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Avionics Rack Structure Strength Analysis during Emergency Landing on CN-XXX Aircraft

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***Abstract* - The aviation industry is currently developing rapidly. The Avionics rack is one of the most important parts of an aircraft which functions to place various electronic devices to support the aircraft during flight. As explained in CASR 25 point 25.561, of course, the avionics rack itself is specially designed so that the rack structure can withstand various flight conditions, one of which is when the aircraft experiences an emergency landing. Emergency landings that are generally experienced by aircraft will experience a G-Force of 9G forward, 6G downward, 3G upward, 3G sideward, and 1.5G rearward. This research aims to measure how strong the structure and materials used are to support the devices stored on the avionics rack. Through the Finite Element Analysis method using software, hand calculations in calculating the Margin of Safety, as well as shear force analysis and bending moment diagrams, results can be obtained that the analysis carried out on the identified structure is declared safe if something crucial occurs such as an emergency landing.**

Keywords: Avionic rack, emergency landing, Finite Element Analysis, Margin of Safety, Shear Force and Bending Moment Diagram.

I. INTRODUCTION

In this era, the aviation industry is experiencing very rapid growth. The aviation industry carries out continuous development to create new technology from previous products to obtain better aircraft performance. In the course of developing an aircraft, making a completely new aircraft will be an expensive process for the manufacturer. Adapting a new technology to existing aircraft is a process that has been widely carried out and this method has the advantage of requiring cheaper funds. One of the technologies that is the focus of this research is part of the avionics rack to achieve modernization in aircraft development. This rack contains several main devices in aircraft control to increase the functionality of the aircraft itself. This avionics rack analysis aims to have a strong structure with low weight, ease of production, and a cost-effective structure [1].

An airplane is a system consisting of a number of subsystems and components that are interconnected with the function of each device which is useful for achieving the goal of being able to fly well in the air [2,3]. The main goal is that the aircraft can be used with the use of complex components and control systems that are low cost, reliable, have a strong structure, and safe during flight.

Avionics is an electrical system and electronic device on an airplane. These systems include a complex combination of sensors, actuators, controllers, computers, and displays that must be connected and integrated in real-time while maintaining high standards of safety and reliability in high-stress environments [4]. High safety and system reliability on aircraft is important in the aviation industry. Therefore, the development of an avionics system must obtain certification so that its implementation can be accepted. The certification process is especially important in safety-critical systems, where failure of the avionics system can result in loss of human life [5]. If a system function is deemed safety-critical, aviation regulators require a demonstration that the framework used for system development is acceptable.

An emergency landing is a situation where a pilot must take action to land a plane under certain conditions. This situation of course refers to safety in order to ensure the safety of passengers as well as navigation and communication on the plane. Therefore, the aircraft structure is designed in such a way that when experiencing an emergency landing it can minimize critical parts of the aircraft when a collision occurs and limit acceleration in terms of magnitude and time duration. This study aims to investigate the impact phenomenon which is often not aimed at understanding whether and how a structure can change shape but rather whether the structure distributes the kinetic energy due to the impact and what the impact is on the impact process when a collision occurs on a critical part of the aircraft [6].

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To measure the quality of the avionic rack structure when experiencing an emergency landing situation which results in deformation failing the structure to contain the control system on the aircraft, this research uses a margin of safety calculation to ensure whether the structure is strong enough to withstand impact loads from various force directions due to the emergency landing.

II. RESEARCH AND METHODOLOGY

Figure 1a and 1b shows the avionics rack type 2XXX with 17 main devices on the CN-XXX aircraft. Table 1 also shows the load of each main device on the CN-XXX aircraft accompanied by the G-Force experienced on the aircraft during an emergency landing.

