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Design Drop Weight Impact Testing for Landing Gear UAV LSU (LAPAN Surveillance UAV) Series

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ABSTRACT

The use of UAV (Unmanned Aerial Vehicle) by government and private institutions has been widely practiced. One is for monitoring needs, mapping an area to another, and more specific military needs. UAV carry a variety of sophisticated electronic equipment, and landing gear must be capable of supporting the load. Absorbing impact energy is essential to prevent damage to the equipment. The landing gear drop test simulates the stiffness of the landing gear to receive an impact load when the aircraft lands. The primary purpose of the tool's design is to facilitate the effective and efficient research and development of landing gear design in the future. This study's landing gear drop weight test was designed for all types of LSU unmanned aircraft (Lapan Surveillance UAV). Landing gear drop weight is designed with several systems to support the ability to determine the speed before the impact, impact force, and deformation on the landing gear strut as a parameter for future landing gear research. This test tool utilizes gravity as an impact propulsion. The test equipment design refers to the CASR 23 standard test. This study compared the test equipment design solutions and the construction deflection analysis to ensure the design results could be made. The bending value of the hoist plate on the rig design that has been made is 57.7 MPa. The value of critical buckling in the rig column is 28,353 kN.

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INTRODUCTION

An unmanned Aerial Vehicle (UAV) is a type of unmanned aerial robot explorer. In general, it has a function for monitoring and mapping both civil and military needs so that it is more efficient. With the continued development of the UAV, it must ensure the reliability of each component so that the UAV can be operated properly. One very important component in UAV aircraft construction is landing gear [1].One burden that occurs on landing gear is the impact load during the initial landing. The landing gear must absorb an aircraft's vertical kinetic energy through the shock absorber and tire deflection [2]. If it exceeds that ability, it can cause damage to the landing gear structure. Impact loads can also be loosened, and even damaged bonds can be formed, generally in electronic equipment such as telemetry sensors, GPS, or cameras [3]. In this case, the landing gear plays an important role in the safety of the aircraft during take-off and landing, where such interests become apparent to the UAV [4].

Drop impact weight testing is a tool for landing gear experiments when receiving impact loads on a UAV when it hits the ground [5], [6]. In general, fabricating test equipment independently has advantages, including looking for a more economical price and greater flexibility of work tools. However, professionals primarily in installing and implementing electronic equipment are a must. Drop impact weight testing is prioritized for testing UAV-made UAVs such as LSU 02, LSU 03, LSU 04 and LSU 05 and their development. The tool is also expected to be able to test specimens such as crash boxes and other specimens for impact testing [7].

This research has steps in designing a landing gear drop weight test. This research aims to design a universal drop weight impact testing tool with system integration according to the needs of impact tests such as landing gear, crash box and other components that require impact testing.This device is designed in accordance with the needs of the aerostructure lab at the Aviation Technology Research Center, National Research And Innovation Agency (BRIN). This device is expected to be able to fulfill research needs, especially in the field of crashworthiness. The research began by conducting a literature study on landing gear testing and knowing the standard landing gear dynamic test requirements. A finite element was used to simulate the structure of the component drop weight test impact, especially the rig system to estimate strength.

Figure 1. Lapan Surveillance UAV Series

METHODS

As a consideration in making device specifications, CASR (Civil Aviation Safety Regulation) standards carry out landing gear test calculations by exemplifying LSU 05 due to the largest UAV in the LSU Series. The requirements for landing gear testing on CASR 23 are then considered. when deciding the tool's specifications. As for these calculations, the authors enter the specifications of the largest aircraft that will be tested on the tool LSU-05 shown in Table 1.

Drop weight impact testing was designed to use gravity as propulsion for efficiency. Impact test equipment using gravity is a simple thrust and can be used repeatedly to a speed of 25 m/s[9]. Utilization of gravity as impact load propulsion is cost-efficient. Based on the objectives and standard requirements defined above, conclude the minimum Design Requirement and objective (DRO) of the landing gear drop weight test device as follows.

- Maximum impact speed can be simulated at approximately 10 m/s, requiring an ideal fall height of 5 meters (no friction on the guide path).
- The guide path can provide a precise direction of impactor fall without considerable friction and with good reliability.

