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Research Simulation of the Transmission System of the Hydraulic Steering System with Automation Studio Software

Ngoc Tuyen Pham*

†Vietnam Maritime University, Haiphong city, Vietnam.

Abstract:

In the current trend of technology and automation development, the application of automation simulation software for control and transmission systems in learning and research at universities is essential. For the shipping industry, the role of simulation software applications in the research and production process is more practical and urgent. There is much commercial software that supports the simulation of hydraulic transmission systems on ships, but the most popular and easy-to-use software is Automation Studio. The article presents the results using Automation Studio software to simulate the drive system of the hydraulic steering system used on ships. The results of this study have successfully simulated the W-130 steering machine with a maximum torque of 13 T.m on the Automation Studio software. The built-in hydraulic control system model can be the basis to support students and researchers in understanding and more intuitive about hydraulic steering system.

Keywords: *Research simulation, transmission system, hydraulic steering, Automation Studio software.*

1. INTRODUCTION

Volumetric hydraulic transmission is increasingly widely used in industries, especially the Shipbuilding Industry. They have many advantages over other types of drives[1]. On ships, volumetric hydraulic drives are commonly used in steering systems, windlass winch systems, crane winches, first hatch systems and in some hydraulic control systems[2]. The primary propulsion system of the ship includes marine diesel engines[3] and auxiliary engines that provide sufficient and reliable power to the vessel. Therefore, the improvement of the primary driving system will help improve the serviceability of newly built ships. Measures for engines such as using advanced technology engines[4], utilizing engine exhaust heat sources[5], using alternative fuel sources[6] to reduce harmful emissions to the environment[7]. Besides, the application of simulation systems to modernize and automate engine room plays a significant role.

At present, the technical means of transportation, construction machines, works, ... are applying many different modes of transmission: motorized transmission, electric transmission, hydraulic transmission, etc. Through the application of such drive methods, it has been shown that hydraulic transmission has superior advantages over other modes of transmission, thus being applied more widely[8].

We can understand that hydraulic transmission is a mode of transmission in which moving mechanisms are driven by fluid pressure control[2]. Hydraulic transmission is often coupled with the concept of the hydraulic system and can be understood as a combination of energy transfer mechanisms by using the high-pressure liquid. The hydraulic system usually consists of 3 groups of equipment: hydraulic pump, hydraulic motor, and hydraulic support elements (valves, pipes, hydraulic oil, ...). Depending on the type of hydraulic machine used in the hydraulic system, the hydraulic drive is divided into hydraulic drive or volumetric hydraulic drive. Hydrodynamic hydraulic transmission is a hydraulic system which uses hydraulic hydrodynamic devices (hydraulic impeller and lead-in hydraulic motor). Volumetric hydraulic transmission is the hydraulic system in which the equipment is used as a hydraulic device (volumetric hydraulic pump and motor)[9].

In the framework of this research, the authors only focus on research and analysis of hydraulic steering system on ships. A simple hydraulic ship steering system consists of a hydraulic pump (a variable-sized pump, constant output) of hydraulic oil suction from a storage tank, granted to 2 hydraulic engines (hydraulic cylinders) to control the rotation angle of the steering wheel according to the captain's command (left or right).

The hydraulic-electric steering system using a pump with constant output and direction consists of two main steering gear assemblies and a standby steering gear assembly, supplying oil to the two cylinders to the revolving rudder[10]. The primary steering gear assemblies can work independently or in parallel. When the system works, the hydraulic pump is hybridized by the electric motor, which operates continuously[8]. However, there is no control signal from the cockpit, so the electromagnetic suction coil of the distribution valve has not been powered. Thanks to the impact of the two springs, it will keep the distribution valve in the middle position, hydraulic oil pumped out by hydraulic pump should not be supplied to the system but follow the oil return to the tank[11].

A hydraulic-electric steering wheel using a pump with output and direction changes, the steering angle control is essentially an impact on the structure to adjust the output and the height of the hydraulic pump, thereby changing the amount and direction of hydraulic oil to the actuator. The structure of the system consists of a pump capable of changing the output and the dimension that is crossed by the electric motor[12]. This hydraulic pump is usually a radial rotor-piston pump or vane pump. The two doors of the pump are connected to the two chambers of the force cylinder tape with the check valves. After one-way valves, two-way safety valves are arranged to protect the system from overvoltage caused by hydraulic impulses from the rudder[13].

The study simulation of the hydraulic drive system of onboard steering machine has been studied by many authors to evaluate the parameters affecting the reliable operation of the system in complex conditions[14]. In Vietnam, there have been some groups of authors studying simulating small-capacity hydraulic power transmission systems mounted on vehicles such as excavators, excavators, ... The use of simulation software will help improve and improve the quality of fuel injection[15], fuel quality, and reduce the ability to create deposits[16][17] in the combustion chamber of an engine. Therefore, using simulation software will help researchers soon find scholarly solutions to basic design[18]. At the same time, it is possible to improve the conditions of engine exploitation and meet IMO's increasingly stringent requirements for environmental pollution caused by ships[19]. In the world, research projects simulating hydraulic drive systems according to general principles, or ship hydraulic systems are also studied and simulated by some groups of scientists[20]. However, the results obtained are often programmed and packaged into independent software at a high price. There are many tools and software that can simulate hydraulic transmission systems such as WaterGEMS (of Bentley - USA), FluidSim (of Art Systems Software GmbH) and Automation Studio software[21].

