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Research Paper

DESIGN OPTIMIZATION OF A MISSILE CONTROL COMPONENT USED IN A GUIDED MISSILE

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This paper presents a finite element model for strength analysis of a missile's missile control component under different conditions like pitch, roll and Yaw. Characteristics of stress distribution and high stress locations are determined according to the model. The high random vibration loads imparted on Missile control component by the other hardware during launch create an adverse design requirement that all hardware have a natural frequency greater than that of the Missile control component, in order to avoid damage and failure due to dynamic coupling. Maximizing natural frequency is generally accomplished by creating as stiff and lightweight a design as possible. However, designing for the resultant high loads also requires a high stiffened structure. These two opposing design requirements drive an optimization between a lightweight and high strength structure. This paper also presents a finite element analysis for strength analysis of a missile's Missile control component under random loading conditions. Static, Modal RSA and Power spectrum density (PSD) analysis will be carried out to plot graph of the PSD value versus frequency, where the PSD may be a displacement PSD, velocity PSD, acceleration PSD, or force PSD. Based on the results obtained, optimization of the control component was also done in this project.

Keywords: Missile control component, FEA, Guided missile

INTRODUCTION

Missile control component have been, and are arguably still, the most efficient means of controlling a missile and guiding it to a target. They can efficiently generate the required manoeuvring force by a direct action near the centre of gravity. Affecting all of these aerodynamically controlled configurations are the sizing and power requirements of the control surfaces. In missiles the control function is to ensure stability of the missile and implement the guidance signals received from external sources or generated onboard. The control, after processing the guidance signals, actuates the aerodynamic surfaces on thrust vector to generate turn of the missile speed and direction as required.

The missile must sense and correct for

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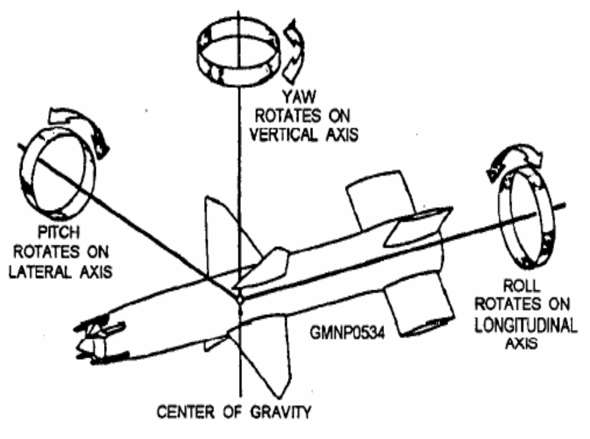
each degree of moment to maintain an accurate and stable flight path. This stable flight path is often called "attitude" and refers to the position of the missile relative to a known (horizontal or vertical) plane. The control system contains various components used to maintain a proper flight attitude.

Figure 1: Rotary Moments of a Missile: Pitch, Roll, and Yaw



The objective of my project is to perform finite element analysis for strength analysis of a missile's control bay under different conditions like Pitch, Yaw and Roll moments. Analysis has been carried out for Aluminium material.

EXPERIMENTAL METHODOLOGY

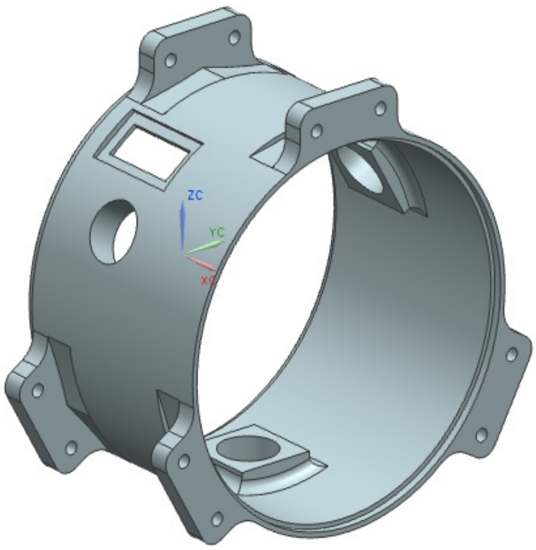
This paper presents a finite element model for strength analysis of a missile's Missile control component under different conditions like pitch, roll and Yaw. The high random vibration loads imparted on Missile control component by the other hardware during launch create an adverse design requirement that all hardware have a natural frequency greater than that of the Missile control component, in order to avoid damage and failure due to dynamic coupling. Static, Modal and Spectrum analysis will be carried out on Missile control component.

