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Requirements and design structure for Surya Satellite-1

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Abstract. Currently, there are various references on the manufacture of nanosatellite specifications weighing 1KG - 10KG.The Surya Satellite-1 is the first nanosatellite made by universities in Indonesia. The Surya Satellite-1 team gets a launch offer from Japan Aerospace Exploration Agency (JAXA) and, all the nanosatellites manufacturer racers at ICD (Interface Control Document) obtained from JAXA. The formation of the Satellite-1 Surya framework is also based on the provisions of JAXA. The various specifications and requirements specified by the JAXA space agency consisting of specific specifications such as the mass of nanosatellite 1U (10cm x 10cm x 11.65cm) size of at least 0.13KG and a maximum of 1.33KG, with the determination of a gravity point not exceeding 2 cm from the nanosatellite geometry center point. In the case of preventing solar radiation in space, there is a requirement that the structure of satellite structures on hard black anodization should be more than 10 meters in the surface of the satellite structure. In terms of detail, the satellite structure is a black hard anodized aluminum after its manufacturing process derived from the MIL-A-8625 document, type 3.

1. Introduction

In many developed countries, Nanosatellite design by students has become very common, but in Indonesia, this is a remarkable achievement. Surya Satellite-1 is a Surya University student project that works with National Institute of Aeronautics and Space (LAPAN) and Amateur Radio Organization of Indonesia (ORARI). The aim of this project is to become a pioneer in making the first cubesat in Indonesia and to be the inspiration of other students to design their own cubesat that meets the criteria and space agency requirements. The Surya Satellite-1 mission is an Automatic Packet Reporting System (APRS) communication that orbits in Low Earth Orbit (LEO). The Surya Satellite-1 mass is 1.15 kg which is planned to be launched with Japan Aerospace Exploration Agency (JAXA) J-SSOD (JEM-Small Satellite Orbital Deployer) module. So all the requirements and design of Surya Satellite-1 refer to the standards contained in JEM Payload Accommodation Book Vol.8 Small Satellite Development, Interface Control Document, JAXA [1,2].

Like satellite in general, the role of satellite structure is very important, causing the research and development of Surya Satellite-1 structure to be very important as well. Therefore, this paper will explain the design, analysis, manufacture, and testing of Computer Aided Design (CAD), Engineering Model (EM) model, to Surya Satellite-1 Flight Model (FM) [2,3,5]. Satellite structures must be able to withstand the burden and force provided by the rocket when launched into space. Structures should be designed with careful calculations and careful considerations, both from their own mechanical systems and every subsystem contained in the satellites. The inspiration in the Cubesat structure design process can be obtained from the design developed by the spacecraft company, which is tailored to the needs and requirements of the launcher, due to the lack of practical experience in designing the satellite while the small error in the design of satellite structures can cause fatal damage on the satellite as a whole as well as on each component of the satellite subsystem [4,6]. The purpose of this research is to design an optimum Surya Satellite-1 structure in accordance with the satellite mission and in accordance with the requirements of the launcher.

In making the Surya Satellite-1 structure, the Research Team refers to the Interface Control Document (ICD) provided by the JAXA Space Agency. The construction of the Surya Satellite-1 Structure is 1U in shape, which means it has a volume of 100 mm x 100 mm x 113.5 mm with a structure weight of approximately 554 grams. The material selection process for the Surya Satellite-1 structure not only takes into account the weight factor, but also the thermal power factor of conductivity, manufacturing process and cost. The design process of the Surya Satellite-1 CAD model is done by using Solidwork 2015 software by considering several factors. In addition to the design drawings, the design of this CAD model can be used for Finite Element Method (FEM), Buckling, and Vibration testing in ANSYS 2014 software [15,16]. The test results using this software will serve as an initial prediction of the strength of satellite structures prior to laboratory scale testing which should be done as validation.

2. Surya Satellite -1

2.1. Standart Cubesat Requirement

The design of the Surya Satellite-1 structure design refers to the ICD provided by the JAXA to any cube maker that will launch its satellites using JAXA's launch vehicle. The launcher provided various requirements regarding the cubesat structure design specifications to be launched [9,11,13]. The requirements consist of Mass Requirement, Dimension Requirement, and Material Structure Requirement [7,8,10,12,14].

2.1.1 Mass Requirement

1. Mass Total Satellite size 1U minimum 0.13 kg and maximum 1.33 kg.
2. Center of gravity of all satellites cannot be more than 2 cm from satellite geometry center.

