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Acceptance Testing of Electro Hydraulic based Aircraft Actuator using LabVIEW

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Strictly as per the compliance and regulations of:

Acceptance Testing of Electro Hydraulic based Aircraft Actuator using LabVIEW

Karthik SP [α] & Vijay Desai [σ]

Abstract- This paper presents an approach to perform aircraft actuator Acceptance Testing capability. Efforts include design and development of Test system for Electro Hydraulic aircraft actuator, in nominal condition that may be used along with measurement data to generate effective test results. LabVIEW platform is used for developing the test system.To develop communication between the LabVIEW based Test software and Actuator, Portable Test Controller (PTC), is used.

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I. Introduction

Being relatively new to the aerospace industry, Electro Hydraulic actuators are being used widely in aircraft. The quantum of knowledge as compared to ones accumulated for the other actuator types are much less and especially when it comes to Acceptance Testing. Lack of health monitoring data from the system installed in field and prohibitive costs of carrying out real flight tests push for the need of building system models and designing affordable but realistic experimental setups.

An electro-hydraulic system comprising an electromagnetic actuator and a hydraulic actuator relatively arranged such that the movement of the hydraulic actuator is controlled by the movement of the electromagnetic actuator.

The electromagnetic actuator is preferably a linear motor with a piston rod arranged to reciprocate in response to electric signal supplied to the electromagnetic actuator. A pump is preferably arranged between the electromagnetic actuator and the hydraulic actuator and causes movement of the hydraulic actuator as a result of the movement of the shaft of the linear motor. [J. Edge, 1978] [G. Daneker, 1973].

Electro-Hydraulic Actuators (EHA) are presently used in numerous aerospace applications, from robotic applications to thrust vector control of rocket engines, where they accomplish a range of rotational and translational functions [Pawel Rzucidlo, 2006].

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Of the various kinds of actuators, EHAs were chosen for this study because of their growing role in the aerospace field. They are relatively compact and can offer high power-to-weight ratios and motion velocities. [Andrew Goldenberg & Saeid Habibi, 1999].

Actuator Acceptance Testing at Assembly and Production Flooris to determine, if the requirements of a specification or contract are met. It may involve functional tests, physical tests, or performance tests. But for EH based actuator it's a performance testing, which included Testing the aircraft actuator for its basic functionality, including sensors functionality under the hydraulic pressure and real condition environment. [H. Moon and W. Knowles, 1970] [G. McGrath, 1964].

Electrical actuation technologies have to comply with demanding aircraft requirements concerning reliability, performance, weight, and environmental conditions. Electro Hydraulic actuation use comes from customer and airworthiness requirements for clean and more environment friendly aircraft.

The use of Electro Hydraulic actuators helps in aircraft maintenance. Airlines across the globe are looking for more efficient aircraft that can increase their net profit. The increasing fuel price is a major driving factor, forcing the aircraft manufactures to opt for more fuel efficient actuation systems.

With the primary functions in the aircraft more powered by electrical and hydraulic system; rather than conventional Pneumatic system aircraft will be able to achieve reduced fuel burn, higher reliability, reduction in maintenance cost, and more dispatch availability. Many R&D programs are going on in this industry for saving fuel and enhancing operational efficiency.

The instrumentation requirements in the area of automotive testing has increased many folds owing to the increasing and stringent demands imposed by several regulatory bodies such as the BIS, CMVR, EEC, etc. The type of tests to be carried out depends upon the purpose of evaluation such as for certification, design validation, etc. The parameters to be evaluated pertaining to the testing of vehicles are many. Presently, a number of dedicated instruments are being employed for the above purpose, each instrument meant to carry out evaluation of a specific parameter. However, one of the major disadvantages in such instruments is that their functionality is rigid and is difficult for reconfiguration. It requires the adjustments of many hardware components to achieve the desired functional behavior. It was, therefore intended to have an instrumentation system, which could be completely customized to the users requirements and at the same time be flexible enough to cater for the changing requirements of the test methodologies pertaining to the variation in the test standards.[S V Londhe et al, 1999]In view of this Moog Inc has developed test controller hardware for testing and validating the EH actuators.

A detailed description has been provided about the architecture of acceptance systems and how various cases for acceptance are tested in the test environment and corresponding data is collected to verify the physics based models.