The methodology followed in my project is as follows:

- Design of Missile control component is done in NX-CAD.
- Perform Static analysis to find max. Deflections and max. Stress on Missile control component for operating loading conditions.
- Perform Modal analysis to find natural frequencies on the original model of the Missile control component.
- Perform spectrum analysis to find maximum deflections and stress on Missile control component for dynamic loads.
- Optimize the original model to minimize the deflections and stress distributions at high stress locations are determined according to the model.
- Design of modified Missile control component is done in NX-CAD.
- Perform Static analysis to find max. Deflections and max. Stress on modified Missile control component for operating loading conditions.
- Perform Modal analysis to find natural frequencies on the original model of the modified Missile control component.
- Perform spectrum analysis to find maximum deflections and stress on modified Missile control component for dynamic loads.

3D MODELLING OF MISSILE CONTROL COMPONENT

Figure 2: 3D Model of Missile Control Component



Static Analysis of Missile Control Component

Material Properties:

Material used for Missile Control component is Aluminium Alloy 24345:

- Young's Modulus: 70GPa
- Density: 2800kg/m3
- Yield strength: 420Mpa

Condition: Yaw

The missile yaws, or turns left and right, about the vertical axis. Moments are applied at the CG of Missile Control component along X-axis. Deflections and stresses are plotted.

Boundary Conditions

All Bolting locations are constrained in all Dof. Moment is applied along X-axis at the CG of the Missile Control component and is transferred to the control bay lugs using couple equation.

Table 1: Max. Deflection and Max. Von Mises Stress

S.No.	Deflection (mm)	Von Mises Stress (MP a)
1	0.059	89

From the above results it is observed that the Von Mises stress (89MPa) is less than the yield strength of the material (420MPa).

Condition: Roll

The missile rolls, or twists, about the longitudinal axis. Moments are applied at the CG of Missile Control component along Y-axis. Deflections and stresses are plotted.

Table 2: Max. Deflection and Max. Von Mises Stress

S.No.	Deflection (mm)	Von Mises Stress (MP a)
1	0.088	129

From the above results it is observed that the Von Mises stress (129MPa) is less than the yield strength of the material (420MPa).

Condition: Pitch

Moments are applied at the CG of Missile Control component along Z-axis. Deflections and stresses are plotted.

Table 3: Max. Deflection and Max. Von Mises Stress

S.No.	Deflection (mm)	Von Mises Stress (MP a)
1	0.072	127

From the above results it is observed that the Von Mises stress (127MPa) is less than the yield strength of the material (420MPa).

Hence according to the Maximum VonMises Stress Theory, the Missile Control component design is safe for the above operating loads.

Modal Analysis

From the above modal analysis results it is observed that only 5 natural frequencies exists in the operating range of 0-1000 Hz.

From the modal analysis, The total weight of the Control bay is 14.2 kg.

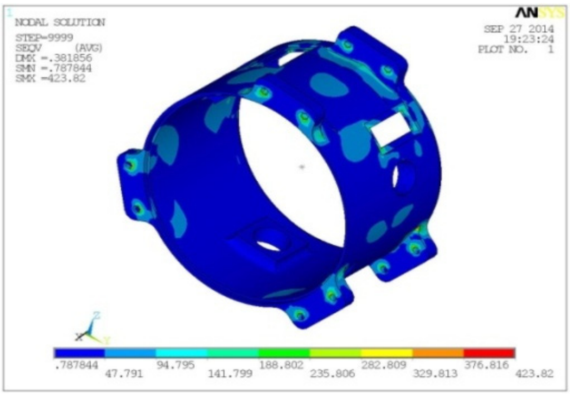
- It is observed that the maximum mass participation of 13Kgs observed in X-dir for the frequency of 902Hz.
- It is observed that the maximum mass participation of 12Kgs observed in Y-dir for the frequency of 666Hz.
- It is observed that the maximum mass participation of 12Kgs observed in Z-dir for the frequency of 723Hz and 997.

