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Analysis of Vibration in Payload Room Due to Engine Vibration on LSU-05 NG

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Abstract. LSU-05 NG is one of the Unmanned Air Vehicles (UAV) developed by the aviation technology center LAPAN. The LAPAN aviation technology center designed the LSU-05 NG to be able to carry a larger payload and broader range than other types of LSUs. Therefore, the LSU-05 NG uses an engine that has enough power. LSU-05 NG uses a piston-type engine with a capacity of 170 CC. UAV engine is the primary source of vibration in the UAV structure. Excessive vibration can cause damage to the UAV structure and malfunction of the UAV payload, such as sensors, control systems, and cameras. In this research, vibration measurements were carried out at 2 locations. The measurement location is on the engine and where the payload is installed. The vibration measurement on the LSU-05 NG was carried out during the ground test. The accelerometer sensor is used to measure vibrations and is connected to the NI data acquisition system and displayed with LabVIEW. The data to be taken are acceleration and frequency data with variations in the RPM value on the LSU-05 NG engine. With these measurements, the vibration characteristics caused by the engine in the LSU-05 NG structure, primarily where the payload is stored can be known.

Keywords: Engine, Vibration, Accelerometer, LabVIEW, UAV

Introduction

The LSU-05 NG is one of the Unmanned Air Vehicles (UAV) variations developed by an aviation technology center LAPAN. The LSU-05 NG is a variation with the most significant dimensions and weight of all LSUs under development. The LSU-05 NG is designed to have a total weight of about 85 Kg and can fly as far as 400 Km [1]. Therefore, the LSU-05 NG uses an engine with enough power to produce thrust and lift by its total weight [2]. LSU-05 NG uses a piston-type engine with a capacity of 170 CC [3].

The engine on the UAV is one of the sources of vibration in the UAV structure. The occurrence of this vibration is normal as long as it does not exceed the tolerance limit [4]. Excessive vibration can cause damage to the UAV structure and malfunction of the payload on the UAV, such as sensors, control systems, and cameras. For example, if it happens to the camera, the resulting photo becomes out of focus [5]. In addition, if it occurs in the IMU sensor, it will affect the control system [6].

Previous research in aviation technology center LAPAN has only discussed the propeller and thrust [7]. Whereas the UAV engine, in addition to producing thrust, also produces vibration. In this research, vibration measurements were carried out at 2 locations. The measurement location is on the engine and where the payload is installed. The vibration measurement on the LSU-05 NG was carried out during the ground test. Similar studies have also been carried out on cars to determine the response of car floor vibrations due to engine vibration [8]. Vibration is

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measured using an accelerometer sensor. The measurement data is in the form of the acceleration value with units of g. The accelerometer sensor is connected to the data acquisition system made by NI. The vibration measurement results will be displayed with the interface display software developed with LabVIEW. The value of the vibration magnitude that occurs in the LSU-05 NG is calculated using the RMS calculation formula resulting from the acceleration reading. The calculation of the RMS value is used to determine the magnitude of the vibration value that occurs in an object [9].

Measurement of vibration on the engine and payload space on the LSU-05 NG aims to determine the effect of the vibration generated by the engine on the amount of vibration that occurs in the payload space. By knowing the amount of vibration that occurs in the LSU-05 NG payload space, it can be used as a reference for the treatment of the payload so that it is not damaged or fails to function.

Research Methods

In this research, the method used is experimental. This research consists of several stages. The following are the steps carried out, including:

1. Collect information relating to vibration measurements on the engine. The source of this information can be an engineering journal or other technical information.
2. Design a data acquisition system that will be carried out to perform vibration measurements. The software used for data retrieval, processing, and storage uses LabVIEW software.
3. Validate the output of the accelerometer sensor using a vibration test system.
4. Prepare for testing requirements by setting up a data acquisition system and installing sensors on the LSU-05 NG.
5. Perform the test by measuring the vibration. Vibration measurements are carried out several times with variations in engine speed or RPM. It is hoped that with this variation, it will be known at the time of RPM what is the largest vibration value received by the LSU-05 NG structure.
6. Analyze test result data and make conclusions. In this study, the analysis is limited only by reading the acceleration that occurs in the LSU-05 NG in the time domain and determining how big the vibration value is.

The preparation activities are carried out in several stages.

