

# Using Simhydraulics in didactic applications

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## Abstract

*SimHydraulics is one of specialized modeling toolboxes, developed by The MathWorks, which models and simulates hydraulic transmissions. The product was released first in 2006, into two new versions of Matlab, Matlab R2006a and Matlab R2006b. This program is an excellent mean to improve the quality of didactic process and to short the time of knowledge transmission. The paper presents an application used in teaching process.*

**Key words:** Matlab, SimHydraulics, hydraulic systems, teaching means

## Introduction

SimHydraulics is one of specialized modeling toolboxes, developed by The MathWorks, which models and simulates the conversion of hydraulic power into driving torques and forces for mechanical motion [1]. It also provides a library of common hydraulic fluids and more. The product was released first in 2006, into new versions of Matlab, Matlab R2006a and Matlab R2006b. SimHydraulics can be used for a variety of automotive, aerospace, defense, and industrial equipment applications, such as modeling automatic transmissions, and actuating flight control surfaces and heavy equipment. It enables to describe multidomain systems containing connected hydraulic and mechanical components as physical networks, so we can model complex interactions in hydromechanical and hydroelectrical systems [2].

This program is an excellent mean to improve the quality of didactic process and to short the time of knowledge transmission [3]. In SimHydraulics we build a model of a system as we assemble a physical system. The symbols used in our model are based on the ISO 1219 fluid power standard. SimHydraulics employs a physical network approach to model building: components (blocks) corresponding to physical elements such as pumps, motors, and valves, are joined by lines corresponding to the physical connections that transmit power. This approach lets us describe the physical structure of a system rather than the underlying mathematics. From our model, which closely resembles a hydraulic schematic, SimHydraulics automatically constructs equations that characterize the behavior of the system. Following we shall show an example of using this program into an application, emphasizing teaching aspects.

## The Achievement of Hydraulic Model

The example treated into this paper consists into a typical hydraulic scheme (fig. 1): a fixed displacement pump (Pump1) driving by hydraulic power a hydraulic motor (Hydraulic Motor).

The hydraulic motor has an inertial charge, which express joint with working machine. Between pump and motor there is a directional valve (4 - Way Directional Valve); it has five joints: P - to pump; T – tank; A, B - hydraulic motor; S - electric command. SimHydraulics libraries provide more than 45 models of hydraulic and mechanical components, including models for pumps, cylinders, accumulators, and hydraulic flow lines, (fig. 2).

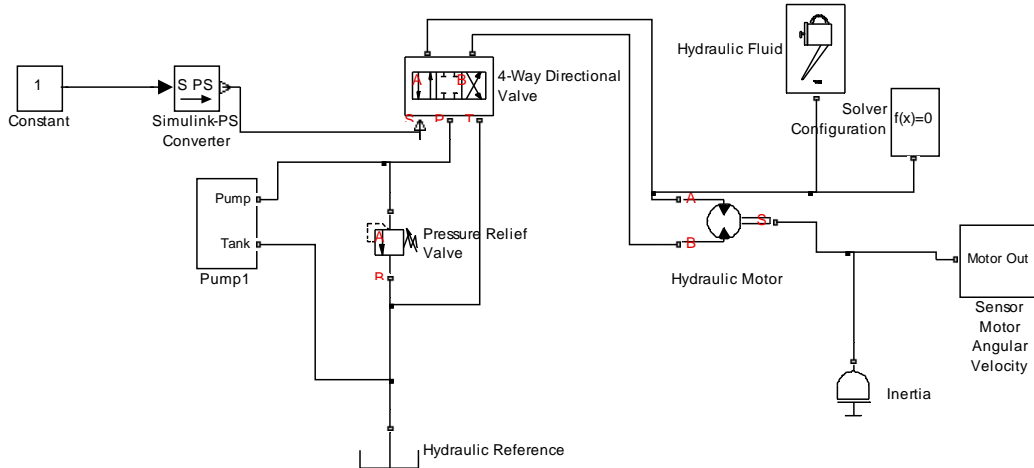


Fig.1. Hydraulic scheme realized in SimHydraulics.