2.1.2 Dimension Requirement

1. 1U magnification size of 100mm + -0.1mm for X and Y coordinates, for Z coordinates of 113.5mm + -0.1mm.
2. Minimum Rails width should be 8.5mm.
3. The outer surface of Cubesat shall not touch the inside of the J-SSOD module, other than the rails portion of cubesat.
4. No component exceeds the total area of the cubesate of 6.5 mm.
5. The creation of the cubesat accesss window must be in the coordinates of -Y or + X.
6. For cubesat size 1U and 2U there shall be a hole for separation spring provided by the space agency, for 3U cubesat size is not required.

2.1.3 Material Structure Requirement

1. All materials and components must be installed during launching, ejection, and cubesat operation.
2. Aluminum 7075 and 6061 materials should be used for the manufacture of main structures and Cubesat rails.
3. The cubesat surface and rails shall be anodized with a minimum thickness of 10 microns meters, in accordance with the requirements of MIL-A-8625, type 3 document.
4. Toxic and hazardous materials should not be used in the manufacture of cubesat.

2.2. Methodology of Surya Satellite - 1 Structure

In essence, the construction of the Surya Satellite-1 structure is based on satellite and ICD missions provided by the launcher. Preparation of satellite structure design requires several steps in the engineering process, among others: initial design, material selection, analysis using simulation method, discussion of simulation results, to obtain Engineering data from the simulation process [17-19]. The simulation results are then analyzed and interpreted based on ICD. For more details, the following schematic diagram of the design of Surya Satellite-1 structure design:

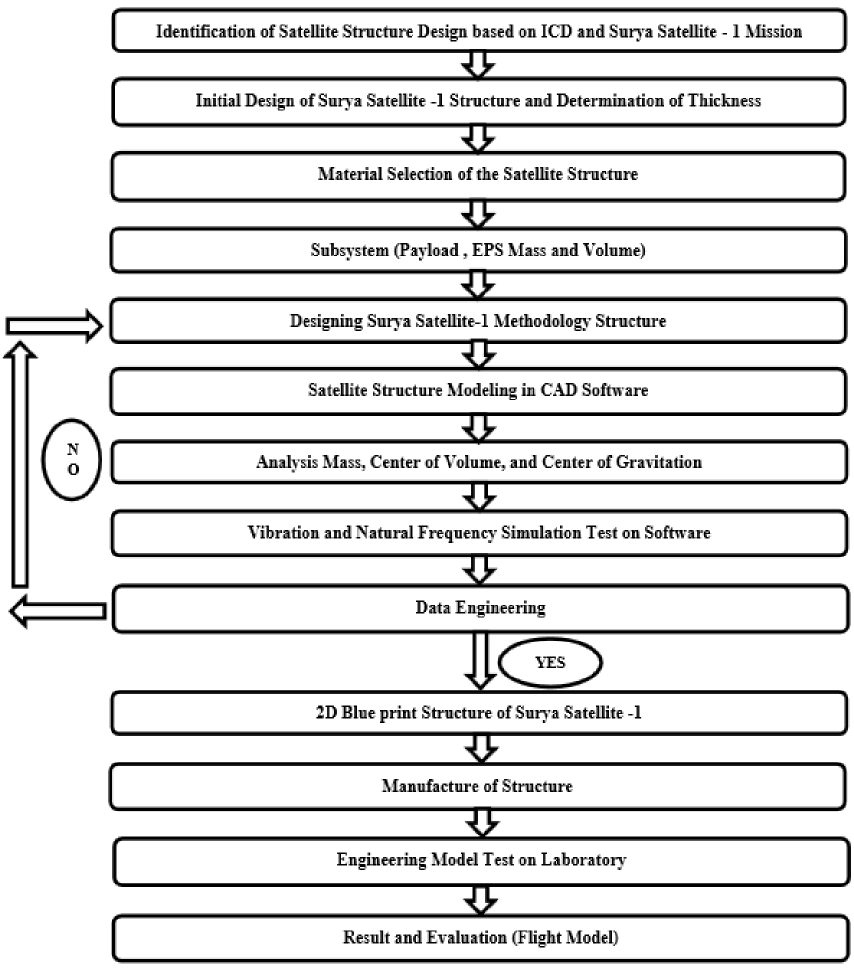

Figure 1. Methodology of Surya Satellite-1 structure making.