Automation Studio is software for designing and simulating hydraulic, pneumatic, electric and electronic systems developed by Famic Technologies Inc., Canada. The latest version is now 6.2[22]. Automation Studio was chosen as the simulation software for this topic based on its outstanding features as follows:[23]

(1) Allow designers to share drawings with other people in the group, not only those who have this software but also for people who do not use Automation Studio. Allows to display design drawings in many different formats, including specialized drawing printers can also read this drawing;

(2) Embedding Component: this feature allows the creation of loose component structures, then merged under various strata. This feature is useful for displaying circuits by splitting clusters and groups and naming that group with proper names as symbols. The new version also includes Hydraulic, Pneumatic and Block Diagram drawing libraries;

(3) Electrotechnical Protection Builder: this feature allows to create many different configurations and allows simulation of protection traits. Attributes are integrated into the software, including the management of part number changes, extended features of the component;

(4) Sharing and interacting in experiments and exercises: The software allows interaction between members, hydraulic, pneumatic, and electric technologies. Including design drawings, motion animations, animate animation, simulated images, and features demonstrations;

(5) Update the manufacturer's element library: Automation Studio automatically updates, identifies new elements to update for the manufacturer and adjusts, and additional catalogs of existing components into ongoing projects. Users can select the elements they want to update into their library.

(6) Sizing Sheets Transfer to Enterprise Standards: Design, size, quantity, or general data sheets are delivered and reused between designs using the conversion function to Enterprise Standard.

(7) Block Diagram Module: Graphical feature allows to reconstruct components in the geometric form. Useful for creating a design test and loop control features[1].

(8) Analytical Tools: Virtual simulation tools and analysis in 2D, 3D, and automatic printing. Compare results from different simulations[24].

(9) New product simulation mode: New simulation mode for both newly designed models, components, connectors, pumps, electronic elements, or even pneumatic components[25].

The goal of the project is the Automation Studio software application to simulate the principles of construction and operation of hydraulic steering systems used on ships. Simulate the impact of working parameters on the operation of the system. Simulation of structure, the working principle of some commonly used hydraulic steering systems on ships allow studying the operation of the system as well as the impact of working parameters on the operation of the system.

2. METHODOLOGY AND EXPERIMENTAL SET-UP

2.1. Hydraulic circuit diagram of the steering machine

Figure 1 shows the principle diagram of the hydraulic drive system (also called the hydraulic circuit diagram) of the W-130 steering machine.

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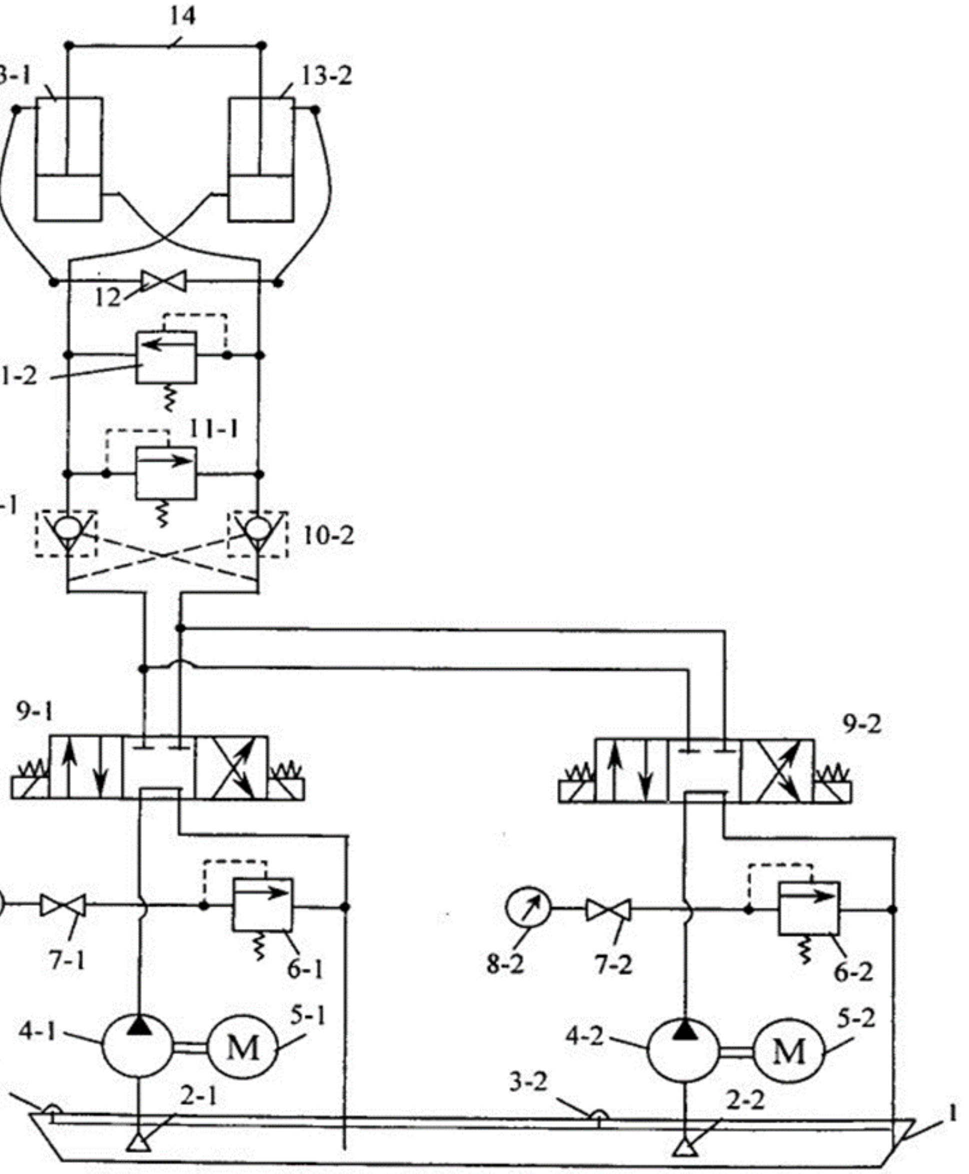