1. Sensor Validation
   Validation activities are carried out to determine whether the sensor readings are appropriate or not. Validation activities are carried out by comparing the vibration readings using the accelerometer sensor mounted on the vibration test equipment. The vibration test equipment will be given variations in the form of changes in acceleration and frequency. The readings of the acceleration and frequency values on the vibration test equipment are carried out by the control module, which can also be used to obtain data so that the values from the readings can be used as a comparison on the vibration measurement system that will be used. Tool settings for validation can be seen in Figure 1.

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Figure 1. Accelerometer sensor validation activities using a vibration test system

2. Sensor Installation
Measurement of vibration in the payload space LSU-05 NG is using the accelerometer sensor. The accelerometer sensor used is a product of SENZ with part number SZ3055B2. The sensor is IEPE type with one axis direction. In this measurement, four sensors are used, which are placed on the engine as many as two pieces with the direction of the X (Horizontal) and Z (Vertical) axis, while two more are installed in the payload space with the same axis direction as those installed on the engine. The sensitivity and placement of the four sensors can be seen in Table 1. The installation of the accelerometer sensor can be seen in Figure 2.

Table 1. Sensor specifications and their placement on the structure of PTTA LSU-05 NG

Code	**Location**	**Direction**	**Sensitivity** (mV/g)
Sensor 1	Engine	Z-axis (Vertical)	98.08
Sensor 2	Engine	The X-axis (Horizontal)	98.92
Sensor 3	Payload Room	Z-axis (Vertical)	98.19
Sensor 4	Payload Room	The X-axis (Horizontal)	96.94

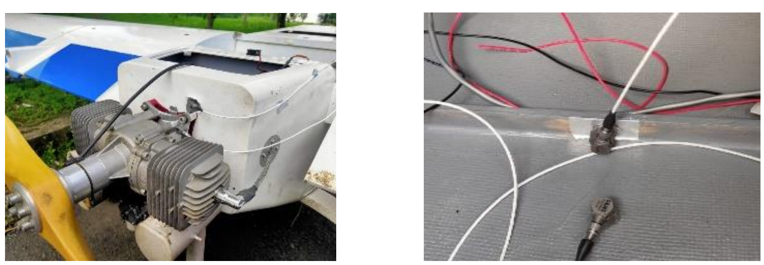

Figure 2. Mounting sensors on LSU-05 NG's structure

3. Data Acquisition System Settings
Measuring vibrations in the engine and payload bay of the LSU-05 NG using National Instrument's hardware data acquisition system. The hardware consists of the cDAQ 9148 combined with the NI 9234 module which functions to acquire data from the accelerometer sensor. The cDAQ 9148 hardware is on a computer using an ethernet cable [10]. The NI 9234 module is a hardware device used for signal processing from piezoelectric sensors both IEPE and non-IEPE types such as accelerometer, tachometer, and proximity sensors [11]. In addition, it also uses software developed using LabVIEW, which functions to process, display, and store data. The software has a sampling rate of 25,000 data per second so that

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it can detect vibrations. The settings for the data acquisition system used can be seen in Figure 3, and the interface that was developed using LabVIEW can be seen in Figure 4.

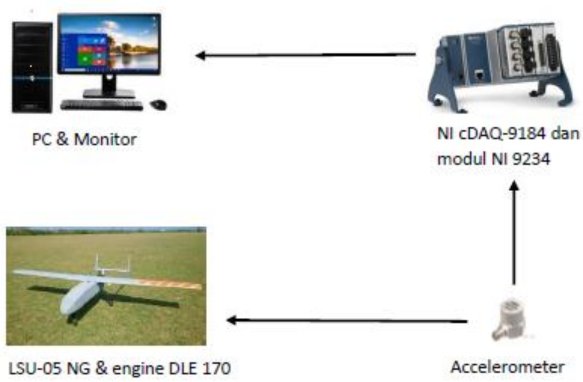

Figure 3. Data acquisition system

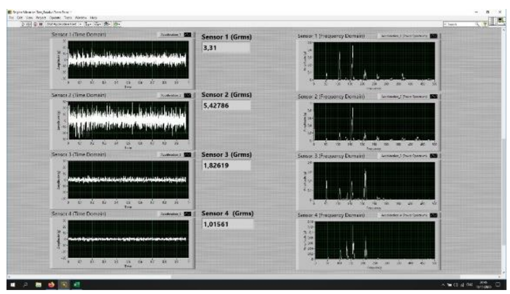

Figure 4. LabVIEW user interface

4. Measurement Procedure

Vibration measurement activities are carried out referring to previous research, namely regarding vibration measurements in vehicles. Vibration measurements are carried out on the ground with the vibration source only from the engine and ignore the surrounding environment's vibration source [8]. At the time of measurement, the LSU-05 NG is tethered with a rope on a solid pole, and this is done so that when the engine is started, the LSU-05 NG will remain in position.