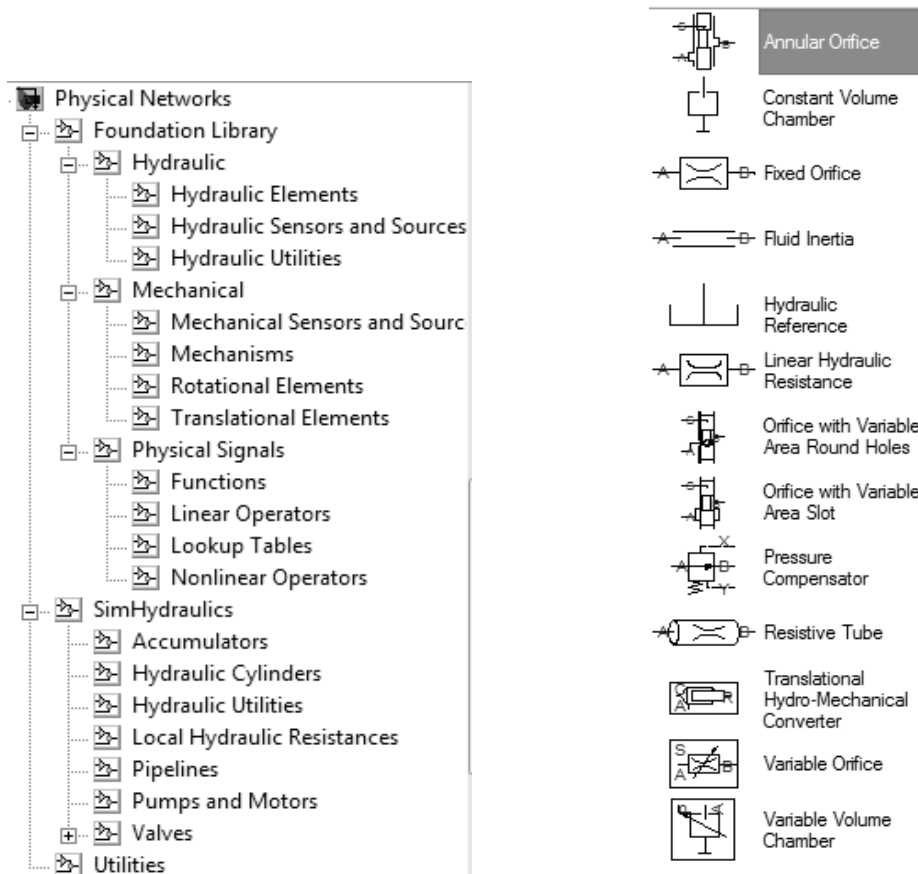


Fig.2. An image of Physical Networks Library that includes SimHydraulics instruments.

