Data Acquisition System in LSU-02 NG LD Wing Static Test Based on Whiffletree

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Abstract. Full wing configuration of LSU-02 NG LD main wing was tested statically based on whiffletree method. This test was conducted using 12 tensile point loads which are located precisely on the wing ribs. Three load cells are used to measure force; one for measure the total amount of aerodynamic lift load, and two others for measure the aerodynamic lift load on the left and the right wing respectively. Two strain gauges are glued to the aluminum spar in the inner wing, and one displacement transducer is installed on the left-wing tip to measure wing deflection. NI 9237 module is used to read load cell data and displacement transducer, and NI 9235 module is used to read strain rate data. Experiment result shows that wing structure fails at load factor 1.7 (306 N) with maximum wing tip deflection recorded at 120 mm. Structural failure occur in the middle of the inner wing, which is become valuable input for the design team to take necessary measure to prevent similar structural failure.

INTRODUCTION

Aeronautics Technology Center (Pusat Teknologi Penerbangan/ Pustekbang) is one of directorates under National Institute of Aeronautics and Space (Lembaga Penerbangan & Antariksa Nasional/ LAPAN) which responsible for research, development, and engineering in aeronautics technology and its application. This directorate established in 2011 and one of the mission is to improve aeronautics technology products to solve nationwide problems. To materialize those mission, Pustekbang design a low drag unmanned aerial vehicle (UAV) to improve flight endurance which is called LSU-02 NG LD. The LSU-02 NG LD series will be suitable for carry a surveillance mission on coastal and sea area by day operations [1], and disaster mitigation such us earthquakes, floods, forest fires and landslides [2]. On previous test, the engineers use sandbags on wing static test. However, due to inability to simulate continuous lift load, safety issue, and accommodate multiple axis, sandbags are replaced with whiffletree [3]. Wing static test based on whiffletree system for UAV structural test has been used on several occasion such as [4] and [5]. On whiffletree system, engineer could measure lift load using load cell, wing deflection using displacement transducer, and strain on the frame structure using strain gauge. To simplify data acquisition on those sensors, NI 9235 and NI 9237 is used. To monitor and to store experiment data LabVIEW 2014 is used.

DESIGN REQUIREMENT

LSU-02 NG LD main wing which is tested is made from balsa wood, except insert section in the inner wing which is made from aluminum. All wing section will be covered with e-glass fiber composite for wing skin purpose. The LSU-02 NG LD wing design shown in Fig. 1 below.

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FIGURE 1. Design structure of LSU-02 NG LD wing

The structure wing of LSU-02 NG LD was design to produce lift force as 18 kg maximum take of weight (MTOW) and hold operational aerodynamic load until load factor 3.8, which is equal to 68.4 kg [1]. In order to design verification, the wing must be tested with static test. This result will be increase confident level for design engineer [6].

The static test is based on whiffletree, where load distribution on wing were conduct by attaching load arms such that every edge of those arms has different load [7]. The whiffletree mechanism is designed four levels, the first level with stand the load distribution on the wing and the fourth level withstand the overall load.

Testing were conducted using full wing configuration using 12 tensile point load which is located precisely on the wing ribs, as shown by Fig. 2. Three load cell is used to measure force; one for the total amount of lift load, two other is used to measure lift load on the left and the right wing. Two strain gauges is glued to the aluminum spar in the inner wing, and 1 displacement transducer on the left-wing tip. Table 1 provides a more description of the sensor:

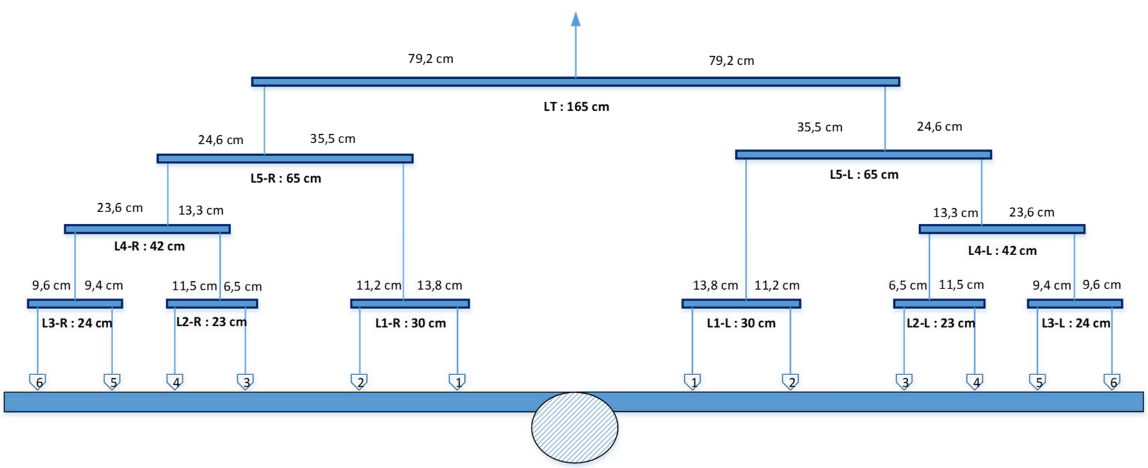

FIGURE 2. Whiffletree design for wing static test

TABLE 1. Wing static test sensors

No.	Sensor	Description	Quantity
1.	Load cell	S-type; capacity 500 kg	1
		S-type: capacity 100 kg	2
2.	Displacement transducer	Bridge configuration; range 0-30 cm	1
3.	Strain gauge	120 Ohm; Gauge factor = 2	2

TEST SET UP

Hardware and Software

The acquisition data used in this test is NI 9184 with two analog input modules; NI 9237 and NI 9235. The NI 9184 is a CompactDAQ Ethernet chassis designed for small, remote, or distributed sensor measurement systems and has 4 channel slot [8]. The NI 9237 is 4-Channel Strain/Bridge Input Module which has sampling rate 50 kS/s/channel [9]. The NI 9235 is 8-Channel Strain/Bridge Input, 120 Q Quarter-Bridge Module used for measures dynamic strain on all channels simultaneously and has sampling rate 10 kS/s/channel [10]. Two NI 9237 module is used to read load cell data and displacement transducer, due to the two sensor needs different input voltage: 10 V for the load cell and 2.5 V for the displacement transducer. Strain gauge is connected to the module NI 9235 to measure strain on the aluminum.

To run all the hardware above, it is done using LabVIEW. LabVIEW is software for applications that require test, measurement, and control with rapid access to hardware and data insights, and usually for system engineer [11]. Using LabVIEW 2014, engineer could modify which indicator that will be shown and create execution button to facilitate data acquisition in order that the other engineer could understand experiment result. For the LSU-02 NG LD static test purpose, there are several parameters displayed on the GUI to monitor the testing process including total lift force, load factor, lift force and strain changes that occur on the left and right wing, wing deflection changes, and indicators data recording. In addition, buttons are also provided to do data filtering, reset, and data recording. The GUI design results are shown by Fig. 3. The sampling rate is set at a value of 10 Hz so that every 1 second there will be 10 recorded data simultaneously.