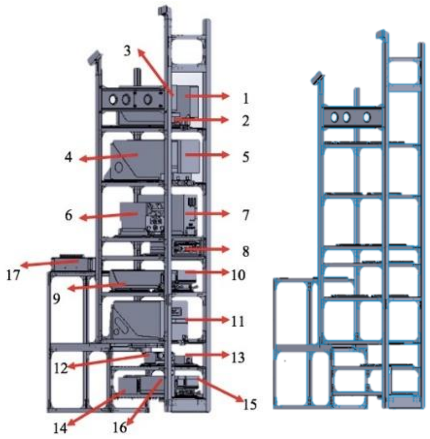

Figure 1: (a) avionics rack 2XXX and its main devices, and (b) the section views of the avionics rack

Table 1: Load and G-Force at the main devices of avionics rack

No	Name	Loads (kg)	9G Forward (DaN)	3G Upward and Sideward (DaN)	6G Downward (DaN)	1.5G Rearward (DaN)
1	Video Interface Unit	0.390	3.4433	1.14777	22.9554	0.573885
2	Battery Unit	5.896	52.0558	17.351928	34.703856	8.675964
3	Data Concentator Unit	3.447	30.4336	10.144521	20.289042	5.0722605
4	Taws Computer	4.354	38.4415	12.813822	25.627644	6.406911
5	Mini FDAU	6.350	56.0642	18.68805	37.3761	9.344025
6	VHF Transceiver	4.540	40.0837	13.36122	26.72244	6.68061
7	Remote Electronic unit	3.107	27.4317	9.143901	18.287802	4.5719505
8	SSDTU	1.089	9.6148	3.204927	6.409854	1.6024635
9	Radio Altimeter	1.800	15.8922	5.2974	10.5948	2.6487
10	Auto Pilot Computer	1.680	14.8327	4.94424	9.88848	2.47212
11	TCAS Proccessor	7.300	64.4517	21.4839	42.9678	10.74195
12	Transponder	3.800	33.5502	11.1834	22.3668	5.5917
13	Control Dimmer	0.272	2.4015	0.800496	1.600992	0.400248
14	Control Adapter	0.310	2.7370	0.91233	1.82466	0.456165
15	ADF 60A	1.910	16.8634	5.62113	11.24226	2.810565
16	Receiver ADF	0.950	8.3876	2.79585	5.5917	1.397925
17	Relay Box	1.000	8.8290	2.943	5.886	1.4715
	TOTAL	**48.195**	**425.5137**	**141.8379**	**283.6758**	**70.9189**

According to the Civil Aviations Safety Regulation (CASR) section 25 point 25.561 concerning emergency landing conditions which states "The structure must be designed to give each passenger a reasonable opportunity to escape serious injury in a mild emergency landing when the passenger experiences ultimate inertial forces" [7]. Figure 2a-2c will show the forces acting separately relative to the surrounding structure and the location of the avionics rack and its cross-section on the CN-XXX aircraft.

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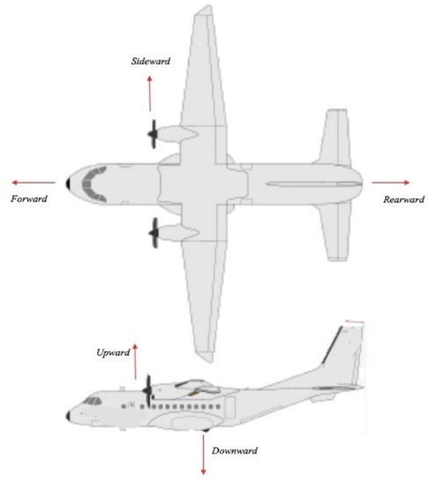
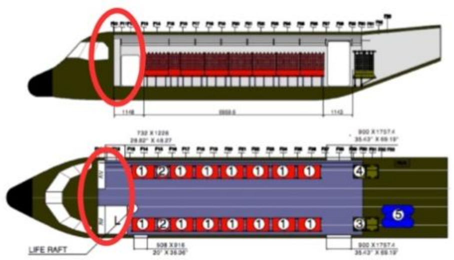


(a)



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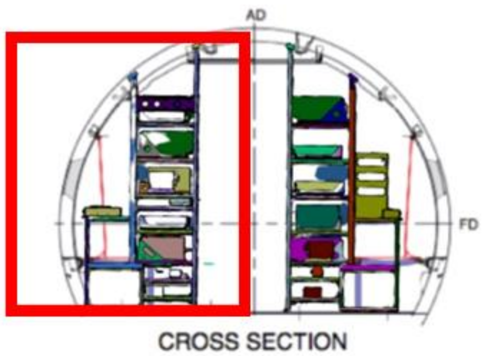

