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ISO Pipe Testing Process Analysis and Virtualization

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Abstract

The new procedures for testing casing and tubing connections require more accuracy for the qualification of the threaded connections. In this situation is necessary a better analysis of the pipe testing process in respect with the test frame behavior. This paper analyze a modality to virtualized the pipe testing process by identify his mathematical model. After that a real controller can be interfaced with the Simulink Model using a virtualization interface technology like LabView simulation interface toolkit (SIT). This presented method can be useful to test new controllers and to train technicians in a virtual environment.

Key words: *hydraulic actuator, virtualization, process modeling.*

Introduction

A reliable tubing and casing connection can be delivered to the petroleum industry just if this one is validated with tests specified or recommended by an international standard. The target of the international standards is to establish minimum design verification testing procedures and acceptance criteria for casing and tubing connections for the oil and natural gas industries.

The well operations like: drilling, completion and work over rely on the casing and tubing connections. The most critical point in the oil and gas tubular is represented by the treaded connection.

For the validation, tubing and casing are subject to complex loads (axial, bending, torsion), internal or external pressure and temperature cycles. To qualify tubing and casing connections is necessary to use a full-scale testing frame able to generate extreme combined loads. The frame must be designed to simulate the borehole conditions and to allow the online evaluation of behavior of the specimen. The measurement system must be able to provide coherent information to control system and eventually, to estimate values that cannot be measured with installed configuration. The ISO 13679 require to be recorded the axial load in compression and tension, the internal and external pressure, the temperature and the leak. The control system must manipulate in real time the process values in order to obtain an accurate position of the states with respect of the sequence and the trajectories between states.

This paper presents the facility structure by focusing on the axial load subsystem. The subsystem model is described in Simulink and after that is interfaced with LabView.

Test Frame Description

The high tension test facility RP5 (Fig. 1) consists of a rigid frame in which the specimen can be mounted using bending adaptors. The adaptor of the upper end of the specimen is connected to the frame fixed end and the lower end to the piston rod of the high pressure cylinder. A quick rig in of the specimen is realized by using clamping connections of the adapters which can be operated hydraulically. Actually the entire concept of RP5 is to improve the control and load of the specimen. The axial loads are created with the floating piston by pressurizing two chambers. The pressure applied in the upper chamber is creating tension and the pressure from the bottom chamber is generating compression. The piston separates two pressure chambers and is used to apply the axial loads. The upper part of the specimen is mounted by an adapter to the autoclave and the lower part is connected to the floating piston.

The frame is able to apply uniform bending by using two opposite cylinder in order to create rotational moments at the bouts pipe ends. The temperature generator is represented by an induction heating coil is mounted around the joint. A second coil connected to a pressurized water system is installed in order to perform the cool down process by water spray. This allows cooling down within a given time and for very short cooling times a special container can be flooded with water in order to accelerate the process. The external pressure is created with water by an autoclave around the connection. The internal pressure system is composed of a high volume accumulator and a high pressure compressor. The accumulator is used to reduce the pressurizing time and to accumulate the gas in order to eliminate the nitrogen expenses. The maximum pressure for this vessel is 1400 bar. The high pressure compressor increase the pressure once the accumulator is empty or over the 1400 bar. The maximum pressure for gas tests is 3500 bar. To reduce the internal gas volume, the specimen is filled by a massive bar. The leak system is able to determine the internal and external leakage by using two transparent water filled tubes and an optical system to log the water level in the tubes.

The control of the facility is done by using PI controllers switched by logical conditions for different scenarios. The controller’s tuning parameters are chosen by the test technician depending on the type of test.

Mathematical Model of the Axial Load

In order to design a suitable controller for the facility is necessary to elaborate a reference mathematical model. Because this model is from beginning a partial representation of the process the controller must refine the mathematical relations by tuning the parameters.

In the actual moment the facility has two issues: the way haw the controlled values are measured and the control quality. The axial loads are estimated by measuring the pressure in the cylinder chambers and bending severity is directly measured with strain gauges. In order to have an accurate measurement of the pure axial loads in required a load cell on the pipe shaft or to have strain gauges attached on the test frame. Unfortunately a load cell for huge compression and tension loads is a complicated issue. In another way the attached strain gauges on the test frames must accurate calibrated and are generating unexpected results when the pipe is bended, because the frame is absorbing a part of the bending load. The bouts measurements are affected by the temperature fluctuation.

Because a direct measurement of the load is physically difficult to implement, this value can be estimated by measuring the by measuring the relative elongation on the specimen. For this procedure the distance measurement system can be placed away of temperature influenced arrears in order to avoid external disturbances, and in another way the mechanical vibrations can be easily rejected.

The mathematical model of the pipe test process will correlate the electrical commands for the actuators with relative elongation of the specimen.

