Strength Analysis of Avionics Rack Structure during Emergency Landing on NC-XX Aircraft with Simulation

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Abstract - **Avionics rack is one of the most important parts of an aircraft that serves to place various electronic devices to support the aircraft during its flight. Certainly, the avionics rack itself is specifically designed so that the structure of the rack is able to withstand various flight conditions, one of which is when the aircraft experiences an emergency landing. The research aims to measure how strong the structure and materials used in supporting the devices stored on the avionics rack. Through the Finite Element Analysis method using software and hand calculation in calculating the Margin of Safety, it was found that the analysis carried out on the identified structure was declared safe in the event of crucial things such as emergency landing.**

Keywords: Avionic rack, emergency landing, finite element analysis, margin of safety.

I. INTRODUCTION

The aviation industry is an industry with constant growth. With the development of technology and experience gained in this field, newly designed aircraft have become much more useful than old aircraft. However, because designing a completely new aircraft is an expensive process for manufacturers, as is replacing used aircraft with new ones for customers, adapting new technology to existing aircraft is a widely undertaken process. The equipment rack structure designed in this research is part of one of the modernization projects. These racks are designed to carry new equipment developed to improve aircraft functionality. This goal must be achieved with low weight, ease of production and cost effective structure [1].

The aviation industry is a rapidly growing industry, the most comfortable and fastest way to travel. An aircraft is a system consisting of a number of interconnected parts that work together for a common aerial objective or purpose in the air [2]. Key objectives include safe flight achieved at low cost. Airplanes are extremely complex products consisting of many subsystems, components and parts [3].

Avionics is a term used to refer to the electrical and electronic systems in aircraft. Today, these systems are complex combinations of computers, sensors, actuators, controllers and displays that need to be connected and integrated into a very compact space. They must operate in real-time while maintaining high standards of safety and reliability in high-pressure environments. Avionics plays an increasingly important and central role in modern aircraft. As technology advances, the need for this system also increases [4].

Avionic Rack is one of the critical structures on an aircraft, ensuring their function and reliability during flight. These racks are usually made of lightweight and durable materials, such as aluminum or composite materials, to minimize weight while maintaining structural integrity. Avionics racks are designed to meet specific industry standards and regulations, ensuring compatibility, safety and efficient integration of avionics equipment.

Safety is an important issue in the aviation industry. High reliability of the aircraft and all its systems, components and equipment. If a system function is considered safety critical, aviation regulators require demonstration that the framework used for system development is acceptable [5-9].

Emergency Landing in aviation refers to the act of landing an aircraft in an emergency. In situations like this, structure is of course the main thing in ensuring safety when dangerous situations such as Emergency Landing occur in order to continue to ensure the safety of passengers and maintain navigation and communication on the aircraft.

In an emergency landing, the first requirement refers to the ability of the airframe to preserve critical space for the passenger upon impact and then limit the passenger's acceleration in terms of magnitude and duration time.

The purpose of this study concerns the impact phenomenon, which is often not addressed to understand whether and how the structure deforms, but rather whether the structure distributes the kinetic energy due to impact touch or not and whether it can fully participate in the absorption of impact process [10-12].

