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AUTOMATION SYSTEM OF A MANEUVERING OPERATION WITHIN A DRILLING INSTALLATION

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ABSTRACT

The Oil and Gas industry is pursuing major changes in automation, with the aim of reducing the risk involved in operations and increasing efficiency, speeding up processes to reduce costs. Internationally and especially in the Offshore environment, deposits with high productive potential are targeted, which are put into operation through a small number of wells with a high flow rate, due to the complexity of marine drilling. The high costs in this sector of the industry make it necessary to optimize all operational times, thus we very often encounter automation elements in the marine drilling process. This work intends to present the advantages of using the Simulink program package in the simulation of the processes, respectively of the maneuver operation in a drilling installation, to predict their real behavior.

Keywords: drilling, automation, oil & gas, offshore oil & gas industry

INTRODUCTION

The longest time in the well drilling and construction operations is the maneuvering time – insertion into the wellbore and extraction of tubulars to the surface. Some downhole equipment thus implies insertion speed restrictions, and the installation must be able to accommodate these requirements. Some of the main solutions in reducing the maneuvering time are the introduction of slickline or wireline equipment into the borehole, but these operations can be limited to a limited number of technologies that only cover a few of the well construction needs. Another solution is the complete automation of the pipe-handling and make-up operations, thus the times are optimized according to the requirements, and the predictability of the times leads to a better possibility of planning and cost optimization. The latest trends in the industry aim for autonomous drilling, achieved through integrated systems that have decision mechanisms through artificial intelligence, supervision mechanisms and total control of the equipment involved in the process.[1]

THE MANEUVER SYSTEM

In figure 1 is presented the structure of maneuver system with its main components. The draw works is one of the most important components of the drilling rig. The unit supplies the hoisting power, the draw works spools the drilling line as the drill pipe is run into and pulled out from the well.

The Crown Block as a drilling rig component is a fixed set of pulleys located at the top of the derrick or mast, over which the drilling line is wound.

The Traveling Block is a set of sheaves that move up and down in the derrick. The drilling line is threaded over the sheaves on the crown and through the sheaves in the traveling block. Attached to the bottom of the traveling blocks, the hook is required to hang the swivel and kelly, and the elevator bails. [6]

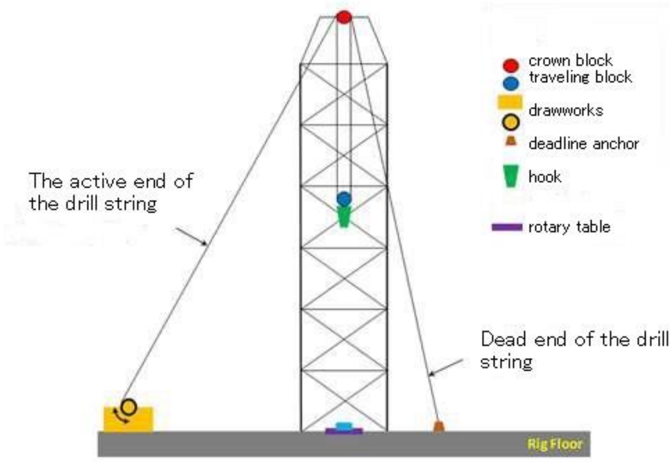

Fig. 1. The structure of a maneuver system

The control of the maneuvering operation is done by operating the draw works motor forward and backward, as well as its brake. Braking is mechanical, hydraulic or electromagnetic. The cable, of a certain diameter, is wound on the drum, and by turning it back and forth by the winch, the translational movement of the crane takes place. Regarding the automation of this process, an automatic operation of the motor of the drilling draw works, as well as of the braking system, can be discussed.

The technological evolution of the drilling draw works has followed several directions, from classic chain transmissions and direct current motors, to alternating current systems with the ability to regenerate energy by braking, to which is added the possibility of compensating the movement of waves in marine environment and integration of automatic control systems [2]. Draw works can be configured with classic manual control – the operator must act on the brake and steering lever, but the latest ones come with the possibility of modular attachment to a control system.