(c)

Figure 2: (a) Force direction during emergency landing, (b) avionics rack location, and (c) cross section at CN-XXX

So that we can understand the phenomena experienced by aircraft during emergency landing with various force directions through the data that has been obtained, it is necessary to carry out a problem-solving analysis as shown in Figure 3. This avionics rack uses Al 2024 T-3 material, which is the material is a 50% nickel-based and stainless steel alloy. This material is often used in various applications, including applications in aviation structures because it has a high strength-to-weight ratio and excellent stress corrosion cracking. Apart from that, Al 2024-T3 also has the advantage of being able to withstand high thermal conditions, namely 400°C [8-10]. The thickness of avionics rack plat is 1 mm.

For more comprehensive results, the author also provides shear force diagrams and bending moment diagrams. Shear force can be defined as "the algebraic sum of loads to the left or right of a point (so that adding that force restores vertical balance)". A shear force diagram is one that shows the variation of shear force along the length of a beam. A bending moment can be defined as "the sum of the moments of all the external forces acting on one side of the part". Moments at any point are calculated by multiplying the magnitude of the external forces (loads or reactions) by the distance between the moment determining point and the external forces (loads or reactions) [11].

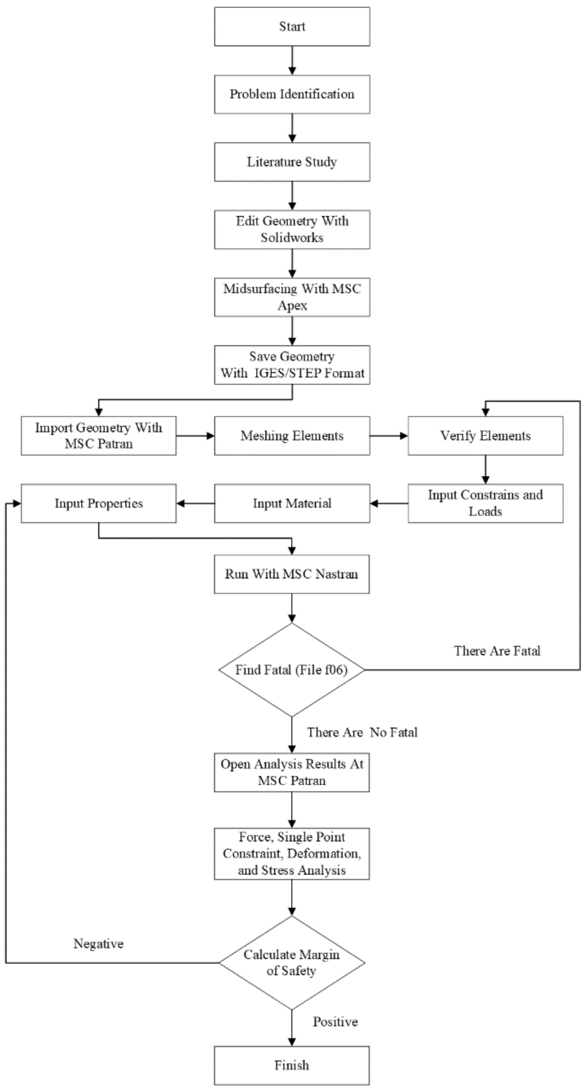

Figure 3: Flow chart of problem-solving process

III. RESULTS AND DISCUSSION

3.1 Force Analysis

Force analysis is the process of figuring out the forces acting on an object and how they affect its motion. This

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involves considering factors like the object's weight, any applied forces (pushes or pulls), and its resistance to movement (friction). Figure 4a-4e shows the variations in the influence of forces on the avionics rack. The results show that each level has a different force value, this is because each main device at each level has a different load. Level 2 (TAWS Computer and Mini FDAU) has a greater total force because the total load is greater than the main devices at other levels. The resulting force will have a significant impact on the stress and deformation of this avionics rack.

