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Performance Analysis of a Flow Passage Opening Device through Low Speed Aircraft Captive Flight Tests

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Abstract

In a pressurized fuel supply system of aircraft, a flow passage opening device is required to keep fuel continuously transferred from one tank to the other. The device utilizes balancing weights in order to follow up an acceleration at special conditions such as negative g. It is very difficult to test the device in a real high-speed and high-altitude test since severe test conditions and expensive supports are needed. Therefore, this paper deals with performance analysis of a flow passage opening device through low speed aircraft captive flight tests (CFT) including roll and negative-g maneuvers. It is shown that balancing weights in the device can open the passage in accordance with fuel position.

Key Words : Pressurized fuel-supply system, Flow passage opening device, Acceleration follow-up, Low speed aircraft captive flight test, Roll maneuver, Negative g

1. Introduction

Some high-speed vehicles adopt a pressurized fuel tank system due to their distinctive structure and operational characteristics. As shown in Fig. 1, the system has several sections and fuel carrying parts in order to prevent the disconnection of fuel transfer [1]. In special situation such as negative g maneuvers, fuel is driven to upper corner so the situation can separate fuel from a passage to the next tank. Therefore, a flow passage opening device is developed to actively transfer fuel by chasing a position of fuel in the tank [2, 3].

Normal ground tests such as motion simulator and centrifuge tests are carried out as basic measures to find the operational trend of a flow passage opening device. A real high-speed and high-altitude test with the device needs severe test conditions and expensive supports, so a low speed aircraft captive flight test (CFT) is generally done before conducting a real test [4]. This paper deals with performance analysis of a flow passage opening device through low speed aircraft captive flight tests including roll and negative-g maneuvers.

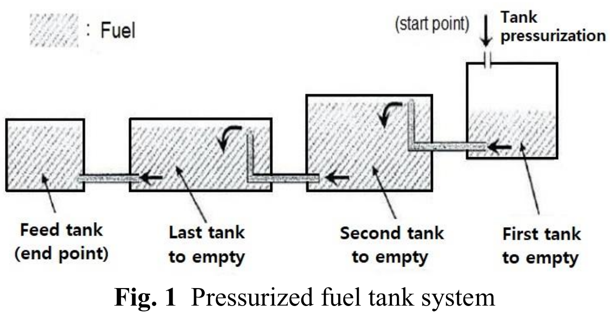

Fig. 1 Pressurized fuel tank system

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2. CFT and Test Object

2.1. Captive Flight Test

Low speed aircraft CFT is one of the tests to figure out the performance of various test pieces. In our tests, the flow passage opening device is mounted in a fuel tank of a pod and the pod is installed under the wing of the aircraft, KT-1. The fuel tank is filled with fuel, Jet A-1. As described in Fig. 2 and mentioned before, tests are including roll and negative-g maneuvers.

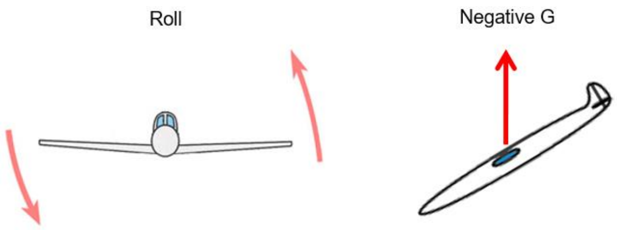


Fig. 2 Schematic Diagram of a Test

2.2. Flow Passage Opening Device

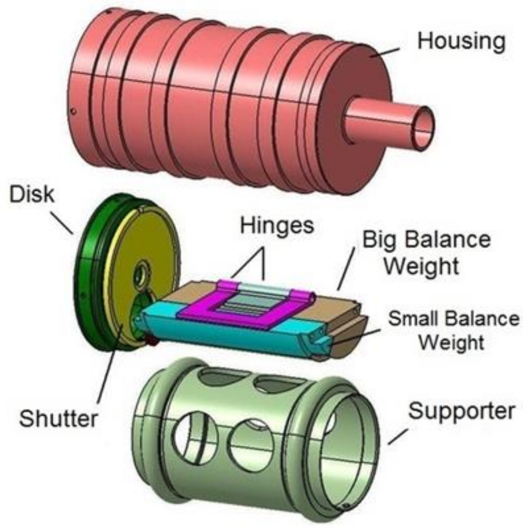
A flow passage opening device uses momentum of a weight to follow the position of fuel so that it can open the proper passage and let fuel flow continuously during the flight. While the device opens the passage for fuel, it also prevents an inflow of pressurized gases.