A design and development of test system has been included to outline the details of experimental data collection and calculate the results depending upon the collected data and predetermined data. Furthermore, some idea about how actuator performs in real flight environments through actual flight tests and using real flight data have been presented. Finally, the roadmap leading from this effort towards developing successful Test System for aircraft electro-hydraulic actuators is discussed.

II. Overview of the System

The Moog Portable Test Controller is made user friendly with only having a small amount of control keys available. The majority of the functions can be controlled through the push/turn knob that is located in the middle.

The test system uses PTC, a digital servo controller to command and control the load and position. It is a 1 to 4 channel digital servo controller with Liquid Crystal Display (LCD). This controller gives the flexibility to add additional hardware like the digital and analog inputs and outputs that includes vibration inputs, strain gauge amplifier inputs, remote control units etc.

The connection between the SCU's and the real-time front end is established by using a low-cost real-time Ethernet communication link, enabling the controller to be placed very close to the actuator. The analogue cabling, usually an expensive and noise prone part of a test system, can be kept as short as possible, introducing very high signal-to-noise ratios.

The Test System has capability to measure Linear Variable Differential Transformer (LVDT) sensor on UUT (Unit Under Test), to measure the position and communicate as a voltage signal back to the PTC for the position loop closure. The Acceptance Test Procedure (ATP) test setup is shown in Figure 1.

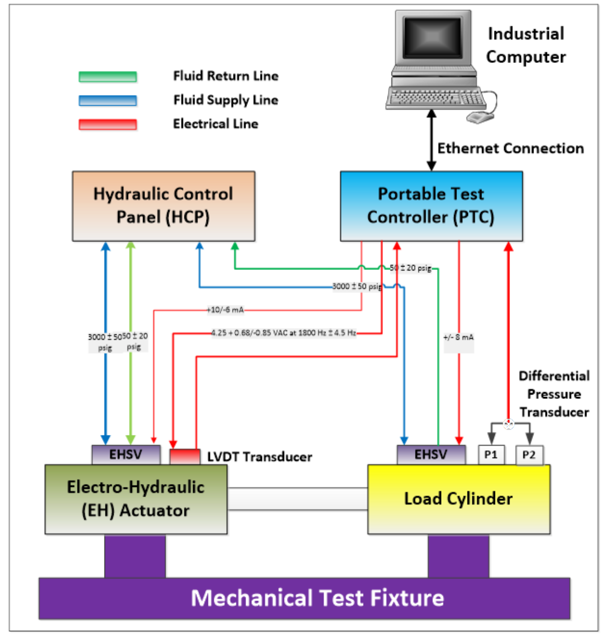

Figure 1 : Acceptance Test Setup

III. Implementation

a) Software Implementation

Acceptance test software has three major parts.

- LabVIEW Software Module
- Hardware Abstraction Layer(HAL)
- PTC Low Level Drivers

Figure 2 shows the interface between the LabVIEW Software Module and PTC Low Level Drivers through HAL layer. The PTC hardware is connected to LabVIEW software through the IP address. Hence, Test System and Host Computer are connected using a Cross Cable or on Local Area Network (LAN).

HAL: A hardware abstraction layeris an abstraction layer, implemented in system software, between the physical hardware of a computer and the software that executes on that computer.

b) PTC Module has three major functions

- *Safety Module:* It basically consists of an E-Stop, failsafe conditions.
- *Position Loop:* PTC generally uses the FCSLoop to bind position loop with SCU1.The FCS loop is a Moog unique control loop with dual mode controller, which allows to switch between force and position control modes. The SCU has all necessary I/O hardware to connect a typical actuator. Usually this will be a hydraulic, servo-controlled actuator. Each SCU is connected to its own actuator. It's the job of the controller to modify the output connected to the actuator in such a way that the feedback is always as close as possible to the commanded value.

- *Load Loop:* In this the PTC uses the FCS Loop to bind Load loop with SCU 2.

Host Computer gives the input command to PTC low level Drivers which will interact with hardware system and hardware system gives the feedback command to Host Computer through PTC.