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2.3. Component of Surya Satellite -1

The 1U Surya Satellite -1 array consists of various subsystems inside which are arranged in 6 layers of Printed Circuit Board (PCB). To find out the mass detail of each subsystem are found in Table 1.

Table 1. Component of Surya Satellite-1.

No.	Subsystem	Mass (gram)
1	Structure	554
2	Deploy Antenna System	21
3	Module Radio	45
4	Payload	40
5	On Board Data Handling	42
6	Battery	174
7	Electronic Power System	53
8	Solar Cell	189

3. Selection Material of Surya Satellite –1

3.1. Structure Material

The selection of the next material becomes one of the most important elements in making the Surya Satellite-1 structure. In order to minimize failure / damage, in addition to being based on ICD of JAXA, the selection of materials must also be in accordance with the recommendations that have been published by space agencies such as NASA, ESA or space agencies, particularly regarding the strength of the material and its outgassing properties in vacuum chamber and others [20,21]. Particularly in the creation of a 1U satellite structure a small design change alone can affect subsystems in satellites. Not only is the weight factor considered, but many other parameters such as thermal conductivity, manufacturing process, and cost [22,23]. Based on these factors selected material used in the manufacture of Surya Satellite -1 structure is Aluminum type 7075-T6. This type of material is in addition to use for satellite skeletons, many also used for other aerospace needs such as commercial aircraft frameworks. For more details, the materials and composition contained in the aluminum 7075 type can be seen in Table 2 and Table 3.

From Parties JAXA allows 2 types of aluminum that is 7075 and 6061 in the manufacture of cubesat structure. After doing various research and search some reference got comparison of characteristics and criteria contained in Table 4.

Table 2. Component of material Aluminum 7075.

Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Wt. (%)	87.1 - 91.4	0.18 - 0.28	1.2 - 2	Max 0.5	2.1 - 2.9	Max 0.3	Max 0.4	Max 0.2	5.1 - 6.1

Table 3. Material properties of Aluminum 7075.

Material Properties			
Physical Properties		**Electrical Properties**	
Density (gr/cc)	2.81	Electrical Resistivity (ohm.cm)	5.15 e-006
Material Properties		**Thermal Properties**	
Hardness Brinel (Hb 500)	150	Specific Heat Capacity (J/g – °C)	0.96
Ultimate Tensile Strenght (MPa)	572	Thermal Conductivity (W/m-K)	130
Tensile yield Strenght (MPa)	503	Melting Points (°C)	477-635
Elongation at break (%)	11	Solidus (°C)	477
Modulus of Elasticity (GPa)	71.7	Liquidus(°C)	635
Poisson's Ratio	0.33	**Processing Properties**	
Fatigue Strength (MPa)	159	Annealing Temperature (°C)	413
Machinability (%)	70	Solution Temperature (°C)	466-482
Shear Modulus (GPa)	26.9	Aging Temperature (°C)	121
Shear Strength (MPa)	331		

Table 4. Comparison of Alumunium 7075 dan 6061.

Criteria	Percentage	Al 7075		Al 6061	
		Score	Value	Score	Value
Stiffness to Mass Ratio	40	10	400	9	360
Manufacture Time	15	10	150	10	150
Uniformity	25	10	250	10	250
Durability	20	10	200	10	200
Total			1000		960
Priority		1		2	

3.2. CAD Modelling

The purpose of this research is to design an optimized Surya Satellite-1structure in accordance with the satellite mission and in accordance with the requirements of the launcher. Things to consider in designing satellite structures are the size of the rails contained in the corners of the structure, the installation of solar panels, and the six sides of the satellite structure that must conform to the "Cube Sat Design Specification". The selection of Aluminum 7075 material as a Surya Satellite-1 structure material has become the best choice in accordance with the given requirements. In addition, the satellite structure must be adaptive so that if during installation and testing stages, hindrance occurs in subsystems or other disturbed parts, there is no need to redesign the entire satellite structure [24-27]. From the various requirements, the main model of Surya Satellite -1 is designed, which also consists of 6 sides, including Antenna Deployment System section. These 6 sections will be combined using the M3 and M2 size bolts.

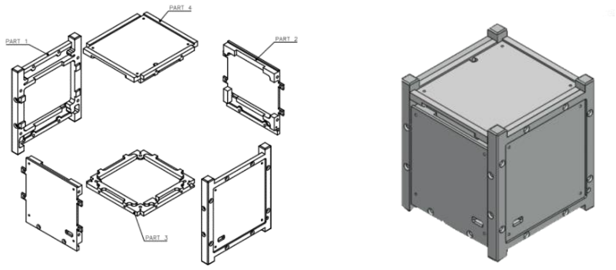

Figure 2. The unification mechanism of Surya Satellite Structure-1.

