Study of Multi-system Co-Simulation of Automation Studio in the Equipment Hydraulics Training

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Abstract. Aiming at the new equipment's training problems such as fragmented teaching contents, shortage of practice training facilities and limitation of time, the virtual experiment is fully brought forward into the class in order to improve the engineering capabilities. The problem-oriented experiment items are designed based on multi-system co-simulation mechanism. In one common environment of Automation Studio software, the hydraulic, mechanical and electrical systems are modeled, parameter linked and co-simulated. Taking one type recovery vehicle hydraulics training as an example, the basic steps and usage of virtual experiment in the class are illustrated. Result shows that the multi-system co-simulation experiment promotes the trainees engineering capabilities effectively.

Keywords: hydraulic system, practice training, Automation Studio, co-simulation

1 Introduction

Nowadays, the new developed equipment is usually a highly integrated combination of mechanical, hydraulic and electrical systems. As the construction and working principle become more complicated, the training difficulty increases to a new level. Among the integrated systems mentioned above, hydraulics plays a power transmission, control and connective role. Good understanding hydraulics is critical for mastering the whole systems [1-3]. Temporarily, three main problems exist in the equipment hydraulics training. Firstly, the teaching content is constrained only in the hydraulics but the related knowledge of mechanical and electrical systems is seldom mentioned. Thus, the connection between different systems such as how they are interacted and related is not shown clearly. Secondly, new equipment develops fast, but the corresponding practice training facilities and time are insufficient and fall far behind the equipment developing speed. Thirdly, because of the complicated construction, the obscure working principle, the high risk, cost and energy consumption of real equipment training, the practice training effect is not satisfied.

Bringing the virtual experiment into the hydraulics training, modeling the high precision virtual system and carrying out the interactive virtual training is an effective way

Y. Kuang et al. (eds.), *Proceedings of the 2024 5th International Conference on Education, Knowledge and Information Management (ICEKIM 2024)*, Atlantis Highlights in Computer Sciences 22,
https://doi.org/10.2991/978-94-6463-502-7_11

in practice training of the equipment professional courses. By utilizing Automation Studio（AS）software, the virtual experiments items are fully developed and applicated in the class. Aiming at the training objectives of the new developed equipment. The virtual experiments items based on multi-system co-simulation are designed. The interactive training of construction and principle, fault injection and diagnosis, operation and usage of equipment hydraulics are fulfilled. Thus, the training dimensions in the class are expanded and the training quality increases.

2 Benefits of AS Software in Training

Automation Studio（AS）is an innovative system design, simulation and project documentation software for the design and support of automation and hydraulic systems [4-5]. It offers a unique combination of user-friendly system design features, advanced engineering capabilities, a dynamic and realistic simulation, comprehensive animation features in one common environment and plays a useful role in the design and training support in the hydraulics, pneumatics, electrics and PLC etc. AS allows the seamless integration of design engineering, prototyping, testing, troubleshooting, diagnostics, training and generating technical publications [6-7].

By utilizing AS software in the training, the principle and characteristics of the real hydraulic system can be simulated and verified. The trainees can understand the working process of the hydraulic system more clearly and deeply [8-9]. In one common environment, the hydraulics, electrics and mechanics can also be co-simulated. This good feature is mostly suitable for the training of the system-integrated equipment [10]. Table 1 lists the advantages of AS software in training compared with the traditional training.

Table 1. Advantages of AS software compared with the traditional training

Training items	Training with AS software	Traditional training
1. Construction and principle	Dynamic 2D/3D animation with trainees' interactive participation	Unidirectional theory teaching
2. Hydraulics Characteristics test	1.All the trainees participate 2.Powerful interactive virtual test enhances the deep thinking 3.Without limitation of time and space.	1.Only part of trainee participate 2.With the limitation of time and training facilities
3. Hydraulics trouble-shooting	1.Kinds of failure injection and animation 2. Powerful failure analysis with various sensed data 3.Without safety problem and cost	Theoretical demonstration

3 Virtual Experiment Design

3.1 Working Mechanism of Multi-system Co-simulation Experiment

Based on many years of teaching experience, the problem-oriented training strategy for virtual experiment is put forward. It emphasizes on improving the trainee's capabilities of engineering practice, problem analyzing and solving.

As mentioned above, good understanding of the hydraulics only by theoretical teaching is far from enough. The training items of multi-system co-simulation experiment are designed. The working mechanism of this kind of experiment is shown in Fig.1.