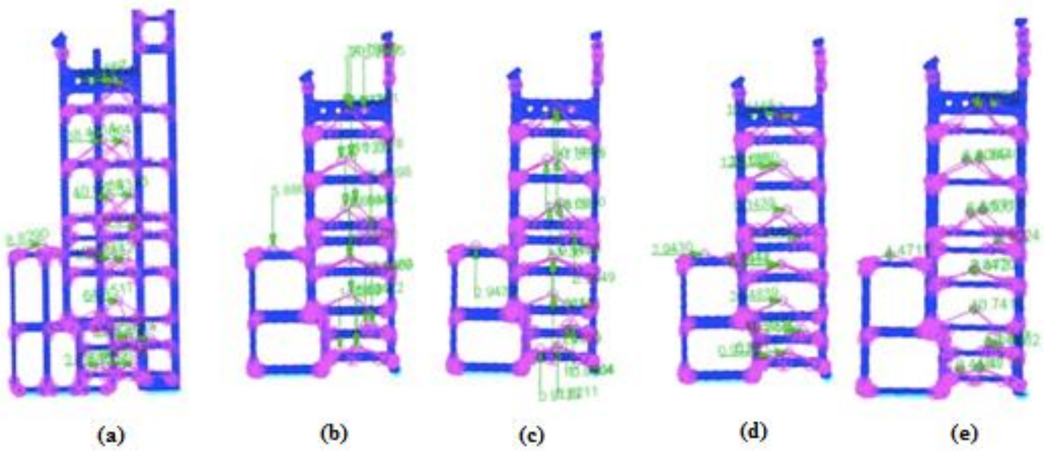

Figure 4: Avionics rack force direction at (a) 9G forward, (b) 6G downward, (c) 3G upward, (d) 3G sideward, (e) 1.5G rearward

3.2 Stress Tensor Analysis

Stress tensor analysis is a mathematical tool used in engineering mechanics to study internal forces within a deformable object. The stress tensor is often decomposed into tensor components or principal stress magnitudes and directions so that feature statistics and similarity are evaluated separately [12].

3.2.1 9G Forward

The analysis results show that there is material stress in level 2 (the storage of TAWS computer and Mini FDAU) with a total maximum stress of 49.6 DaN. The stress area that occurs can be seen in Figure 5.This value indicates that the stress is very high, so it can result in excessive deformation which causes fractures. To provide a lower value, the thickness size is improved to 1.5 mm as in Figure 5 where the total maximum stress decreases to 23.5 DaN.

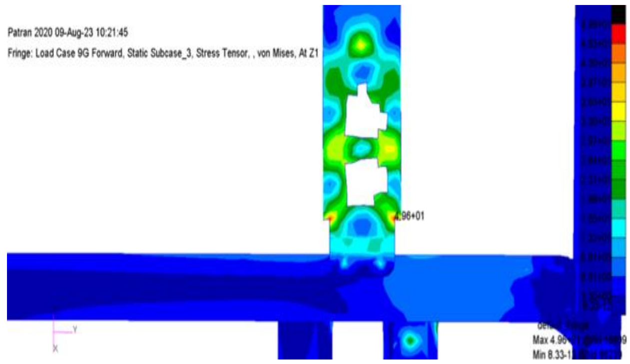

Figure 5: 9G Forward Tensor area before improved

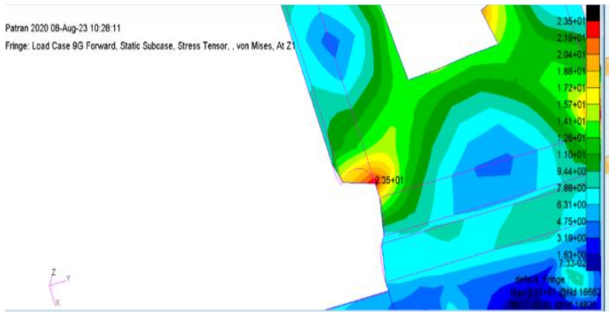

Figure 6: 9G Forward Tensor area after improved

3.2.2 6G Downward

The analysis results show that there is material stress on the TAWS computer and mini FDAU with a total maximum stress of 57.6 DaN. The stress area that occurs can be seen in Figure 7. This value indicates that the stress is very high, so it can result in excessive deformation which causes fractures. To provide a lower value, the thickness size is improved to 1.5 mm as in Figure 7 where the total maximum stress decreases to 39.3 DaN.