Figure 1. Hydraulic principle diagram of steering machine W-130 (Kitagawa, Kogyo, Japan)

1- oil tank; (2-1), (2-2) - suction filter; (3-1), (3-2) - level alarm and exhaust; (4-1), (4-2) - hydraulic pumps; (5-1), (5-2) - hydraulic drive motor; (6-1), (6-2) - safety valve; (7-1), (7-2) - hydraulic lock; (8-1), (8-2) - manometer; (9-1), (9-2) - distribution valve; (10-1), (10-2) - one-way valve with control; (11-1), (11-2) - overload protection valve; 12- hydraulic lock; (13-1), (13-2) - driving cylinder; 14-driver sector.

The W-130 steering wheel uses two two-way actuator-driven cylinders, the cylinder heads and the reciprocating rolling heads each have a self-aligning ball joint. The steering machine has a hydraulic power system for central electric steering and a hydraulic system for auxiliary drivers when the primary driver has trouble, also runs on electricity. Main pumps and sub-pumps are all gear-mounted hydraulic pumps. In a hydraulic system, type 3/4 control valve is used to control the load when the system is inactive. The steering machine can be controlled directly from the push button from the driver's cabin or the indirect-type indirect control with the command by turning the steering wheel to set a given steering angle. When the motor turns to the specified steering angle, the control error signal will cancel, the stop distribution valve stops working and stops. The steering machine allows connection to work with the compass, gyroscope, and GMS navigation system to perform the autopilot mode completely[2].

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Table 1. Technical specifications of the W130 steering machine

Content	Unit	Value
Drive torque	T.m	13
Working pressure	kG/cm^2	180
Safety valve opening pressure	kG/cm^2	225
Cylinder diameter	mm	125
The diameter of the piston rod	mm	70
Secto driving radius	mm	470
Stroke	mm	H/700 = 540
The maximum steering rotation angle		± 35°
Drive rotation time	s	t/70° = 23
Incident driving time	s	t/30° = 60
Electric motor capacity	kW	5,5
Motor speed	rpm	1430

The process of simulating hydraulic system by Automation Studio software:

Based on the features of Automation Studio as well as the work to be done in the design of a hydraulic drive system, we can determine the sequence of steps to be taken to simulate a system. Hydraulic transmission with software Automation Studio is as follows[9]:

Step 1. Understand the hydraulic circuit, essential hydraulic elements, working principle as well as how to control the elements of the hydraulic drive system to be simulated;

Step 2. Run the Automation Studio software with the full opening of the necessary libraries for the simulation, opening and naming of the new project, opening the hydraulic circuit diagram of the project (Diagram Editor);

Step 3. Drag and drop essential hydraulic elements to use from the respective libraries to the hydraulic circuit construction window. In this step we need to roughly estimate the appropriate position of the elements in the diagram and place them in the right position;

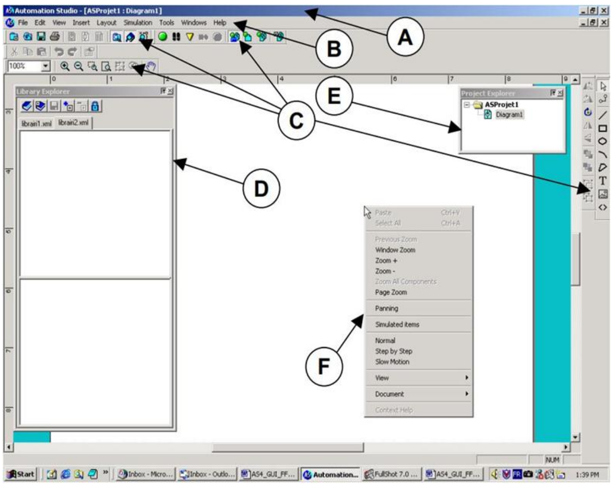

Figure 2. Components of the window working software Automation Studio 5.0.

