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STRUCTURAL DESIGN ANALYSIS OF BYPASS CASING FOR AN AERO ENGINE

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Abstract - *Bypass casing is situated between the intermediate casing and load ring. Bypass casing houses the core of an aero engine and forms the skin of the engine body. In the present work a structural design analysis of bypass duct for an aero engine is considered. The main objective of this work is to reduce the weight, while meeting the strength and buckling requirements, In order to achieve this objective different types of grid stiffened patterns are analyzed. The types of grid-stiffeners used in this study are Ortho-grid and Iso-grids. Grids when arranged in 60˚ pattern is known Iso-grids; when oriented in 90˚ pattern is termed as Ortho-grids. Finite Element model of the bypass duct is generated and carried out the structural analysis for internal pressure and temperature with respect to the critical operating condition and evaluated the strength margins. Buckling analysis is carried out for different configurations of bypass duct and computed buckling factor for different configurations. Iso-grid configuration which meets strength and buckling requirements with the weight reduction of 15% is finalized.*

***Key Words*: Bypass Duct, Ortho-grid, Iso-grid, Finite Element Model, Strength and Buckling factor.**

1. INTRODUCTION

Bypass casing plays a vital role in an aero engine in cooling and noise reduction. It is a cylindrical shell shaped structure situated between the intermediate frame and load ring in an aero engine. It houses the core engine of an aero engine which comprises of High pressure compressor unit (HPC), Combustion chamber and High pressure turbine (HPT) and forms the skin of the engine body. This paper presents the design and analysis of bypass duct for an aero engine using different types of grid-stiffened pattern in order to reduce the weight, while meeting the strength and buckling requirements. The types of Grids used in this Study are Ortho-Grid and Iso-Grid. Buckling analysis is carried out for a Grid-stiffened casings. Grids when arranged in 60˚ pattern is known as Iso-grids; when oriented in 90˚ pattern is termed as Ortho-grids. The Buckling factor for each grid is obtained and compared.

The Titanium alloy (Ti-64) is used as the casing material in the present design. Due to the advantages of light weight, low manufacturing cost, high strength, high stability, great energy absorption, and superior damage tolerance grid-stiffened casing panels have been applied in aerospace engineering. The types of grids Ortho-grid and Iso-grid are shown in Fig-1 and Fig-2 respectively.

Fig -1: Ortho-grid Stiffened patterns

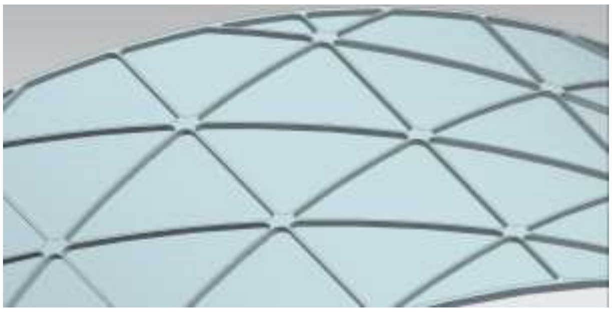

Fig -2: Iso-grid Stiffened patterns

2. CONFIGURATION

Bypass duct design analysis is carried out for different types of grid configurations as described below.

2.1. Configuration -1

This is the baseline configuration of bypass duct made of Ti-64 material with 1.1 mm thickness. It consists of ortho-grid stiffened pattern with the rectangular size of 80 mm x 16 mm. Height of the rectangle is 3 mm. thickness is 1.3 mm. This configuration is shown in Fig-3.