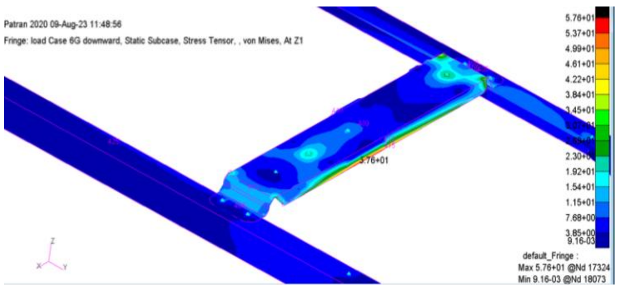

Figure 7: 6G Downward Stress area before improved

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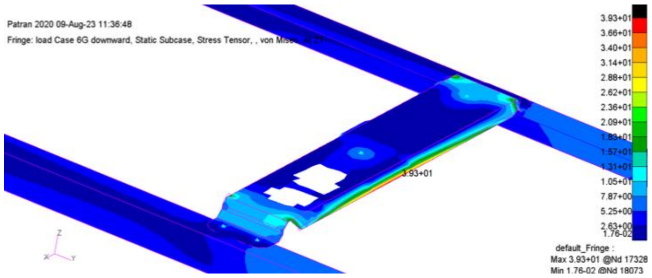

Figure 8: 6G Downward Stress area after improved

3.3 Margin of Safety

Margin of safety is the value of a part being loaded to its maximum load, then the part will never see in service, how much more load with the same force can it withstand before failing. The use of the margin of safety is as a measure of meeting design requirements. Margin of safety can be conceptualized to represent how much of a structure's total capacity is held "in reserve" during loading [13]. If the margin is 0, then the part will not take any additional load before failing, if the margin is negative, the part will fail before reaching its design load in service. If the margin is 1, then it can withstand one additional load with a force equal to the maximum load it is designed to support. In the material used, the stress tolerance used is 43.4 DaN.

3.3.1 9G Forward

Before the avionics rack was given an improvised thickness of 1.5 mm, the resulting margin of safety was negative.

$$\mathbf{MS = \frac{\sigma_{allowable}}{\sigma_{applied}} - 1 => \mathit{MS} = \frac{43.4}{49.6} - 1 = -0.125}$$

After improvising the thickness of the mini FDAU and TAWS computer, a positive margin of safety value was obtained.

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43.4}{23.5} - 1 = 0.88$$

23.5 DaN is obtained from the results of stress analysis in the structure in 9G forward force, and the margin of safety value is 0.88.

3.3.2 6G Downward

Before the avionics rack was given an improvised thickness of 1.5 mm, the resulting margin of safety was negative.

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43.4}{57.6} - 1 = -0.246$$

After improvising the thickness of the mini FDAU and TAWS computer, a positive margin of safety value was obtained.

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43.4}{39.3} - 1 = 0.10$$

39.3 DaN is obtained from the results of stress analysis in the structure in 6G downward force, and the margin of safety value is 0.10.

3.4 Deformation Analysis

In order to make sure that the system design created is safe and does not fail during operation, deformation analysis is used to model how a system or structure changes shape due to fluid loads received during operation. It also estimates and visualizes the deformation that occurs in the system or structure.

3.4.1 9G Forward

The maximum deformation that occurs is 9.72 millimeters in the forward direction. The deformation that occurs can be seen in figure 9.

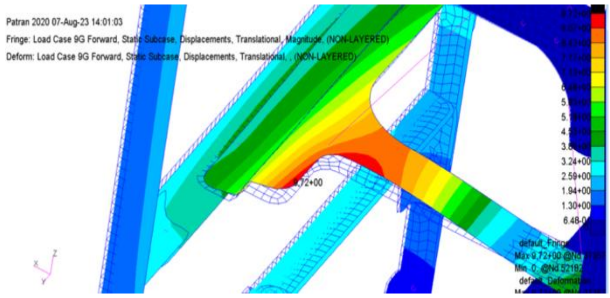

Figure 9: 9G Forward Deformation

3.4.2 6G Downward

The maximum deformation that occurs is 23.3 millimeters in the downward direction. The deformation that occurs can be seen in figure 10.

