tests analysis of stringer and frame stiffened aluminium fuselage panel with longitudinal cracks [7], weight comparison analysis between a composite fuselage and an aluminium alloy fuselage [8], impact of engine debris on fuselage skin panel [9], damage analysis of aircraft structure due to bird strike [10], damage prediction in airplane flap structure due to bird strike [11], and analysis of high energy impact on a sheet metal aircraft structures [12]. The researchers have worked on aircraft fuselage analysis, but they took flat riveted panel for analysis but fuselage has a circular arrangement with assembled parts due to this it is very difficult to find a critical area where maximum Von-Mises stress occur in fuselage structure under uniform axial compression or shear. The scope is to study the effect of buckling on circular assembled fuselage skin panel with or without airframe [3].

As Studied by Attaullah Khan *et al.* mostly aluminium 2024 T3 is used for skin stringers and frames. Airframe designers still demand strong, stiff material at an acceptable weight and cost. So, alloys of aluminium, steel and titanium are the most suitable for airframe design. Other aluminium alloys i.e. aluminium iron molybdenum zirconium, function well at high temperature to be competitive with titanium up to 600^0F [13].

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III. METHODOLOGY

Flat panels are naturally less stiff than curved panels under uniaxial loading, indicating that flat panels can sustain less uniaxial loading and critical buckling stress will be achieved faster than the curved panel and the critical buckling stress value will be lower in the flat panel than the curved panel. For the calculation of the critical buckling stress for flat panel with all edges simply supported and subjected to uniaxial uniform compression loads on two opposite edges as shown in Fig.1, we use the formula (1) mentioned below [14].

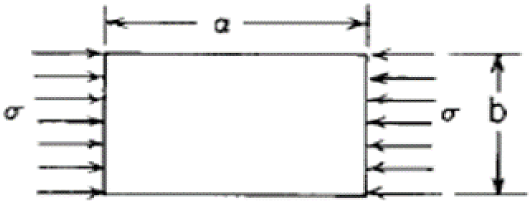

Fig. 1. Uniaxial Compressive load on a flat panel.

$$\sigma' = K \frac{E}{(1-\upsilon^2)} (t/b)^2 \quad (1)$$

Where,
σ' is critical compressive stress.
K can be found from the $\frac{a}{b}$ ratio.
E is modulus of elasticity.
t is the thickness of the plate.
υ is the Poisson's ratio.
a is the horizontal dimension of the plate.
b is the vertical dimension of the plate.

Flat panels can be in different shapes and size such as square, rectangle, triangle, trapezoidal etc, as per the requirement. Flat panels can be subjected to biaxial loading, pure shear or combined loading as well, there are different formulas for different loading and support conditions. Flat panels can be stiffened and critical buckling stress can be increased by the incorporation of the suitable stringers.

Curved panels are mostly seen in the leading edge of the wing, leading edge of vertical stabilizers and horizontal stabilizer, also the fuselage is mainly a combination of several curved panels. Main structures such as frames and bulkheads are covered by curved panels which make up the complete fuselage. Fuselage is divided into three separate sections which are front section, mid-section and rear section, all these sections are joined together with the help of fasteners. Flush-head rivets are predominantly utilized for this purpose. Though curved panels can sustain more uniaxial loading and has higher critical stress value compared to the flat panels, the loading on curved panels is possible only in uniaxial direction and it is not suitable for a panel to have high loads on both direction (biaxial direction). They can also sustain uniform shear on all edges and the loading should always be on the vertical section of the curved panel. As the radius of curvature of the panel increases, it's stiffness also increases and it achieves higher critical stress. For the calculation of the critical buckling stress for a curved panel shown in Fig.2, when it is subjected to uniform compression on two opposite edges and when all the edges are simply supported, we use formula (2) as follows [15].

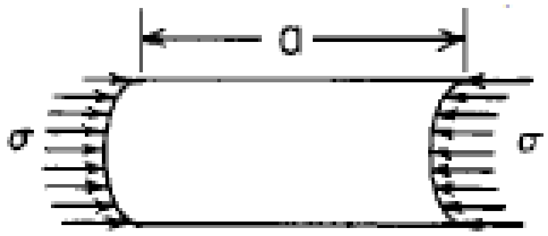

Fig. 2. Curved panel under uniform compressive loading condition.

$$\sigma' = \frac{1}{6}\frac{E}{1-\upsilon^2}\sqrt{12(1-\upsilon^2)(t/r)^2 + \left(\frac{\pi t}{b}\right)^4 + \left(\frac{\pi t}{b}\right)^2} \quad (2)$$

Where,
σ' is critical compressive stress.
E is modulus of elasticity.
t is the thickness of the plate.
υ is the Poisson's ratio.
a is the horizontal dimension of the plate
b is width of the panel measured on arc

For a curved panel loaded under uniform shear and simply supported on all four edges as shown then the Fig.3, the formula to calculate critical buckling stress (3) is given as follows [16].

