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Diagnostic and Correction of the Spreader´s Inclination Hydraulic Circuit of the Transtainer Crane

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Abstract: *This paper exposes the diagnosis and correction suggestion to the hydraulic circuit of inclination of the spreader of a crane transtainer, type Rail Mounted Gantry of a containers terminal that frequently was out of service. The questions: why happen and how to solve them. We applied the deductive-inductive method and inferred that the mishaps were caused by dynamic loads as a consequence of the free fall of the container broken by the rope. We carried out a mathematical modeling the phenomenon; we obtained models with a combination of mechanical variables and the behavior of the fluid in the pipes. We have carried out an algorithm and it was programmed in MATLAB, and through the result of the simulation we obtain the parameters to make the new components of the modification proposed. It consists of adding relief valve type cartridge of short time response and an accumulator to dampen the picks.*

Keywords: *Spreader, antisnag, mathematical modeling, transtainer crane, hydraulic oil.*

1. Introduction

The main questions in this article: Why happen? and How to solve the mishaps? We expose diagnosis and correction proposal to the hydraulic circuit of inclination of the spreader of a crane transtainer, type Rail Mounted Gantry of a containers terminal due to frequent and accidental mishaps caused by picks of pressure of very high values (load dynamic), causing efforts bigger than acceptable in the materials of the screws and the body of the valves, destroying them, figure 1.

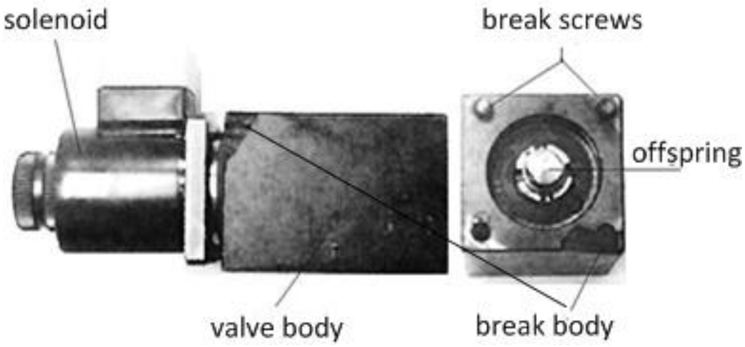

Fig. 1. Valve out of service

The assembling of figure 2: cylinders of the mechanism of deviation of the spreader, elevation drums, the rope and the pulleys that support to the spreader, in charge of fixing the contender when introducing and to rotate the spinning tops in the holes of the corners, co axial is required between the axes of spinning tops and holes, say otherwise, it is necessary parallelism between spreader and container.

When there is not parallelism, for example by irregularities on the floor, the mechanism of inclination of the sprider has the function of solving this inconvenience. It is a hydraulic system with eight cylinders whose stems notice the cables, when extending or to retract the stem it varies their longitude, to consequence, the spreader rotates with regard to the Cartesian axes (trim, list, skew) to reach the position. In figure 3 a segment of the hydraulic circuit is shown.

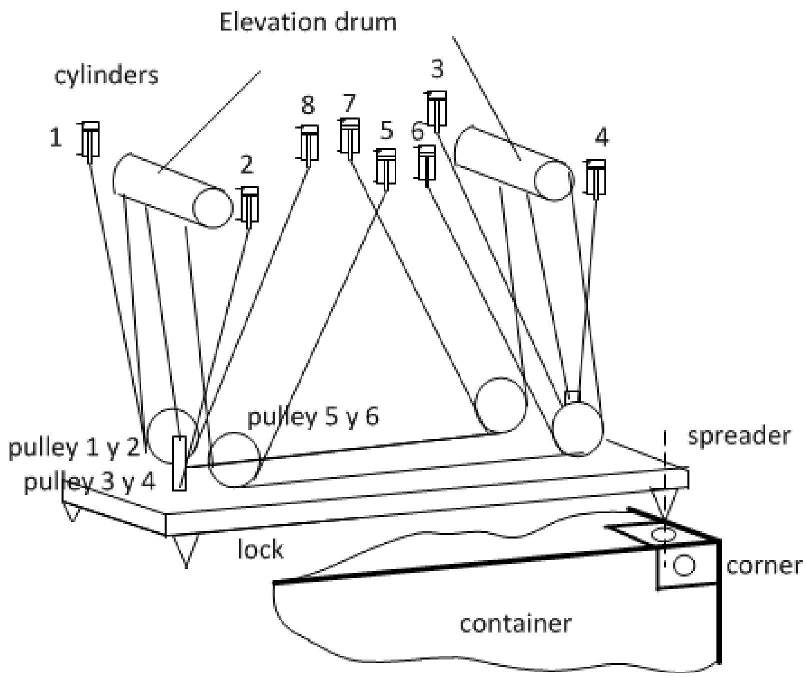

Fig. 2. Spreader and cylinders of the mechanism of inclination

The revised literature [1,2] picks up two effects that produce dynamic loads in the hydraulic circuit of inclination of the spreader: the <sway> effect is the one provoked for the spreader swinging and the <snag> effect, where dynamic loads of traction or compression, unaware to the process, are applied in the ends of the stem by the cables, transforming the cylinders into bombs; the theoretical power reached by the cylinder is superior to 600 Kw; this is transformed into heat [pamphlet of TCH].

