Components of Fatigue Test Controller

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Abstract: ***This paper describes about the development of computer controlled single channel controller used in servo hydraulic test system for fatigue testing of materials. The closed loop control obtained with load cell and LVDT which provides an electrical signal to the controller proportional to the mechanical position of the actuator or load exerted by it. The electrical signal is passed through signal conditioning circuitry for amplification of the signal which is fed to the servo-controller to generate an error signal. The feedback mode whether in stroke (LVDT) or Load mode is compared with respective set points using a differential amplifier. Add -on boards of digital to analog converter is used to convert the set-points which are in digital form to analog value. The operations of the controller are displayed on the console of the computer.***

Keywords: Fatigue test, Controller DAC,ADC, Load mode and stroke mode

1. Introduction

Fatigue testing is critical requirement of aircraft to determine the life span of the aircraft. A fatigue test helps determine a material's ability to withstand cyclic fatigue loading conditions. By design, a material is selected to meet or exceed service loads that are anticipated in fatigue testing applications. Cyclic fatigue tests produce repeated loading and unloading in tension, compression, bending, torsion or combinations of these stresses. Fatigue tests are commonly loaded in tension – tension, compression – compression and tension into compression and reverse.

To perform a fatigue test a sample is loaded into a fatigue tester or fatigue test machine and loaded using the pre-determined test stress, then unloaded to either zero load or an opposite load[1]. This cycle of loading and unloading is then repeated until the end of the test is reached. The test may be run to a pre-determined number of cycles or until the sample has failed depending on the parameters of the test[2]. The purpose of a fatigue test usually is to determine the lifespan that may be expected from a material subjected to cyclic loading, however fatigue strength and crack resistance are commonly sought values as well. The fatigue life of a material is the total number of cycles that a material can be subjected to under a single loading scheme. A fatigue test is also used for the determination of the maximum load that a sample can withstand for a specified number of cycles. All of these characteristics are extremely important in any industry where a material is subject to fluctuating instead of constant forces.

Types of fatigue tests:
There are several common types of fatigue testing as well as two common forms: load controlled high cycle and strain controlled low cycle fatigue. A high cycle test tends to be associated with loads in the elastic regime and low cycle fatigue tests generally involve plastic deformations.

Types of materials for fatigue tests
Most of the materials may experience fatigue in one way or another during the lifespan of their application. However, in applications where fatigue is a factor it is common to find components made from metals or composites. These materials have a higher fatigue limit than others because of the rigidity and ductility, which are characteristics that tend to increase fatigue strength. Other materials, such as, polymers, ceramics and wood may experience fatigue and also need to be tested to understand how they will respond to these unique stress combinations.

Fatigue testing specified mean load (which may be zero) and an alternating load are applied to a specimen and the number of cycles required to produce failure (**fatigue** life) is recorded. Generally, the **test** is repeated with identical specimens and various fluctuating loads.

2. Closed Loop Servo-Hydraulic Testing System

Closed -loop position or load control is obtained by the use of a linear -variable differential transformer(LVDT) or load cell which provides an electrical feedback signal to the controller proportional to the mechanical position of the actuator or the load exerted by it[3]. A standard manifold is mounted an each actuator to which electro-hydraulic servo-valves are fitted and to which a pressure line filter, accumulator and a dump valve are attached. The manifold also provides connections for hydraulic pressure and return hoses. The closed loop servo hydraulic testing system is as shown in fig (1)

The machine is used to conduct various axial tests on the specimen to understand the fatigue behavior of materials. It consists of a servo hydraulic actuator to load the specimen. This is essentially a piston cylinder arrangement in which the movement of the piston is controlled by the direction of flow of hydraulic oil. The direction and rate of flow of oil is controlled by the control current given to the servo valve which responds to the same in a proportional manner.

The servo -valve is basically a power amplifier that regulates fluid flow to the actuator as a function of the control current from the console. The computer sends load signals to the loading machine called set-points. This set-point is in digital form and cannot be directly be fed to the loading machine. Therefore a digital to analog converter is used to convert the same into analog form. The transducers LVDT and Load cell sense the amount of stroke or load applied and convert them into proportional voltages. Depending on the mode selected the feedback is compared with the respective set points using a difference amplifier to produce error. This signal is amplified by an OPAMP to match the current specifications of the electro hydraulic servo valve which drives the actuator.