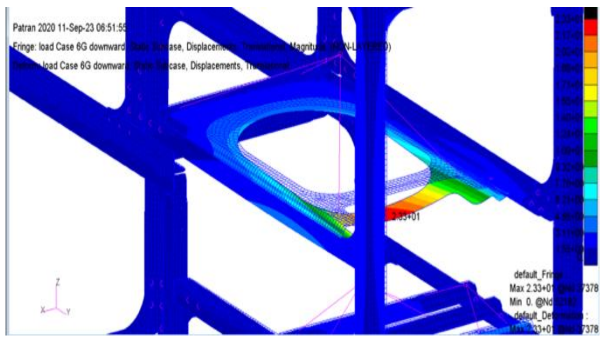

Figure 10: 6G Downward Deformation

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3.4.3 3G Sideward

The maximum deformation that occurs is 4.73 millimeters in the sideward direction. The deformation that occurs can be seen in figure 11.

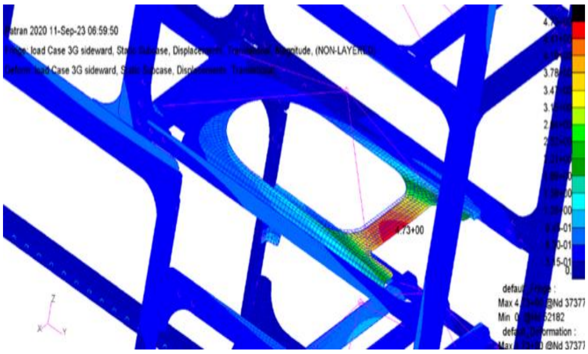


Figure 11: 3G Sideward Deformation

3.4.4 3G Upward

The maximum deformation that occurs is 11.6 millimeters in the upward direction. The deformation that occurs can be seen in figure 12.

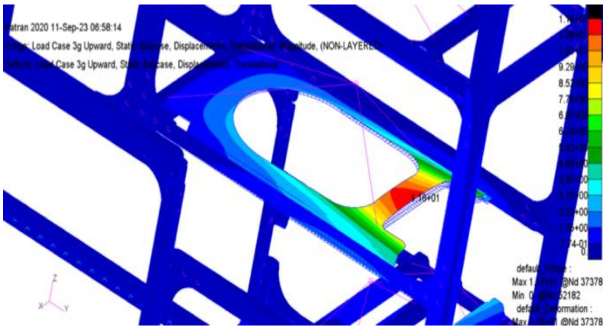


Figure 12: 3G Upward Deformation

3.4.5 1.5G Rearward

The maximum deformation that occurs is 1.62millimeters in the rearward direction. The deformation that occurs can be seen in figure 13.

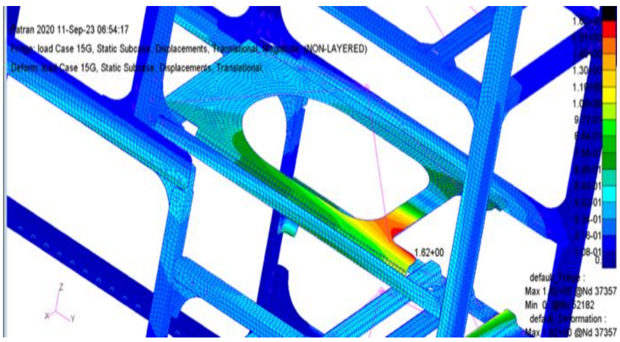
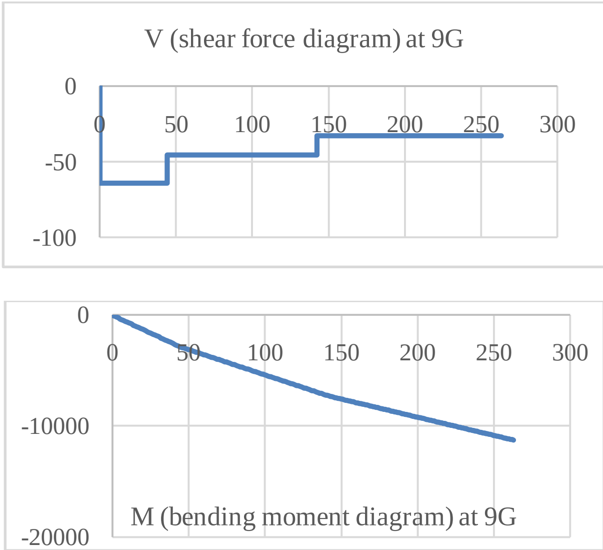