Vibration measurement is done by varying the RPM on the LSU-05 NG engine. The remote control is used to set the RPM variation on the LSU-05 NG engine. The RPM variation starts when the engine is idle, which is 1500 RPM. Furthermore, the RPM Variations are 2500 RPM, 3500 RPM, 4500 RPM, and a maximum of 5500 RPM.
The measurement data is in the form of data from the accelerometer sensor, namely the acceleration value in g. The data is then stored on the computer. The stored data is then processed offline using a software interface to get the RMS acceleration value. The RMS value is the root of the sum of the values squared at several measurement points [12]. Photos of measurement activities can be seen in Figure 5.

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Figure 5. Measurement and data collection activities

Results and Discussion

The vibration data retrieval on the LSU-05 NG is carried out at rest on the ground by considering the assumption that the received vibration source only comes from the aircraft engine. The results of the acceleration measurements detected in the engine and the structure of the payload space can be seen in the graph of acceleration measurements in the time domain in Figure 6-10.

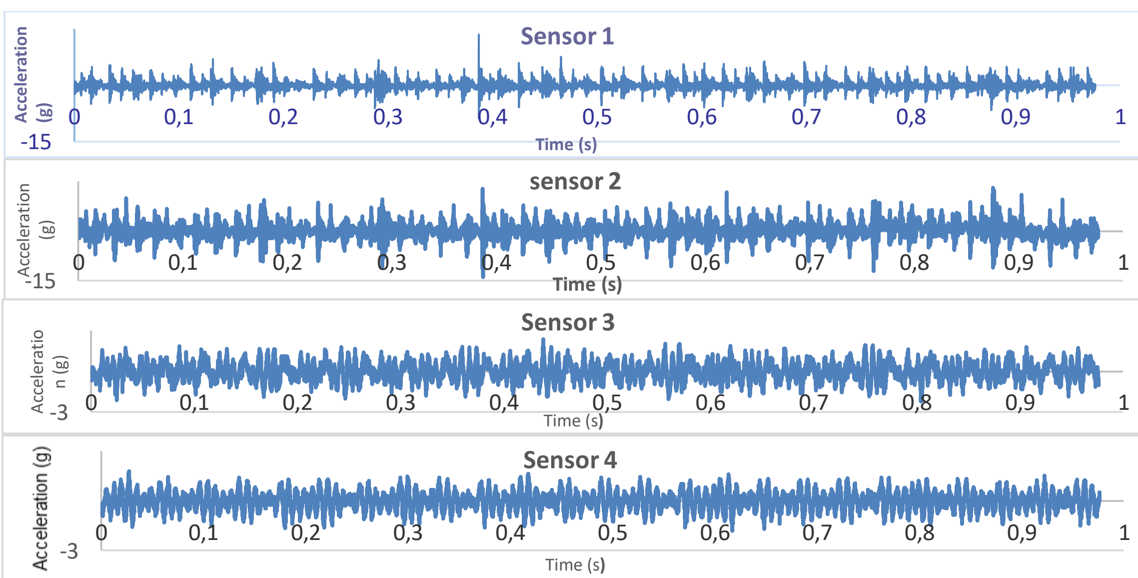

Figure 6. The magnitude of the acceleration in the time domain due to engine vibration at 1500 RPM to 4 sensors placed on the LSU-05 NG structure.