A: Header block; B: menu block; C: Range of different tools; D: Search library; E: Refer to the topic; F: Turn on the menu - for example, do this by right-clicking on the background of the currently designed Diagram frame.

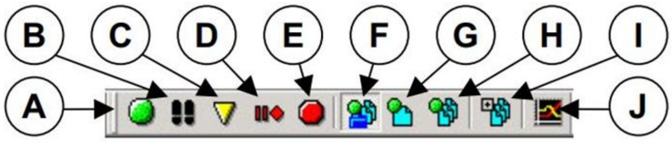

Figure 3. Command buttons of the Simulation Toolbar bar

Step 4. Use the appropriate button of the Insert Toolbar (see Figure 4) to connect the corresponding ports of the elements by the hydraulic circuit diagram to be simulated. These seams act as hydraulic oil pipes in practice;

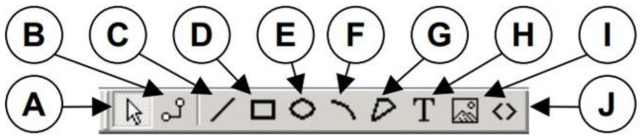

Figure 4. Command buttons of Insert Toolbar

A: Selection - allows selecting an element in the workspace; B: Links - creating technology links; C: Line - draw straight lines; D: Rectangle - draw a rectangle; E: Ellipse - draw ellipses; F:% Arc - drawing arcs; G: Polygon - drawing polygons; H: Text - insert text box; I: Image - insert image; J: Field - insert other fields.

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Step 5. Use the element properties dialog (Component Properties, Figure 5) to set the parameters for hydraulic components according to the system's working parameters;

Step 6. Install appropriate control methods for the controlled hydraulic components of the system;

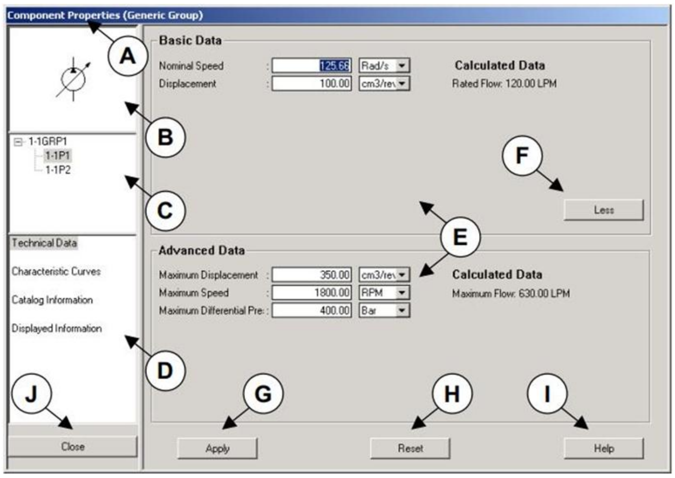

Figure 5. Element properties dialog of an individual element or group of elements

A - The title bar, this is the bar that contains the name of the dialog box next to each other by the element's name; B - The window displays, this window displays the symbol of the element. It will display the form in which the element is edited; C - The structure tree of the group, this window appears when there is a group of elements; D - Display window of a property value family. Just move the mouse and select it by left-clicking on the lines on the window; E - Feature section, this section shows the adjustment in the properties field of the selected feature branch; F - More / Poor. This button allows to use to display or turn off the Advanced Data area of the element; G - Apply. This button allows users to enforce modifications on properties; H - Reset. This button allows users to remove pre-correction of validity with the Apply button; I - Help; J - Close.

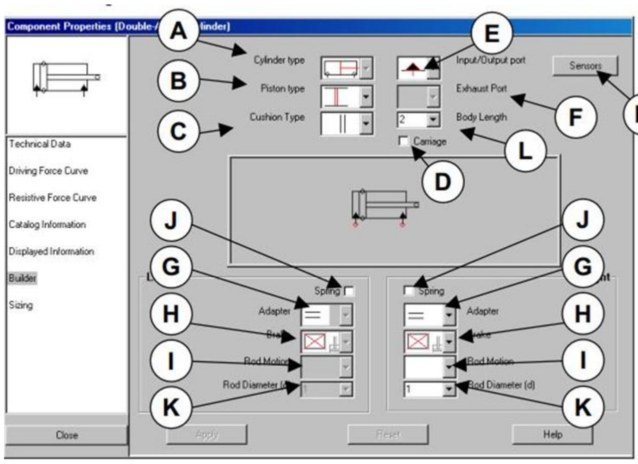

Figure 6. Elements of the cylinder in the properties dialog box

A - Cylinder form. B - piston form. C - Buffer form.
D - Navigation. E - Input / output port. F - the Discharge port.
G - Connector. H - Braking. I - Motion bridge. J - Springs.
K - Diameter of the bridge. L - Length of the cylinder body.
M - Sensors.