RSA Spectrum Analysis

Spectrum analysis has been carried out to check the structure behaviour for random vibrations in the frequency range of 0-1000Hz.

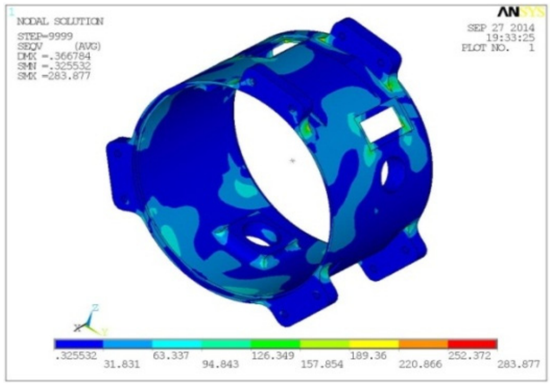
From the RSA analysis in X- dir.

Figure 3: VonMises Stress of Missile Control Component for RSA Analysis in X-Dir



From the RSA analysis in Y- dir.

Figure 4: VonMises Stress of Missile Control Component for RSA Analysis in Y-Dir



From the RSA analysis in Z- dir.

Figure 5: VonMises Stress of Missile Control Component for RSA Analysis in Z-Dir

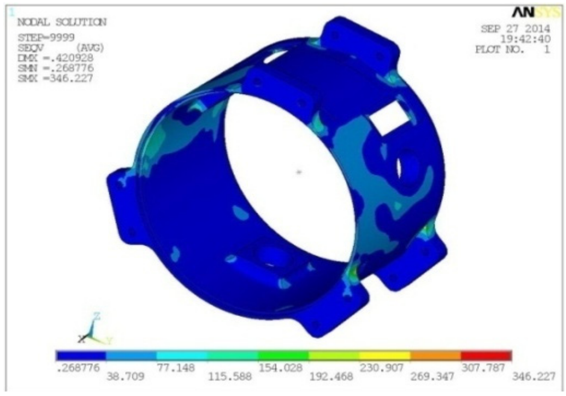


Table 4: Deflection and Stress of Missile Control Component for RSA Analysis in X ,Y and Z- Dir

S.No.	Deflection (mm)			Von Mises Stress (MP a)		
	X	Y	Z	X	Y	Z
1	0.38	0.36	0.42	423	283	346

From the above results VonMises stress of 423MPa, 283MPa and 346MPa for RSA analysis in X, Y, and Z directions observed respectively. The yield strength of the material used for Missile Control component is 420MPa.According to the VonMises Stress Theory, the VonMises stress of Missile Control component is higher than the yield strength of the material. Hence the design of Missile Control component is not safe for the above dynamic loading conditions.

Design modifications are required to reduce high stress values to achieve high FOS model of Missile Control component. From the results obtained in RSA analysis in X - Direction, high stress regions are identified and modifications are made accordingly. The high stress values are observed at pocket and fixing locations. Design modifications are made on Missile Control component model by increasing surface area near pocket regions to distribute stress uniformly and bolting locations are rearranged.

Static Analysis of Modified Missile Control Component

Condition: Yaw

The missile yaws, or turns left and right, about the vertical axis. Moments are applied at the CG of Missile Control component along X-axis. Deflections and stresses are plotted.

Table 5: Max. Deflection and Max. Von Mises Stress

S.No.	Deflection (mm)	Von Mises Stress (MP a)
1	0.05	80

From the above results it is observed that the Von Mises stress (80MPa) is less than the yield strength of the material (420MPa). Hence according to the Maximum VonMises Stress Theory, the Modified Missile Control component design is safe for the above operating loads.

Condition: Roll

The missile rolls, or twists, about the longitudinal axis. Moments are applied at the CG of Missile Control component along Y-axis. Deflections and stresses are plotted.

