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CONCEPTION OF HYDRAULIC TANDEM CONTROL FOR ARTIFICIAL DUMPER CHAMBER

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Abstract: The subject of this article is to show conception of hydraulic tandem drive when two different linear fluid engines work together. This cooperation is necessary to provide accurate forces for one of the project scoping liquid's behaviour in fluid damper by artificial dumper chamber where damper's valve is flown by liquid which is moved by model of hydraulic drive. First experiments have been done on system with one linear hydraulic drive but one piston has appeared not to be strong enough to act on the system by proper power.

Keywords: Hydraulic, tandem, control.

1 INTRODUCTION

There is a Hydrodynamic Laboratory in the area of Technical University of Liberec. It is situated in college area in Liberec - Vesec, building I. Laboratory was built in 1997 supported by Ministry of Education and Science. It is equipped by 9 linear hydraulic engines with load frames enabling both static and dynamic loading on machine elements and systems by periodical and random signals in kinematical or power feedback with possibility to check voltage, power and deformation response.

One of the projects investigates behaviour of fluid damper by model of hydraulic drive which is filled by oil for dampers. Real linear hydraulic drive acts on model and it makes inner damper oil flow. This fluid flow is driven through damper parts to investigate the behaviour of the fluid in the valve part. Problem appears when higher fluid flow speeds are requested. Although first experiences have been done with one linear hydraulic drive, simple piston has appeared not to be strong enough to act on the system by proper power. This is the reason why second unit should help to provide requested motion and power. Both units to cooperate are in one axis with pistons one against the other and they have to act on the system between them. One of the aim is that solving of this problem should not be expensive – expensive solution is to buy a new stronger hydraulic unit.

2 GENERAL PROBLEM OF TANDEM DRIVE

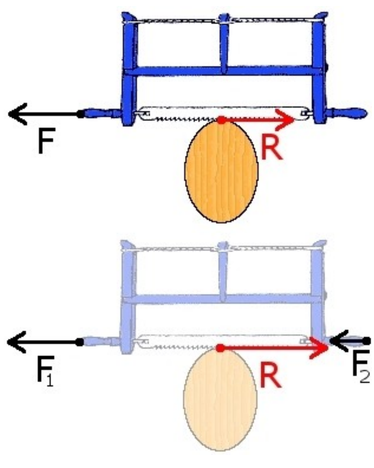

Fig. 1. Simplified problem of two-man hand saw

If there are two slightly different linear hydraulic units to cooperate, it is not possible to control them both in trajectory feedback as it is common when controlling one unit. Even if there were the same requested positions, regulation difference is never equal to zero and finally there may happen, that one piston acts against the other.

Tandem cooperation really isn't a new problem. The most similar problem to this is handwork which used to be a part of daily life in times when there were no machines and people needed to cut the trees or saw a timber wood for heating. Such a common activity as sawing by two-man saw should be the base example for tandem drive, when there are two linear hydraulic engines one against the other with pistons in one axis acting on the rigid system between them same as two men (lumber-jacks or joiners) one against the other with their elbows in one axis as they are holding and acting on two-man hand frame saw.

Nor two joiners work both in trajectory feedback. Usually one of the men is leader and second one acts on the saw in the same direction to help to leader.

Simplified problem of two-man hand saw is shown on figure 1. Schemes are very simplified, no moments and radial forces are taken into account in these schemes. Even scope on the problem is very simplified and suits more to the idea of hydraulic tandem drive. Rigid frame enables to act on the saw in both directions as well as rigid system between pistons of hydraulic drives enables force transmission. Reaction of the log (fluid damper chamber) is equal to the summation of both forces.

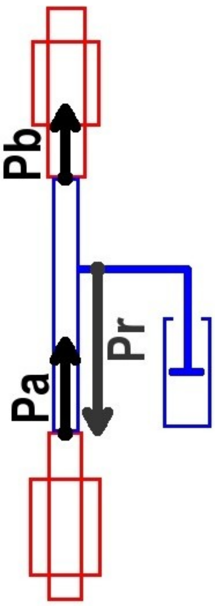

Fig. 2. Simplified scheme of hydraulic tandem

There is simplified problem of hydraulic tandem drive (figure 2), with rigid mechanical feedback. (Hydraulic units are red, system to be moved is blue.) In this case where arms becomes pistons and saw becomes measuring chamber, forces becomes powers. Rigid mechanical feedback means that there is rigid system between both pistons of linear hydraulic drives and this system enables forces transmission. When one of the drive is controlled to observe motion trajectory and second one is observing only the direction, trying to help him, the rigid system between them has function of feed-back. If this feedback is rigid enough it provides accuracy of both units. That is the reason to call it rigid feed-back. This feedback can work well only when passive fluid flows provides flexibility of second hydraulic unit.