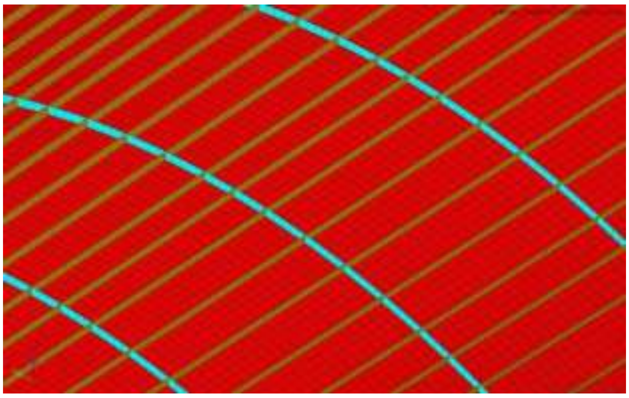

Fig -3: Baseline configuration Ortho grid stiffened bypass duct

2.2. Configuration -2

In order to reduce weight, configuration - 1 is modified by removing the one longitudinal stiffeners alternatively and ortho-Grid stiffened bypass duct with rectangular size of 80 mm * 32 mm as shown in the Fig-4 is obtained and carried out the stress and buckling analysis. All other dimensions are kept same as baseline configuration.

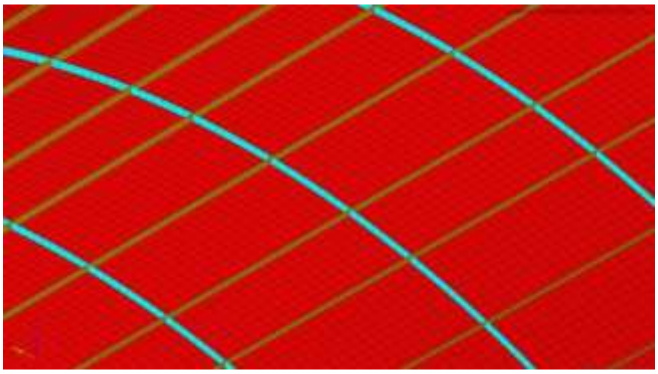

Fig -4: Configuration-2 ortho grid stiffened bypass duct

2.3 Configuration - 3

This configuration is arrived by removing the two longitudinal stiffeners alternatively from the base line configuration.

Ortho-Grid stiffened bypass casing with rectangular size of 80 mm * 48 mm as shown in the Fig-5 is obtained and carried out the stress and buckling analysis. All other dimensions are kept same as baseline configuration.

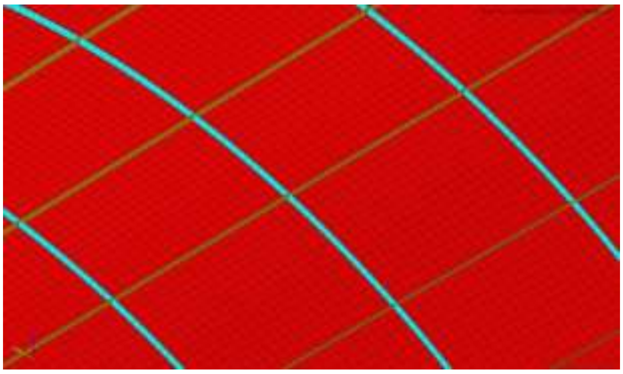

Fig -5: Configuration-3 Ortho grid stiffened bypass duct

2.4 Configuration - 4

Baseline configuration is modified and ortho-Grid stiffened bypass duct with rectangular size of 80mm*90 mm as shown in the Fig-6 is created and carried out the stress and buckling analysis. Casing thickness is 1.1mm and other dimensions are kept same as baseline configuration.

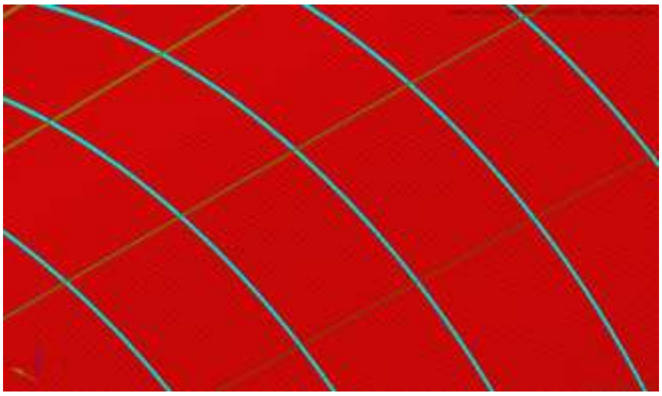

Fig -6: Configuration-4 Ortho grid stiffened bypass duct

2.5. Configuration – 5

In order to reduce weight while meeting strength and buckling requirement, new Iso-grid Stiffened bypass duct is considered in this configuration. The angle between different stiffeners are set to be 60° and dimension of 60mm each side respectively as shown in the Fig-7. All other dimensions are kept same as baseline configuration and carried out the stress and buckling analysis.