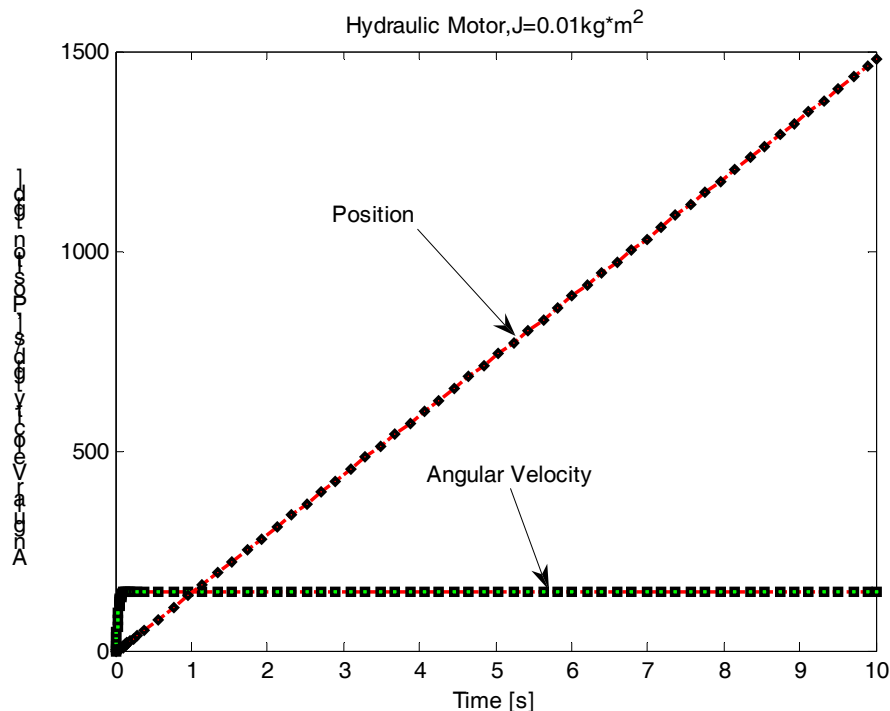
Electrical command is realized by a constant block (Simulink source) with an instrument (Simulink PS Converter) which makes a joint from Simulink to SimHydraulics. The valves library lets us model: directional valves, including 2-way, 3-way, 4-way, shuttle, check, and

pilot-operated check valves; flow control valves, including ball, needle, poppet, and pressure-compensated flow control valves; pressure control valves, including pressure-reducing and pressure-relief types. We use a Solver Configuration block that assures the starting of simulation in stable conditions. We employ a Hydraulic Fluid block to define fluid properties. SimHydraulics provides some commonly used hydraulic fluids; it employs efficient methods for defining density, viscosity, and bulk modulus—the fluid properties that affect system behavior. Properties for these fluids are automatically calculated when you input the temperature and amount of trapped air.

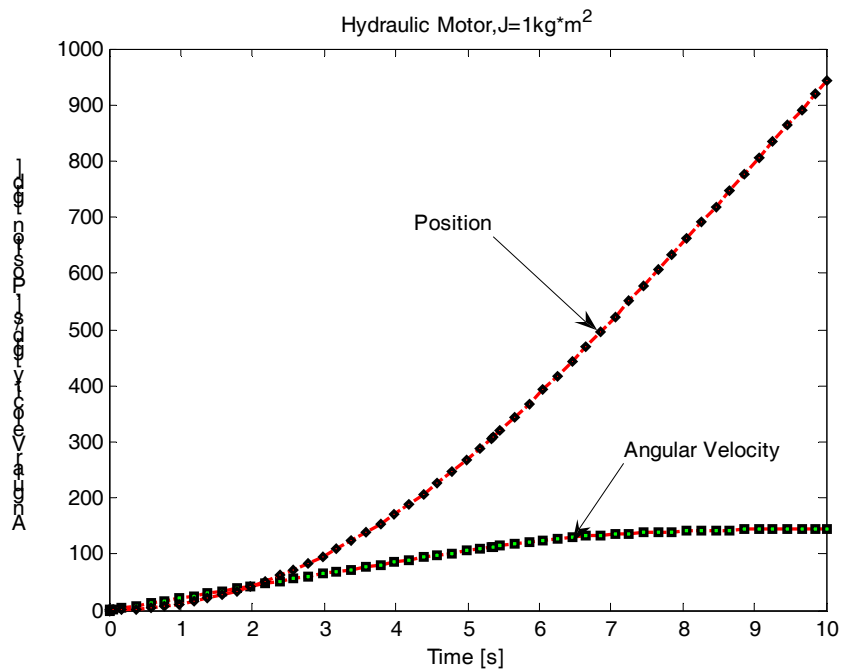
We use a sensor (Sensor Motor Angular Velocity) to determine the velocity and position of motor shaft. We simplified our model by neglecting the connections elements; but SimHydraulics includes two pipeline models: standard pipeline block models pipelines with circular and noncircular cross sections and accounts for frictional pressure loss and fluid compressibility; segmented pipeline block accounts for frictional pressure loss, fluid compressibility, and fluid inertia and enables us to model phenomena, such as water hammer. A library of local resistance blocks lets us include pressure loss associated with elbows, bends, and cross-sectional flow area changes. The structure of system element can be more complicate and in this situation we use subsystems as Pump1 and Sensor Motor Angular Velocity.