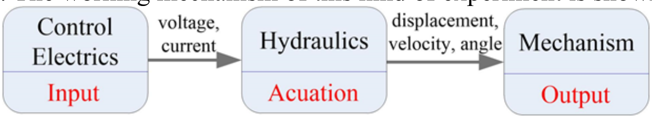

Fig. 1. Working mechanism of multi-system co-simulation experiment

3.2 Experiment items

According to the training objectives and content, different levels of virtual experiment items are designed which covers the basics and advanced, single component, basic circuits and complex equipment systems. Table 2 shows the advanced experiment items, basic procedures and time needed of the equipment hydraulics.

Table 2. Virtual experiment items

Items	Main steps	Hours
Propeller hydraulics of APC	1.System modeling and variables linking of the hydraulic system, control system and mechanical system. 2. Working process simulation and performance analysis. 3.Diagnosis the propeller motors' speed out of sync failure.	2h
Hydro-pneumatic suspension hydraulics of AAAV	1. Same as above. 2. Same as above. 3. Diagnosis the suspension cylinder not retracting failure.	2h
Control mechanism hydraulics of AAAV	1. Same as above. 2. Same as above. 3. Diagnosis the rear surfboard cylinder automatic extending failure.	3h
Operation hydraulics of recovery vehicle	1. Same as above. 2. Same as above. 3. Diagnosis the spade cylinder automatic retracting failure.	3h

3.3 Experiment implement step

The basic step of virtual experiment is shown in Fig.2.

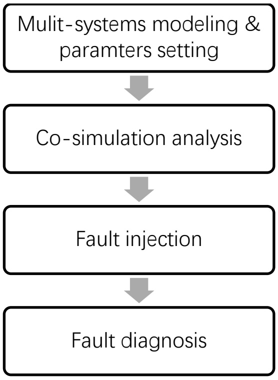

Fig. 2. Basic step

In this paper, one typical recovery vehicle's hydraulics training is taken as example to illustrate the implement process. Firstly, models of the hydraulics, mechanism and control electrics are established as shown in Fig.3. The links and values of different parameters of the multi-system are set and adjusted. Secondly, the co-simulation of control input, hydraulics working principle and 3D mechanical animation are fulfilled. Thirdly, according to the typical hydraulic failures, the failure mechanics is injected and the simulated failure diagnosis training is conducted.

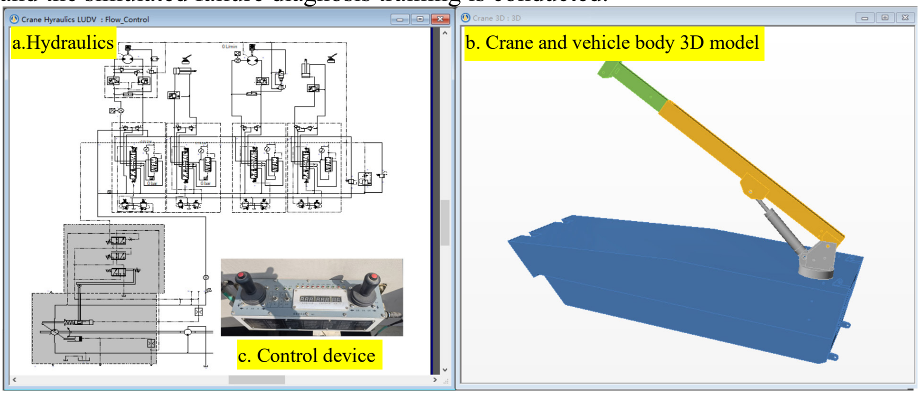

Fig. 3. Multi-system modeling in AS software

Multi-system Modeling

Under the teacher's guide, the trainee completes the establishment of the model of the hydraulics, mechanism and control devices. The parameter values are also set and adjusted.

(1) Hydraulics modeling

Modeling of the hydraulics is based on the real vehicle's system. The exact modeling can make the simulation results be more reliable. In this paper, the recovery vehicle's hydraulic system is a typical LUDV system. Except the power source, each circuit is combined by a proportional solenoid direction control valve, a cylinder and some other control valves. In the Automation Studio, the whole system which contains 4 circuits is formed as shown in the Fig.3-a. The initial parameter values of the pump, the solenoid valve and cylinders are set as shown in the Table 3.