II. RESEARCH METHODOLOGY

In the analysis, a flow chart is created that illustrates the problem-solving process.
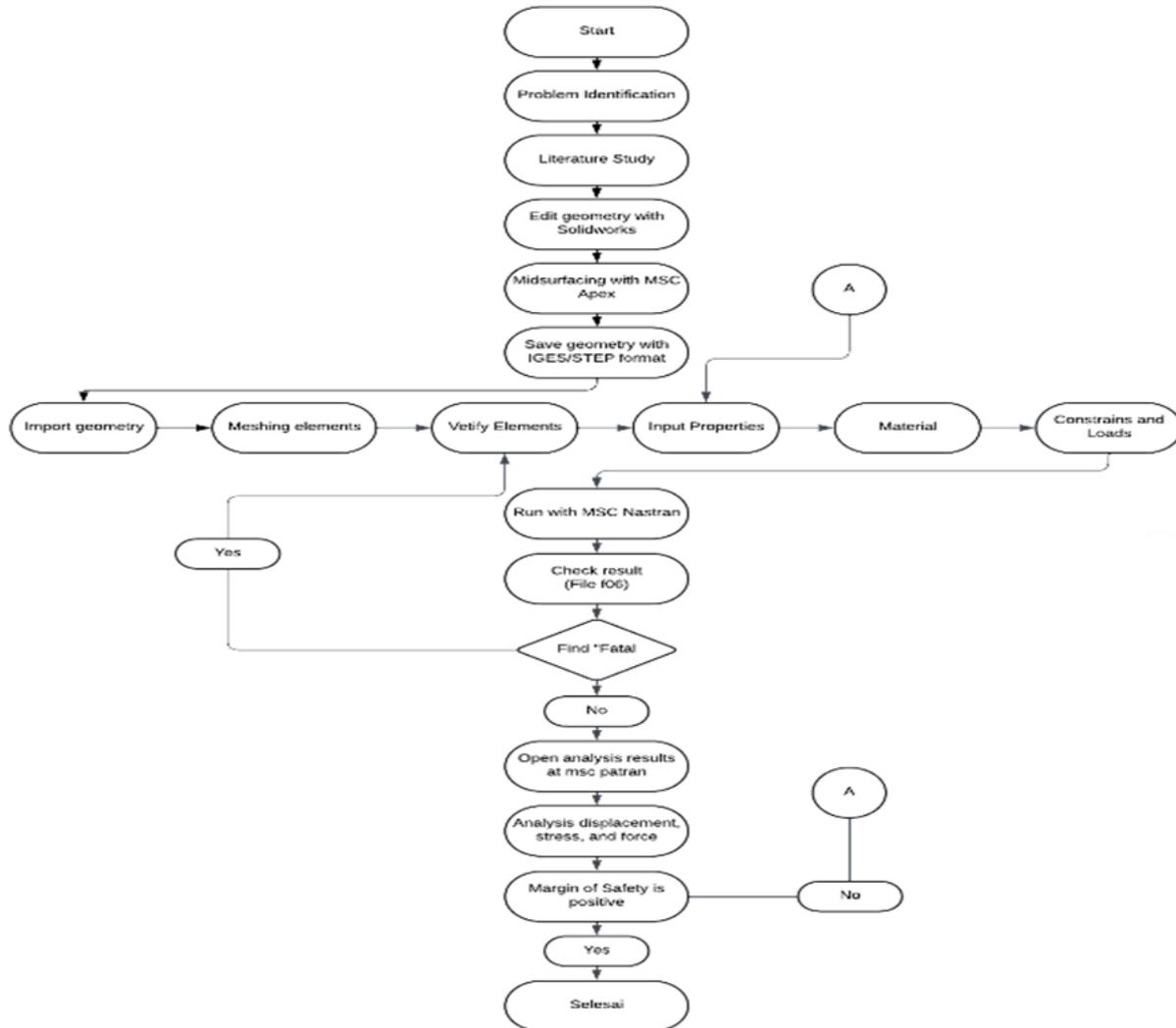

Figure 1: Flowchart of problem-solving process

2.1 Edit Geometry Process

The geometry editing process involves several steps, including:

a) Designing: Edit some components to be able to analyze the structure to see how it affects strength.
b) Remove rivet: to create a hole that functions as a point where the force will be distributed as a connector between rods.
c) Midsurfacing: to determine the efficient thickness of the structure.

The process of edit geometry is used to edit some components that are needed or not needed in the analysis so that the results of the analysis are more optimal.

2.2 Meshing Process

The process of meshing geometry involves several steps, including:

a) Select the element type: to obtain accurate and efficient analysis results. The type of element selected should be appropriate to the geometry of the model, the type of analysis being performed and the desired level of accuracy analysis being performed, and the desired level of accuracy.
b) Determine the mesh size: to strike a balance between accuracy and efficiency a small mesh size will produce.
c) More accurate analysis results in a longer time. A large mesh size will produce less accurate analysis results, but the time will be faster.

d) Verify elements: The mesh should be checked to ensure that the elements are properly sized and distributed, that no element is too small or too large, and that there are no overlapping elements.