3. Operation

The loading machine operates in two modes namely position or stroke mode and load mode. The position or stroke mode is used to monitor variations in length of the specimen using LVDT as transducer and the load mode is used to monitor the load applied to the specimen during the test using load cell as transducer. When no specimen is mounted on the machine , the load mode is in open loop and always load cell reads zero. The error card which senses the difference between the set-point and feedback signal will always sense some error and hence the system continues in applying the load leading to breakage of the gripper arms. Whereas the position mode is in closed loop at start because the gripper arms start moving as soon as the load signal is sensed by the loading machine and hence the LVDT which is a displacement transducer gives a proportional feedback voltage signal. Therefore always the machine should be started in position mode.

4. Block Diagram

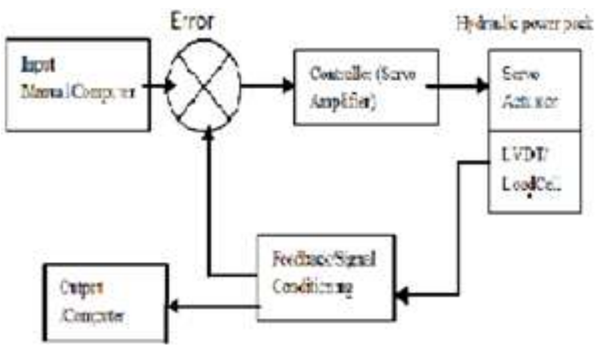

Figure 2

Interfacing devices

a) DAC (digital to analog converter) is a device which converts binary set points given by the computer into an analog voltage.
b) ADC (analog to digital converter) is a device used for acquisition of load or displacement data. It converts voltage signals obtained from transducers into binary numbers which are recognized by the computer.
c) **Error card:** This is electronic circuit used to compare the set point and feedback signal and generate an error signal used to actuate the servo-hydraulic actuator. It is essentially a PID controller. The sign of the error signal (+/-) decides the direction of movement of the gripper thereby applying tensile or compressive loads.
d) **Signal Conditioner:** It consists of circuit which is an Instrumentation amplifier and a filter circuit. The output of a transducer will be in milli volts which requires amplification. The amplified signal undergoes filtering with Low pass filter circuit.
e) **Ports & Relay:** These are digital channels to allow flow of digital data of the DAC and from the ADC. All ports have hexadecimal address values. The Relay used is to select between load mode or displacement mode and is again connected to the computer means of a port.
f) Maximum/ Minimum limit setting: The Limit circuit developed consists of two op amps which are used as comparator for maximum and minimum limit setting as threshold separately.

5. Control Methodology:

Strain gauge load cells are the most common in industry. These load cells are particularly stiff, have very good resonance values, and tend to have long life cycles in application. Strain gauge load cells work on the principle that the strain gauge (a planar resistor) deforms/ stretches/ contracts when the material of the load cells deforms appropriately. These values are extremely small and are relational to the stress and/or strain that the material load cell is undergoing at the time. The change in resistance of the strain gauge provides an electrical value change that is calibrated to the load placed on the load cell [4].

Strain gauge load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gauges are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension can be represented as T1 and T2,and two in compression can be represented as C1 and C2, and are wired with compensation adjustments. The strain gauge load cell is fundamentally a spring optimized for strain measurement. Gauges are mounted in areas that exhibit strain in compression or tension. When weight is applied to the load cell, gauges C1 and C2 compress decreasing their resistances. Simultaneously, gauges T1 and T2 are stretched increasing their resistances. The change in resistances causes more current to flow through C1 and C2 and less current to flow thro ugh T1 and T2. Thus a potential difference is felt between the output or signal leads of the load cell. The gauges are mounted in a differential bridge to enhance measurement accuracy. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load.

A transducer for providing an electrical output that is linearly proportional to a mechanical displacement is the linear variable differential transformer(LVDT). It is an electro-mechanical transducer of induction variation type in which mechanical displacement acts on a movable core. Three coils are wound on a cylindrical coil form with the center coil acting as primary inducing a voltage in each secondary coil on either side of it. The magnetic core is free to move axially inside the coil assembly and the motion being measured is mechanically coupled to this movable core.

When the primary is energized with AC voltage, voltages are induced in two outer coils, in which the secondary coils are connected in series opposition so that the two voltages in secondary coils are opposite in phase and net output of LVDT is the difference of these voltages.

