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Design and validation of a digital twin to the intelligent well completion

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The intelligent completion (IC) has been implemented in new oil wells, especially in the pre-salt exploration areas. One of the most relevant components is the Interval Control Valve (ICV), responsible to execute the switching between production zones. The use of ICVs is critical to the O&G completion and drawbacks in their operation can lead to productive losses. Given the hard and costly maintenance, it is fundamental to have means for diagnosis and prognosis of this component. Digital twin (DT) has been increasingly researched for emulating physical assets in a computational environment, in order to understand their behavior in several operation conditions and carry out failure analyses. The present work develops a DT for a hydraulic ICV system, considering simulations of ICV normal and anomalous operation, comparing with open-source databases. The DT includes modeling of hydraulics and thermal exchanges phenomena, as well as different control sequences applied to the valve systems.

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1. Introduction

In the recent years, the criation of virtual models that represents a physical object is beeing used for research purposes. The tool known as Digital Twin concept has been firstly presented on 2002 (Rathore et al., 2021), and can be used for reliability estimations.

The study of well completion in the Oil and Gas (O&G) field can be enhanced by and application of a Digital Twin of the physical model. There is a trend to electronically monitor and control actuators and sensors distributed along a well to switch between production lines to better produce oil. This makes possible to acquire experimental data in order to validate a DT model.

In some Pre-Salt basin, interval control valves (ICV) are used to produce oil, and a well usually has some of them installed taking turns to equally produce oil. These ICVs are hydraulically operated by one pressure pump from the platform once every few weeks. It is possible via DT to make a virtual model that can provide reliability results for the model.

2. Digital Twin

The first step of the concept of a DT is to build a numerical or virtual model of the physical ICVs hydraulic actuators along with the oil lines and pumps. The second would be to validate it with real or experimental data in order to adjust the parameters so the DT model representes a real ICV actuation system.

The assembly of a model was already proposed by Moura et al. (2022) which shows the ICV analysis within a second ICV stucked and also for a pump failure. It was built on the software Matlab® with Simulink® and also Simscape® toolbox, which has models for the many components of the ICV actuation line. The ICV itself has no modeling among the toolboxes modules, but it can be represented by a Double-Acting Hydraulic Cylinder.

3. Parameter Estimations

The parameter estimation can be done manually by varying some specific parameters and running the code until the desired results match an experimental data or via Parameter Estimation application built in Simulink®.

The procedure to use the App is basically to change whichever parameter one wants to estimate into a variable and open the Parameter Estimation App on simulink. One must have either a physical experimental data or a generated data to estimate which parameters values would make the DT model closer to it. The software also has a learning curve built while estimating the parameters. Fig. 1 shows the proceedure: on top, after running the first initial guess for all the variables, and at the bottom a couple of iterations after with a better estimation.

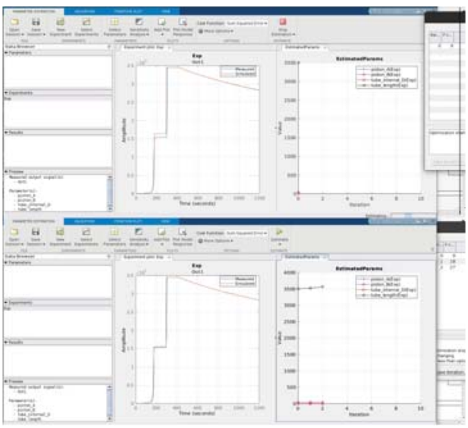

Fig. 1. Parameter Estimation.

The target of the present parameter estimation was the increase in pressure until 2500 psi at around 3 minutes and then a drop to 2000 psi while the piston starts to move, and after the end of the actuation at around 7 minutes the pressure should increase to 5000 psi which is the pump working pressure. The best results are presented in Fig.2 showed below, with a peak at 2370 psi and returning to 2220 psi during actuation.

The times for the piston movement were not as accurate as needed, 2 minutes instead of 4, but it is representing reasonably the experimental data within the time limits that were required by the company that provided the data. As the velocity of the actuator movement increases, it reaches the region where the cylinder friction starts actuate. Resulting in a pressure increase of almost 10% of the actuation desired value and then drops due to the velocity being higher than the value specified

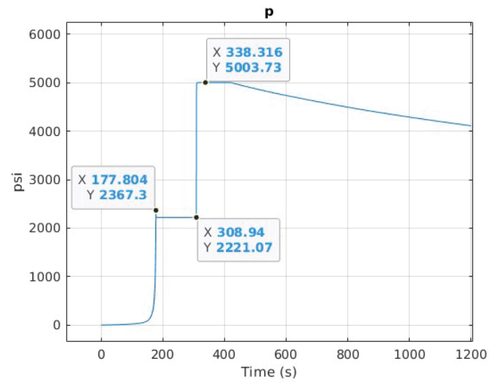

Fig. 2. Hydraulic actuator pressure.

in the friction block parameters.

4. Conclusions

Parameter estimation can be used to find closer values of many variables that otherwise would be time consuming. In the present work 10 variables were analyzed and the results were close to the experimental conditions. It is possible now to use the validated model for reliability studies.

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