This process of meshing is to divides the geometry of an object or component into smaller elements for analysis.

2.3 Input Properties

The process of input properties involves several steps, including:

a) Create material: To define the physical properties of the material to be analyzed.
b) Input to elements: provide the material characteristics of the structure to be analyzed according to the specified material.

The purpose of inputting properties on the element during analysis is to determine the physical characteristics of the element; the material used in this structure is Al 2024 T3 with a density of 72.39495 and a poison ratio of 0.33.

2.4 Input Constrain and Loads

Input constraints and loads are very important in CFD (Computational Fluid Dynamics) analysis. These inputs make it possible to provide important parameters and inputs needed in CFD analysis, which ultimately affect the accuracy and validity of the analysis results. In this analysis, many variables are used such as 9G forward, 6G downward, 3G sideward, 3G upward, 1.5G rearward and fixed support forces are inputted to support the structure.

III. RESULTS AND DISCUSSION

3.1 Product Specification

Product Name: Aviation Rack
Type: 2XXX
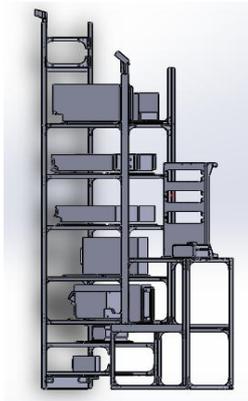The product can be seen in the following Figure 2.

Figure 2: Aviation Rack 2XXX

3.2 Stress Tensor Analysis

Stress tensor analysis is an analysis to determine the stresses acting on an object or component. Stress is the force per unit area acting on an object or component. Stress can cause damage to the object or component.

3.2.1 9G Forward

The analysis results show that there is material stress in the storage of Relay Box and Data Concentrator Unit with a total maximum stress of 42.1 DaN (Deca Newton). The stress area that occurs can be seen in Figure 3.
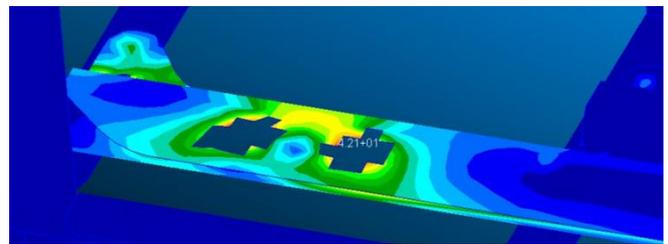

Figure 3: 9G Forward Tensor area

3.2.2 6G Downward

The analysis results show that there is material stress on the Relay Box and Data Concentrator Unit storage with a total maximum stress of 29.2 DaN. The stress area that occurs can be seen in Figure 4.
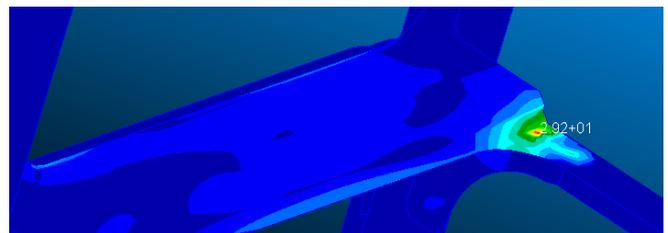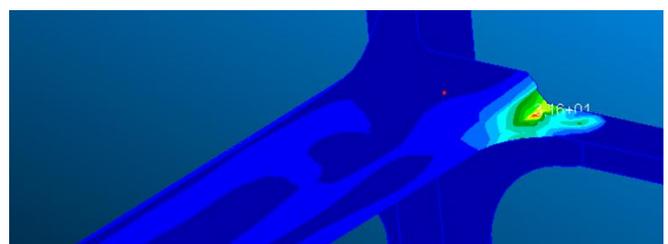

Figure 4: 6G Downward Stress area

3.2.3 3G Sideward

The analysis results show that there is material stress on the Relay Box and Data Concentrator Unit storage with a total maximum stress of 29.2 DaN. The stress area that occurs can be seen in Figure 5.