Table 6: Max. Deflection and Max. Von Mises Stress

S.No.	Deflection (mm)	Von Mises Stress (MP a)
1	0.05	101

From the above results it is observed that the Von Mises stress (101MPa) is less than the yield strength of the material (420MPa). Hence according to the Maximum VonMises Stress Theory, the Modified Missile Control component design is safe for the above operating loads.

Condition: Pitch

Moments are applied at the CG of control bay along Z-axis. Deflections and stresses are plotted.

Table 7: Max. Deflection and Max. Von Mises Stress

S.No.	Deflection (mm)	Von Mises Stress (MP a)
1	0.067	95

From the above results it is observed that the Von Mises stress (95MPa) is less than the yield strength of the material (420MPa). Hence according to the Maximum VonMises Stress Theory, the Modified Missile Control component design is safe for the above operating loads.

Modal Analysis

From the above modal analysis results it is observed that only 4 natural frequencies exists in the frequency range of 0-1000 Hz.

From the modal analysis,

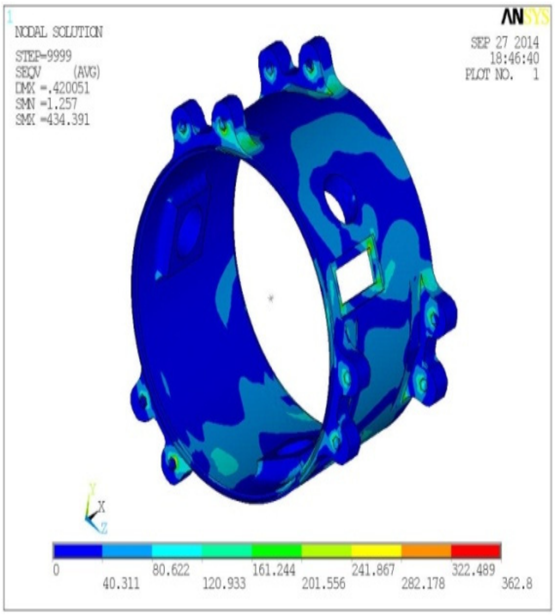
The total weight of the Modified Missile Control component is 14 kg

- It is observed that the maximum mass participation of 11Kgs observed in X-dir for the frequency of 987Hz.
- It is observed that the maximum mass participation of 10Kgs observed in Y-dir for the frequency of 703Hz.
- It is observed that the maximum mass participation of 10Kgs observed in Z-dir for the frequency of 757Hz.

RSA Spectrum

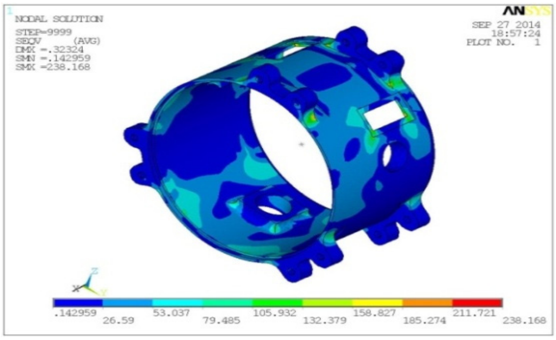
From the RSA analysis in X - Dir.

Figure 6: VonMises Stress of Modified Missile Control component for RSA in X-Dir



From the RSA analysis in Y - Dir.

Figure 7: VonMises Stress of Modified Missile Control component for RSA in Y-Dir



From the RSA analysis in Z - Dir.

Figure 8: VonMises Stress of Modified Missile Control component for RSA in Z-Dir

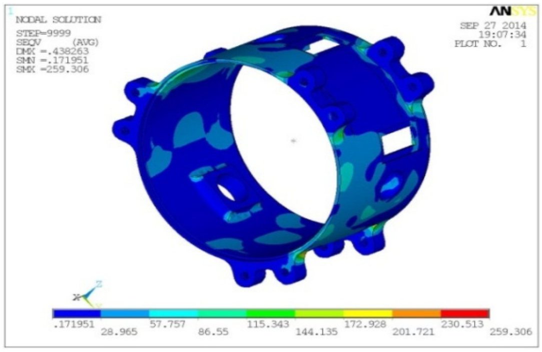


Table 8: Deflection and Stress of Modified Missile Control Component for RSA Analysis in X ,Y and Z- Dir