The main components of the winch are the motor, the drum, the main and auxiliary brake, the gearbox. DC motors have the advantage of changing the rotation speed without using a gearbox, except when using several motors synchronously. AC motors have the advantage of smaller dimensions, lower prices, and a lack of contact between static and moving parts.

As for the maneuvering system, the automation follows two main directions: the auto-driller function, for adjusting the drilling parameters (Weight on Bit - WOB, Rate of Penetration - ROP), a function that can be performed by automatically and gradually releasing the winch brake, until these sizes reach the adjusted values; the second function is anti-collision, the function that executes the emergency stop of the maneuver at safety intervals, to prevent hitting the mast, derrick, rig structure or other equipment. The anti-collision function includes, in addition to the drawworks, sensors that are mounted on the travelling block, the Top Drive or other moving equipment.

The Auto-Driller module takes data from the weight, torque, rotation transducers of the other components and modulates a brake system command until the WOB/ROP reaches the set values. The control is based on a PID type controller, which can be configured directly from the integrated systems interface or come pre-configured for stand-alone systems. There are control systems for all types of brakes found on drilling winches: belt, disc, electromagnetic, etc. The best adjustment is made by the electromagnetic brakes, which are also used in the recovery of electrical energy.

The weight of the string is measured using force transducers located at the anchor of the drill string, near the dead end. The load cell thus measures the tension and compression in the drill string and converts it into a 4...20 mA signal for the electronic transducers, and for classic non-automated systems, a hydraulic fluid is used that is pressurized to a certain value, depending on the forces in the cable and translated into force on the weight indicators.

The main disadvantage of measuring the weight in the dead end of the drill cable is the disturbances that appear in the maneuvering installation that have nothing to do with the drilling itself: friction effects, forces and vibrations from storms, equipment rigidity.

For the automatic drilling function, as accurate a measure as possible is required for real-time adjustment of the bottom-hole parameters. New trends in the industry to improve automated processes are to integrate transducers into the Top-Drive system shaft. Thus, the measurements are made directly in the drill string, which gives much more accurate data and helps in optimal control of the automated process, by calibrating friction factors and torque & drag models. Studies conducted on these technologies have shown in some cases major differences in direct measurements compared to dead-end measurements [3].

The Anti-collision system (as is shown in figure 2) is represented by a PLC that receives data from several sensors, to determine the position and speed of the hook, the weight of the string, the hook-speed, the distance to certain reference-points, the position of certain equipment: ramp, Iron Roughneck, bails, etc. It interprets the data received from the sensors and executes a stop command to the auxiliary brake in the case of a downward maneuver or to the engine in an upward maneuver.

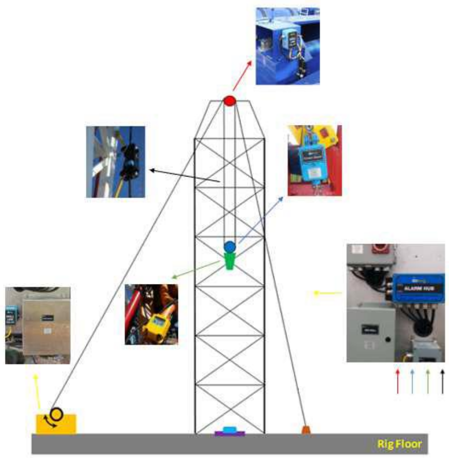

Fig. 2 Anti-collision system sensors positioning. [4]

THE SIMULINK MODEL OF THE MANEUVERING INSTALLATION

In this work, a Simulink model is presented that describes the main components of the maneuvering installation and the interaction between them. The SimScape Multibody component will be used as a working environment, which offers the possibility of integrating components such as joints, pulleys, cables, winches into the model, to which is also added the possibility of integrating 3D CAD models. The advantage of this software is the ease with which the model can be adapted to reality and the possibility of adding technical details to describe a process as close as possible to the real one.