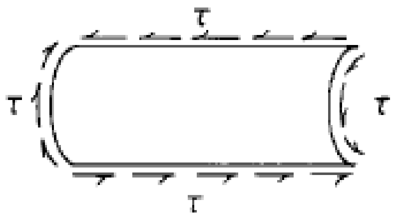

Fig. 3. Shear force acting on the curved panel.

$$\tau' = 0.1E\frac{t}{r} + 5E\left(\frac{t}{b}\right)^2 \quad (3)$$

Where,
τ' is uniform shear force acting on the edges of the plate.
t is the thickness of the panel.
b is width of the panel measured on arc.
r is radius of curvature.

Curved panel located in the leading edge of the aircraft wing, horizontal and vertical stabilizers, the fuselage, the empennage etc. are responsible for sustaining high amounts of compressive loads. The curved panels are stiffer up to an extent due to their inherent nature, but in order to provide for the very high compressive loads that they are subjected to, long continuous stiffening members with suitable cross sections called stringers are provided. If these members are placed between two frames or formers then they are referred to as Longerons, which are continuous heavy machined members.

In this study the methodology involves calculating the critical buckling stress for certain dimensions of the panel, modelling the skin-stringer panel and performing the finite element analysis and analyzing the results, The mathematical calculation is made to find out what is the critical buckling stress of the curved panel which has the dimension of 726mm in the horizontal direction which is considered as 'a' and 853mm in vertical direction which is considered as 'b' with an arc length of 856mm and panel diameter of 6000mm and thickness of 3mm. The material chosen for this curved panel is Al2024 which is Aluminium 2024. Using this measurements and formula as mentioned before calculation of critical buckling stress is performed (4), which is represented as follows.

After substituting the respective values in to the formula we obtain:

$$\sigma' = \frac{1}{6}\frac{E}{1-\upsilon^2}\sqrt{12(1-\upsilon^2)(t/r)^2 + \left(\frac{\pi t}{b}\right)^4 + \left(\frac{\pi t}{b}\right)^2} = 43.9 \text{ N/mm}^2$$

Where,

E represents Young's modulus which is 70000 N/mm^2

υ^2 Represents Poisson's ratio which is 0.3.

t represents the plate thickness which is 3mm.

r represents the radius of the curvature which is 3000mm.

b represents the arc distance which is 853mm.

a is the distance in the horizontal distance which is 726mm.

By the obtained value we can proceed to model the panel and perform the finite element analysis. Depending on the type and size of mesh the loads will be distributed with respect to total number of nodes on the edge 'b'.

Critical buckling stress = 43.94 N/mm^2

Total number of nodes on edge b = 285.

Total number of loads on mid nodes = 397.37 N.

Total number of loads on end nodes = 198.68 N.

Using the above calculations and dimensions, a 2D model of the curved panel is created. As presented in the Fig.4, The size of mesh for the model is. The appropriate boundary conditions are applied to simulate the problem as close to reality as possible. The boundary condition is applied for all the edges as shown in the Fig.5. For the analysis boundary conditions should be simply supported where x and y directions are constrained and z direction will be not constrained which implies that x = 0, y = 0. Another isostatic boundary condition is created where x and y will be without any condition but z = 0, this has to be applied to the centre of the panel.

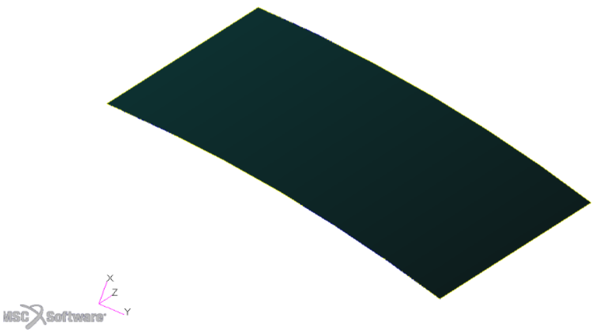

Fig. 4. 2D model of curved panel.

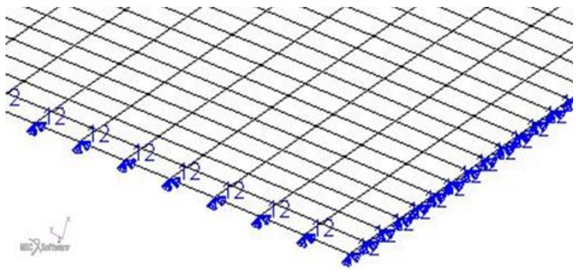

Fig. 5. Boundary condition on each node on the edges for simply supported condition.

After the application of boundary condition load is created where 397.37 N is distributed on ever node of the panel on the b length. On the corner nodes of the panel 198.68 N is distributed which is as shown in the Fig.6.