3.2.1 Antenna Deployment System

The Surya Satellite-1 Antenna Deployment Mechanism uses a nylon string disconnect system by NiCr wire which is powered by certain voltages and currents. The NiCr wire will heat up in a few moments after being set by the timer to disconnect the nylon string. After the nylon is broken then the retainer (blue colour) made of Teflon PTFE is no longer stuck by nylon. Antenna VHF and UHF will certainly force it out of the module, so the holder will be pushed out. Equally important is the satellite antenna deployment module installed 2 switches on each antenna (1 main switch and 1 backup switch) so that there are a total of 4 switches that detect the position of the antenna VHF and UHF is still in folded or has been unfolded [28,29].

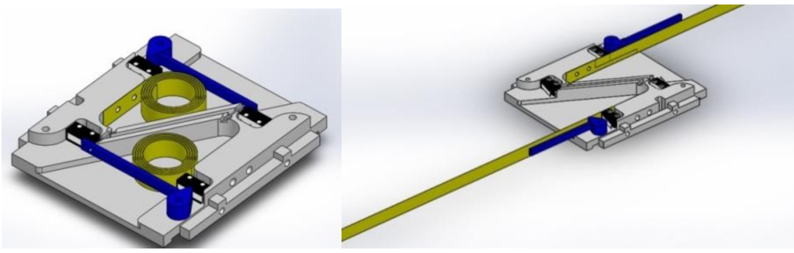

Figure 3. Antenna deployment system.

3.2.2 Surya Satellite-1 CAD Modelling

The Surya Satellite structure -1 is designed to meet the requirements of "Cubesat Standard Design". The structure weighs 554 grams to carry the main load, arranged like a rack with 6 layers of PCB with different functions (see figure 4 left). PCBs are stacked to be reinforced with structures on the Z axis. The connection between PCBs is used spacer made of stainless steel as amplifier between PCB and upper (Z +) and bottom (Z -) structures [30-32]. For the exterior of the structure are made space used for solar panels on the six sides of the satellite (see figure 4 right). Design of the overall design of the Surya Satellite-1 structure is done on Solidwork 2015 software.

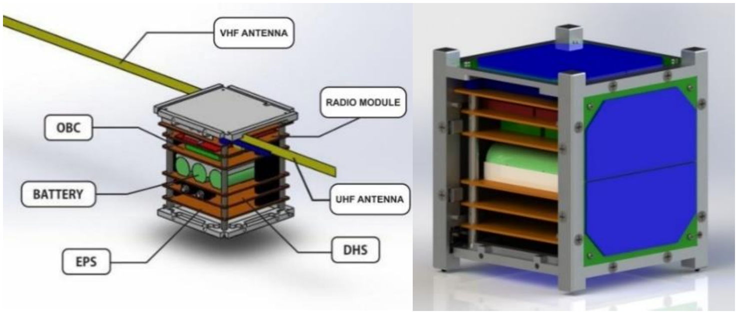

Figure 4. Surya Satellite-1 3D CAD Modelling.

4. Structural Analysis and Results Summary

Analysis of the main satellite structure strength was done by simulation and FEM analysis on ANSYS 14 software [33-34]. Various experiments were conducted to obtain static load values, natural frequencies, and strength limits of satellite structures [35-39]. The analysis of the satellite structure was initiated by modelling 3D in CAD software. Then, simulation of natural frequency and static is performed [41-45]. The reference value / limit value of this simulation is adjusted to the choice of JAXA launcher vehicle offered on the ICD of the launcher rocket [45-49].

4.1 Static Analysis

The first step in performing static analysis on ANSYS software is to process the meshing on the satellite structure model. The meshing process can be done by joining the segments of the image so that the 3D image can be used as a model for simulation in ANSYS software 14. In static experiments analysis of satellite structure of 1U Cubesat satellite yields the total deformation value shown in the figure. The analysis shows the total deformation value of 0.0001242 mm and this value is very small when compared to the thickness of the Surya Satellite-1 structure. The total value of Von Misses pressure is 0.45076 MPa This value is much smaller than the strength of Yield Strength material Aluminum 7075 of 331 Mpa (figure 5)