CAD models of the derrick and the Top Drive system from the MathWorks library were used in the simulation. They have a strictly descriptive role, to support the graphic support of the maneuvering process. The model made is not populated with actual technical details of the components but aims to present the basics of this installation. On top of this model, additional components such as drill string geometry, pulley traversal, AC motor and their behavior can be added for a more elaborate study under various physical control parameters. To operate the drilling winch, the model does not use a motor, but a feedback loop, to which the step command is applied. A PID controller takes this command and transmits the signal to the joint element in the form of kinetic moment (Torque). In the feedback loop, the signal from the end of the process (Scope) is taken as the speed value of the hook.

The simulation carried out is a simplistic one, the step used is 5 units (m/s), and the maneuver takes place in the range of units –10 m/s to 10 m/s. PID controller tuning is done empirically to support the demonstration purpose of this model, that is a basic one, from which a realistic representation can be developed by correlating with field data and correcting the controller parameters [5].

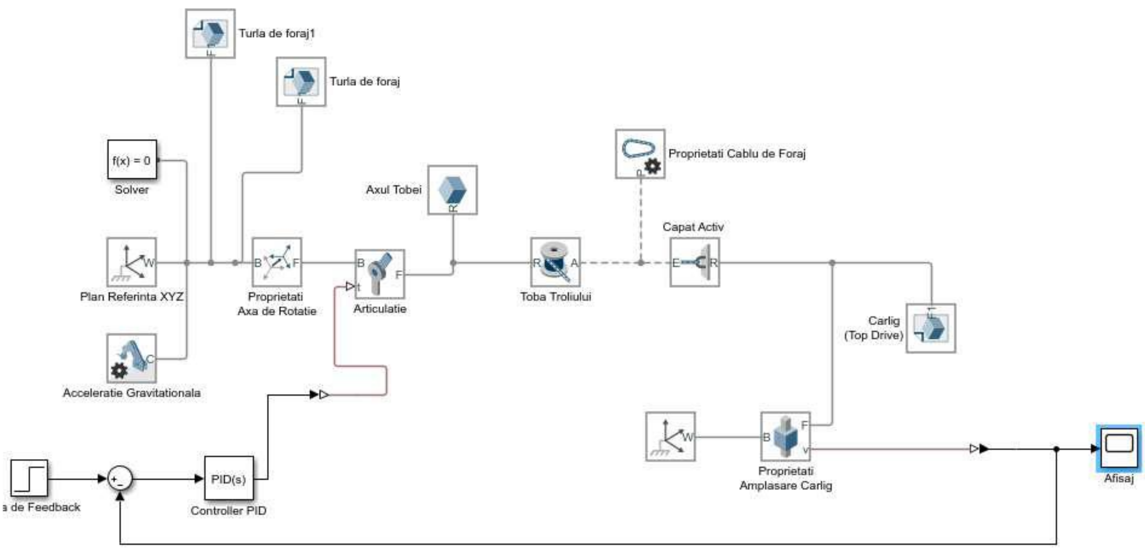

Fig. 3 Simulink SimScape Multibody Model of the Steering Facility.