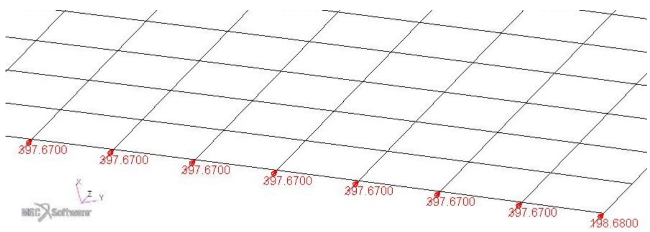

Fig. 6. Load distribution on each node on the b length of the panel.

After the application of the loads on the panel, material property is added. The material chosen for the curved panel is Aluminium 2024. The panel thickness is considered as 3mm and the density of Al2024 material is 0.00278 gm/mm^3 this gives the total mass of the panel as 5183.45gm. Once the problem is given for run in the software, the results can be accessed. Initially curved panel without any kind of stringer is analysed and results are observed as shown in the Fig.7.

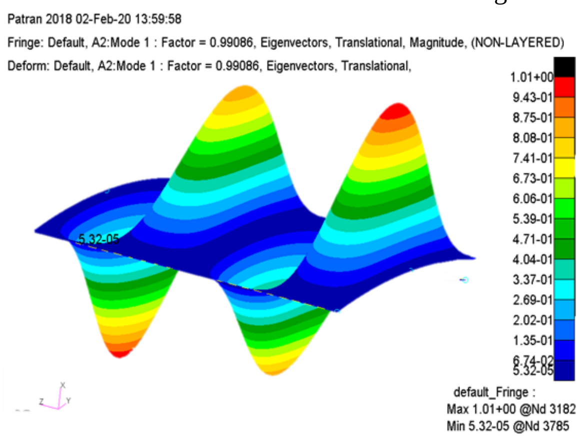

Fig. 7. Analysis result for the curved panel with no stringers.

The first main criteria to be observed in the analysis result is Eigen value which represents buckling factor. If the buckling factor is greater than or equal to 1, we can consider that the panel is stiff for the applied loads, if the Eigen value is less than 1, then it indicates that the panel is not stiff enough. The second criteria to be consider is to observe the mode shape, if there are more than one sinusoidal wave it is known as local buckling mode. These local buckling modes represent that the panel is stiffened and it is buckling within the allowed limit. If there is no local buckling mode then it is considered to be unstiffened panel and global mode shape will be seen, where the mode will not be sinusoidal in nature which will be seen as two half waves on either side of the panel.

Fig.7, represents the analysis for curved panel with no stringer where there is a local buckling modes and Eigen value of 0.99 which indicates the panel is stiff. Though, the Eigen value is 0.99 which is close to 1 it requires stringer to be attached so that panel can sustain even more loads and buckling allowable can be increased which tends to increase of buckling factor. In this paper we have consider the observation between three main stringer cross sections, L, Z and, inverted hat. The stringer mainly consists of flanges and web, where flange is a horizontal section and it can take majority of bending loads whereas the web takes majority of shear loads. Fig.8, Fig.9, shows the stringer shapes and the Table 1. lists the dimensions of the stringers

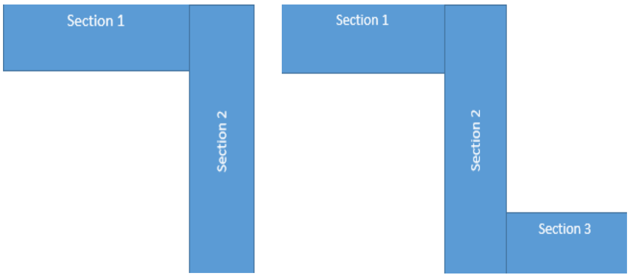

Fig. 8. L and Z shaped stringers.

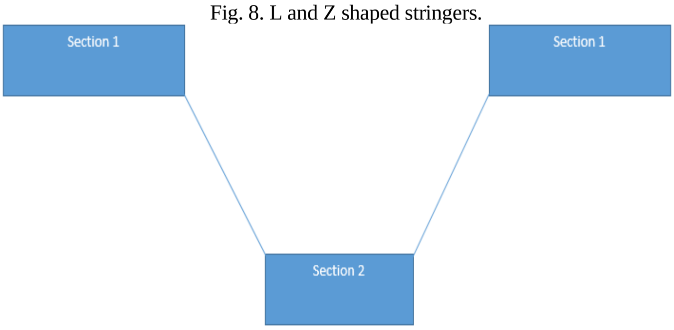

Fig. 9. Inverted hat with tapered angle web.