In Fig. 3-a, a 3D model of main parts of the device is described. A housing covers all other parts and provides space for them. A supporter is fixed with a large weight and rotates in housing. A disk is fixed with the housing and has four holes giving an entrance to fuel. A shutter tightly contacts with a disk and has only one hole to accept fuel selectively. Balance weights create torque as the direction of acceleration changes and then they rotate the shutter. Balance weights are made of an alloy of tungsten and copper, and other parts are made of stainless steel.

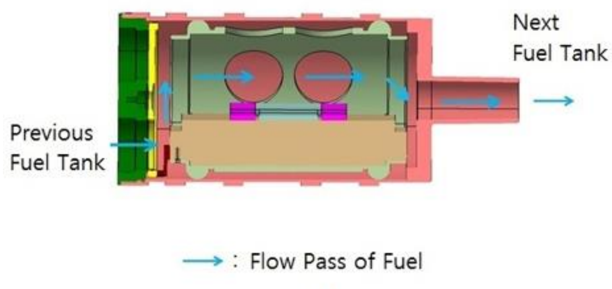
As described in Fig. 3, the device has four entrance at each direction (up, down, right, left) and the entrances are connected to pipes. Four tips of pipes are positioned at each corner of the fuel tank so they can accept fuel from each corner. Since shutter rotating with big balance weight has only one hole, fuel can flow through this entrance. Fig. 3-b shows the passage of fuel at normal flight condition.

3. Results and Analysis

During the flight, two maneuvers, roll and negative g, to test the device are conducted by pilot. Main issue of these tests is how fast and properly balance weights chase the position of fuel, and the device opens a passage. To find the position of balance weights, contact sensor is mounted on one side of the device, and to find fuel position, liquid sensor is installed in the fuel tank as shown in Fig. 4. Data Acquisition System (DAS) is utilized to get and record sensing data from each sensor.

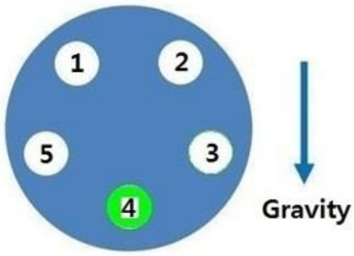


3-a.



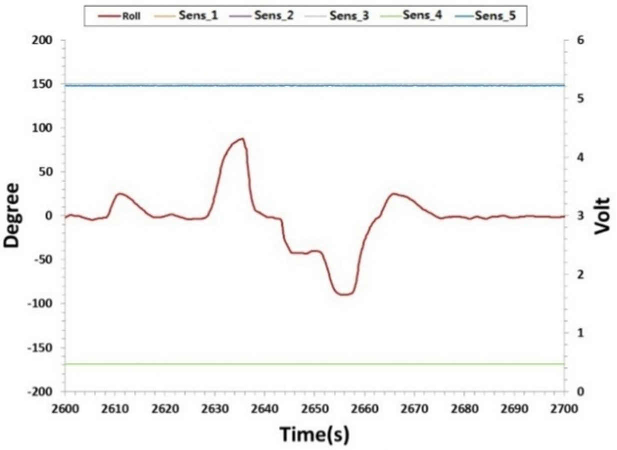
3-b.