Table 3. Initial value of hydraulic variables

Variable	Sym-	Unit	Value
Displacement of pump	q_p	ml•r^{-1}	100
Speed of pump	n	r•min^{-1}	1500
Rating flowrate of solenoid valve	Q	L•min^{-1}	120
Cracking pressure of relief valve	p_c	MPa	30
Piston/rod/stroke dimension of boom cyl-	–	mm	100/75/1200
Piston/rod/stroke dimension of telescopic	–	mm	80/55/1800
Displacement of swing motor	q_{m1}	ml•r^{-1}	160
Displacement of hoist motor	q_{m2}	ml•r^{-1}	120

(2) Mechanism and vehicle body modeling

The mechanism is driven by the hydraulic cylinders and performs the corresponding operation. So, the exact construction and assembling constraints are most important for modeling. In order to get an exact model, the 3D model is firstly established in SolidWorks software. Then this model is transmitted into the Automation Studio 3D working interface which is shown in the Fig.3-b.

(3) Control device modeling

By the graphic function of AS software, the control device is modeled to simulate the actual vehicles control panel as shown in the Fig.3-c. The parameter linkages between the control levers and solenoid valves are matched accordingly.

Multi-system Co-simulation

The multi-system co-simulation is conducted in one common environment. For simplified illustration, the co-simulation of the boom arm is taken as example.

(1) Working principle experiment of the boom

The extend and retract of the boom cylinder is fulfilled by the left control lever. The 3D simulation of the extending process is shown in the Fig.4(①~③). The working parameters such as pressure and input flowrate of the boom cylinder can be shown in display window as the Fig.5. Through this kind of the experiment, the trainees understand the total working process which includes the control input, hydraulics transmission and mechanical action.

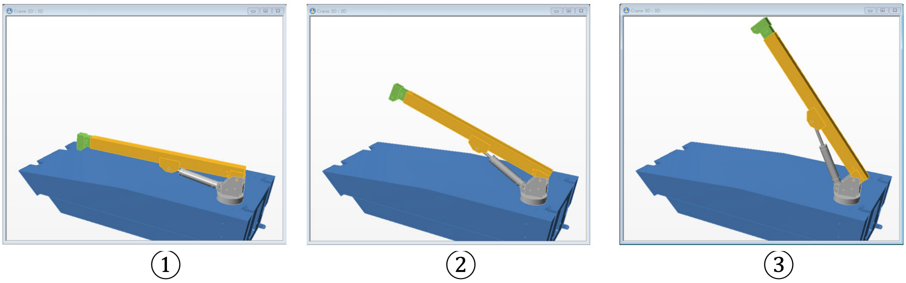

Fig. 4. Extending process of boom arm

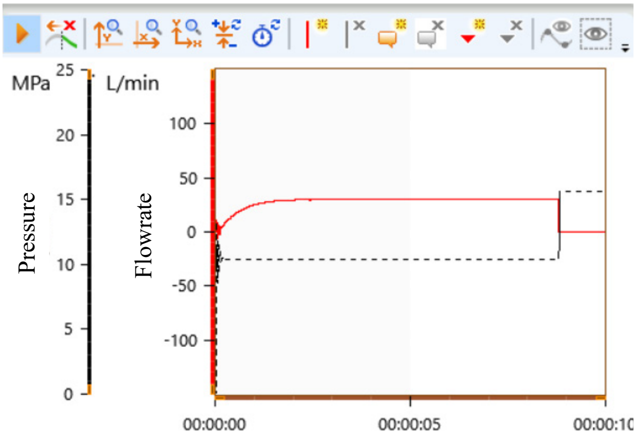

Fig. 5. Pressure and flowrate of the boom cylinder

(2) Experiment of the system characteristics

The recovery vehicle hydraulics is a typical LUDV system. LUDV means the flowrate of the circuit is independent on the load. This feature is most important for the trainees to understand. In order to verify this feature, the loads of different circuits are set by the pedals as shown in the Fig.3-a.

Just suppose the boom cylinder and telescopic cylinder now work simultaneously. When the load pressure of the telescopic cylinder changes, the input flowrates to the two cylinders do not change as shown in Fig.6. Through this kind of virtual experiments, the characteristics of hydraulic systems is illustrated clearly.