TABLE 1. DIMENSIONS OF STRINGER SHAPE L, Z AND INVERTED HAT SECTIONS

Section	**Dimensions [a]**			
	Thickness	***Section 1 Flange***	***Section 2 Web***	***Section 3 Flange***
L	***2***	***25***	***32.5***	*-*
Z	***2***	***25***	***32.5***	*20*
Inverted HAT	2	22	-	18

[a] All dimensions are in millimeters

The total height of the inverted hat stringer is 32.5mm and distance between one end of the flange to the other end is 94mm and third section is the web, which is at a suitable angle. These dimensions were obtained by trial and error method and after performing a careful study, dimensions were finalized. The behaviour of the panel is observed with one-dimensional, two-dimensional and two-dimensional with idealization of rivets approach in finite element.

IV. RESULTS AND DISCUSSION

Fig.10, shows the curved panel with the L shaped stringers idealized as one-dimensional elements. Fig.11, shows the analysis plot for the above definition.

Fig. 10. Curved panel with L stringers as 1D elements.

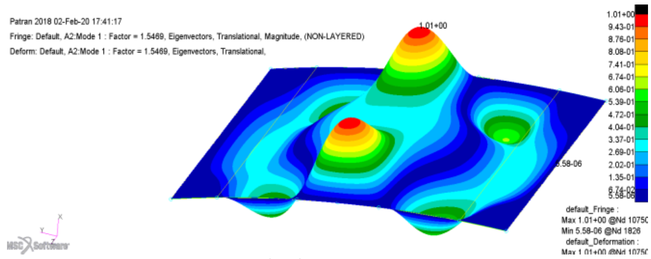

Fig. 11. Analysis result for four L shaped stringer as 1D elements.

When the curved panel is attached with four L shaped stringers at suitable distance idealized as one-dimensional elements, the buckling factor is 1.54 and there are local buckling modes as shown in Fig.11, though the factor is 1.54 we cannot consider this value because it is the one-dimensional approach, in order to arrive at the best possible values and results, two-dimensional approach is made.

In the Fig.12, curved panel and the stringers are modelled with two-dimensional elements. which gives more accurate values of the results in the analysis.

Fig. 12. Two-dimensional model of curved panel with four L stringers.

In the Fig.13, analysis results can be seen where the buckling factor is 1.50 and there is not much difference in mode shapes. The observation to be made here is that in the one-dimensional idealization of the stringer, the factor is 1.54 but in two-dimensional idealization, the value dropped to 1.50 and it can be seen that the web is deflecting. To avoid this, Z stringer is considered, as it consists of 3 sections and further observations are made in the following cases.

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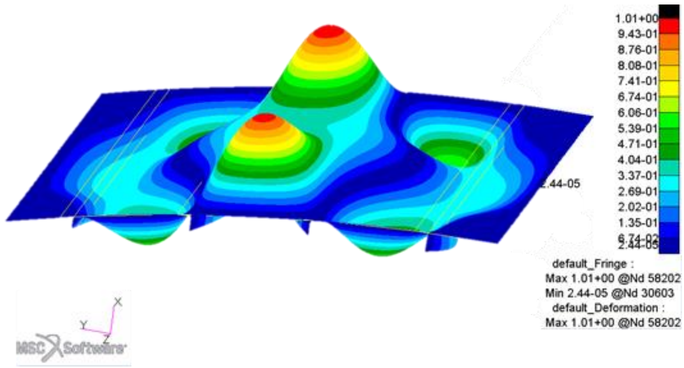

Fig. 13. Analysis results for four L stringer as 2D elements.

To achieve better and more accurate results and to simulate the problem close to reality, it necessary to go with two-dimensional idealization of the stringer along with considerations for the rivets. This is done for the Z shape stringer in our study. Fig.14, depicts the solid model of the curved panel with four rows of Z Stringers

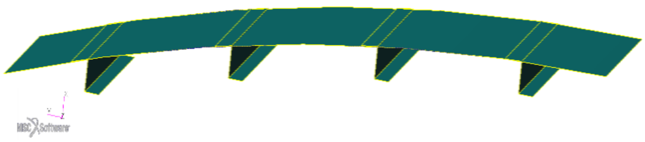

Fig. 14. Solid model of the curved panel with four Z stringers.

In the Fig.15, we can observe that the buckling factor is 1.58 which is greater than the factor achieved with the L shaped stringer and there is no buckling of the web of the stringer, we also observe perfect local buckling modes. This confirms that instead of four Z stringers we can use three Z stringers. When compared with the L shaped stringer, the Z cross section has a higher moment of inertia. With this understanding, we proceed our study with three rows of Z stringers.

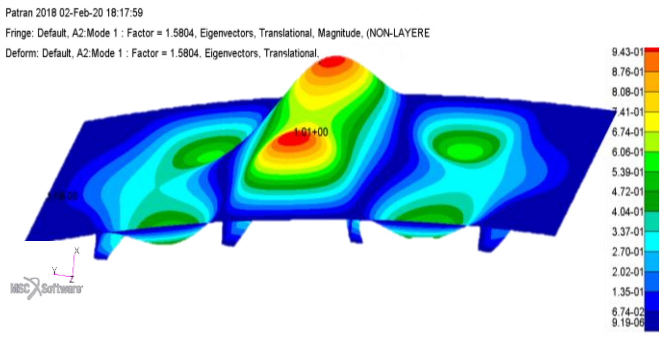

Fig. 15. Analysis result for the curved panel with four Z stringers.