Step 7. Proceed to simulate to determine the property values of the elements which are not suitable to change or adjust. Especially the control parameters of the elements. Use the appropriate buttons of the Simulation Toolbar bar (see Figure 3) for the target to run the simulation;

Step 8. Simulate with changing the parameters to determine its impact on the system's work;

Step 9. Export the results as drawings, graphs of the hydraulic circuit diagram, or working characteristics of the system as well as each hydraulic element.

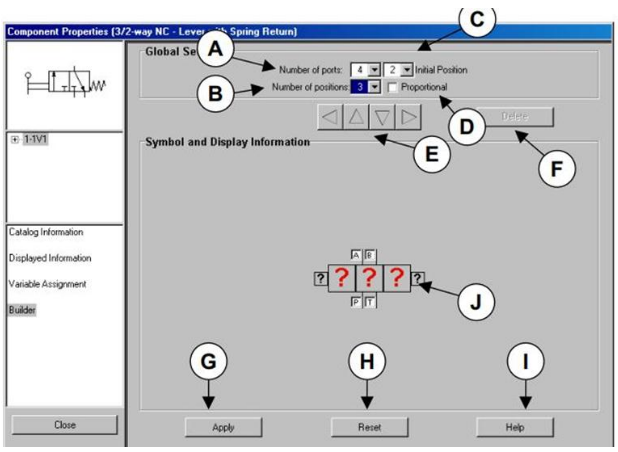

Figure 7. The directional valve creation dialog

A-Port number. B - Number of positions. D - Proportion (proportional). E - Arrow direction. F - Remove the selected amount of control. G - Accept. H - Remove.

3. RESULTS AND DISCUSSION

Based on the hydraulic circuit diagram in Figure 1, the primary hydraulic elements are determined, including:

- Hydraulic oil tank;
- Oil filter pots installed on suction pipes;
- The hydraulic pump is a type of pump with constant flow and direction;
- Safety valve;
- Hydraulic shutoff valve;
- Manometer;
- Distribution valve is a 3/4 valve with 3 working positions and 4 ports;
- Control valve with control;
- Anti-overload valve;
- Dual acting cylinder.

Run the Automation Studio software with the full opening of the necessary libraries for simulation, opening and naming the new project, opening the project's hydraulic circuit building window (Diagram Editor);

Select the above basic element Hydraulics library, drag, and drop essential hydraulic elements to use from the respective libraries to the hydraulic circuit construction window (Figure 8). In this step, we need to roughly estimate the appropriate position of the elements in the diagram and place them in the right position. To do so, we need to turn on the grid mode of the window by selecting View → Tick in the Grid square (Figure 9);

Use the appropriate button of the Insert Toolbar (see Figure 4) to connect the corresponding ports of the elements by the hydraulic circuit diagram to be simulated (see Figure 9). These seams act as hydraulic oil pipes in practice.