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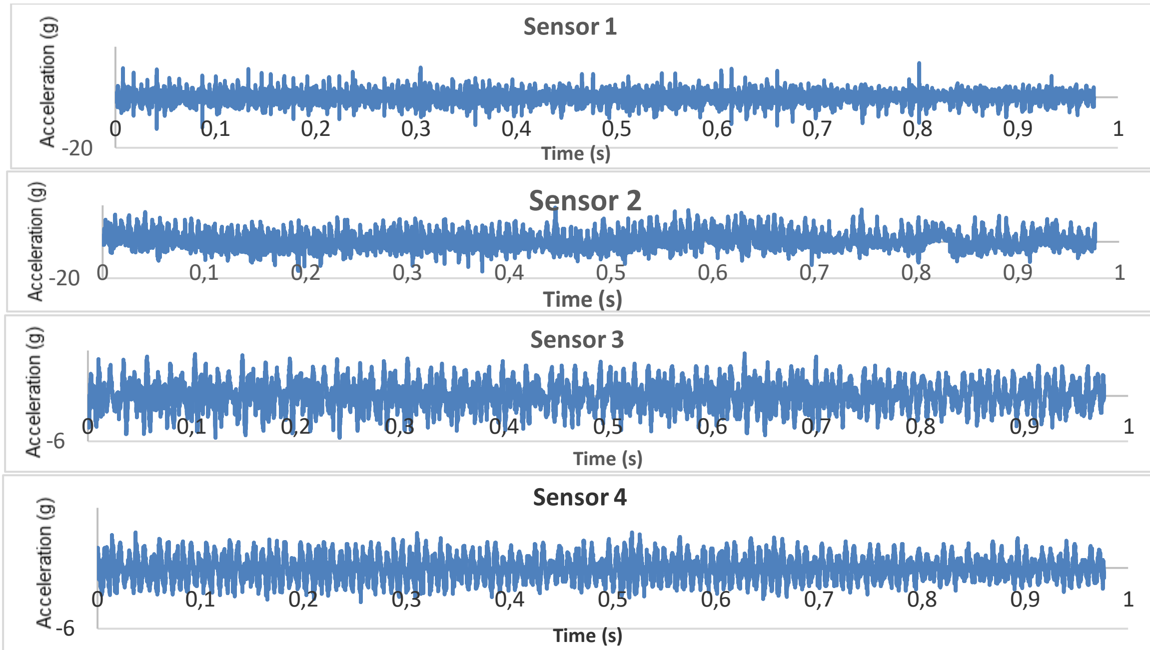

Figure 7. The magnitude of the acceleration in the time domain due to engine vibration at 2500 RPM to 4 sensors placed on the LSU-05 NG structure.

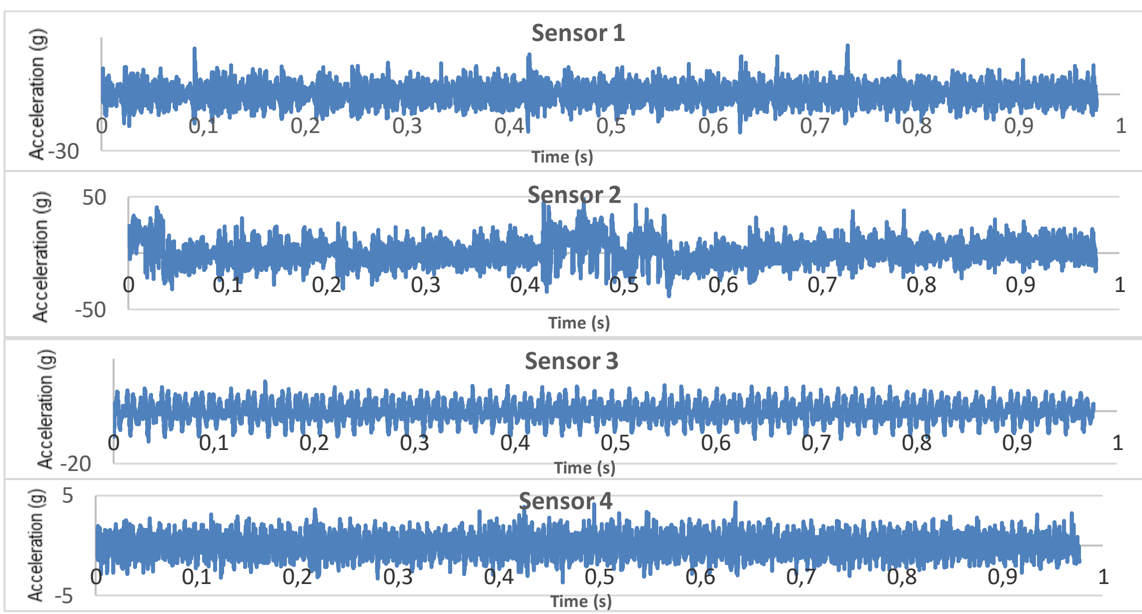

Figure 8. The magnitude of the acceleration in the time domain due to engine vibration at 3500 RPM to 4 sensors placed on the LSU-05 NG structure