- The maximum load that can be simulated is 200 kilograms
- Drop weight impact testing can be applied for testing on LSU 02 - LSU 05 main landing gear and nose landing gear.
- Drop weight impact testing components available on the market to make manufacturing and maintenance easier.
- Can be used for many specimens such as crashworthiness tests on crash box, etc.
- The landing gear position gets the whole picture when a high-speed camera is used to determine the complete response of the landing gear structure.
- Drop weight impact testing has components and systems for safety

Table 1 Requirement Standart [7]

Standard	***Parameter***	***Performance requirement***
CASR 23.473 *Ground Load Conditions and Assumptions*	$V_{descent} = 4.4 \left(\frac{W}{S}\right) \times \frac{1}{4}$ $V_{descent} = 4.4 \left(\frac{187.4\ lbs}{34.45\ ft^2}\right) \times \frac{1}{4}$ $= \mathbf{5.98}\ \mathbf{{}^{ft}/_{s}} \sim \mathbf{1.825}\ \mathbf{{}^{m}/_{s}}$	-
CASR 23.723 *Shock Absorption Tests*	landed 1,2 from *decent velocity* limit, $1,2 \times 5,98\ {}^{ft}/_{s} = 7.18\ {}^{ft}/_{s} \sim 2,2\ {}^{m}/_{s}$	Simulate drop speed $2.2\ {}^{m}/_{s}$
CASR 23.479	load *Level Landing Condition LSU 05.* $V_r = (n - L)\ {}^{a'}/_{d'}$ $V_r = (2 - 0.667)\ 187.4 \left(\frac{3.162}{3.885}\right)$ $V_r = 203.316\ lbs \sim \mathbf{92.22 kg}$	• provide landing gear fall angle 14° • can simulate load 92,22 kg dan 113,31 kg on landing gear
23.725 Limit Drop Tests (a)	▪ Tests on landing gear consist of wheels, tires and shock absorbers ▪ the testing fall height is formulated: $h\ (inches) = 3.6 \left(\frac{W}{S}\right)^{0.5}$	• can be fitted wheels, tires and landing gear strut • Simulate fall height 2132.6 mm
23.727 *Reserve Energy Absorption Drop Test*	(a) (a) The falling height is 1.44 times of that specified on CASR 23.725	• Simulate fall height 3,07 meter

Figure 2 shows the elaboration of several systems contained in the drop weight impact test tool to support its functionality based on the DRO of the device. Each system is elaborated to facilitate the fulfillment of the device's requirements so that each component is expected to fulfill the expected specifications. The drop weight test impact tool system is categorized into four systems such as Rig system, Pulled and Release System, Data Acquisition & Control System, and Safety Shelter.

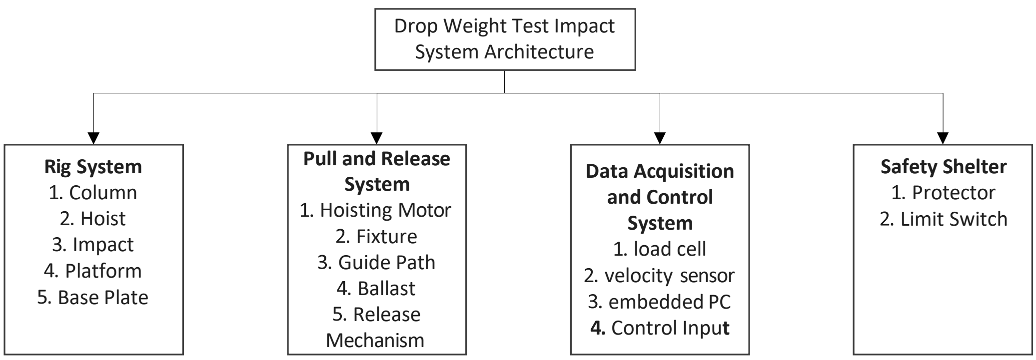


Figure 2 System Architecture

RESULT AND DISCUSSION

Rig System

The column is the main structure of drop weight testing landing gear, and the number of columns used in op weight testing landing gear UAV LSU is considered. The two-column guide was chosen because of its safety, moderate price, and ease of operation [10]. The assessment using two columns gets maximum results on function fulfillment, safety, and ease of operation. However, it gets the lowest value on ease of manufacture and price. Using a two-column landing gear will be balanced in the test and also more awake compared to using one column or not using a column. Drop test devices can minimize friction on column by repetition, but the test device must be resistant to deformation [4].

The hoist plate is a place to attach the pulley and support when lifting the landing gear. As for the requirements on the hoist plate, it must be strong enough to withstand bending loads because it can bend the column towards the inside. The hoist plate is installed as a wire rope on the pulley. This is because the towing motor is placed below to make it easier for maintenance. The base plate serves as the foundation for the drop weight testing landing gear. The requirements on the base plate are that it is the foundation, so it is very critical in its weight, so the weight of the base plate is 50 times the heaviest load on the test[11]. On top of the base plate is an impact platform mounted below, and a load cell sensor is installed to measure the impact force. Landing attitude can vary by tilting the fixture's landing gear or forming an angle in the Impact platform position[12].

damper must be installed at the bottom of the base plate to isolate vibrations and shock loads when testing and prevent the reflection of stress waves that can interfere with the test results. Sand can absorb energy through friction between grains of sand. The size of the grains of sand influences the resulting internal shear angle. The greater the grain size, the greater the inner shear angle produced[13].