Initially the three rows of Z shaped stringers are idealized as one-dimensional elements as shown in Fig.16, and the analysis is performed as shown in the Fig.17. then we idealize the stringers as two-dimensional elements, as shown in Fig.18.

Fig. 16. Curved panel with three Z stringers as 1D elements.

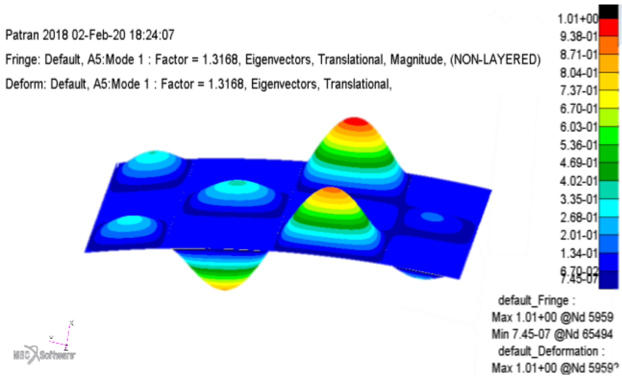

Fig. 17. Analysis results for curved panel with three Z stringers as 1D elements.

From the Fig.17, we can see that buckling factor is 1.31 where as in the panel with four Z stringers it was 1.58. It is also very clearly exhibiting local buckling modes. We cannot reduce the number of stringers any further and have it lesser than three for the given loads and boundary condition. In case it is reduced to two rows of Z stringers then the panel will exhibit global modes while buckling, which, is undesired. In order to improve the accuracy of the simulation we go a step further and perform analysis for curved panel with three rows of Z stringers idealized as two-dimensional elements and then in the next step we idealize the rivets in the skin stringer panel assembly and perform the buckling analysis. Fig.18 shows the model of a curved panel with three rows of Z stringers, and Fig.19, shows the analysis plot for the same.

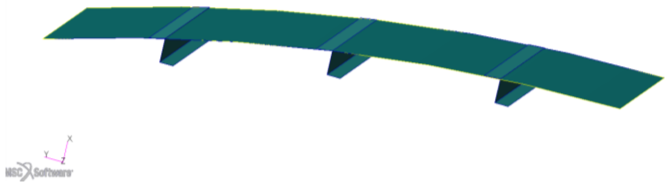

Fig. 18. Meshed curved panel with three Z stringer.

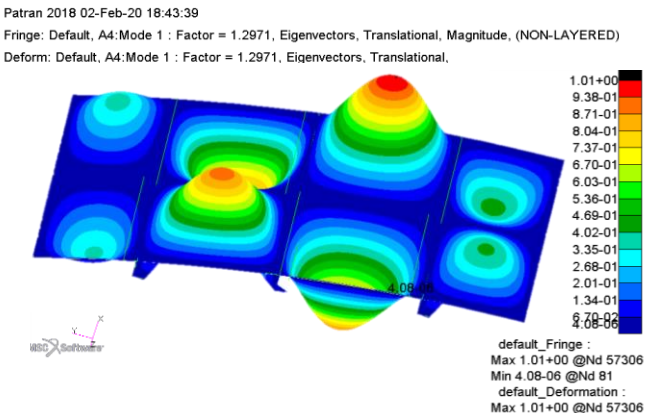

Fig. 19. Analysis results for three Z stringers idealized as 2D elements.

When the panel and the stringers are created with a two-dimensional idealization, the buckling factor is 1.297, with an acceptable local buckling mode shape. In comparison with the results of the one-dimensional idealization of the stingers of the same case, there is a drop of three percent in the buckling factor.

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In the above idealization the load transfer is occurring between the panel and the stringer directly, but in reality, it is not so, the load transfer occurs through the rivets. Fig.20, shows the modelling of rivets and their idealization in the simulation. The blue coloured points represent the rivets which are placed at a distance of two times the diameter from the edge of the panel, and the inter-rivet distance is four times the diameter of the rivets. The diameter of the rivets chosen is 6.25mm.

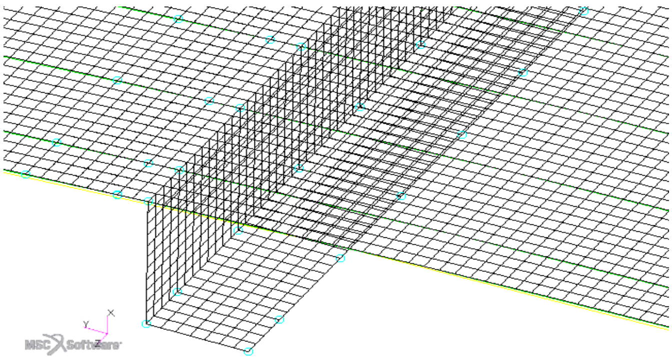

Fig. 20. Curved panel with three Z stringer with rivets.