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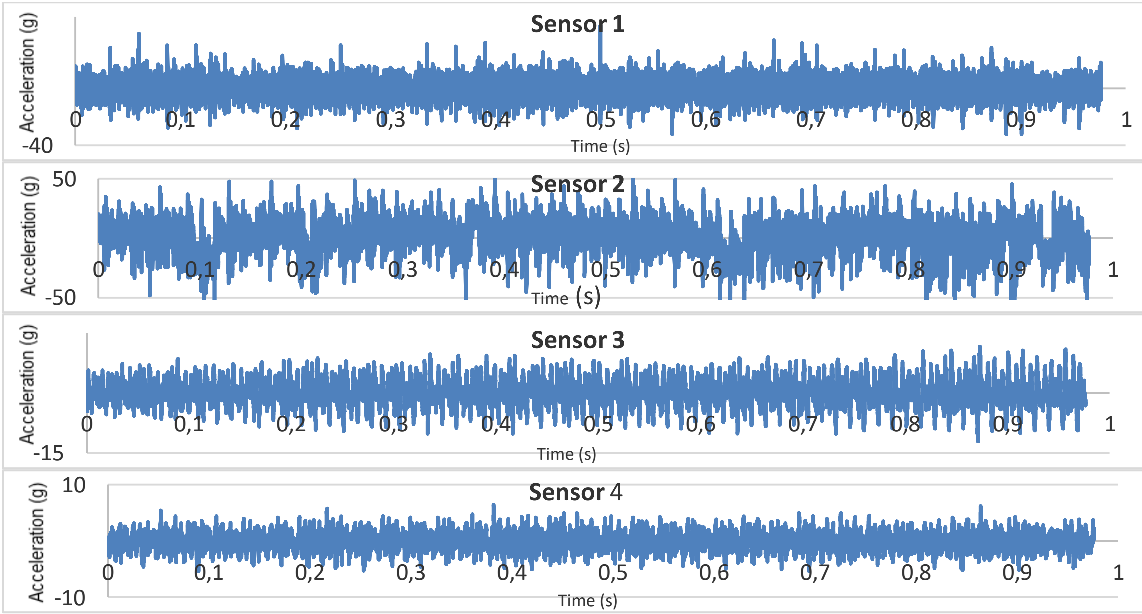

Figure 9. The magnitude of the acceleration in the time domain due to engine vibration at 4500 RPM to 4 sensors placed on the LSU-05 NG structure.

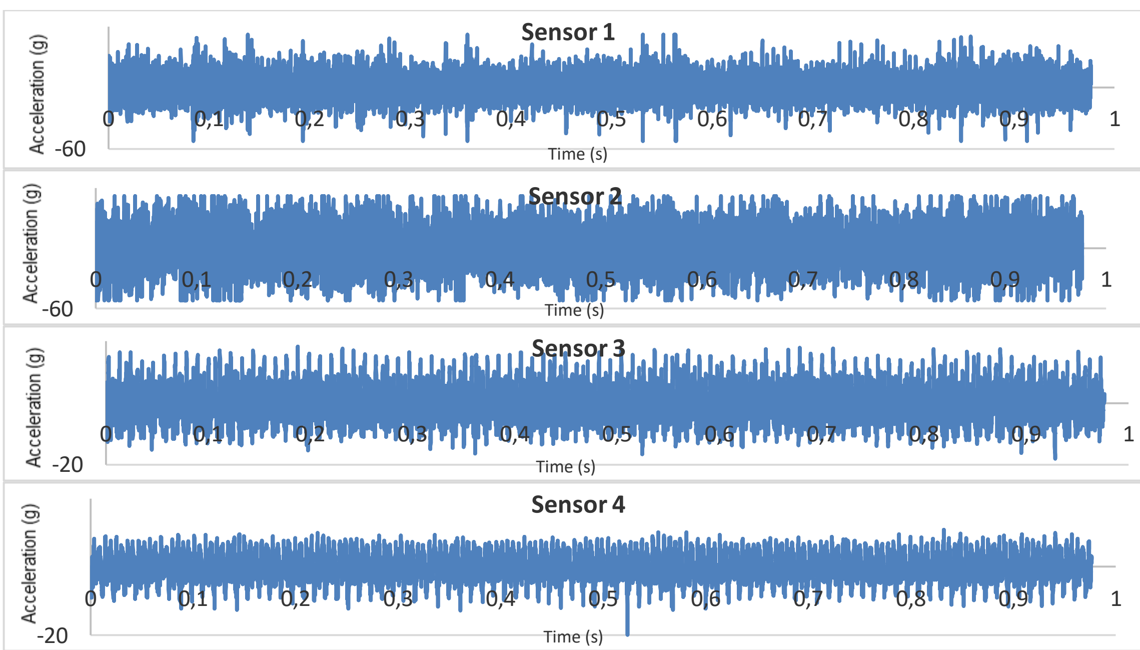

Figure 10. The magnitude of the acceleration in the time domain due to engine vibration at 5500 RPM to 4 sensors placed on the LSU-05 NG structure.