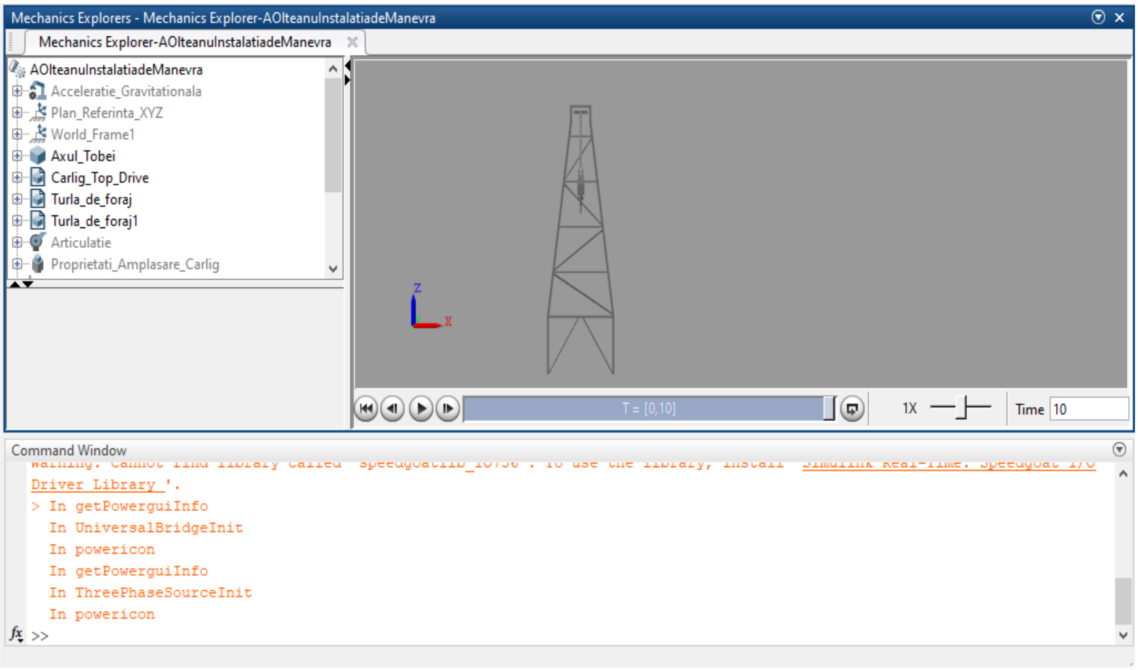

Fig. 4. Model simulation.

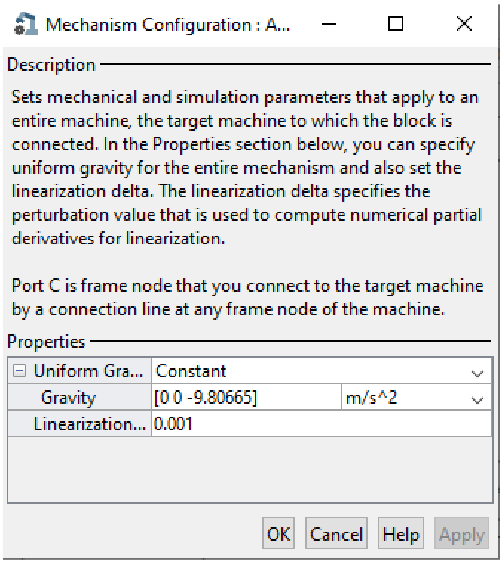

Fig. 5. Introduction of gravitational acceleration.

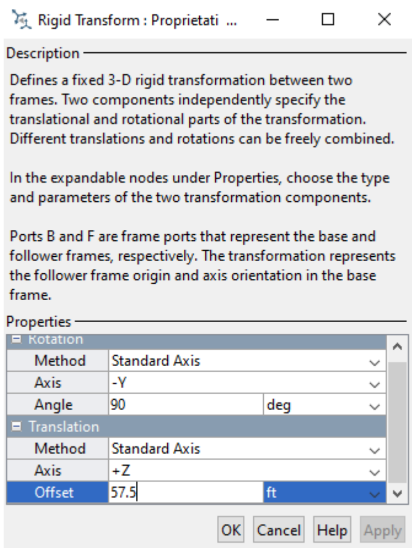

Fig. 6. Defining the properties of the rotation axis of the drilling winch.

In the next window, the drive mechanism of the drilling winch shaft is also defined. This is usually driven by an electric motor and has an associated angular momentum.

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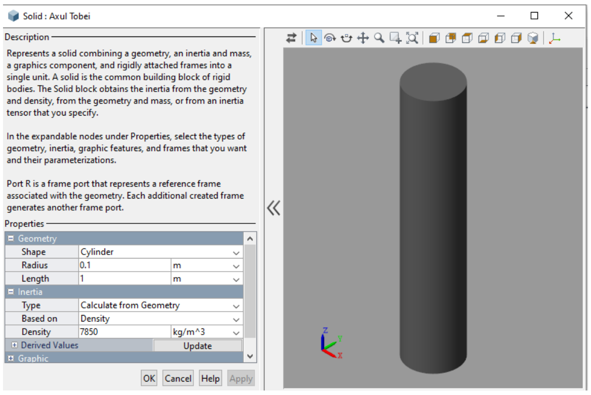

Fig. 7. Defining the Drum Spindle properties.