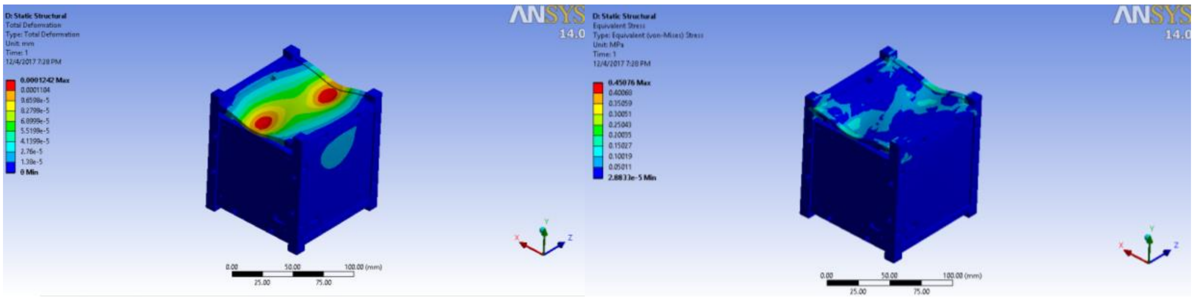

Figure 5. Maximum deformation and maximum von mises stress.

4.2 Frequency of Analysis

The satellite structure must be designed to with stand shocks during the launch process. To prevent resonance at launching, the experiment is performed in several modes. All modes in the natural frequency analysis are in the table 5 and the results of this analysis are in the figure 6.

Table 5. Natural frequencies

S .No	Mode	Natural Frequency (Hz)	S .No	Mode	Natural Frequency (Hz)
1	1	3199.1	9	9	5080.5
2	2	3231.7	10	10	5116.3
3	3	3484.1	11	11	5653.5
4	4	3858.1	12	12	5953.1
5	5	4584.2	13	13	6210.9
6	6	4698.7	14	14	6277.6
7	7	4808.5	15	15	6541.7
8	8	5016.9			

Natural Frequency at mode 1 and mode 15 with the total deformation at first mode and 15^{th} mode of 2011.7 mm and 2743.7mm was shown in figure 6.

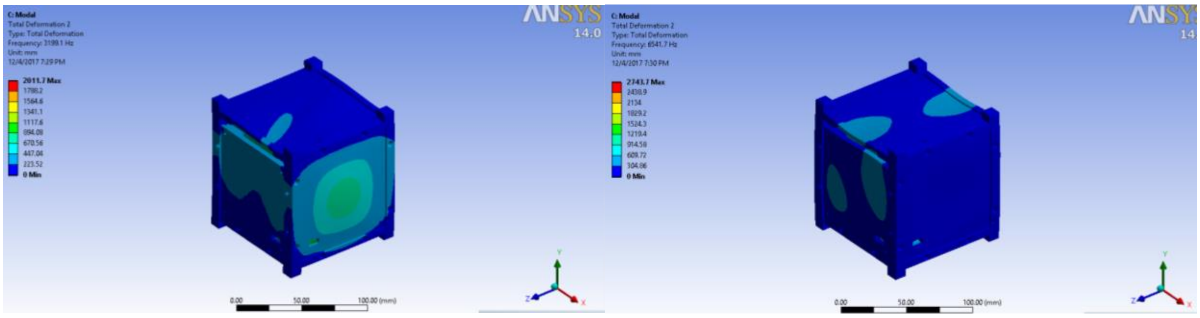

Figure 6. Deformation at mode 1 and mode 15

5. Conclusion

The cubesat Surya Satellite-1 structure design has a mass of 480 grams with a volume of 100mm × 100mm × 113.5mm (h) using Aluminum material 7075-T6. Material selection not only takes into account the weight factor, but many other parameters such as thermal conductivity, manufacture process, and cost. 3D CAD modelling is done on Solidworks 2015 software and simulated in software ANSYS 14. Simulation is done with the aim to get maximum deformation value; maximum von misses pressure, and natural frequency mode of Surya Satellite-1 structure.

The simulation results show the von mises pressure value of 0.45076 MPa which is smaller than the yield strength of aluminum 7075 of 331MPa. While the total deformation value of 0.0001242 mm is still very small when compared to the thickness of Surya Satellite-1 structure. This simulation is done by FEM method and refers to the largest static quasi value. From the results of this simulation we can conclude that the designed Surya Satellite- 1 structure has met the requirements of "Cubesat Standard Design" in accordance with what is written on JAXA ICD. The simulation result would be tested on vibration test by laboratory scale.

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