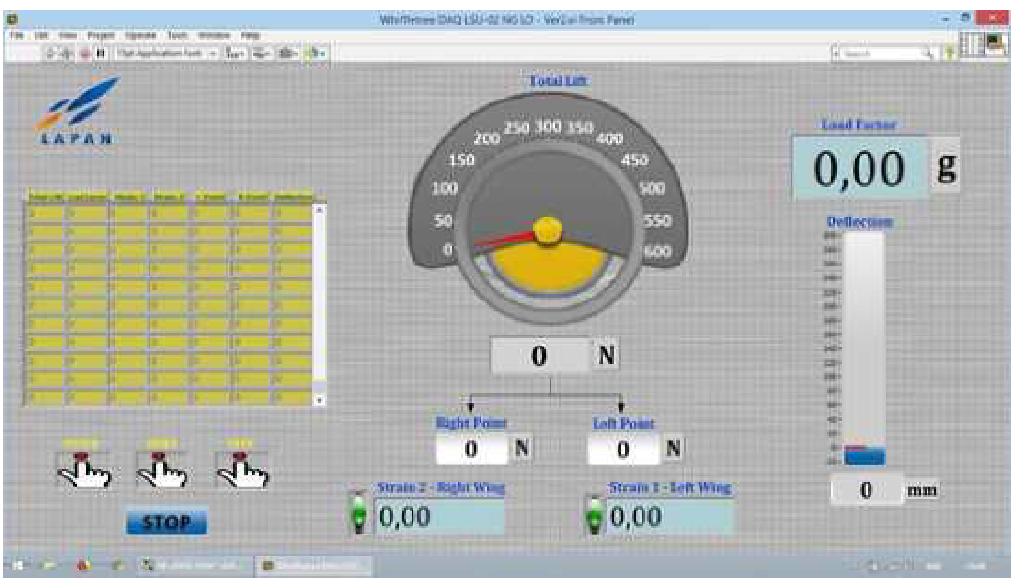

FIGURE 3. GUI design for wing static test

Sensors Installation

Two strain gauge sensors are installed on the aluminum part to measure strain changes. The mounting position is between the inner wing and outer wing joints. The result of mounting strain gauge on aluminum is shown by the Fig. 4. Load cell with a capacity of 500 kg is installed at the very top which is the link between whiffletree and actuators. While the other two load cells are installed one level below to determine the value of loading on each side of the wing. The installation location of the load cell is shown by Fig. 5. Integration results of all static test support components are shown by Fig. 6. The wings that have been installed with whiffletree are placed on the test rig and connected to the actuator. One computer and one monitor are prepared to store and monitor the testing process. A displacement transducer is placed at one end of the wing to determine changes in deflection that occur on the wing. All sensor cables are connected to the acquisition data shown by Fig. 7.