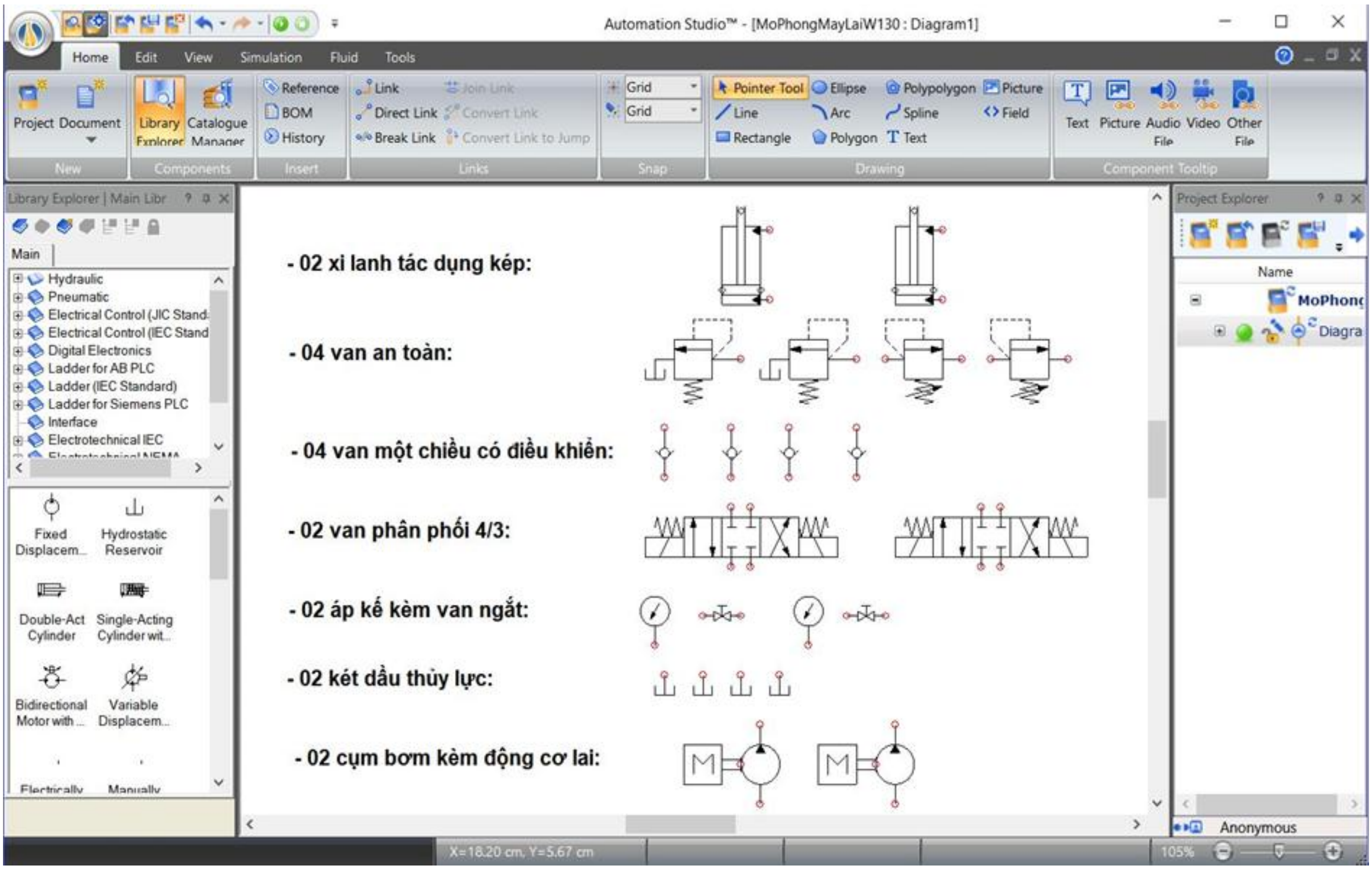

Figure 8. Selection of essential hydraulic elements.

After this step, we have completed the hydraulic circuit diagram of the W-130 driver in the Diagram Editor environment of Automation Studio.

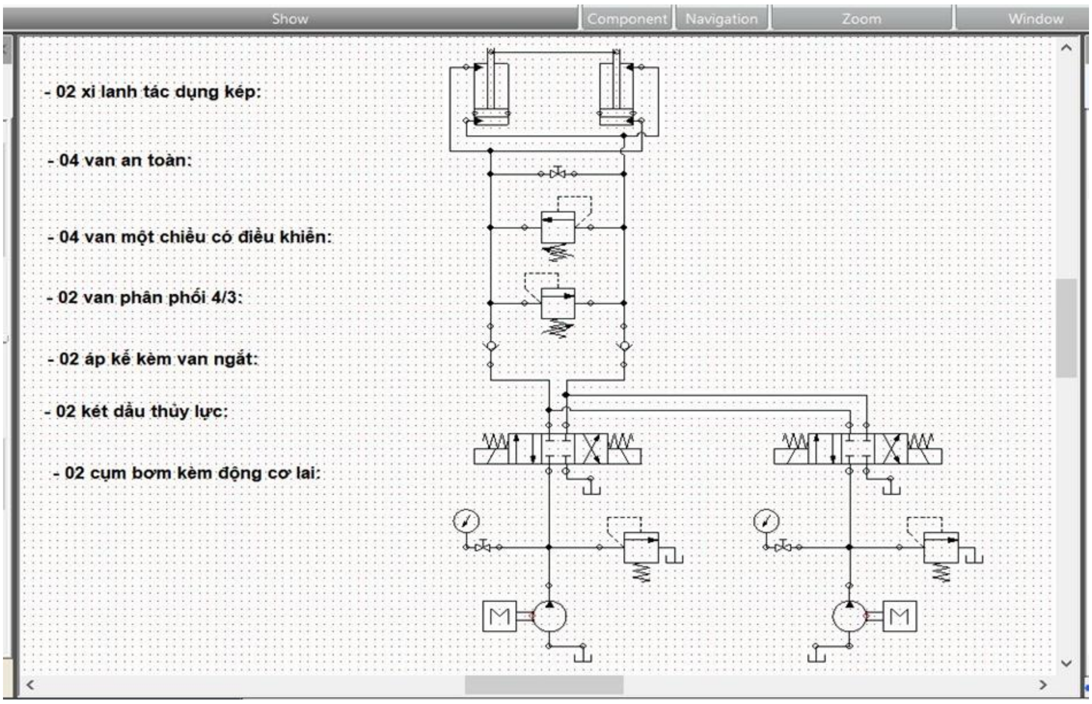

Figure 9. Connecting elements with oil pipes.

The next step is to simulate to determine the property values of the elements which are not suitable to change or adjust. Especially the control parameters of the elements use the appropriate buttons of the Simulation Toolbar bar (see Figure 3) for the target to run the simulation. We can choose one of three modes to run the following simulation: (1) Normal simulation (standard simulation); (2) Step by step simulation; (3) Slow-motion simulation (slow-motion simulation); (4) Stop the simulation.

The simulation results are shown in the figures from Figure 10 to Figure 16. In which Figure 10 corresponds to the working position of the distribution valve is the intermediate position. At this time, the cylinders must not supply the steering system oil in Standby mode.