Fig.21, shows the analysis plot for the panel with the consideration of rivets.

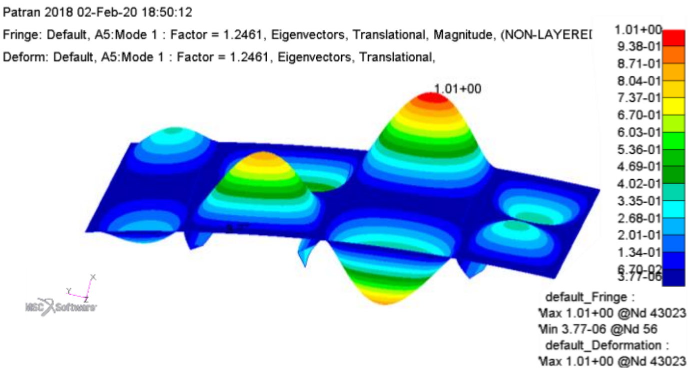

Fig. 21. Analysis result for curved panel with three Z stringers and rivets.

We can observe from the Fig.21, that the buckling factor is 1.246 and the assembly is buckling locally, when compared to the results of three rows of Z stringers there is a significant drop of four percent in the factor, the way to consider the best results would be to choose the simulation which was closer to reality. The number of rivets is higher in case of the four rows of Z stringers when compared with three rows of Z stringers, which increases the cost, and induction of rivet holes will further weaken the structure because certain amount of material is removed. The L stringer configuration presents the problem of the free-web buckling.

Inverted hat stringer is considered for further study, since, it is a combination of two Z stringers together, Fig.22, shows the model of the hat stringers idealized as one-dimensional elements. Inversion in this case was not possible due to the software constraints, an unavailability of such an option. The stringers remain same weight wise. Fig.23, shows the analysis plot for the same.

Fig. 22. Curved panel with three hat stringer 1D condition.

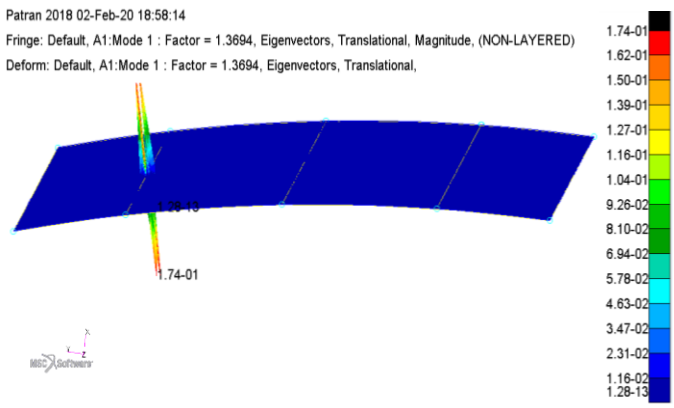

Fig. 23. Analysis result for curved panel with three hat stringers idealized as 1D elements.

When the curved panel is attached with three hat stringers the Eigen value or the buckling factor is 1.369 but there neither local buckling mode nor global buckling mode, instead there is a spike like structure in the panel. This indicated that the panel has over-stiffened, which is addressed by reducing the number of stringers from three to two. Fig.24, shows the model of a curved panel with two inverted-hat stringers and Fig.25, shows the analysis plot for the same.

Fig. 24. Curved panel with two inverted-hat stringers using 2D elements.

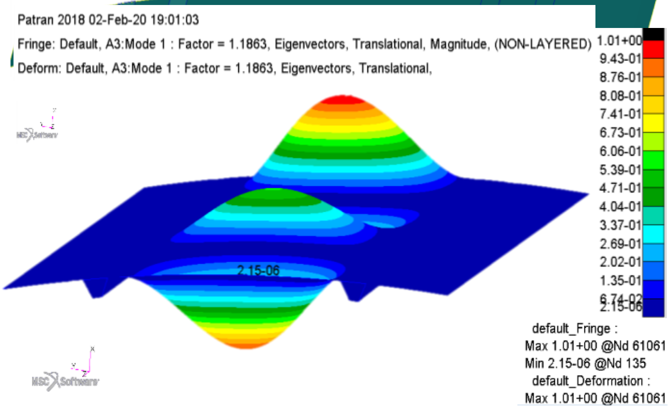

Fig. 25. Analysis result for panel with three inverted hat stringer 2D condition.

The buckling factor is 1.18 and there is local buckling of the panel which indicated that the number of stringers is sufficient to stiffen the panel. To simulate the case closer to reality the rivets are idealized as shown in Fig.26, and the analysis performed as shown in Fig.27.