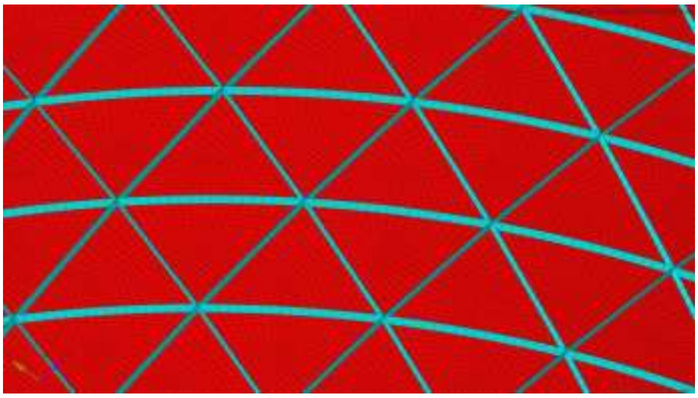

Fig -7: Configuration-5 Iso-grid stiffened bypass duct

3. Structural Analysis

Structural analysis is carried out to evaluate the static strength and buckling factor of the duct under critical operating condition.

The Finite Element model of Bypass duct is generated using Hypermesh software. A three dimensional finite element model of the bypass duct is shown in Fig-8. The FE mesh is generated using 4-noded shell Elements.

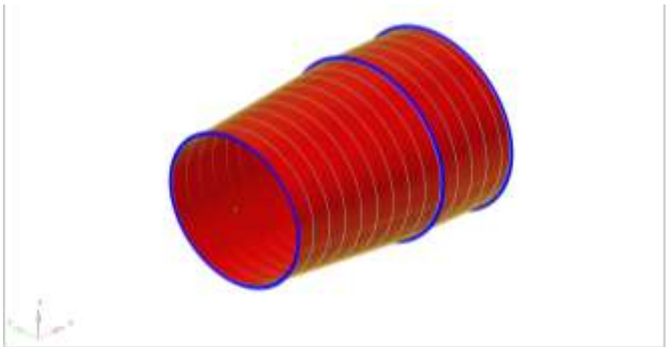

Fig -8: 3d Finite Element Model of Bypass duct

3.1. Stress analysis for Pressure + Temperature Load case

Stress analysis is carried out for pressure and temperature for critical operating condition. The following loads are considered in the analysis – Air pressure distribution along the length of the casing internally of 0.3 MPa. Body temperature for the overall components applied is 300˚C.

Fig-9, 10, 11 shows the radial, axial displacement and von-Mises stress distribution for configuration-1 respectively.