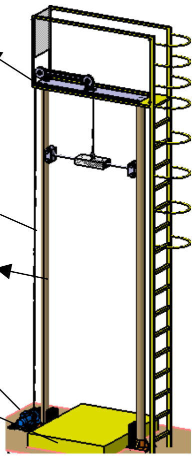


Figure 2 rig system

Pulling and Release System

The hoisting motor is a driving wire rope that pulls or lowers the release mechanism. The release mechanism will hook the fixture to determine the landing gear's fall height. The motor used is an electric motor that is connected to the inverter to regulate the speed of lifting the test object. To simplify maintenance, the motor can be mounted on the ground, and the hoist plate can be delivered using a pulley to deliver the wire rope shown in Figure 2.

The roller serves as an intermediary release mechanism and a fixture on the guide column to orient the landing gear fall. The requirements for the roller are to have as little friction as possible. The motion media should also be made of a corrosion- resistant material resistant to impact, shock, and vibration. The guide wheel is chosen as a motion media by being installed parallel, as shown in Figure 3. Roller bearings are more satisfactory under shock or impact loads than ball bearings [14].

The fixture is a place to attach landing gear and ballast and Install landing gear using a connector. The design of a connector must be adjusted so that it can be used on landing gear LSU 02 - LSU 05 shown in Figure 4. The connector contributes weight to the landing gear test, so the weight of the connector must be measured so that the test results are more valid in the input weight simulation on the landing gear test.

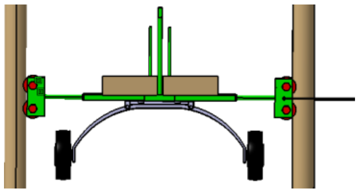


Figure 3. guide wheel

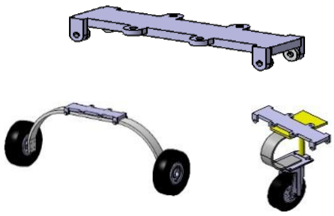


Figure 4 Connector

The ballast simulates the aircraft's weight received on the landing gear when tested. The ballast requirements are flexible weight variations. The maximum weight that can be accumulated is 200 kg. The ballast has a high density, which reduces the ballast volume and makes it more flexible. The Release Mechanism hooks the fixture to lift at a certain height, and then the fixture can be released from the desired height. The release mechanism requirements can be released in two stages: a safety stage to ensure the release system is safe and running well, and three actuators can used to get more ease of use shown in Figure 5.

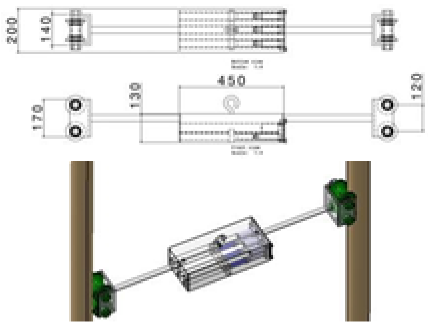


Figure 5.Release Mechanism

Data Acqusition and Control System

The load cell is a sensor that reads the impact load value between the landing gear and the impact platform. The Impact platform requirements are 4 load cells in each corner of the impact platform to maintain plate stability. The load cell used is a strain gauge of compression type. The excess load cell strain gauge has higher long-term stability and most errors can be adjusted. Compression load cells are generally made of materials resistant to rust and scratches because the base plate must be free of all forms of defects to provide accurate results.

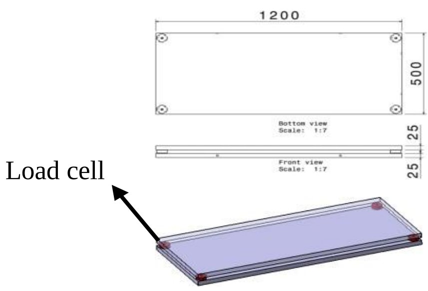


Figure 6. Impact Platform

The velocity sensor is to measure the speed of fall in real time from the height of the fall until just before the collision between the landing gear and the impact platform occurs. The displacement sensor can be used to measure the landing gear fall height and also measure the landing gear fall speed with a minimum specification range of 5 meters