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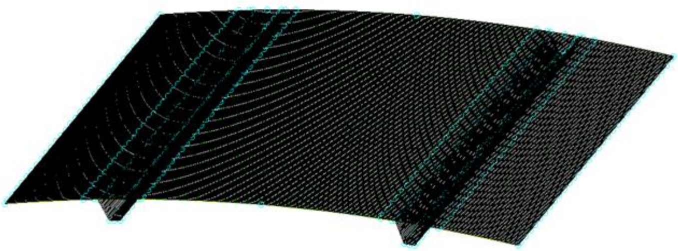

Fig. 26. Inverted-hat stringers with rivet attached to curved panel.

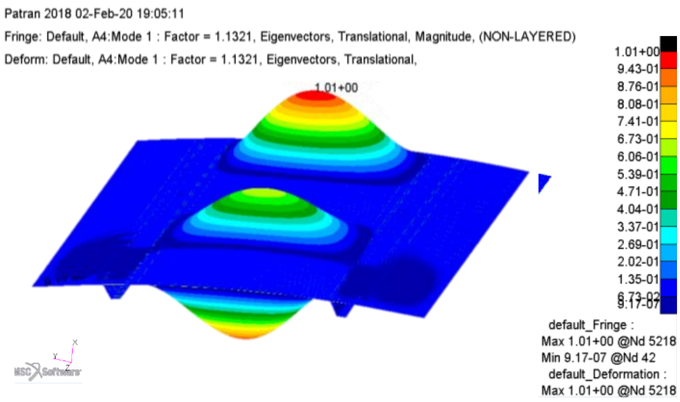

Fig. 27. Results for inverted-hat stringers with rivets idealized.

When a curved panel with two inverted-hat stringers is subjected to uniaxial loading it shows the behaviour as seen in the Fig.27, where the buckling factor is 1.13 and there are local buckling modes, this result is consistent with the result for stringers idealized as two-dimensional elements without the considerations of the rivets. Each inverted-hat stringer requires two rows of riveting and in this study where two rows of stringers are considered, in total four rows of rivets are required. Which increases the cost and also weakens the panel locally due to the holes for the rivets. Each hat stringer is a combination of two Z stringers.

V. CONCLUSION

With the help of finite element analysis method, the skin stringer panel of the fuselage structure is studied in detail and an approach is made to determine the behaviour of the curved panel. Three different configurations, namely L-stringer, Z-stinger and inverted-hat stringer were analysed and studied. The panel and stringers are idealized as one-dimensional, two-dimensional and two-dimensional stringer with one-dimensional rivets. Comparison is made between the different types of stringers depending on their behaviour when subjected to uniaxial compressive load and when the panel is simply supported on all four edges. Initially when the curved panel is analysed without any stringer it gave a buckling factor of 0.99 and local buckling modes were observed. This is the reference and keeping the panel thickness, mesh size, material and loads same further study is made. Behaviour of all the three types of stringers were studied by simulating the problem by idealizing them using one-dimensional elements, appreciable results were obtained. Study of the behaviour by one-dimensional idealization is essential in order to have a base value for the stringer dimensions, such as, the thickness, height of web and flange width etc.

The analysis of four rows of L-stringer using one-dimensional elements resulted in a buckling factor of 1.546 and a two-dimensional element analysis resulted a factor of 1.508, we notice a drop of 0.04 in the factor. Due to the free-web buckling in case of the L-stringer, the scope of the analysis was shifted to Z-stringer. Four rows of Z-stringers idealized using two-dimensional elements gave a factor of 1.580 along with local buckling modes. Since the factor is high, we have an opportunity of reducing the number of stringers from four to three. Analysis using one-dimensional elements for the three rows of Z-stringer resulted a buckling factor of 1.31, whereas the two-dimensional approach showed a buckling factor of 1.29. In comparison with four rows of Z-stringers the three-row configuration gave a lesser factor, but has local buckling modes. The reduction in stringer reduces the overall weight of the skin-stringer assembly. In reality, loads are transferred from panel to stringer through rivets, so a third case was studied where stringers are connected to the panel with the suitable idealization of rivets, and analysis carried out. This resulted a buckling factor of 1.24, the drop in factor is expected, but this result is more accurate as the problem is simulated much closer to reality.

Similar analysis approach is made for inverted-hat stringer as well, where, three rows of hat-stringers idealized using one-dimensional elements gave a buckling factor of 1.36, but the mode shape observed was a spike like structure, which implied over stiffening of the panel and gives an indication to reduce the number of stringers. Reduction of one row of stinger gave a buckling factor of 1.18, with good local buckling mode shapes, and the analysis with the considerations of rivets with stringers idealized as two-dimensional elements showed a buckling factor of 1.13.