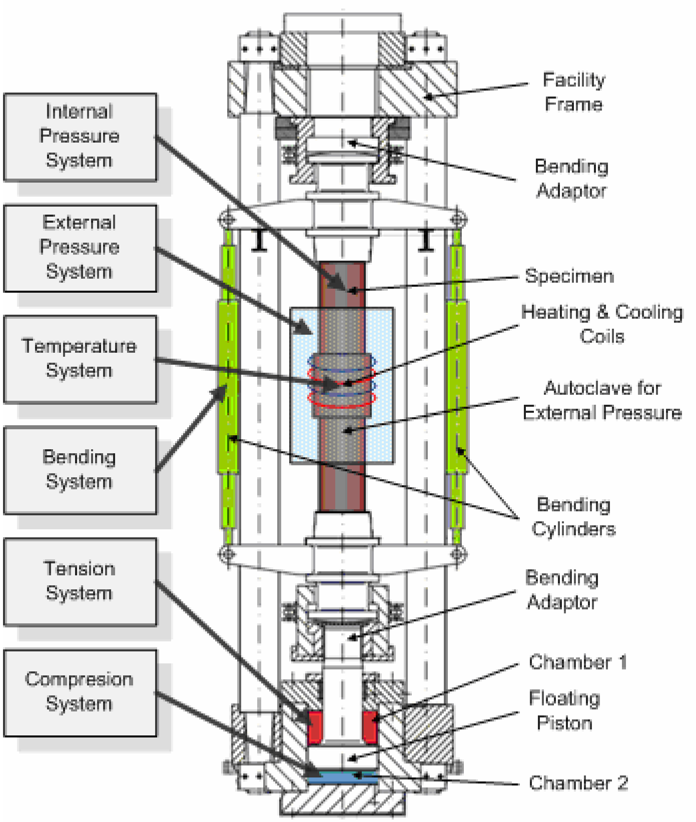

Fig. 1. RP5 test frame main components

Considering that the both pistons have the same active surface then the force balance equation is [3], [4]:

$$F_g = A_p P_L = M_t \frac{d^2 X_p}{dt^2} + B_L \frac{dX_p}{dt} + K X_p + F_L \tag{1}$$

The final equation arises by applying Newton's second law to the forces on the piston. The net force on the piston not only causes acceleration but also has to over come friction B_L.

Taking Laplace's transform we get:

$$P_L = \frac{1}{A_p}\left\{\left(M_t s^2 + B_L s + K\right) X_p + F_L\right\} \tag{2}$$

where *Fg* - force generated or developed by the piston, *[N];*
Mt - total mass of the piston and load referred to the piston, *[Kg];*
BL - viscous damping co-efficient of piston and load, *[N/(m/s)];*
K - load spring constant, *[N/m];*
FL - load or disturbance force on piston, *[N];*

Applying the law of continuity to each of piston chamber yields [1], [2]:

$$Q_L = A_p \frac{dX_p}{dt} + C_{tp} P_L + \frac{V_t}{4\beta_e}\frac{dP_L}{dt} \tag{3}$$

Taking Laplace's transform we get

$$Q_L = A_p s X_p + \left(C_{tp} + \frac{V_t}{4\beta_e} \right) P_L \tag{4}$$

where β_e- effective bulk modulus of the system (include oil, entrapped air, and mechanical behavior of chambers), *[MPa];*

t - time, s*ec, Ap* - Area of piston, *[m²];*

Xp - displacement of the piston, *[m];*

Vt - total volume of fluid under compression in both chambers,*[m³];*

C_{tp} - total leakage coefficient piston, *[liter/sec/MPa].*

With the assumption that valve orifices are matched and symmetrical, the pressure *P1* and *P2* will rise above and below *Ps/2* by equal amounts so that the pressure drop across the two valve orifices are identical. Assuming constant supply pressure and return pressure *P0 = 0*, the linearized equations for load flow can be written as:

$$Q_L = K_q x_V - K_c P_L \tag{5}$$

where *QL* - load Flow,*[m3/sec];*

x_v- - valve displacement from neutral position, *[m];*

Kq - valve flow gain,*[liter/sec/m];*

Kc - valve flow pressure co-efficient, *[liter/sec/MPa];*

PL =P2 – P2 - load pressure difference, *[Mpa].*

Combining equations (2), (4) and (5) we get, the over all transfer function as:

$$X_p = \frac{\frac{K_q}{A_p} x_v - \frac{K_{ce}}{A_p^2}\left(1 + \frac{V_t}{4\beta_e K_{ce}} s\right) F_L}{\frac{V_t M_t}{4\beta_e A_p^2} s^3 + \left(\frac{K_{ce} M_t}{A_p^2} + \frac{V_t B_L}{4\beta_e A_p^2}\right) s^2 + \left(1 + \frac{K_{ce} B_L}{A_p^2} + \frac{V_t K}{4\beta_e A_p^2}\right) s + \frac{K_{ce} K}{A_p^2}} \tag{6}$$

where *Kce =Kc +Ctp* and is called total flow pressure coefficient.
The block diagram of the system is shown in the figure 2.