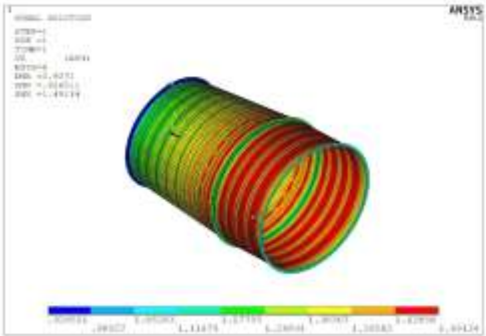

Fig -9: Radial displacement for configuration-1 in mm

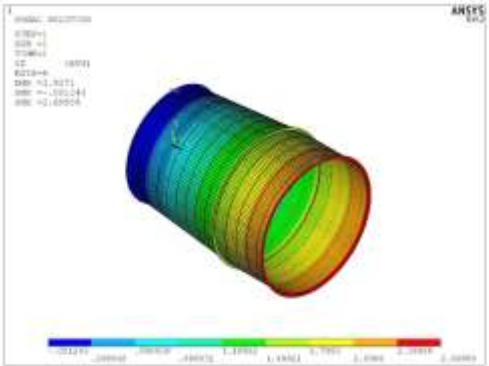

Fig -10: Axial displacement for configuration-1 in mm

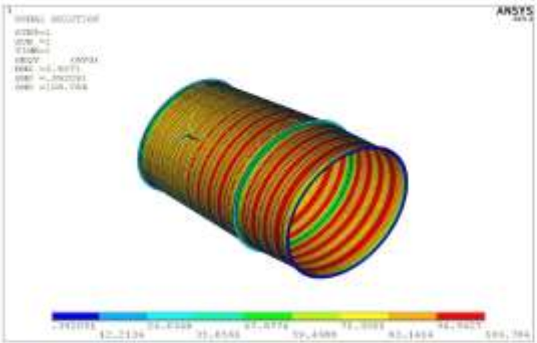

Fig -11: von-Mises stress distribution for Configuration- 1

Fig-12, 13, 14 shows the von-Mises stress distribution for the configuration-2, 3, 4 respectively.

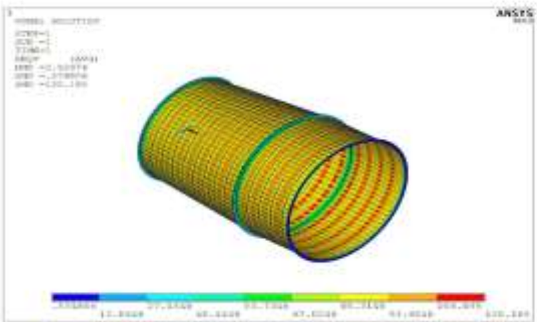

Fig -12: von-Mises stress distribution for Configuration- 2

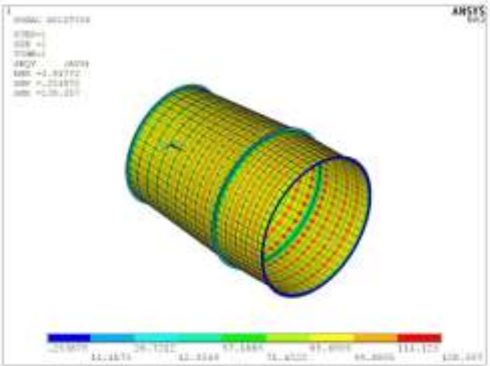

Fig -13: von-Mises stress distribution for Configuration-3

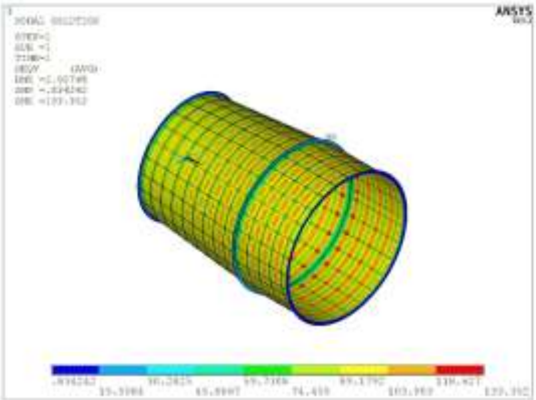

Fig -14: von-Mises stress distribution for Configuration-4

Fig-15, 16, 17shows the radial, axial displacements and von-Mises Stress distribution for the Iso-grid configuration.