Fig. 3 Main parts and flow passage of a flow passage opening device

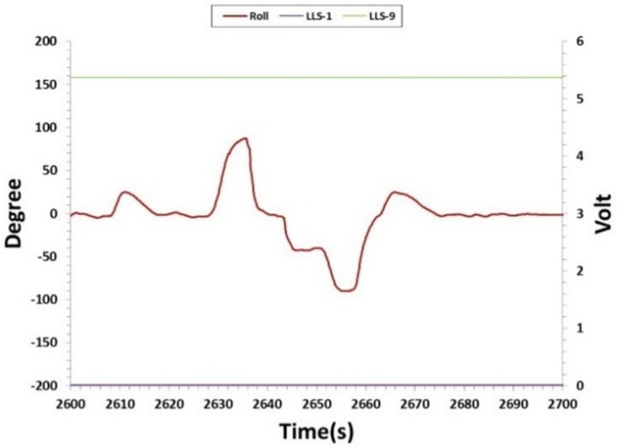


4-a. Contact sensor 4-b. Liquid sensor

Fig. 4 Contact sensor and liquid sensor on the DAS system



5-a. The device

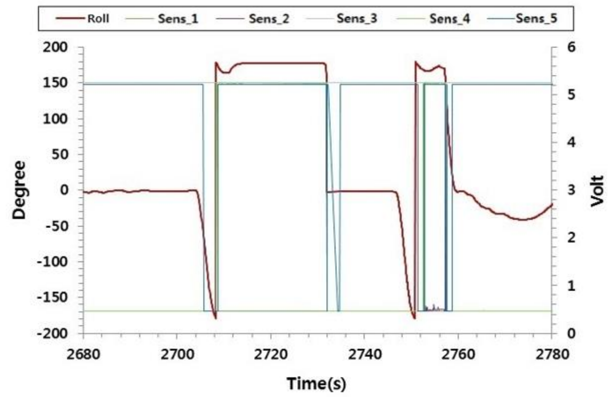


5-b. Fuel

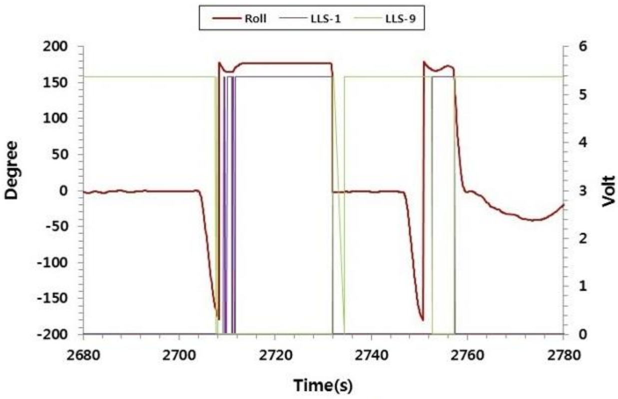
Fig. 5 Example of 90-degree roll test result

First, results of roll test are displayed and analyzed. There are three types of roll tests, 90 degree, 180 degree, and 360 degree. Fig. 5, 6, and 7 shows how the device and fuel react as the airplane turns 90 degree, 180 degree, and 360 degree, respectively.

In these figures, a horizontal axis indicates time with a unit of second, and a left-vertical axis means turned angle (degree). A right-vertical axis represents volt level acquired from sensor. In graphs, the bold line is an angle of roll maneuver, and thin lines are sensor signals. For the contact and liquid sensor, if a sensor is on (a sensor contacts with any material), then it gives 0 volt otherwise its signal is 5 volts. For liquid sensors sensing fuel level, results of top (LLS-9) and bottom (LLS-1) sensors are only displayed in the figures. In Fig. 5 and 7, it is shown that fuel does not express any reaction and the device is not very active. Inertial force is considered to be the reason why the device and fuel do not actively move. In 180-degree roll test (Fig. 6), however, both the device and fuel react clearly. As the airplane turns 180 degree, fuel tank and the device turns upside down, so sensors normally on are turned off and vice versa.



6-a. The device

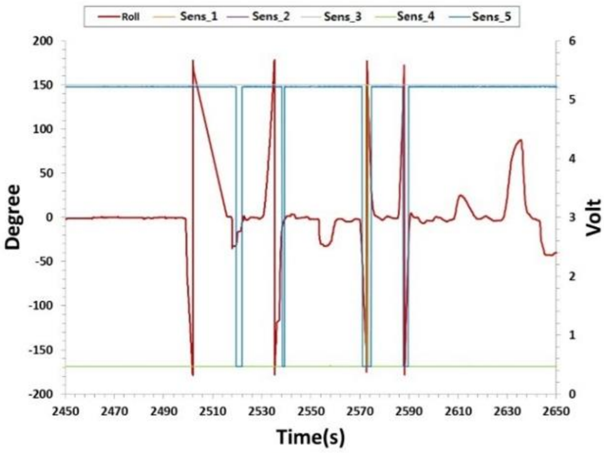


6-b. Fuel

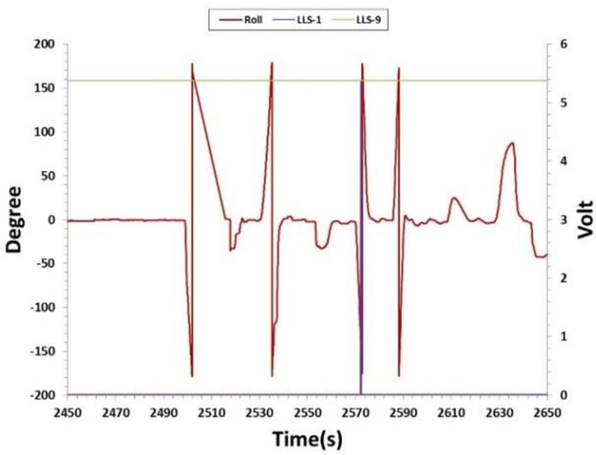
Fig. 6 Example of 180-degree roll test result