First of all, there has to be written about involvement of the system, than there is written more about rigid feedback in next chapters.

3 INVOLVEMENT OF TANDEM CONTROL

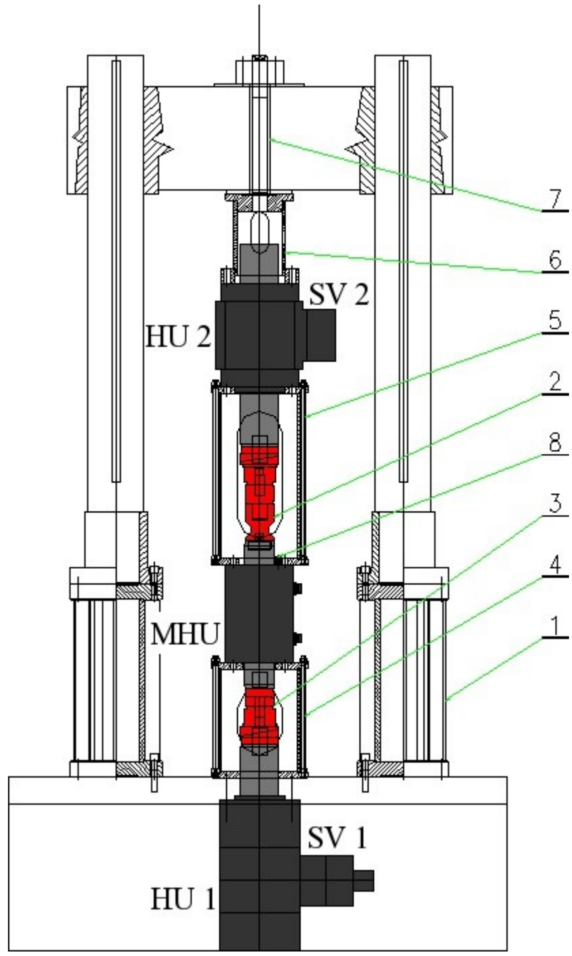

Fig. 3. Scheme of tandem drive with model of linear hydraulic unit between two linear hydraulic unit

Figure 3 shows scheme of tandem drive with Hydraulic units and model are grey coloured, joints are red. By numbers are signed 1 load frame, 2 and 3 joint parts, 4 and 5 delimitation cages, 6 and 7 joint of the upper hydraulic unit to upper part of the load frame, 8 model of linear hydraulic unit which enables joint of damper chamber. By letters are signed HU 1 and HU 2 are hydraulic units, SV 1 and SV 2 are servo-valves and MHU is model of linear hydraulic unit. On model of hydraulic unit there are visible pipe outputs where dumper chamber has to be joined. (Photography of this system including damper chamber is on figure 6).

On figure 4 there is a basic scheme of tandem control of two linear hydraulic units. This scheme does not involve the mechanical feedback. Both units to cooperate are supposed to travel the same trajectory even if they work separately. First unit is controlled with trajectory feedback. First unit's servo-valve's actuating signal becomes (after correction) steering signal of second unit's servo-valve. Slide-valve position of second unit's servo-valve is directly proportional to first (control unit) unit's servo-valve's slide-valve position.

It is necessary to find dependences between signals to make correction. This dependence is in this scheme signed by question mark although there had already been found relation between both servo valves. This dependence is linearized so it can be easily applied by setting of PID controller in second unit's RED when controlled by third sensor's feedback. Basic control scheme of tandem drive expects that position of second unit's valve is directly proportional to first unit's valve position. That is why only proportional part of the controller is important. Although this dependence is one of clues in tandem control it is obvious that constant P has to be modified depending on actuate system behaviour. This is the reason why equation does not have to be verified in measurement error. (To specify the dependence by concrete equation is not the aim of this paper.)

If the control system is involved by the scheme on figure 4, where second linear unit is not controlled in trajectory, the rigid mechanism between both pistons behaves as rigid mechanical feedback.

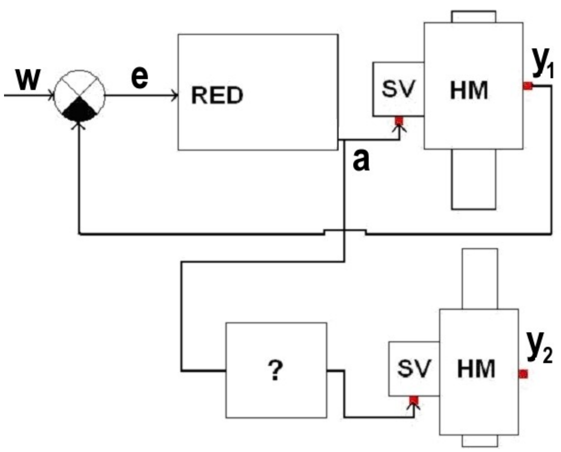

Fig. 4. Basic control scheme

First of all the system has to be established to work with no mechanical feedback – it means it has to work when pistons are separate. If the proper control of second unit according to the first unit is ensured on proper level (proper level means that the move direction is always kept and the piston positions are different only in the rate of millimetres), then there appears possibility to add mechanical feedback.