## Applications

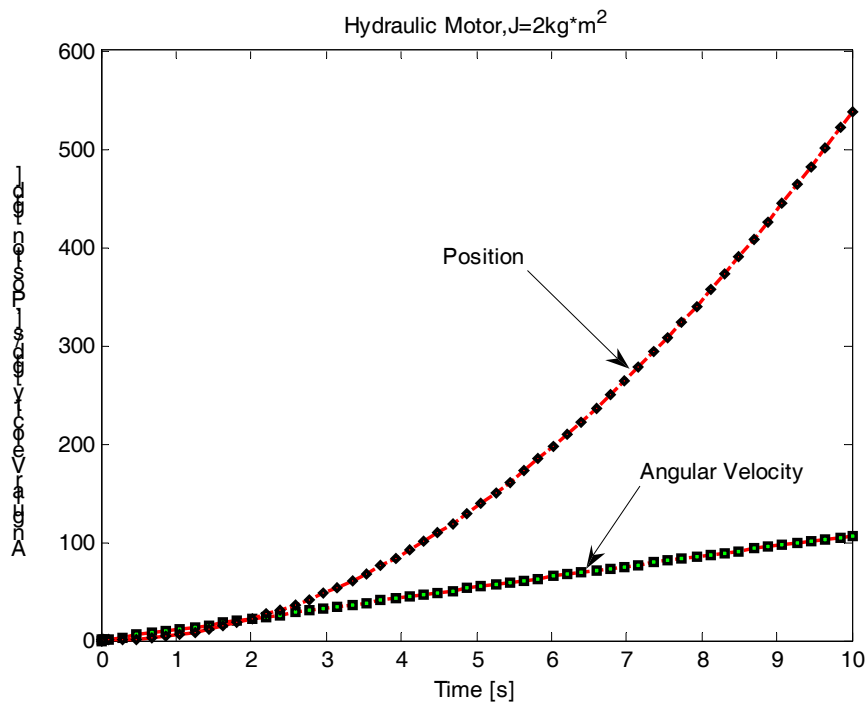
The first goal in teaching is to show the structure of hydraulic system, as we have seen in (fig. 1). The second goal is to show how the system works. We refer on (fig. 3-5), to see what is happening when we change the inertial load at motor shaft. By growing of inertial momentum the achievement of a stable angular velocity is more difficult. A stable angular velocity can not be reached at the end of simulation (after 10 seconds) (fig. 5). We shall make the scheme more realistic by introducing a signal builder, which permits to move the directional valve to each of its three positions. The construction of electric command signal and the new image of system there are showed in (fig. 6) and (fig.7) respectively.



**Fig.3.** The alteration of cinematic parameters of hydraulic motor: inertial momentum  $J=0,01 \text{ kg m}^2$ .



**Fig.4.** The alteration of cinematic parameters of hydraulic motor: inertial momentum  $J=1 \text{ kg m}^2$ .



**Fig.5.** The alteration of cinematic parameters of hydraulic motor: inertial momentum  $J=2 \text{ kg m}^2$ .

After this alteration we can see what happening with hydraulic motor. Three second we try to put up a load; after 4 second (2 in transient regime and 2 in neutral position) we reverse the movement direction. Without any mathematical calculus we see what was happed, (fig. 8). That proves the benefits in teaching process. We showed in fig.4 the angular velocity and position of motor shaft. This simulation was made for a liquid with a cinematic viscosity of 7,1 cSt. Changing the viscosity of liquid at 140 cSt, we observe another shape of starting process;

the angular velocity is more stable, but the shaft of the motor is moving slowly, (fig. 9). We can analyze any element of the system, following after it by virtual instruments.