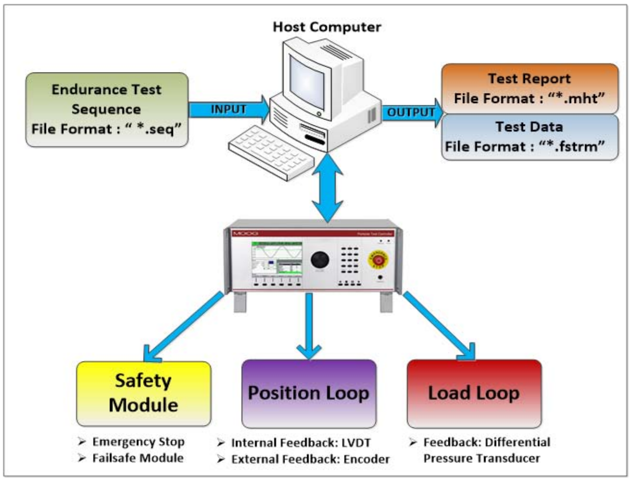

Figure 2 : Acceptance Module Block Diagram

LabVIEW Software Module: This Software interacts with the operators and engineers. The overall functionalityof this module is divide into two major parts, viz; Edit and Graphical User Interface (GUI) window.

Edit Window: The functional logic has four states and every state task is shown in Figure 3.

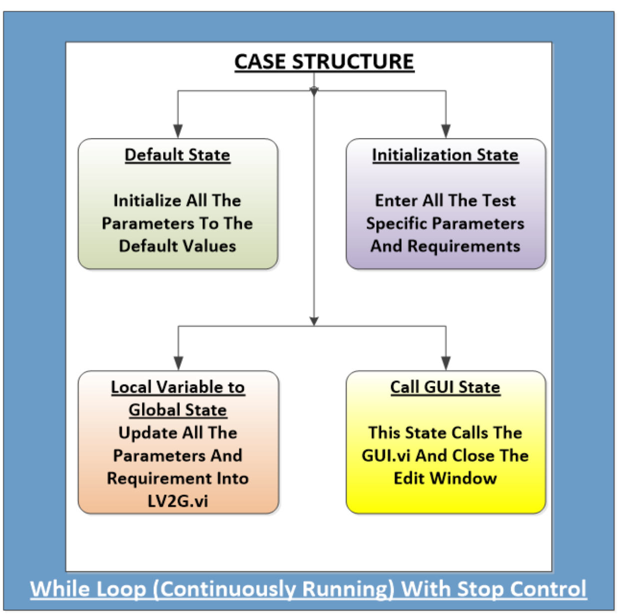

Figure 3 : Edit Window Functional Logic

GUI window: This window has two different while loopswhich are continuously executing andcontrolled with a control button. "While Loop 1"is implemented to execute the Acceptance Test Procedure and a case structure inside the While loop is execute the logic flow. This case structure states contains the HAL and PTC drivers to make communication with the PTC hardware. While Loop 2 is basically used for plotting the Real Time graphs on the GUI front window by means ofcollecting the data from the PTC hardware through User Datagram Protocol (UDP) communication. Loop synchronization is an important part to plot the real and proper data.

The functional logic of GUI for Air Purging Test is shown in Figure 4. Figure 5 and Figure 6 shows the LabVIEW code of the Air Purging Test for both the loops respectively.