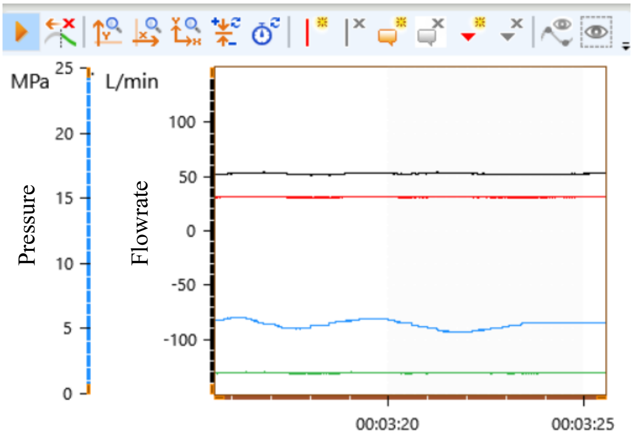

Fig. 6. Characteristics curves of LUDV system

(3) Typical failure simulation experiment

The boom arm automatic drop is one of the typical hydraulic failures. The main reason is that internal leakage of the boom cylinder occurs because of the damaged piston ring. In the AS software, through failure injection, failure display and failure analysis, the trainees can get a deeper understanding of the failure mechanism and improve the ability to solve the problem.

1) Failure injection

Failure injection can be completed through the failure set menu or parameters set menu in the AS software as shown in the Fig.7. Here the internal leakage is set as 3cm^3/s/bar.

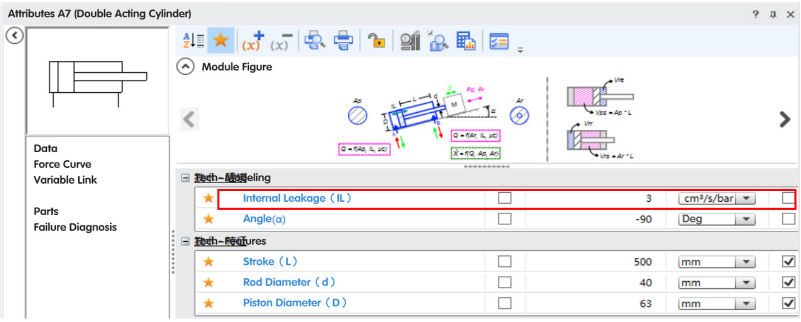

Fig. 7. The boom cylinder internal leakage set

2) Failure display

After start the simulation, the boom cylinder is pushed to retract by the external force and the boom arm drops down slowly. This process can be clearly displayed by 3D animation as shown in Fig.3-b. This kind of simulation makes the trainees observe and feel the hydraulics failure directly.

3) Failure diagnosis

By the powerful function of the dynamic animation and data analysis, the trainee can conduct a deeper failure analysis and get a promotion of engineering capability. Fig.8 shows the dynamic 2D animation of the hydraulic circuit after the internal leakage occurs.

In the figure, different colors in the circuit lines mean pressure differences and the spool position of the check valves shows its open or close state. In the analyzing process, the teacher should guide the trainee to pay more attention on the pressure and valves' state. In addition, some extra virtual sensors in the AS software such as pressure and flowrate could be used to find the failure reasons quickly. Fig.9 shows the leakage flowrate out of the extending chamber of the cylinder.

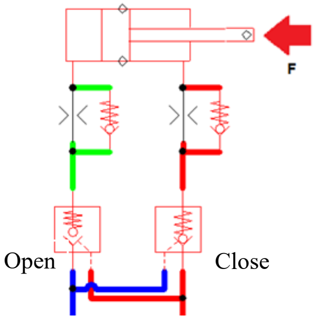

Fig. 8. 2D animation of the boom cylinder hydraulic circuit

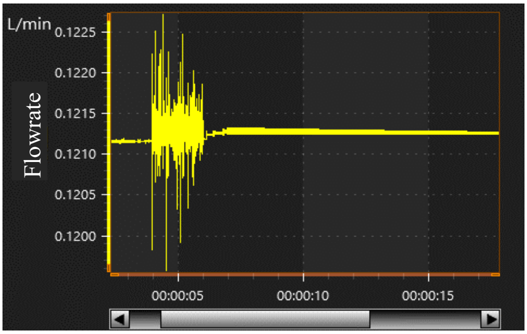

Fig. 9. The leakage flowrate out of the cylinder extending chamber

4 Conclusion

By utilizing the AS software, the virtual experiment items are designed in order to meet the demands of equipment hydraulics training. The different levels of training such as construction, working principle, failure diagnosis and operation are fulfilled. The virtual experiment makes each trainee have enough opportunity in training but not need to consider the hardware insufficiency of the traditional experiment. The engineering capability and eagerness of learning are promoted deeply. Furthermore, the virtual experiment based on AS software decreases the use of real equipment which avoid a lot of safety problems. Lastly, the powerful function of animation and data analysis makes the training more directly and interestingly.