The main purpose of this paper is to propose the most suitable stringer type based on the buckling factor, mode shapes and total weight of the skin-stringer panel. The weight of the curved panel is 5183.45g and the total weight with the four L-stringers attached is 6079.4g. This configuration requires four rows of riveting, and there is a possibility of the free web buckling. The total weight of the panel with three rows of Z-stringers is 6083.53g and requires only three rows of rivets. In case of the inverted-hat stringer the weight is 6292.85g and it requires four rows of rivets. The weight mentioned does not account for the weight of the rivets, once they are added to the assembly the overall weight increases.

Amongst all possible configurations the Z stringer can be considered as the most suitable option since, it is efficient enough in all aspects, such as, weight, good buckling factor and less rows of riveting when compared to other two configuration. The Z cross section has better moment of inertia for less area. The procedure carried out in this paper can be followed for any other stringers and load cases, by keeping this as a reference, procedure study can be made for composite material.

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REFERENCES

[1] Sridhar Chintapalli, Mostafa S.A.Elsayed, RaminSedaghati, MohammedAbdo, Aerospace Science and Technology Volume 14, Issue 3, April–May 2010, Pages 188-198, The development of a preliminary structural design optimization method of an aircraft wing-box skin-stringer panels.

[2] Amandeep Singh Sivia, Jaspalpreet Singh Grewal Student, Amritpal Singh Bhinder, Rajkamal Singh Saini, Students (B.tech, Aeronautical) Gurukul Vidyapeeth Institute of Engineering and Technology. A Study on the Skin-Stringer Panel of an Aircraft, International Journal of Aerospace and Mechanical Engineering Volume 1 – No.1, September 2014.

[3] Sreenivasa R, Kallesh S S, Naveen Kumar K H, Sandeep S H, Assistant Professor Department of Mechanical Engineering, Jain Institute of Technology, Davangere, Karnataka, India. ISSN: 2455-2631 June 2016 IJSDR | Volume 1, Issue 6. Study the effect of buckling on aircraft fuselage skin panel with or without airframe.

[4] Khairi Yusuf, Nukman Y, Dawal S. Z, Devi Chandra, Sofia N (2010), "Conceptual design of fuselage structure of very light jet aircraft", ISSN: 1792-4359.

[5] Linde P, Schulz A, Rust W, "Influence of modeling and solution methods on the FE-simulation of the post-buckling behaviour of stiffened aircraft fuselage panels", Journal of Composite structures, vol., 73 2006, pp. 229-236.

[6] Aleksandar Grbovic, Bosko Rasuo, "FEM based fatigue crack growth predictions for spar of light aircraft under variable amplitude loading", Journal of Engineering failure analysis, vol., 26 2012, pp. 50-64.

[7] Richard D. Young, Marshall Rouse, Damodar R. Ambur and James H. Starnes,Jr "Residual strength pressure tests and nonlinear analysis of stringer and frame stiffened aluminium fuselage panels with longitudinal cracks".

[8] Marco Aurelio Rossi, Sergio Frascino Muller de Almeida, "Design and analysis of a composite fuselage", vol., 2009, pp. 14- 16.

[9] Norman F. Knight Jr, Navin Jaunky, Robin E. Lawson, Damodar R. Ambur, "Penetration simulation for uncontained engine debris impact on fuselage-like panels using LS-DYNA", Journal of Finite elements in analysis and design, vol., 36 2000, pp. 99- 133.

[10] Smojver I, Ivancevic D, "Bird strike damage analysis in aircraft structures using Abaqus/Explicit and Coupled Eulerian Lagrangian approach", Journal of Composites science and Technology, vol., 71 2011, pp. 489-498.

[11] Smojver I, Ivancevic D , "Numerical simulation of bird strike damage prediction in airplane flap structure", Journal of Composite structures, vol., 92 2010, pp. 2016-2026.

[12] MacDonald B. J, "A computational and experimental analysis of high energy impact to sheet metal aircraft structures", Journal of Materials processing technology, vol., 124 2002, pp. 92-98.

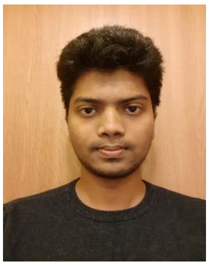
[13] Attaullah khan, Muhammad subhan, Wajahatali, Skin stringers in an aircraft MS MS&E 06, material specification, Page No, 5. 2016.

[14] Warren C. Youngrichard G. Budynas, Roark's formula for stress and strain, seventh edition, McGraw-Hill,formula for elastic stability of plate, Page No, 730, 2012.

[15] Warren C. Youngrichard G. Budynas, Roark's formula for stress and strain,seventh edition, McGraw-Hill,formula for elastic stability of plate, Page No, 734, 2012.

[16] Warren C. Youngrichard G. Budynas, Roark's formula forstress and strain, seventh edition, McGraw-Hill, formula for elastic stability of plate,Page No, 735, 2012.

BIOGRAPHIES



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