Simulate with changing the working position of the main steering valve to the right steering mode of the main steering machine, as shown in Figure 11. The continued running simulation will see the oil is fed into the cylinders and the piston starts to move, as shown in Figure 12.

Next, we change the working position of the main steering valve to the left steering mode of the main steering wheel, which will see the oil supplied to the cylinders and the pistons start to reverse as shown in Figure 13 and Figure 14.

Figure 15 and Figure 16 illustrate the case where the auxiliary driver works with the right and left steering, respectively.

Also, we can view the working characteristics of some elements such as a cylinder, pump, distribution valve by option Component properties → Technical Specifications. From there, the results can be exported as drawings, graphs of the hydraulic circuit diagram, or working characteristics of the system as well as each hydraulic element.

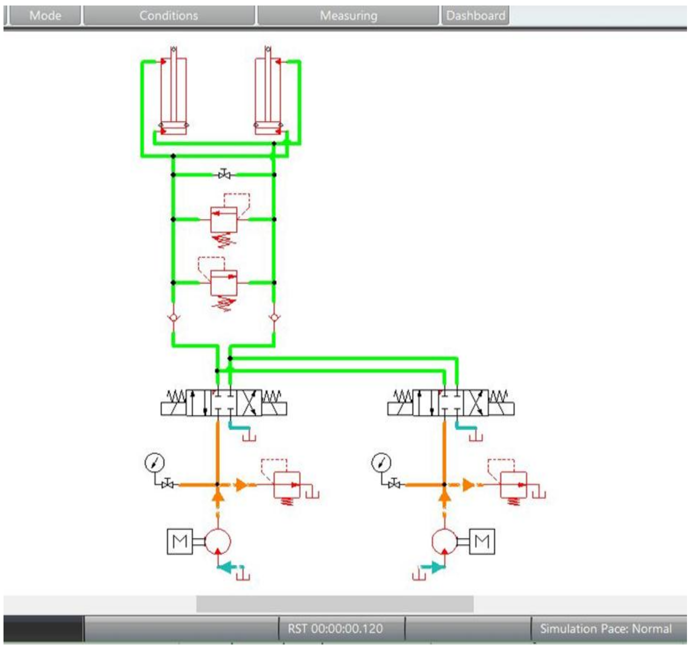

Figure 10. Simulation model of Standby mode of the hydraulic circuit

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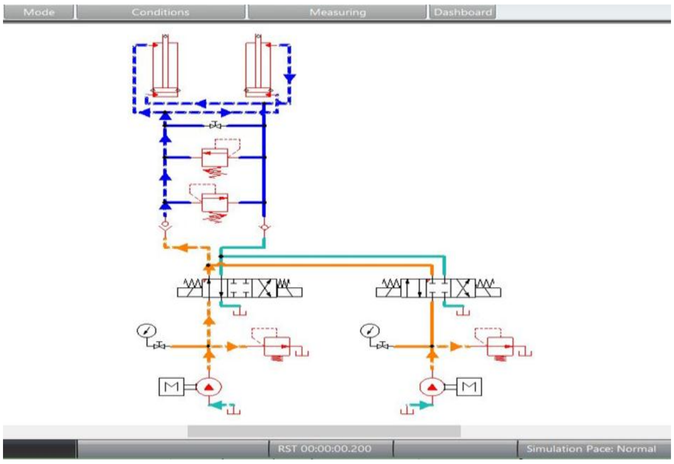

Figure 11. Change the working position of the distribution valve to the right steering mode of the main steering gear