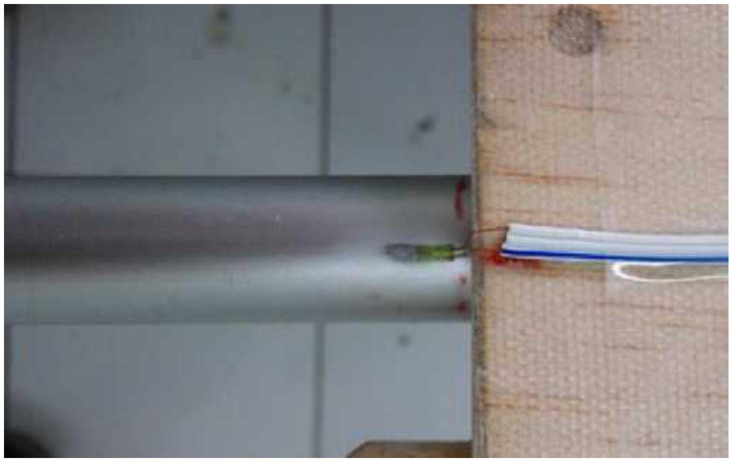

FIGURE 4. Strain gauge mounted on aluminum spar

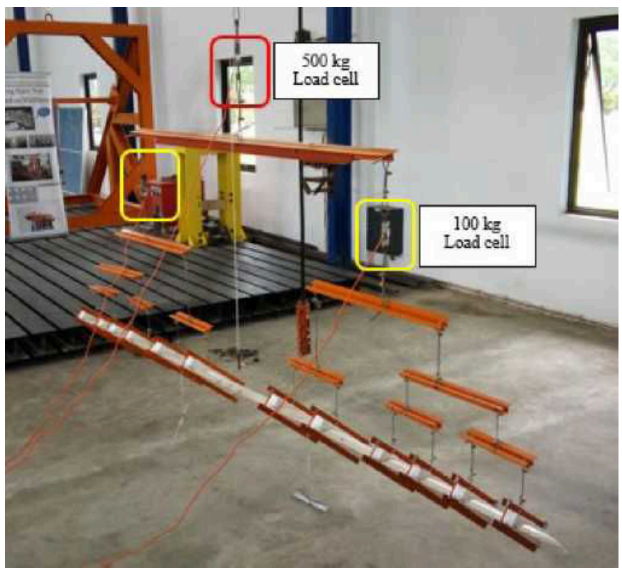

FIGURE 5. Load cell location on whiffletree

FIGURE 6. Test System Integration

FIGURE 7. Connected cable to acquisition data

TESTING

Load is applied gradually, started from load factor 0.3 (60 N) until load factor 2 (360 N). Data is recorded continuously and stored using *.lvm format. Experiment result shows that wing able to withstand load factor 1 (180 N), however when the load is increased to the load factor 1.5, the wing is started to lose its capability to carry the load, this phenomenon can be seen from the lift data which is decreasing. When the load factor 2 is increased, there is a jump on the lift graph which is indicate that there is failure on the wing structure, as shown by Fig. 8 and the process by Fig. 9

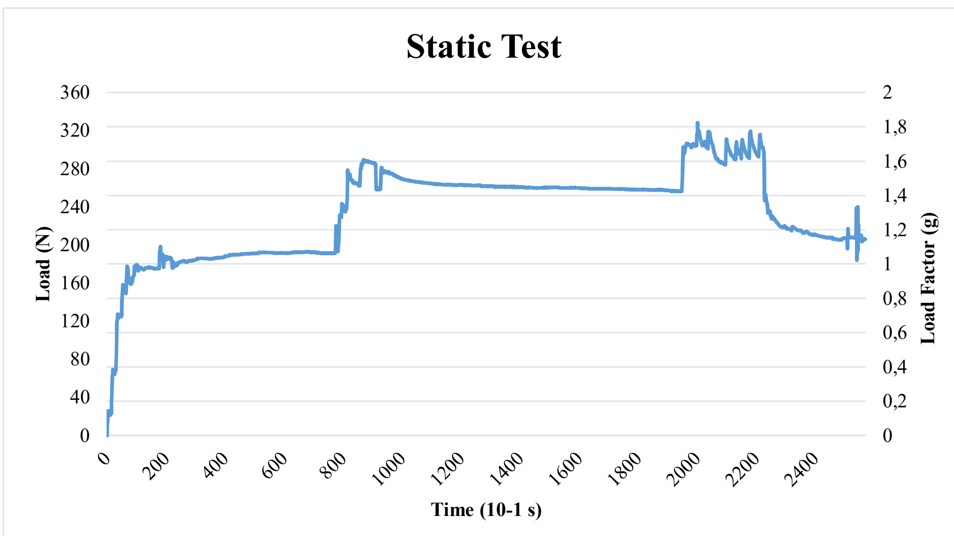

FIGURE 8. Static test graph

RESULT

Experiment result shows that wing structure can not withstand lift load more than load factor 1.7 (306 N) with maximum deflection 120 mm. Structural failure occur in the middle of the inner wing, which is become valuable input for the design team to take necessary measure to prevent similar structural failure. From two other load cell data reading, force that applied to the left wing is higher than the right wing with 6% difference, therefore testing team should minimalize this difference. Overall, LSU-02 NG LD wing static test has been successfully conducted using whiffletree method. This method become a new breakthrough for us where the previous wing static test were using sandbags. As a research institution, the outcome from this activity can be developed into new standard method in designing unmanned aerial vehicle.

FIGURE 9. Static test process

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