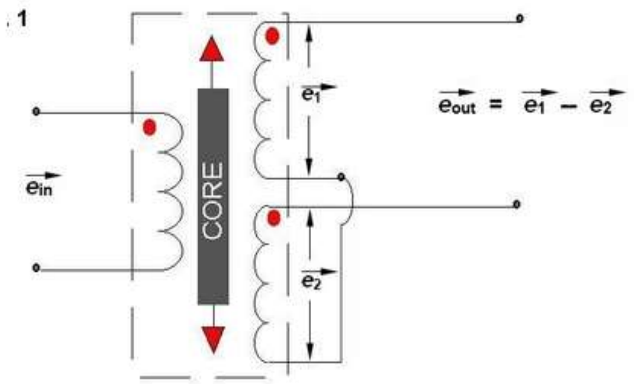

Figure 3

Linear variable differential transformer (LVDT) transducers are widely used for the measurement of displacement, pressure, force, level, flow, and other physical quantities. The differential signal (el - ***e2)*** is obtained from the secondary windings SI and ***S2.***

Servo-Controller

The control waveform and feedback from the transducer are fed to the servo controller which generates an error signal. This signal is used to control the actuator either in stroke mode or in the load mode.

In stroke mode the feedback is from LVDT positioned on the side of the actuator by a clamp. The LVDT is calibrated to give zero feedback at the mid-stroke position of the actuator. In load mode the feedback is obtained from a strain gauge bridge which is mounted on the load cell. When load is applied the bridge is unbalanced resulting in a change in output.

The feedback mode is selected by a knob at the front panel of the unit. Depending on the mode selected the feedback is compared with the respective set points using a difference amplifier to produce error. This signal is amplified by an operational amplifier and fed to the electro-hydraulic servo valve which drives the actuator.

The servo valve is a power amplifier that regulates fluid flow to the actuator as a function of the control current from the control console. The servo valve used is a Moog 72.It is an electro-hydraulic servo-valve. It consists of an electric torque motor and hydraulic stage. The flow regulating portion of the servo-valve generally referred to as power stage, is ported in a four way configuration. Fluid flows into , or out of, either side of the actuator ,or it remains in no flow position. The servo-valve spool position is controlled by a pilot stage, which converts the electrical signal from the controller into a proportional movement of the spool and so provides proportional fluid flow to the actuator piston.

6. Data Acquisition System

The components of data acquisition systems include:
a) Digital values are converted to analog values using DAC.
b) Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Add-on Cards which are compatible to ISA slots of the CPU of computer. The ADC card is Adlink 8112 with 16-Channel 12-Bit 100 kS/s Multi-Function DAQ Cards.The card can be used with 16 channel single ended or 8 Channel differential inputs, with a resolution of 12 bits.

DAC is an ADlink 6126 12 bit 6 channel with 12 bit resolution is connected to ISA slot.

Figure 4: 6126 D/A card

Sample conversion for +/- 5volts range
Analog volts = (10*2498/4095)+(-5) = 1.1 volt

Figure 5: 8112 A/D card

Features:
16-CH 12-Bit 100 kS/s Multi-Function DAQ
16-CH single-ended or 8 -CH differential inputs
Bipolar or uni polar analog input ranges
Programmable gain of x1, x2, x4, x8, x16
Sample conversion for +/- 5volts range
Digital Value = -(-10)*(2498-2047)/4095) = 1.1 volt
Bipolar or uni-polar range can be set by hardware switches on the board.

The Algorithm of the test software is as follows.

1) Initialization of the Cards , if successful continue for acquisition
2) Calculate the Pmax and Pmin with a mean value.
3) Logical steps for static load or dynamic load are done.
4) Few key operation are used to pause, stop the test with preset cycle count .

Completion of tests are done depending on the load requirement. Using C coding the program to convert the digital data to analog and analog data to digital will be done.

7. Results

Fatigue testing in a simple way is obtained with the developed controller which has components of hardware and software for various types of testing such as static and dynamic testing. The advantage of the developed software gives flexibility in testing as it does not require history of the load data for further testing.

8. Conclusion

The Digital Controller provides the facility to test the material with Load Mode or LVDT mode. The LVDT mode is considered only for the movement of the grips provided in the set up as it gives flexible movement. The actual test happen with load mode in which the conversion happens from the digital to analog and analog to digital voltage which is converted to current with servo amplifier further to the controller. Static or dynamic testing can be done using the developed hardware and software. Scope of the present work can be extended with additional features of Data acquisition system.

References

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