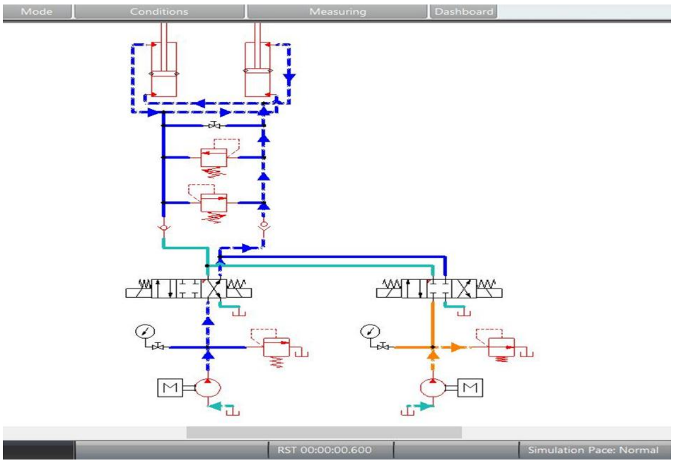

Figure 12. Simulate the right steering mode of the main steering gear

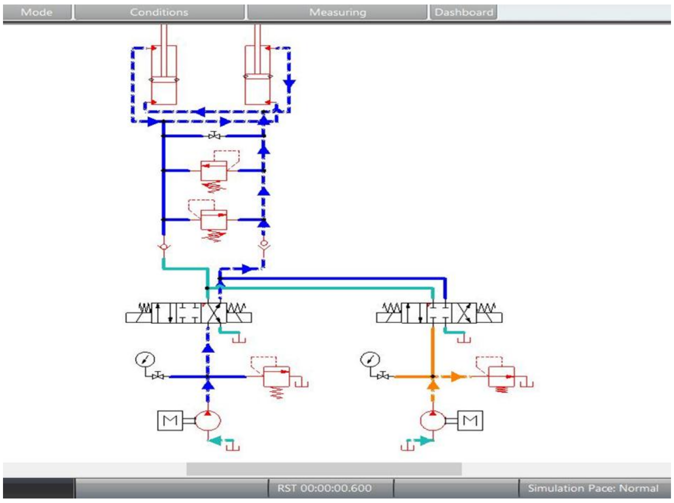

Figure 13. Move the delivery valve's working position to the right

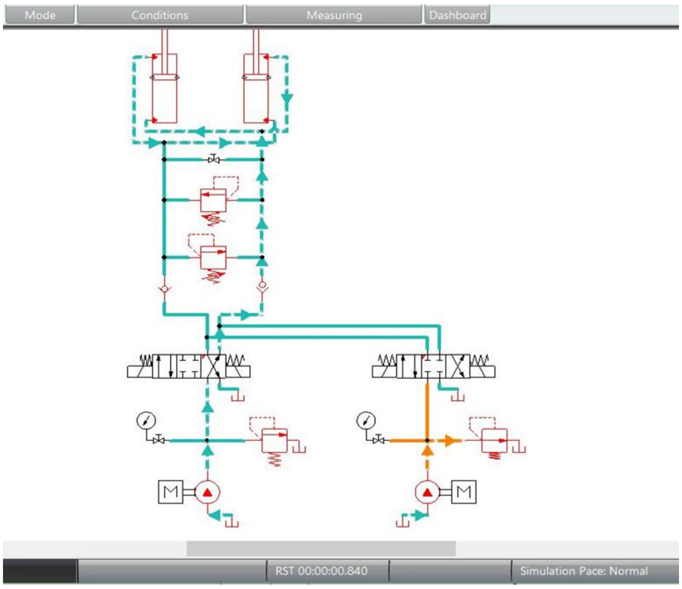

Figure 14. Simulate left steering mode of the main steering gear

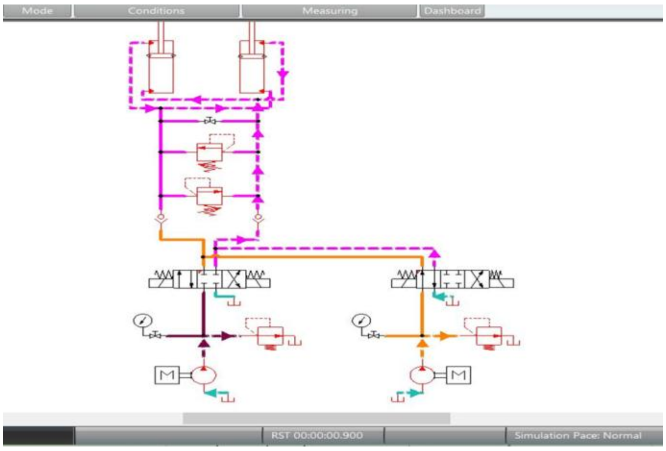

Figure 15. The steering wheel is working, working right

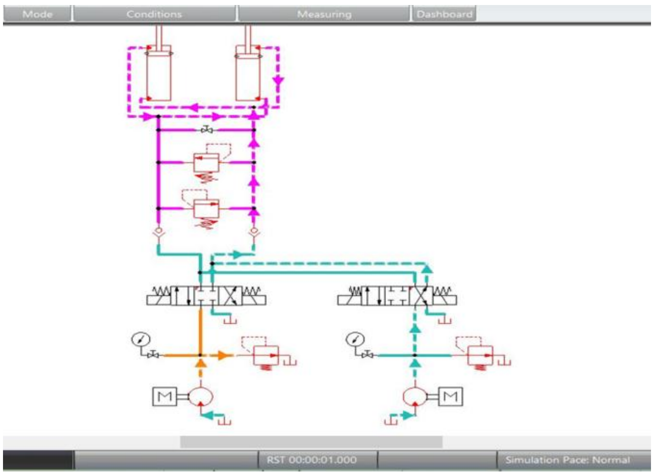

Figure 16. The backup steering wheel is working, working left

4. CONCLUSION

The paper presented the concept of hydraulic transmission in general and hydraulic volume drive system in particular; At the same time, analysis of the structure and working principle of hydraulic machines commonly used in hydraulic transmission systems on ships.

The results of this simulation study were an overview of the current hydraulic simulation software, learn how to use Automation Studio software. Since then build a sequence to simulate a volume hydraulic system in general and how to implement it on Automation Studio software.

The study has successfully simulated a hydraulic system, namely the hydraulic system of the W-130 steering machine with the maximum steering torque of 13 T.m on Automation Studio software. These simulations can be used as references in learning and teaching about navigation systems.

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