4 THREE TYPES OF MECHANICAL FEEDBACK

System of two linear fluid units is first of all a mechanical system. To add the mechanical feedback is enabled by seepages and by elasticity of the fluid medium (hydraulic oil). This feedback is ensured by mechanical connection of both hydraulic units' pistons. In the process of adding mechanical feedback to the system of tandem control there appears three kinds of mechanical feedback.

First of them is useful for basic tuning of the system. It is pleased to use relative elastic, flexible feedback with limited rigidity. This feedback may not ensure accurate copying of the trajectory but in the case that one of the engines does not behave as expected, this type of feedback allows quite big dilatations without being totally destroyed. In case of bigger dilatation is this feedback ruptured or crouched which prevent eventually destruction of the hydraulic engine's piston or other test material.

In further stadium, when the system is tuned enough by flexible feedback with limited rigidity, it is possible to step on to replace flexible component (rod) with rigid one with tensiometers. This second type of mechanical feedback behaves in many views same as the real system, but if it is destroyed it is not so expensive as if the final system (model for dumper chamber) is destroyed.

Third type of the mechanical feedback is the real system for which the work is done. There is selected the only possible part which can be equipped by sensitive semiconductor tension meters. (number 2 on figure 3 and figure 5) Signal calibration of the strain-gauge bridge is realized on shredder as well as in previous case. Surprisingly tension meter's gain which is obtained based on this calibration is in order the same as gain for tension meters on second type of mechanical feedback.

Fig. 5. Set of joints with tension-metric part

Even both engine's piston should be in one axis it is not always possible to make this relation precise enough. This is the reason why third level mechanical feedback is connected with pistons by set of joints. (numbers 2 and 3 on figure 3 and figure 5) This joints can be source of problems. When joints are too firm they do not work as they should. On the other hand if these joints are loose it can be source of vibration. Next chapter describes the system which can be called third level mechanical feedback.

5 RIGID FEEDBACK – DUMPER CHAMBER

Problem of scoping fluid's behaviour inside of an fluid damper is that damper's travel is relatively small, especially when there are high speeds to scope. The whole travel is then traveled within short time period. This is the reason why another method is used to scope fluid flow through throttling valve in fluid damper. Fluid and valve are contra positioned – it means, valve stays fixed and fluid is flown through it.

Needed fluid flow is provided by model of hydraulic drive which is filled by oil for dampers. As real linear hydraulic drive acts on model it makes inner damper oil flow. This fluid flow is driven through damper parts to investigate the behaviour of the fluid in the valve part.

Fig. 6. Final system: load frame with two linear hydraulic units, delimitation cages, model of hydraulic unit and damper chamber

Mentioned model of the hydraulic unit (it's piston) is in the same time rigid feedback for the system of tandem control of two linear hydraulic engines.

There is a picture of the whole system on the figure 6. Both controlled hydraulic units are fixed in the load frame (the first one is hidden in the work bench). Body of the model of hydraulic unit is fixed by delimitation cages. It's piston is connected to working unit's pistons by set of joints. In front of the picture there is dumper chamber connected by pipes to model of hydraulic unit.

6 CONTROL SYSTEM

There is no special hardware as control system for tandem control of two linear hydraulic units. For controlling the system is used the same system, which is used for controlling both units separately – each unit has it's own system. Control system is called RED and is made by INOVA. This system only has to be modified for use in tandem control.

There appeared to be a problem in setting P property of PID controller. Value of regulator's proportional component can be set by control program (SAF from INOVA) in exactness of third decimal position. Experiments with force feedback investigated, that real gain is not according with current value in program. This is the reason why system RED had to be tuned. After tuning there is a possibility to change this gain by added potentiometer in series connection with operational amplifier.

Next tune to do is possibility to shift servo valve's signal. It is simply not possible to balance servo valve in way that zero steering signal means zero fluid flow in the valve. Control system's program enables offset of this signal in value, which is not enough for our needs. Nor potentiometer in control system is able to do this so there is added resistor in series with this potentiometer to increase it's influence.

Some changes must have been done in fluid distribution system in order to avoid problems when starting fluid pressure. There is added valve which closes the fluid flow for second unit. If there is leak value of fluid in second unit it is possible to shift its position by first unit's power.

Software part of the control system is made by programming environment LabView.

7 CONCLUSION

System has been put together, model of hydraulic unit has been filled by dumper oil, non fitting pipes have been fitted. In these times crew is tought to be able to use the system for their research on dumpers.

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