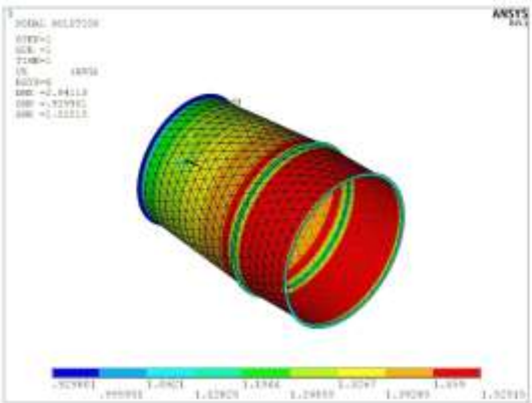

Fig -15: Radial displacement in mm for Iso-grid configuration

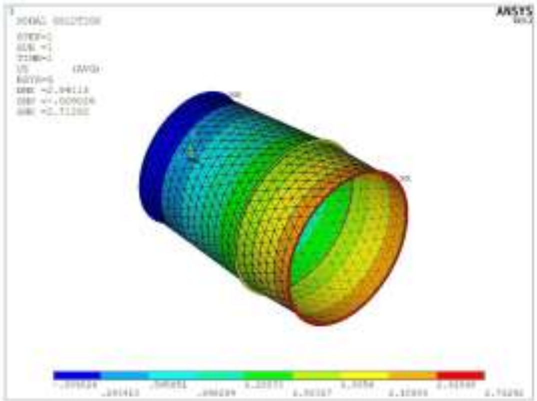

Fig -16: Axial displacement in mm for Iso-grid configuration

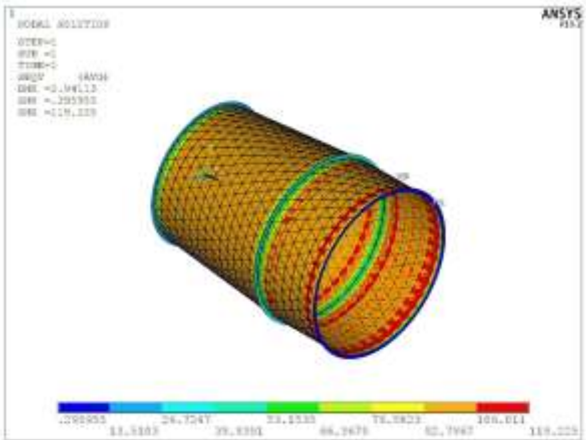

Fig -17: von-Mises stress distribution for Iso-grid configuration

Summary of stress analysis results are given in the following table. 1. Operating stresses are well within the yield strength of the material and meets the strength requirements for an Aero Engine.

Table -1: Summary of Stress analysis results

Configuration	Von-Mises stress in MPa	Displacements in mm	
		Axial	Radial
01	107	2.7	1.491
02	120	2.705	1.502
03	128	2.715	1.514
04	133	2.737	1.552
05	119	2.713	1.525

3.2. Buckling Analysis

Buckling analysis is carried out to evaluate the buckling factor for the axial compressive load of 100 KN along with pressure (0.3 MPa) and temperature (300ºC). One end Fixed, other end free boundary condition is used in the analysis. Buckling factor is estimated by using Block-lanczos buckling analysis. Mode shapes are shown in the Fig-18, 19, 20, 21 and 22 for 5 configurations respectively. Buckling factors and weight of the corresponding configuration is given in table. 2.