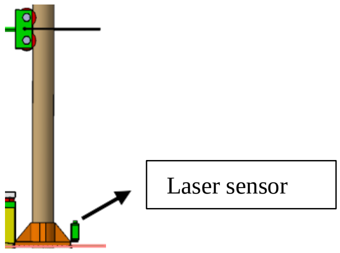


Figure 9 Laser Sensor

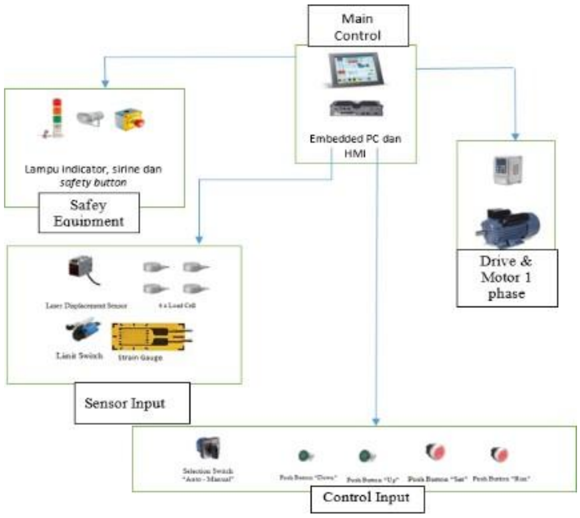


Figure 10 Data Acquisition, control and safety system

In the Control System, the embedded computer is a device designed for a specific purpose. The embedded system consists of hardware and software. Solid Embedded Computer test equipment functions to receive and process data received by the sensor. Then, the results can be displayed on the HMI (Human Machine Interface) for further analysis by the examiner later. HMI is a computer with a display on the LCD monitor that allows us to see the whole system from the screen. HMI functions to display data processed by the Embedded Computer and can also be used to control test equipment. *Digital input* is a physical button in the test equipment connected to the embedded computer. These physical buttons are compliments for ease of use and being a companion for the HMI Touch Screen in controlling the test equipment. The data acquisition and control system integrating was shown in Figure 10.

Safety Equipment

The protector is a high barrier and covers the test equipment. This partition is safe if the test object is detached or broken pieces that can endanger people or other equipment in the environment around the test. Sirens function to make a sound when the test is taking place to warn people around if an experiment is being done. The indicator light gives the code for the process by the test equipment. The red light indicates if the test equipment is conducting a testing process (running), the yellow light indicates the test instrument is conducting test preparation (running preparing), and the green color indicates the test tool is not working (running off). The safety button cancels the testing process if there is an urgent matter. The overall design of the landing gear impact device with integration of each system is shown in **Figure 11**.

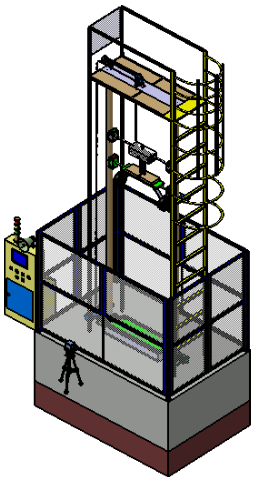


Figure 11 Drop weight impact testing device

Structure Analysis

The rig functions as the main structure of the drop weight test landing gear test equipment. To have confidence in the strength of the frame, structure analysis to check on the strength of the rig structure shown in Figure 12. finite element can be used to predict the elastic deformation stresses that occur with very good accuracy [15], [16], [17].

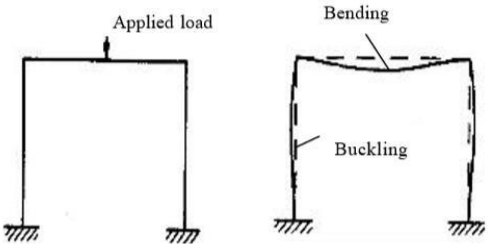


Figure 12 Deformation Rig Structure

The hoist plate must have a rigid structure, and simulation using variations of hoist thickness is necessary. The simulation was used to decide the best geometry of the hoist to hold the operating load and cost-effectiveness. The boundary condition of hoist plate shown in Figure 13.

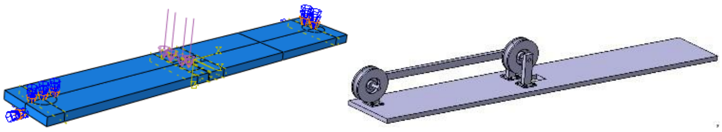


Figure 13 boundary condition hoist simulation

Fixed supports are defined on both sides of the hoist plate ends that are connected to the rig. Load. The type of load used in the simulation is pressure. The pressure position is given according to the location of the pulley pedestal on the hoist plate. The pressure value given is 200 kg multiplied by gravity to 1960 N multiplied by a load factor of 3. The design factor of safety used is 1.7. The material used in the hoist plate is steel A36, many of which are on the market. The mechanical properties of steel A36 in Table 3.