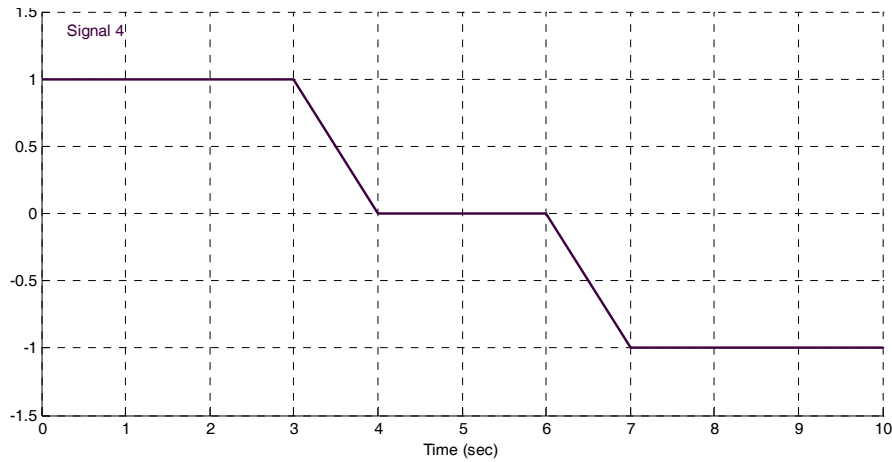


Fig. 6. Simulating of electric command, signal builder.

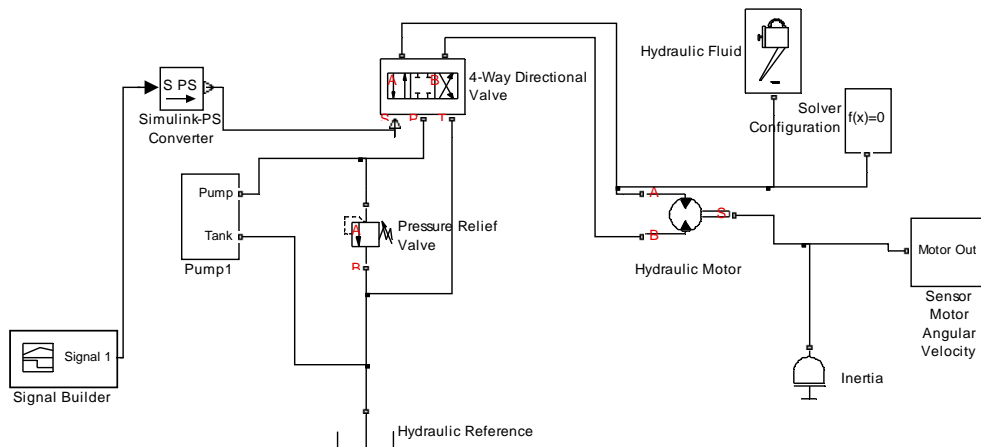


Fig. 7. Inserting electric command of directional valve.