Figure 5: 3G Sideward Stress area

3.2.4 3G Upward

The analysis results show that there is material stress on the Relay Box and Data Concentrator Unit storage with a total maximum stress of 14.6DaN. The stress area that occurs can be seen in Figure 6.
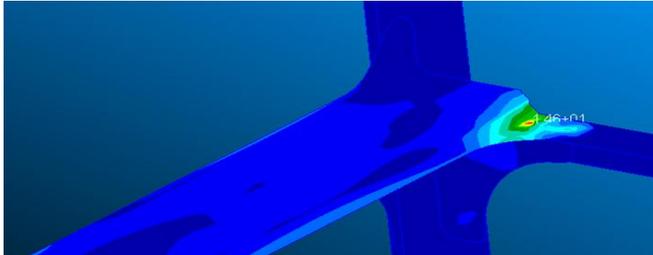

Figure 6: 3G Upward Stress area

3.2.5 1.5G Rearward

The analysis results show that there is material stress on the Relay Box and Data Concentrator Unit storage with a total maximum stress of 9.91DaN. The stress area that occurs can be seen in Figure 7.
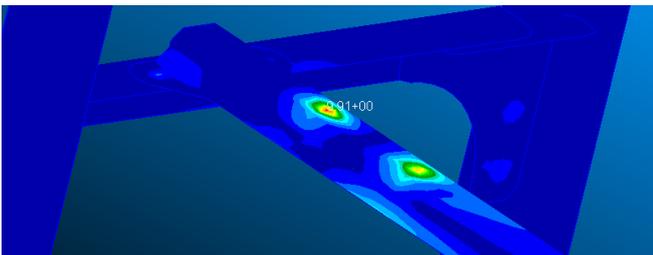

Figure 7: 1.5G Rearward Stress area

3.3 Margin of Safety

Margin of Safety (MOS) is the ratio between the capacity or power of the machine and the load acting on the machine. The function of margin of safety analysis is to ensure that a structural design is safe for use in certain situations or conditions and to measure the extent to which a structural design is within its strength or capacity limits, by calculating material strength, safety factors, gravity and other environmental influences that can influence design. In the material used, the stress tolerance used is 43.4 DaN.

3.3.1 9G Forward

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43,4}{42,1} - 1 = 0,03$$

42.1 DaN is obtained from the results of stress analysis in the structure in 9G forward force, and the margin of safety value is 0.03.

3.3.2 6G Downward

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43,4}{29,2} - 1 = 0,48$$

29.2DaN is obtained from the results of stress analysis in the structure in 6G downward force, and the margin of safety value is 0.48.

3.3.3 3G Sideward

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43,4}{31,6} - 1 = 0,37$$

31.6DaN is obtained from the results of stress analysis in the structure in 3G sideward force, and the margin of safety value is 0.37.

3.3.4 3G Upward

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43,4}{14,6} - 1 = 1,97$$

14.6DaN is obtained from the results of stress analysis in the structure in 3G upward force, and the margin of safety value is 1.97.

3.3.5 1.5G Rearward

$$\text{MS} = \frac{\sigma_{\text{allowable}}}{\sigma_{\text{applied}}} - 1 => MS = \frac{43,4}{9,91} - 1 = 3,37$$

9.91DaN is obtained from the results of stress analysis in the structure in 1.5G rearward force, and the margin of safety value is 3.37.

3.4 Deformation Analysis

Deformation analysis is used to model how a system or structure changes shape due to fluid loads received during operation, as well as to estimate and visualize the deformation that occurs in the system or structure so that it can ensure that the system design created is safe and does not experience failure during operation.