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To facilitate the analysis, the results of the acceleration measurements that occur on the LSU-05 NG are then processed to determine the RMS value of each graph in each measurement. Measurements are made with variations in engine speed or RPM. The results of processing the RMS value can be seen in Figure 11.

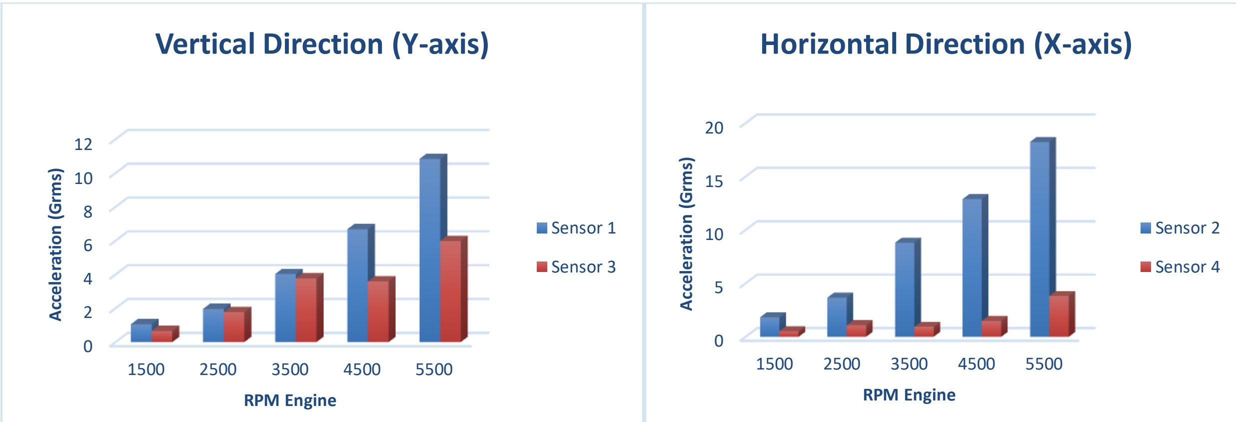

Figure 11. The magnitude of the vibration value occurs in the LSU-05 NG for each axis of the direction of motion.

Based on the graph in Figure 11, it can be seen that the value of the vibrations that occur around the engine, namely on sensors 1 and 2, will increase along with the number of engine revolutions or RPM. Based on the direction, the X-axis (Horizontal) has a higher vibration value than the Z-axis (Vertical). On the X-axis, the magnitude of the vibration around the engine occurs at 5500 RPM, which is 18.25 g-RMS. While on the Y-axis, the magnitude of the vibration around the engine occurs at 5500 RPM, which is 10.84 g-RMS. On sensors 3 and 4, namely sensors placed in the payload space, it can be seen that overall, the higher the RPM, the greater the vibration value. However, at 3500 to 4500 RPM, the opposite happens. This can be due to inaccuracies in controlling RPM that causing the readings of RPM are error.

The comparison of the vibrations in the area around the engine and the payload space shows that the vibrations in the payload space are smaller than those in the engine. This indicates the occurrence of vibration attenuation in the structure of LSU-05 NG. On the X-axis, the magnitude of the vibration in the payload space occurs at 5500 RPM, which is 3.82 g-RMS. While on the Y-axis, the magnitude of the vibration in the payload space occurs at 5500 RPM, which is 5.98 g-RMS. When the engine is idle, the vibration value measured in the engine area is 1.82 g-RMS on the X-axis and 1.06 g-RMS on the Y-axis. While in the payload space, the vibration value is 0.53 g g-RMS on the X-axis and 0.66 g-RMS on the Y-axis.

Conclusions

The test results show that the detected acceleration is directly proportional to the engine speed. This is seen from the sensors placed in the engine area. The results of the vibration reading in the payload space have a smaller value than in the engine area. This indicates the occurrence of damping due to the structure of the LSU-05 NG. However, it is still necessary to do further

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research on whether the measured vibration value still influences the payload, which will later be installed on the LSU-05 NG.

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