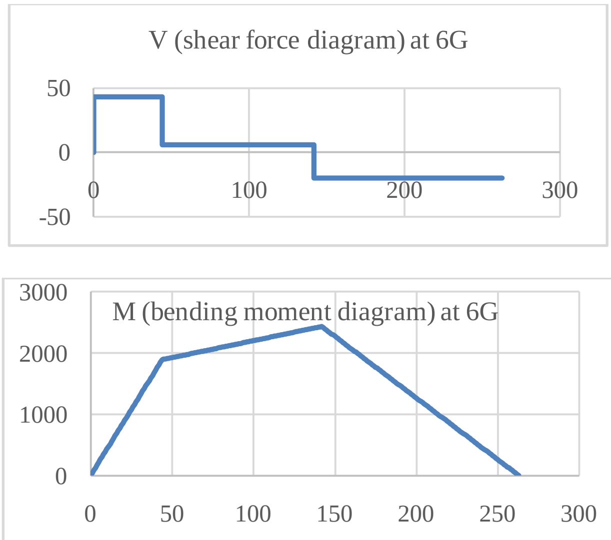
Figure 13: 1.5G Rearward Deformation

3.5 Shear Force and Bending Moment Diagram

To understand the interactions due to G-Force (9G, 6G, 3G, 1.5G) that occur in the avionics rack, we can look at the shear force diagram and bending moment diagram as in Figure 14a-14e. Each shear force diagram and bending moment diagram has a different distribution of values caused by different G-Force loading at each point.



(a)



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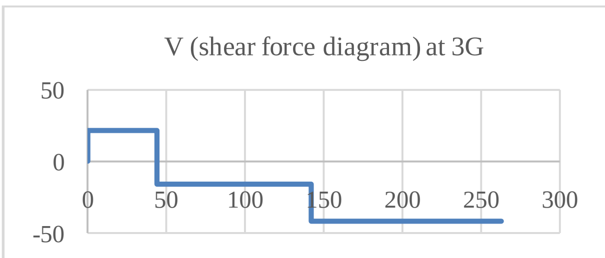

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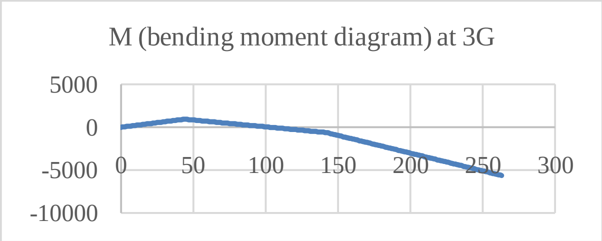
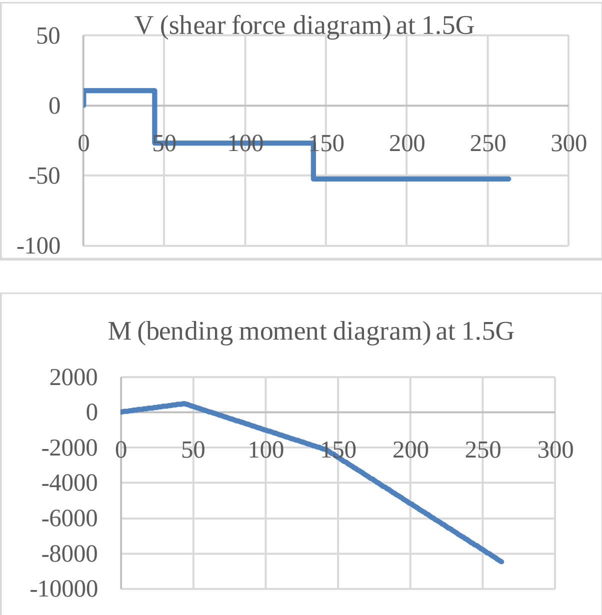