S.No.	Deflection (mm)			Vonmises Stress (MP a)		
	X	Y	Z	X	Y	Z
1	0.42	0.32	0.43	363	238	259

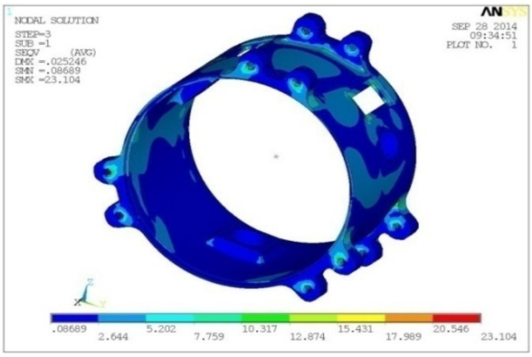
From the above results observed 362MPa, 238MPa and 259 MPa VonMises stress of RSA analysis in X, Y, and Z directions with respectively. The yield strength of the material used for Modified Missile Control component is 420MPa.According to the VonMises Stress Theory, the VonMises stress of Modified Missile Control component is less than the yield strength of the material.

Hence the design of Modified Missile Control component is safe for the dynamic loading conditions.

PSD Spectrum

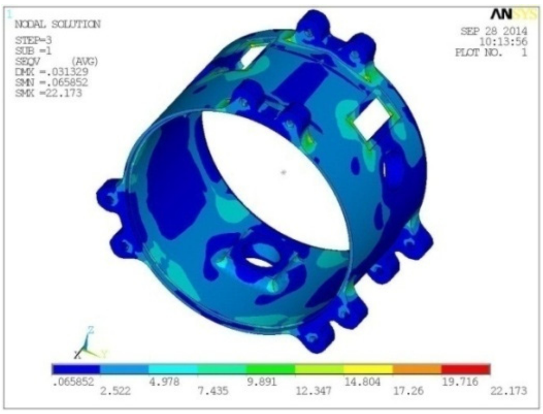
From the PSD analysis in X-Dir.

Figure 9: VonMises Stress of Modified Missile Control component for PSD in X-Dir



From the PSD analysis in Y - Dir.

Figure 10: VonMises Stress of Modified Missile Control component for PSD in Y-Dir



From the PSD analysis in Z - Dir.

Figure 11: VonMises Stress of Modified Missile Control component for PSD in Z-Dir

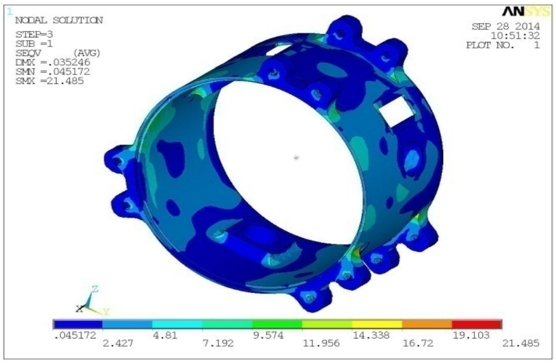


Table 9: Deflection and Stress of Modified Missile Control Component for PSD Analysis in X ,Y and Z- Dir

S.No.	Deflection (mm)			Vonmises Stress (MP a)		
	X	Y	Z	X	Y	Z
1	0.075	0.09	0.105	69	66	63

From the PSD results the maximum 3 sigma stress of 69MPa, 66MPa and 63MPa are observed in X,Y and Z directions respectively and are less than the yield strength of material used for Modified Missile Control component. Hence the design of modified Missile Control component is safe for the random vibrations.

CONCLUSION

In the present project, the Missile Control component has been studied for structural behaviour and optimised for safe structure.

The Missile Control component was studied for 2 different cases:

- Static loads
- Dynamic loads

From the above analysis it is concluded that the modified Missile Control component has stresses and deflections within the design limits of the material used. The deflections and stresses obtained in the dynamic analysis are also under the design limits of the material used.

Therefore it concluded that the Modified Missile Control component is safe under the static and dynamic loading conditions.

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