Table 3 Mechanical Properties Steel A36[18]

Physical Properties	Metric
Density	7.85 g/cc
Mechanical Properties	Metric
Ultimate Stress	400-550 MPa
Yield Stress	250 Mpa

Modulus of Elasticity	200 Gpa
Poisson's ratio	0.26

Table 4. Deformation and Stress Hoist Static Test

Thickness (mm)	Deformation (mm)	Stress, Mises (mm)
10 mm	29.4 mm	251 MPa
15 mm	7.4 mm	154.4 MPa
20 mm	3.005 mm	96.3 MPa
25 mm	1.526 mm	75.26 MPa
30 mm	0.88 mm	57.7 MPa

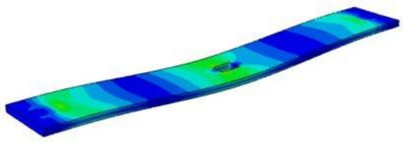


Figure 14. Deformation Elastic Hoist Plate

Buckling analysis aims to determine the critical load value on the column. The analysis discussed a linear buckling failure analysis. The linear buckling analysis consists of 2 subcases. The load is applied in the first subcase and the eigenvalue extraction is performed using the Subspace method in the second subcase. The part used in the simulation is a shell type with a length of 5000 mm and provides a thickness when inputting material of 2 mm. The material used is 316 stainless steel because it has good corrosion resistance. Boundary condition of column shown in figure 15.

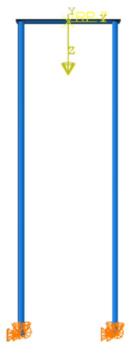


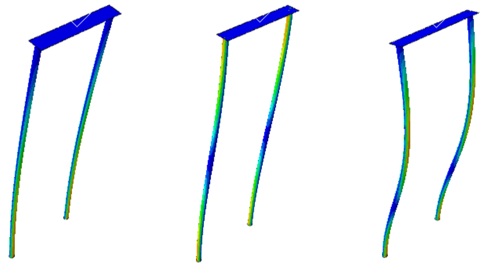
Figure 15 Boundary Condition Column in buckling analysis

The number of iteration values in the process is the number of vector iterations of 3, the vector used for each iteration is 10, and the maximum number of iterations is 300. The critical buckling load value on the structure is obtained by multiplying the eigenvalue with the total load applied to the model[19]. Load input is given at the center of the hoist plate, which as shown in Figure 15 is 1 N, and will simulate the buckling value of the column. Mechanical properties of Stainless Steel 316 L shown in Table 5.

Table 5 Mechanical Properties Stainless Steel 316 L

Physical Properties	Metric
Density	8.00 g/cc
Mechanical Properties	Metric
Ultimate Stress	505 MPa
Yield Stress	215 MPa
Modulus of Elasticity	193-200 GPa
Poisson's ratio	0.29

The lower the critical buckling load value, the easier the column will experience buckling failure. Based on the simulation results, the column buckling value on the column structure is 28353 kN shown in Figure 16. Based on the factor of safety th, the e column has a value of 2.41. Column resistance to buckling failure can be increased by increasing the column's thickness without increasing the column's outer diameter, which will affect the size of the guide wheel.



1. Eigen Value = 28353 2. Eigen Value = 1.13×10^5 3. Eigen Value = 2.54×10^5

Figure 16. Buckling analysis

CONCLUSION

The design of the drop weight test device landing gear for UAV LSU and other tests such as cashbox and other impact tests. The tool design is based on DRO (Design Requirements Objective) and the study of effective and efficient solutions. Two columns with an outer diameter of 100 mm and a minimum thickness of 2 mm can be the main structure, and a fall guide with a length of 5 meters. The load received by the column is 6832 N, which is the maximum weight value and weight of the hoist plate multiplied by a load factor of 3. It has a Factor of safety value of 4.15. Based on numerical analysis with the finite element method, a hoist plate with a thickness of 30 mm experiences a bending stress of 57.7 MPa and only experiences a deformation of less than 1 mm. The Design of an drop weigh test device include data acquisition used for UAV landing gear testing needs has been obtained. In addition, bending and buckling tests on the rig system to show the geometry has good durability. testing of the personal frequency of the test equipment is needed because vibration can interfere with the data acquisition system which can produce noise in the results and can damage the sensor at a certain period of time so that it needs to be done in further research.

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