(c)



(d)

Figure 14: The shear force diagram and bending moment diagram at (a) 9G, (b) 6G, (c) 3G, and (d) 1.5G

IV. CONCLUSION

From this analysis there are several things that can be concluded, such as:

1. From the simulation of structural strength, it is known that the structure on the avionic rack has a less safe design with the smallest value of 0.10 because the analysis results show that the Margin of Safety (MS) value is close to 0, the smaller the Margin of Safety value, the weaker the strength of the structure.
2. From the deformation analysis, the structure moves too far with the largest deformation in the 6G force with a deformation value of 23.3 mm but because the structure does not support any device, it is in the safe category.
3. From the shear force diagram and bending moment diagram, it can be seen that the load covering 9G, 6G, 3G, and 1.5G has varying values. This is caused by different loading weights at each level.

REFERENCES

[1] M. E. Yalcin (2009) 'Design and Analysis of an Equipment Rack Structure of a', Master of Science, Middle East Technical University.

[2] Prabha, S. and Raghavendra, S. (2020) 'Overview on development of multi-dimensional aircraft arresting system at the time adverse failure of landing gear', Materials Today: Proceedings, 45.

[3] Sadraey, M.H. (2012) Aircraft Design: A Systems Engineering Approach, Aircraft Design.

[4] Carbonari, A. (2004) 'Avionic systems overview', Proceedings - 17th Symposium on Integrated Cicuits and Systems Design, SBCCI2004, p. 6.

[5] Baron, C. and Louis, V. (2023) 'Framework and tooling proposals for Agile certification of safety-critical embedded software in avionic systems', Computers in Industry, 148.

[6] Guida, M. and Marulo, F. (2014) 'Partial modeling of aircraft fuselage during an emergency crash landing', Procedia Engineering, 88, pp. 26–33.

[7] Ministry of Trasportation. (2013). Cetak CASR (Civil Aviation Safety Regulation) − Part 25 Airworthiness Standart: Transport Cat. Airplane, Rev: 05 | UNIT PERPUSTAKAAN DAN DOKUMENTASI. UNIT PERPUSTAKAAN DAN DOKUMENTASI. https://e-library.poltekbangsby.ac.id/index.php?p=show_detail&id=4446.

[8] Ge, J., Feist, T., Elmore, A., Reji, R., McLaughlin, B., Jin, Y., & Sun, D. (2022). Open hole surface integrity and its impact on fatigue performance of Al 2024-T3/Ti-6Al-4V stacks. Procedia CIRP, 108, 234–239. https://doi.org/10.1016/j.procir.2022.03.041.

[9] NeoNickel Ti 6Al-4V (Grade 5) n.d.https://www.neonickel.com/generate-alloy-pdf/?id=177.

[10] AMS4461 | 2024 Aluminium. (n.d.). https://www.smithsadvanced.com/ams4461.htm?gad_source=1&gclid=CjwKCAjw5v2wBhBrEiwAXDDoJXwjRPAQGvXHMwlb5Rrd4otd9pK7MN9Ek224dSXRLlwuqDj7wB9UeRoCUWYQAvD_BwE.

[11] Understanding Shear Force and Bending Moment Diagrams n.d. https://web.mit.edu/course/3/3.11/www/pset03/Rec5.pdf

[12] Brown, E. T., & Hoek, E. (1978). Trends in relationships between measured in-situ stresses and depth. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts/International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 15(4), 211–215. https://doi.org/10.1016/0148-9062(78)91227-5.

ISSN (online): 2581-3048
Volume 8, Issue 5, pp 104-111, May-2024
https://doi.org/10.47001/IRJIET/2024.805016

[13] Ahmad, W. (2012). Factor of Safety and margin of safety - Mechanical 360. Mechanical 360. https://www.mechanical360.net/updates/factor-of-safety-and-margin-of-safety/

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