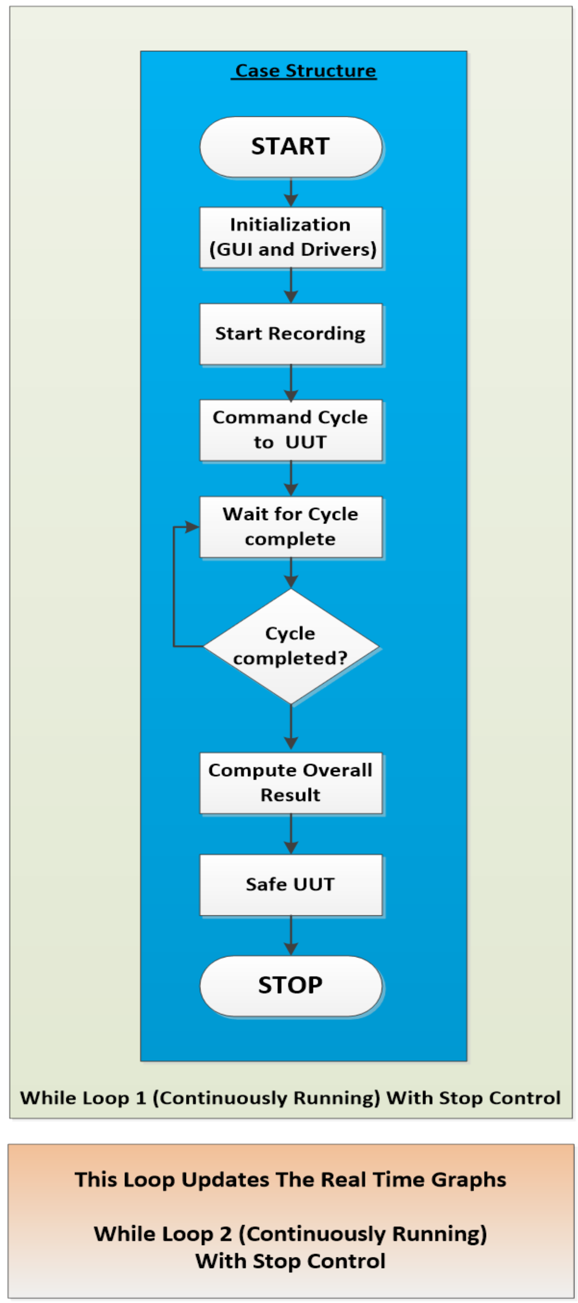

Figure 4 : GUI window functional logic

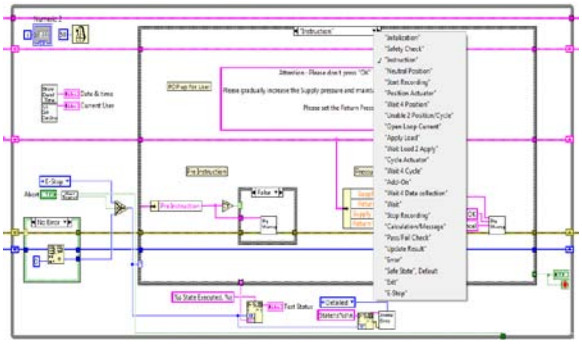

Figure 5 : LabVIEW code of the GUI window with different states

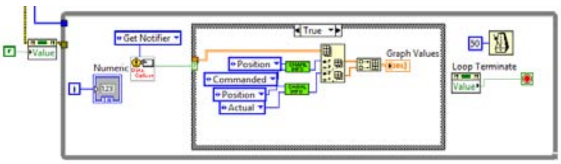

Figure 6 : LabVIEW code for plotting Real Time graph

a) Hardware Software Integration

To interface hardware with software, the settings of the PTC need to be changed according to the project requirements.

b) Loop Configurations

Two channels are required to bind to open/closed loops.

Channel1 is for Position Loop, which is bound with SCU1 and connected through FCS type Loop.

Channel2 is for Force Loop, which is bound with SCU2 and connected through FCS type Loop.

Figure 7 shows the selected PTC channels and Figure 8 shows how these channels bind with respective SCU's.