References

1. CHEN Jin-qiang, ZHAO Li-ping, XIE Shao-feng, et al. Teaching design and practice of virtual simulation experiment for high-speed railway traction power supply system[J]. Research in Higher Education of Engineering, 2021, (01):67-71+107. https://kns.cnki.net/kcms2/article/abstract?v=WVDzDAe5jxaJ77iZO-crsjsDbJDDCVOrDVTHCbpg7H09LJP69fH9HUCYSKV8Js9U7GCowJsQui3bd4NvyJ19GPijII9wTcJQ-4-r7Tecs7cd064AM5P2LWvsPuDcGxc0r9CKgZ8CYYo=&uniplatform=NZKPT&flag=copy
2. KOU zi-ming, GUO Ning, WU Juan, et al. Design and application of virtual simulation teaching system for lifting equipment[J]. Education and teaching forum, 2019, (04):201-202.https://kns.cnki.net/kcms2/article/abstract?v=WVDzDAe5jxbPvVvSvn-NUlrMyCKcVjjtBv8Nvs4q2_nTZ-mSOzrQEGdGZNkKRAMbvp_fnTeY4pNjWJ6ahYP9hdlLzGsH2GacnYwYLayL-sZi2VoxoAggCCY6yfPWpcozLnRGCn1Mgut2w=&uniplatform=NZKPT&flag=copy
3. HE Jun, YANG Xing, ZHANG Jun. et al. Construction method of wet mix concrete spraying machine co-simulation model based on Automation Studio[J]. Machine Tool & Hydraulics, 2022, 50(13):168-173. DOI: 10. 3969 /j. issn. 1001-3881. 2022. 13. 030.
4. WANG Ya-nan. Modeling and Simulation of Tower Crane Based on Automation Studio [J]. Modern Manufacturing Technology and Equipment,2021,57(07):52-54. DOI:10.16107/j.cnki.mmte.2021.0538.
5. LIU Yi-fu, SUN Rui-xia. Characteristics Analysis of the Lifting Mechanism in Construction Vehicle Based on Automation Studio [J]. Machinery Design & Manufacture, 2021, (07):32-36. DOI:10.19356/j.cnki.1001-3997.2021.07.008.
6. GUO Lian-jin, WANG Guo-sheng. Research on the teaching mode of hydraulic and pneumatic based on FluidSIM software [J]. Laboratory Science, 2014, 17(01):4-7. https://kns.cnki.net/kcms2/article/abstract?v=WVDzDAe5jxZPEeMiq-nuq--4iD-miTTXEb3wZ5-g-1Ls-Y6-H_UARk5XkPCYHnC2eezUqRcjnltkB7vxwYvCmdgpo2Sht-PLAHuJCHYUfqvbXv-5DGvCtwgUzPx8wIII7l&uniplatform=NZKPT&flag=copy
7. LIU Xia, LI Xiao-Bin. Application of virtual simulation experiment in the engineering ability training. [J]. Journal of Higher Education, 2020, (05):115-117. DOI:10.19980/j.cn23-1593/g4.2020.05.036.
8. JIN Lei. Hydraulic and Pneumatic Virtual Simulation Platform Based on OPC Technology [J]. Hydraulics Pneumatics & Seals, 2022, 42(09):72-75. https://kns.cnki.net/kcms2/article/abstract?v=WVDzDAe5jxYIfGaovGv1uIt-napDLYVUjK3Ha8lTaAfuf5CFDHUZ73viR3pXDMZ-GZ5YVG5OJHnLRbqlYQk9zQwawPrGyQwjf6oX2qw3n3Mzb9NKVTa7aesMOMaCBudki63dgG67GBag=&uniplatform=NZKPT&flag=copy
9. TIAN Duo-lin, ZHANG Jia. Exploration on the Construction of Simulation Training Platform of Mechatronics in Higher Vocational Colleges [J]. Education Modernization, 2020, 7(41):28-30. DOI:10.16541/j.cnki.2095-8420.2020.41.008.

10. CHEN Yu, WANG Yi-gang, ZHANG Zhi-ming. Exploration on Experimental Teaching of "Fluid Mechanics and Hydraulic Transmission" in the Context of Emerging Engineering Education [J]. Education and teaching forum, 2023, (13):34-37. https://kns.cnki.net/kcms2/article/abstract?v=WVDzDAe5jxZbY-gVf00OP00XU60G_u9Fxth9dlufOiMv6syKJISbeaYVoLXhAFBpQoY4Qf0197e2D99VIc0RwmuyElcOILcwaM4c0-t9GdEpcHAi6HHpB-GPPuD5XOLXDIAE34D0DQU=&uniplatform=NZKPT&flag=copy