3.4.1 9G Forward

The maximum deformation that occurs is 41.8 millimeters in the forward direction. The deformation that occurs can be seen in figure 8.
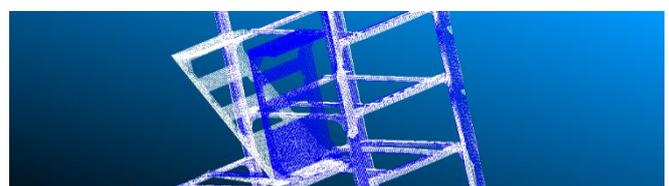

Figure 8: 9G Forward Deformation

3.4.2 6G Downward

The maximum deformation that occurs is 62.7 millimeters in the downward direction. The deformation that occurs can be seen in figure 9.
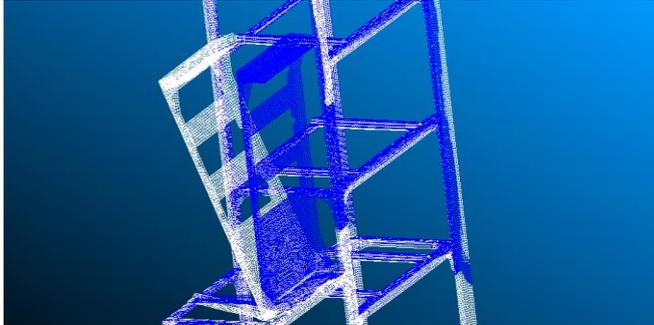

Figure 9: 6G Downward Deformation

3.4.3 3G Sideward

The maximum deformation that occurs is 17.6 millimeters in the sideward direction. The deformation that occurs can be seen in figure 10.
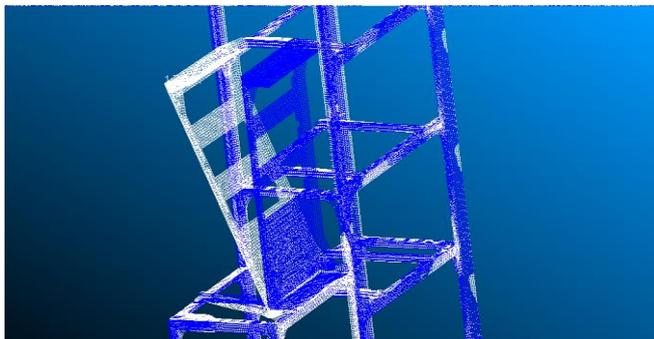

Figure 10: 3G Sideward Deformation

3.2.4 3G Upward

The maximum deformation that occurs is 31.3 millimeters in the upward direction. The deformation that occurs can be seen in figure 11.
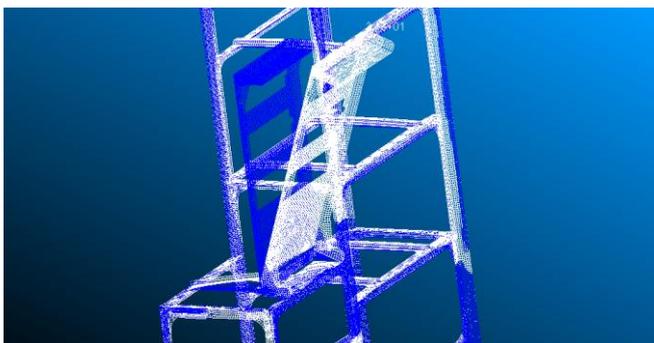

Figure 11: 3G Upward Deformation

3.2.5 1.5G Rearward

The maximum deformation that occurs is 6.96 millimeters in the rearward direction. The deformation that occurs can be seen in figure 12.
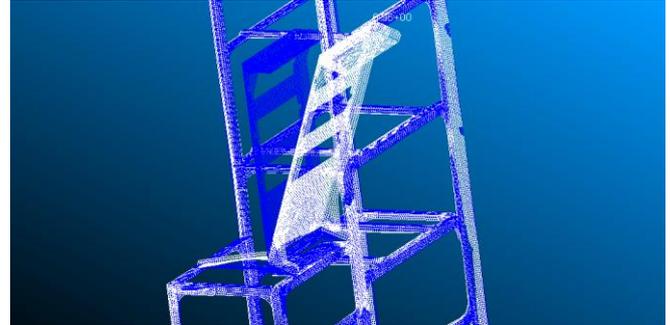

Figure 12: 1.5G Rearward Deformation

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 0.03 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 9G force with a deformation value of 41.8 mm but because the structure does not support any device, it is in the safe category.

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