Results of negative g test are described and discussed next. In order to find negative g level when the device start to move, specific range from −0.5 g to −1.2 g is determined and performed by pilot in the test. An example of negative g test result is drawn in Fig. 8. A left-vertical axis means level of acceleration (g) in this figure. Measured negative g of this example is −0.81 g. From Fig. 8, it is shown that the device starts to react about 1 second later than the time fuel moves. The g value when the device reacts is −0.8 g, and that for fuel is −0.3 g. When airplane returns to normal condition, the device returns slower than fuel, too. For all tested range of negative g, a flow passage opening device works slower than fuel. This means there will be a disconnection of fuel flow for that time delay.

During several repeated tests, the device shows similar results as described above.

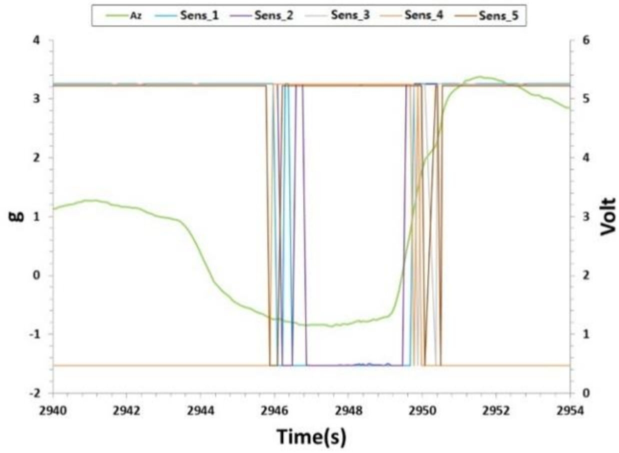


7-a. The device

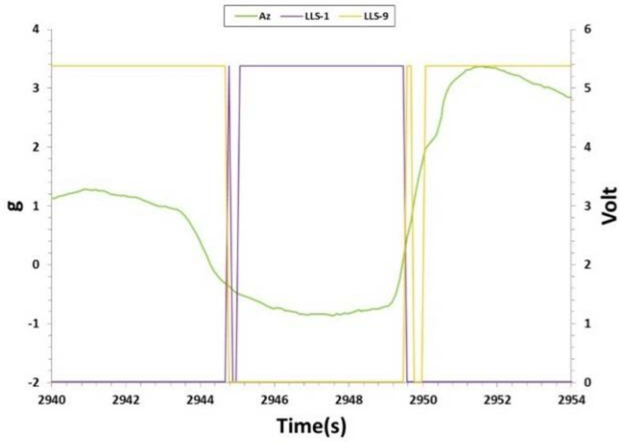


7-b. Fuel

Fig. 7 Example of 360-degree roll test result



8-a. The device



8-b. Fuel

Fig. 8 Example of negative g test result

4. Conclusions

This paper contains analysis of a flow passage opening device through low speed aircraft CFT including roll and negative-g maneuvers. In the roll test, the device follows fuel position very well, however for all tested range of negative g, the device works slower than fuel. To reduce this time delay and disconnection of fuel flow, it needs to be improved more in hardware and material.

Through low speed aircraft CFT, valid data about operational characteristics of a flow passage opening device is obtained and analyzed before conducting a real high-speed test. Based on these results, it is expected to improve its performance and broaden it to a wide range of application in high-speed vehicle.

References

[1] R. Langton, C. Clark, M. Hewitt, and L. Richards, *Aircraft Fuel Systems*, 1st Ed., John Wiley & Sons. Ltd, Wiltshire, UK, 1989.

[2] J. Park, S. Min, Y. Kim, and B. Park, "Development of Flow Path Opening Device using Weight Momentum," *2012 Conference of the Korea Institute of Military Science and Technology, Gyeongju, Korea*, pp. 1875-1878, 2012.

[3] S. Jung, Y. Kim, J. Park, and P. Jun, "Analysis of a Flow Passage Opening Device using RecurDyn", *Journal of the Korean Society of Propulsion Engineers*, Vol. 18, No. 3, pp. 78-83, 2014.

[4] S. Jung and J. Park, “Performance Analysis of a Float-Type Fuel Supply Valve through Flight Tests”, *Journal of the Korean Society of Propulsion Engineers*, Vol. 20, No. 1, pp. 76-81, 2015.