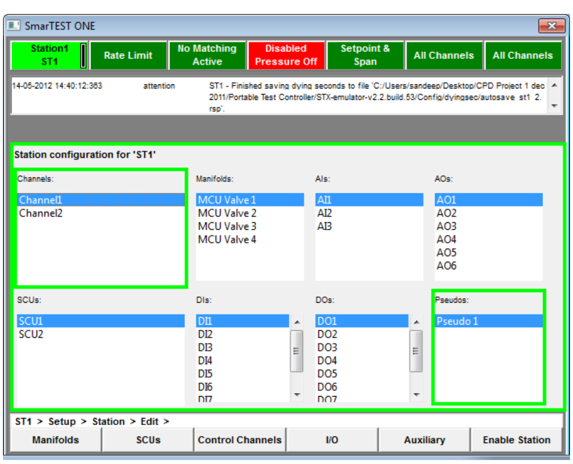

Figure 7 : PTC Channel Configurations

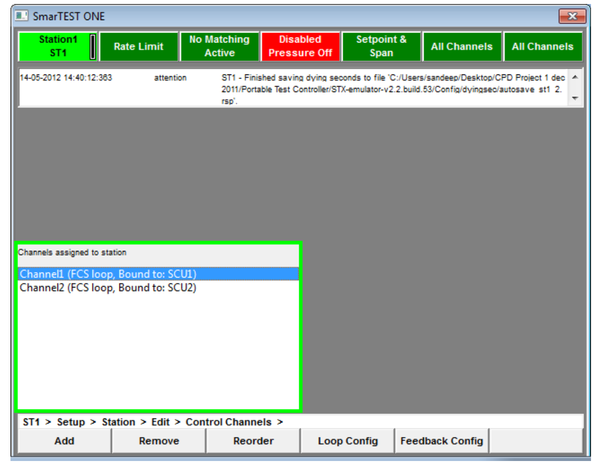

Figure 8 : Channel Bindings

c) Calibrations

Before calibration and tuning can be performed on a Test controller system, we have to make sure that the channels Loop. Polarity is correct. The loop polarity tuning parameter changes the polarity of the control loop by effectively reversing the connections to the servovalve. LVDT Calibration is performed with the Vendor Calibration report and the PTC calibration utilities. The following figure shows the calibration procedure of LVDT:

i. Select the LVDT sensor in Figure 9 and press next.

ii. Fill the giving values with the help of vendor calibration report in Figure 10.

iii. Measure the LVDT value at specific points and enter these values in the measured box of Figure 11.

iv. Do the calibration for minimum five points and save the calibration settings.

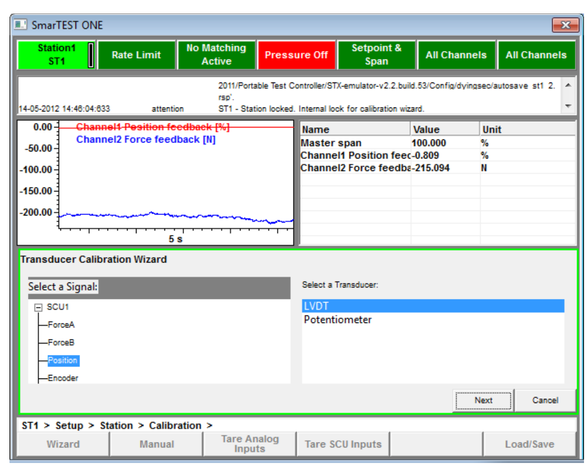

Figure 9 : LVDT Calibration - Step 1

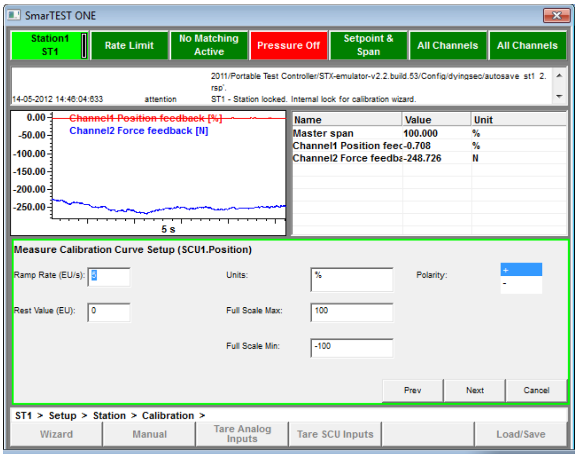

Figure 10 : LVDT Calibration - Step 2

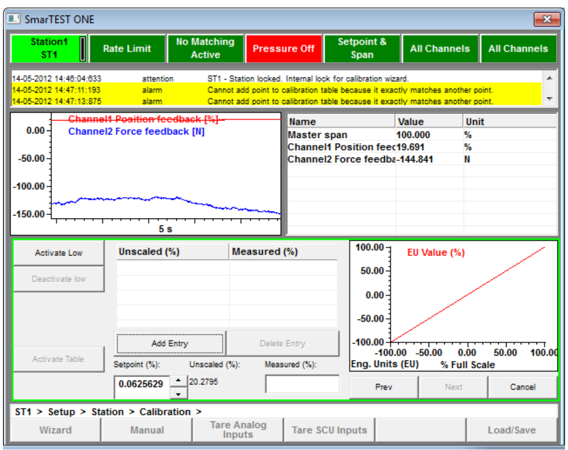

Figure 11 : LVDT Calibration – Step 3

a) Position Loop Tuning

After binding the loop and LVDT calibration, Tuning has to be performed for better output following with respect to input commands. A Proportional–Integral–Derivative controller (PID controller) is uses to control the loop feedback mechanism. PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process control inputs. Figure 12 shows the Position loop tuning.

i. *Position Loop Tuning procedure*

- Set all the PID values to zero, so that the closed loop becomes the open loop.
- Now apply the null bias servo value offset current to the UUT.
- Now slightly increase and decrease the offset current to move the UUT in Extend and Retract direction respectively.
- Now Set the PID values in such a way that the system will not go in unstable mode. And set the optimum PID values so that output signal follows the input command exactly or nearly exact.