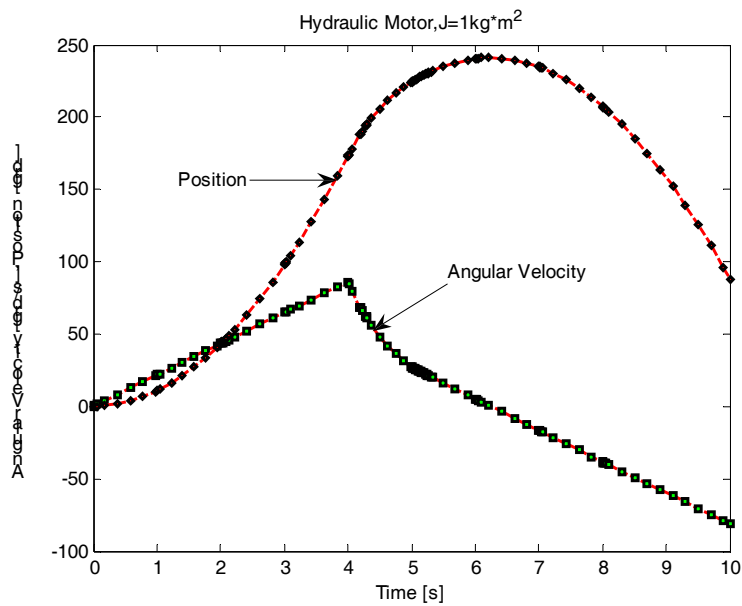


Fig. 8. Angular velocity and position function of valve command.

We can use the sensor blocks in SimHydraulics to measure values for any hydromechanical variable, such as pressure, flow, position, velocity and force, and then pass these signals into standard Simulink blocks. Source blocks enable Simulink signals to assign values to any hydromechanical variable. Sensor and source blocks let us develop an entire control algorithm in Simulink and connect it with a SimHydraulics network.

In (fig. 10) there is introduced an flow meter (Ideal Hydraulic Flow Rate Sensor) which shows the flow of liquid that goes to the tank during simulation; we respect command signal showed in (fig. 6). In (fig. 11) the motor has an reduced inertial momentum  $J=0,01 \text{ kg m}^2$ , so pressure is low and pressure relief valve is closed (excepting neutral position); all the flow is transmitted into hydraulic motor. At a higher inertial momentum  $J=1 \text{ kg m}^2$ , the pressure will grow, so the relief valve is opening and a part of liquid goes into tank through valve, (fig. 12). Ideally it is to use the program and to demonstrate in laboratory by measurements the same effects. We can more see, simulate our systems and understanding them better.

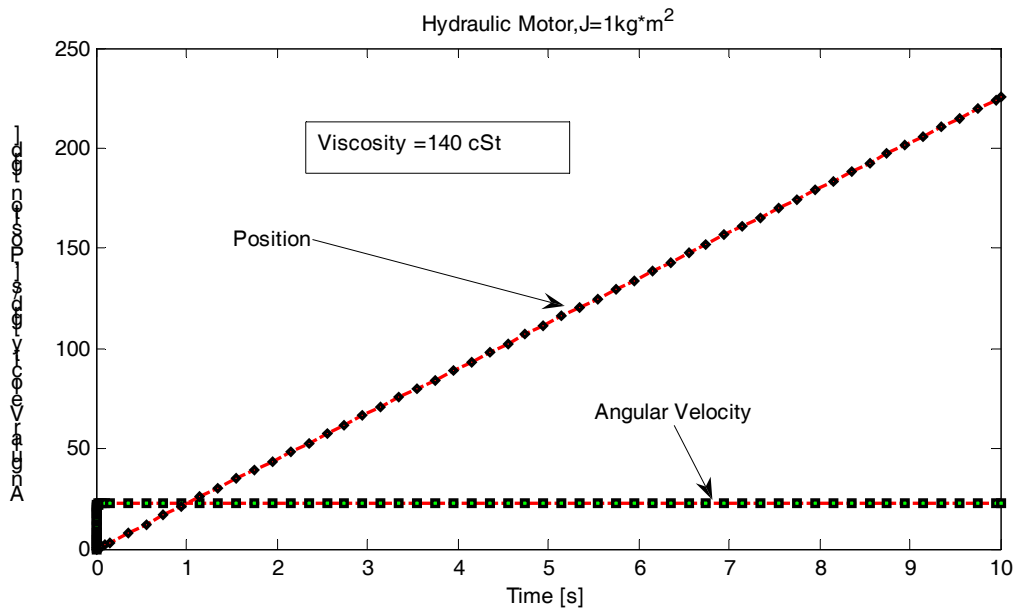


Fig.9. Effect of alteration of liquid viscosity.