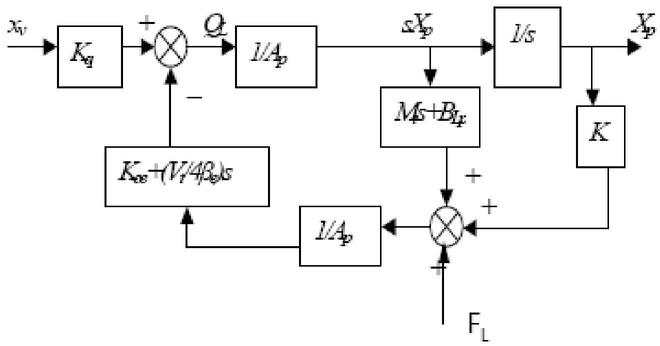

Fig. 2. Block diagram of valve-cylinder combination.

Model Interface with LabView

Simulation Interface Toolkit (SIT) is a client-server environment produced by National Instruments in order to connect a model from Simulink with control procedures provided by

LabView in a virtual environment. The system is using the following components [5] (see fig. 3):

- Model- A simulation block diagram in graphical form. Models contain inputs and outputs that send and receive data. Models contain parameters that can by manipulate and signals whose values can be viewed. Models can be built using The MathWorks, Inc. Simulink application software.
- Host Virtual Instrument (VI) - The VI that you use to manipulate a model. The host VI consists of a front panel and a block diagram. You use front panel controls to manipulate model parameters.
- The block diagram of the host VI contains the code that defines mappings between front panel controls/indicators and model parameters/signals.
- SIT Server - the server that uses a TCP/IP connection to transmit data between the host VI and the model.
- Host Computer- The computer on which you run the host VI. The host computer must be a PC running Windows NT, 2000, or XP.
- Execution Host - The computer on which you run the MATLAB application software, the SIT Server, and the simulation itself. The execution host can be the host computer or a Windows computer on the same TCP/IP network as the host computer.

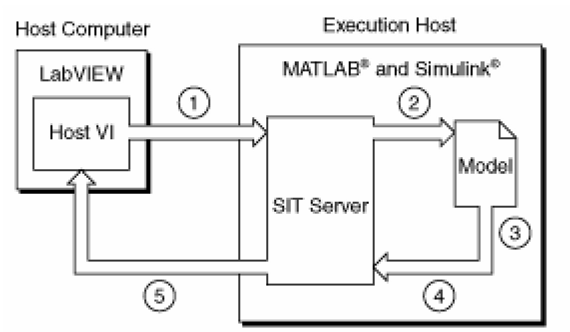

Fig. 4. Connection between SIT components [5]

An important test is low-cycle fatigue and assumes to apply loads on the pipe in order to induce controlled plastically deformations in tension and compression like illustrated in the figure 5. In this scenario is necessary to control the loads by deformation using as feedback the displacement transducer. By replacing the K factor and using the yield point of the material as saturation in the model the strain-stress trajectory will get a severe hysteresis. At this point the model is able to simulate just the behavior for the first cycle because the fatigue and the failure are not predictable.

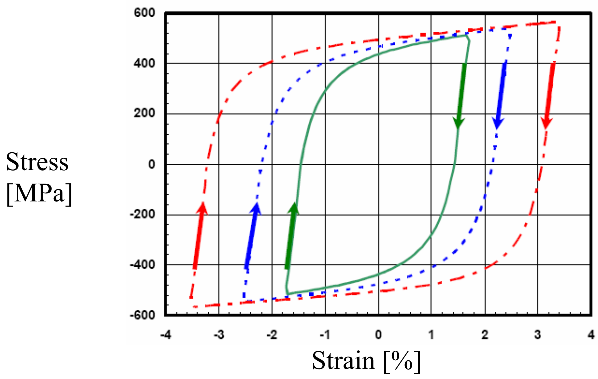

Fig 5. Estimated cyclic strain-stress response for tree three strain amplitudes

Conclusion

This paper dealt with the nonlinear control of an pipe testing facility consisting of an servo valve, a hydraulic cylinder and a pipe with specified physical properties. The scenario proposed in this paper is useful to analyze the behavior of a hydraulic test frame in order to improve the control quality in especially on the limit between elastic and plastic deformation. The obtained model represents a modality to tune the controller parameters and a way to develop a model based controller. With a better understanding of the frame behavior the technicians can use the system offline for training purposes.

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Analiza şi virtualizarea procesului de testarea a materialului tubular conform standardelor internaționale

Rezumat

Noile proceduri pentru testarea materialului tubular din industria petrolieră necesită acuratețe ridicată pentru evaluarea îmbinărilor filetate. În această situație este necesară o mai bună analiză a procesului de testare a țevilor ținând cont de comportamentul instalației de testare. Acest articol analizează o modalitate de a virtualiza procesul de testare a țevilor prin indentificarea modelului matematic. Ulterior un controler poate fi interfațat cu modelul Simulink al procesului utilizând o tehnologie de vitrtualizare precum LabView Simulation Interface Toolkit (SIT). Metoda prezentată poate fi cu succes folosită pentru implementarea de noi regulatoare precum şi pentru instruirea tehnicienilor într-un mediu virtual.