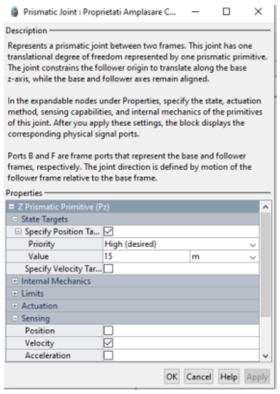

Fig. 8. Drill hook positioning.

A speed sensor is integrated into the drill hook to feed the feedback loop. To simulate the presence of the drilling rig, the model can be simplified by assimilating its weight to the weight of the hook.

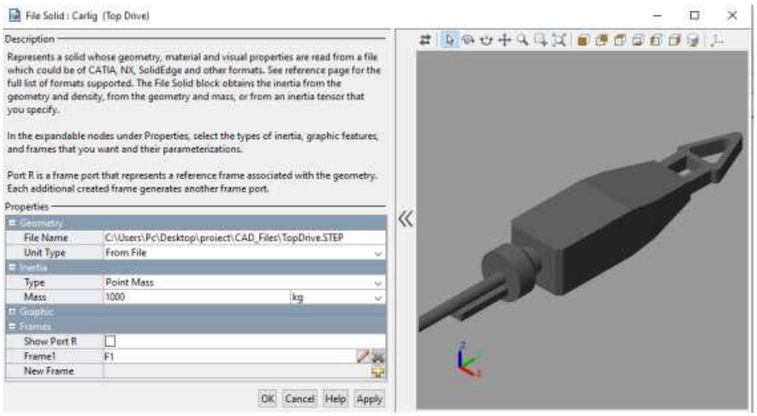

Fig. 9. Defining the properties of the drill hook.

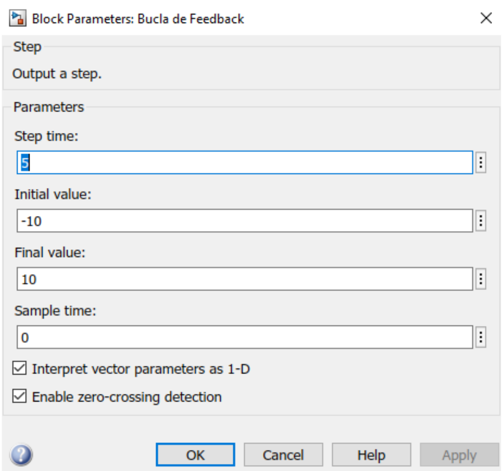

Fig.10. Setting the step input in the feedback loop

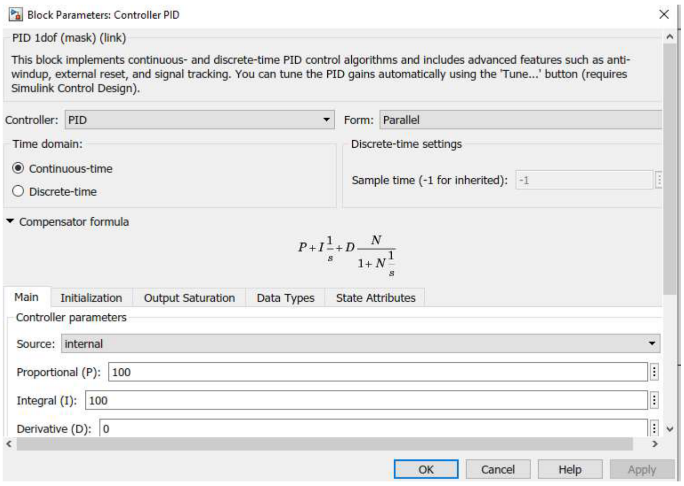

Fig. 11. Adjusting the parameters of the PID controller

As the basis of the simulation, different weights were assigned to the hook to simulate several scenarios. Thus, the behavior of the system was followed in situations where the hook weighs 100 kg, 1000 kg and 10000 kg. The response of the simulation was close to reality, a decrease in the reactivity of the system to the increase in weight and implicitly inertia can be observed, which in reality translates into an additional braking effort during the downward and traction operation, during the upward movement of the drill string.