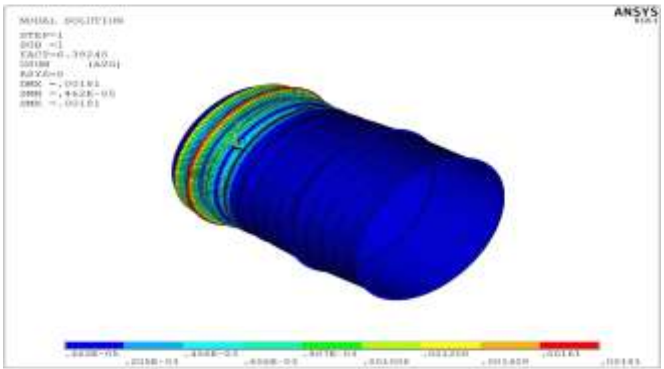

Fig -18: Mode Shape for Configuration -1

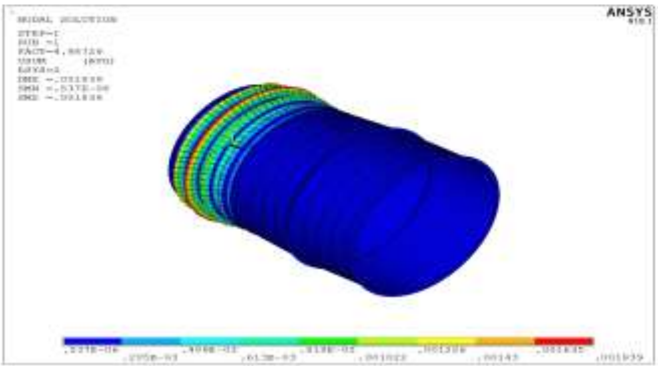

Fig -19: Mode Shape for Configuration – 2

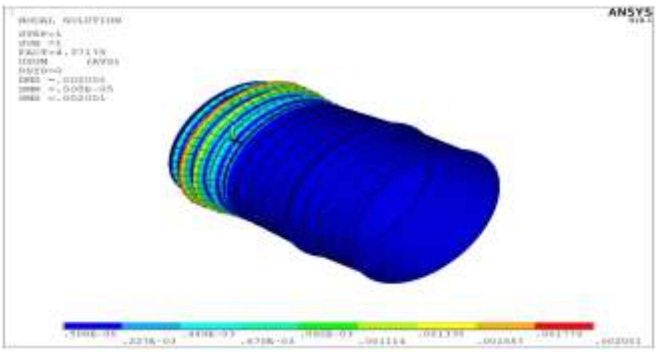

Fig -20: Mode Shape for Configuration – 3

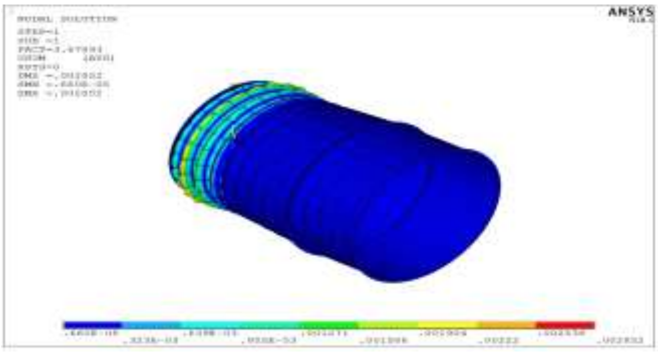

Fig -21: Mode Shape for Configuration – 4

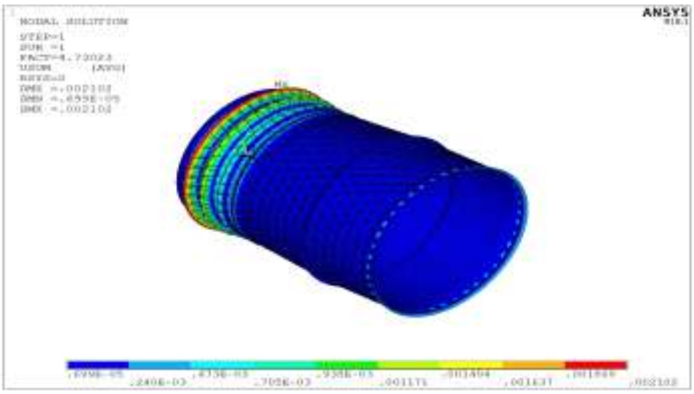

Fig -22: Mode Shape for Configuration – 5

Table -2: Buckling factor and Weight for various Configurations

Configuration	Buckling Load Factor	Weight (Kgs)
Baseline configuration 01 (Ortho grid)	6.3	22.4
Configuration 02 (Ortho grid)	4.9	20.9
Configuration 03 (Ortho grid)	4.3	20.4
Configuration 04 (Ortho grid)	3.6	19.9
configuration 05 (Iso grid)	4.7	19.0

4. CONCLUSIONS

Thus the structural design and analysis of Bypass casing for an Aero-engine is carried out to meet strength and buckling requirement. Main objective of this work is to reduce weight of the baseline configuration of bypass duct while maintaining structural integrity of the component. Carried out the design iterations for ortho-grid and Iso grid stiffened bypass casing configurations. Stress levels are well within the yield strength of the material and meets strength requirements. But the weight reduction in the ortho grid configuration found to be less compared to Iso grid configuration. It is evident from structural analysis that Iso grid configuration provides high strength and buckling factor when compared to ortho grid configuration with weight reduction.

Iso-Grid stiffened configuration which meets strength and buckling requirements with weight saving of 15% (3.4kg) when compared to baseline configuration is finalised.

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