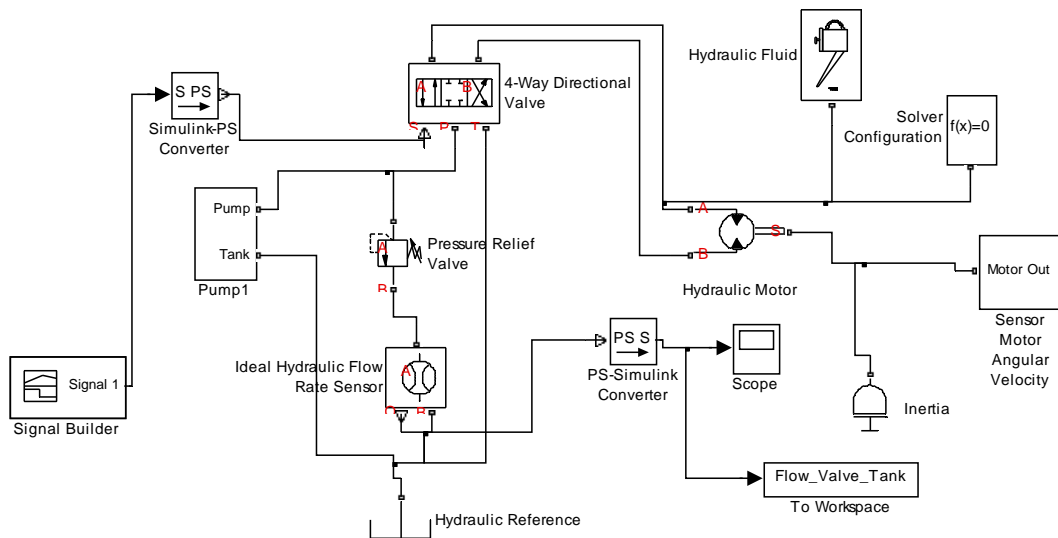
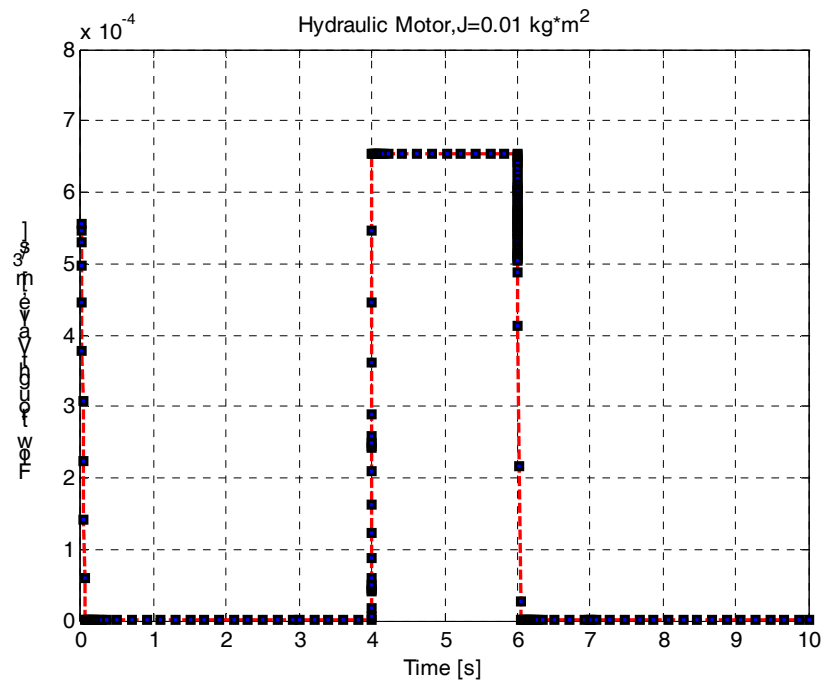
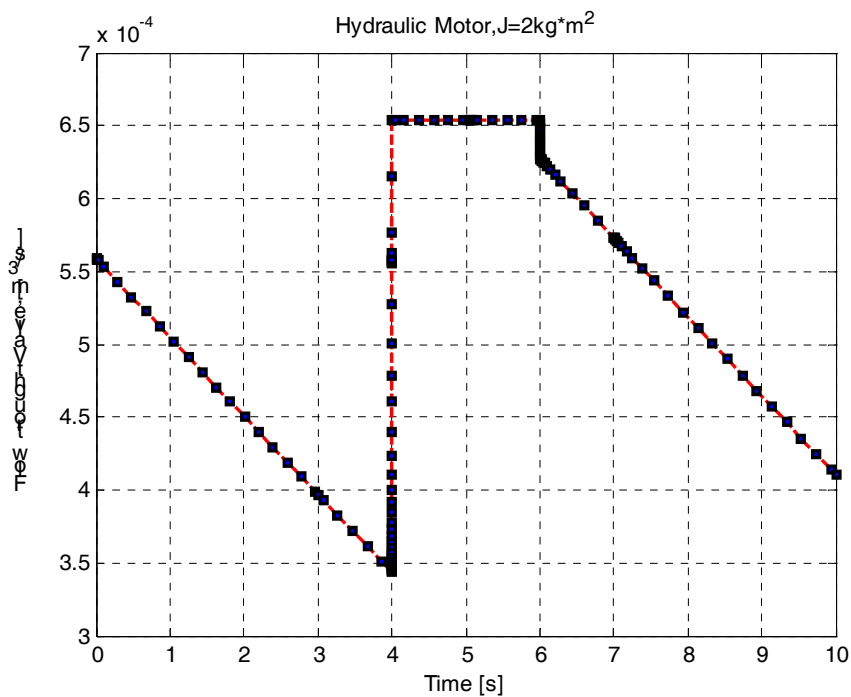