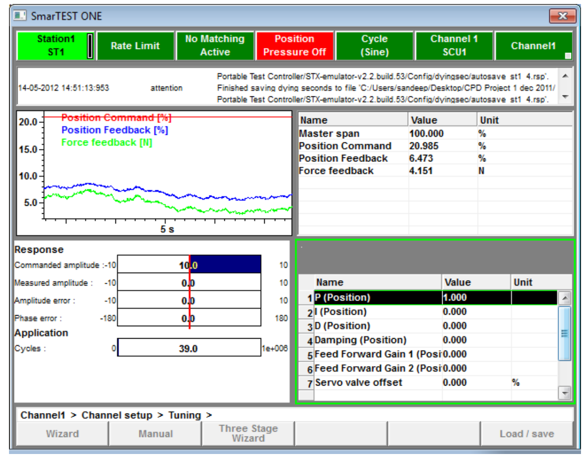

Figure 12 : Position Loop Tuning

IV. Test Results

Acceptance Testing is used to test the performance of the Electro-Hydraulic actuator in the real environment conditions. For Electro-Hydraulic actuator, there are several tests. All the tests have different test conditions and parameters. The test steps are classified into two categories:

- Open Loop Command Test
- Closed Loop Command Test

Open Loop Command Test: In this, servo current is used as an input command and actuator will move according to the amount of current giving to the EHSV. Electrical Phasing Test comes in this category.

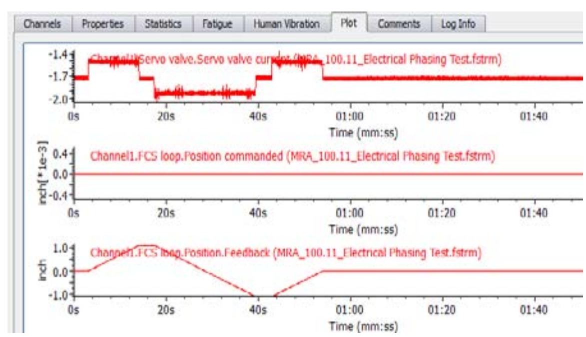

Figure 13 : Electrical Phasing Test Result

- *Analysis*

In Figure 13, the Servo valve current is changing +/- from its null bias value. Therefore the actuator is moving in Extend and Retract direction respectively. Position Command signal is not playing any role in this type of test.

Closed Loop Command Test: In this Position Commanded signal is used as an input command and Electro-Hydraulic actuator will move according to the commanded signal position value. Air Purging Test comes in this category. And actuator shall cycle smoothly throughout the entire stroke range after the fourth cycle.

- *Analysis*

In Figure 14, Position Feedback signal is changing according to the Position Commanded signal. Actuator is moving smoothly after the 4th cycle.

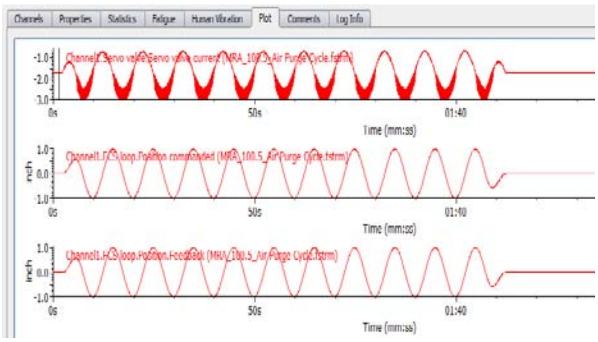

Figure 14 : Air Purging Test Result

V. Conclusion

The intended test equipment has been built and system software for controlling the test equipment has been developed in LabVIEW. A new approach used in this paper to test the actuator using PTC hardware. The advantage of PTC used in Acceptance software is cost reduction of the Testing and the reduction in the development time. On the basis of this approach and its derivative system design, we can further make different test system with large scale testing, which is going to be applied widely in the automation and industrial field.

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