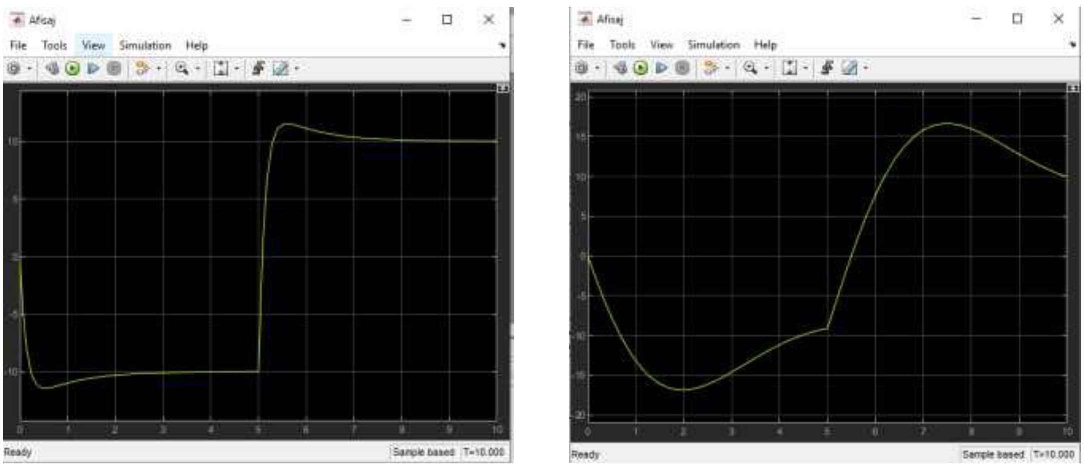

Fig. 12. System behaviour at different hook weight values.

CONCLUSIONS

Automation of the drilling process aims to ease manual processes, and many studies look at the impact of these technologies on the stress level of operators, as well as on the physical and mental well-being of the well crew.

The automation of the maneuver operation involves an automatic operation of the motor of the drilling winch, as well as of the braking system.

In the proposed work, a model was presented that describes the operation of the maneuvering facility, by presenting its main components and the interactions between them. The model was implemented in Simulink, using the SimScape Multibody component, and the behavior of the system was followed for different values assigned to the weight of the hook. The response of the simulated system was close to reality.

It was also concluded that, using the Simulink environment, several scenarios regarding the use of the equipment associated with the maneuvering facility can be simulated and thus, various practical problems that may arise in operation can be detected and solved. The models obtained in Simulink are simulated in conditions very close to the real situations, thus providing a fairly good prediction of the behavior of the real system.

REFERENCES

[1] Levett B., Improved Safety of Rig Automation with Remote Monitoring and Diagnostics, SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, Calgary, Alberta, Canada, March 2004, Paper Number: SPE- 86600-MS;

[2] Soukup I.M., Boudreaux M.S., Ramirez R., Anderson J.R., Shim J., Improve Auto driller Performance with Direct Drillstring Measurements in the Drawworks Control Loop, SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, October 2017, Paper Number: SPE-187043-MS.

[3] Wylie R., Soukup I., Mata H., Culf S., Ho A., The Drilling Optimization Benefits of Direct Drillstring Surface Measurements – Case Studies from Field Operations, SPE/IADC Drilling Conference and Exhibition, London, UK, March 2015.

[4] https://rigsmart.com/system/anti-collision/

[5] https://www.mathworks.com/videos/drilling-systems-modeling-automation-part-2-introduction-to-simulink-and-simscape-1593690570899.html

[6] https://www.drillingmanual.com/drilling-rig-components-illustrated-glossary-pdf/

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