Fig.10. Introducing hydraulic sensor to show the action of relief pressure valve.



**Fig.11.** Action of relief pressure valve at low inertia.



**Fig.12.** Action of relief pressure valve at great inertia.

## Conclusions

The nature of hydraulic systems makes the simulation approach exceptionally well justified [4-7]. Considering drilling systems, production series are relatively small and unit price high. Due to this, physical prototypes are rarely available for machine designer and researchers.

There are also a lot of variables to be measured; a comprehensive study of fluid power system may required many flow and pressure measurements. Fields measurements are difficult to arrange and very costly. Changes in mechanical structure require a lot of manufacturing, and installations allow a very limited number of variations can be tested in practice. It results a necessity for dynamic simulation of these systems [8]. The elements of simulation described previously, are currently used in applications with undergraduates of Faculty of Mechanical and Electrical Engineering from our University. It results a better understanding of Hydraulic Machines and Hydraulic Transmissions. An advanced way of using program consists into a combination of the existing blocks in the SimHydraulics libraries to create custom hydraulic models. SimHydraulics provides expanded capabilities for modeling hydraulic systems. We can create our physical plant model using SimMechanics, SimDriveLine, and Stateflow and connect them with SimHydraulics, [1, 3]. As a result, we can test our entire system within the Simulink environment.

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## Utilizarea programului Simhydraulics în aplicații didactice

### Rezumat

*Simhydraulics este unul dintre programele specializate dezvoltate de compania Mathworks, care modelează și simulează transmisiile hidraulice. Produsul a fost lansat în anul 2006, în două variante ale programului Matlab, R2006a și R2006b. Acest program este un excelent mijloc de îmbunătățire a calității procesului didactic, scurtând timpul de transmitere a cunoștințelor. Lucrarea prezintă o aplicație utilizată în procesul de învățământ.*