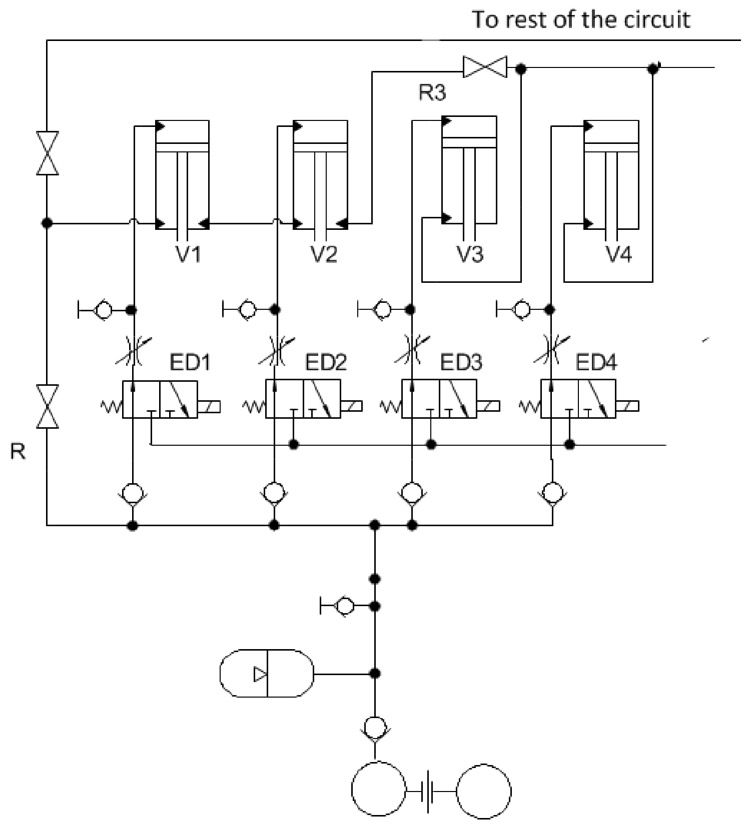

Fig. 3. Original circuit

To eliminate these effects the designers [3,4,5,6,7] have established solutions anti-sway and anti-snag in the hydraulic circuits. For the latter they used valves constrainers of pressure, the conventional ones [8] in advance of response of 100 milliseconds are not recommended, valves cartridge are recommended or logical in advance of opening among 15 -20 milliseconds.
Figure 4 shows the operation of an antisnag. The load applied in the cable, firstly they elongate it and later on the residual load applied in the stem's end deforms the column of hydraulic oil in the cylinder when it is being pumped, generating a pick of pressure, the valve of security opens up, allowing the offspring's displacement. Also, it shows the time from the beginning of the application of the force in the stem until reaching the pick of pressure and the time consumed by the valve to open up totally.
Using the deductive-inductive method we assume that the origin of the causing dynamic loads of the mishaps was the fall free of the container, when being broken by the cable it caused an event Snag. It was modeled and it was simulated the event. The main conclusion: to modify the circuit adapting to it an anti-snag (valve cartridge constrainer of pressure and accumulator as a damper to end the picks of pressure).

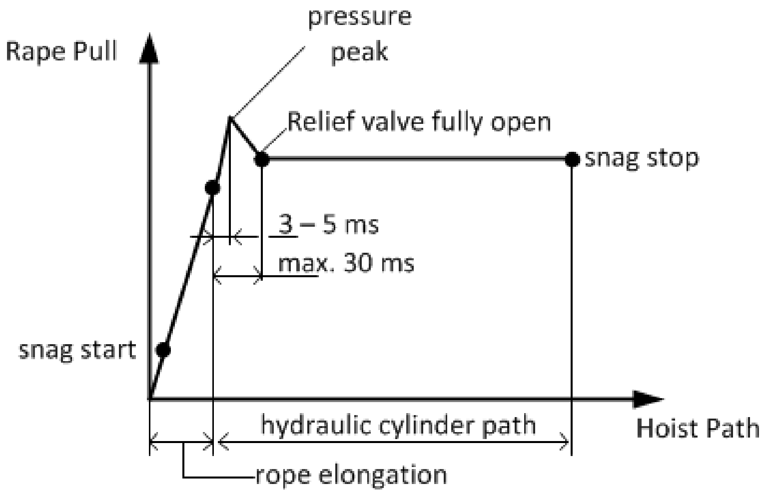

Fig. 4. To come from the antisnag (taken and edited [8])

2. Fall free of the container

When applying the deductive-inductive method it was found that the causing dynamic loads of the mishap were consequence of the fall free of the container when for an erroneous manipulation this was supported for other, later on it slips for the interaction with the cable and it fell.
When studying the original hydraulic circuit it was determined that this didn't possess protection antisnag since the valves of security they aren´t action express and the distance to those that the elements are located they don't allow the protection.
The expressions (1) and (2) model the longitude of the cable L_{CD} when being loosened by the operative.

$$L_{CD} > \overline{ab} + \overline{bc} + 2H \qquad (1)$$

$$L_{CD} \leq \overline{ab} + \overline{bc} + 2H \qquad (2)$$

In the situation (1) the free fall concludes with the impact of the container because h is bigger than H, (see figure 5), in the (2) h is smaller than H and the container is braked by the cable being suspended, the kinetic energy is transferred, firstly, it produces an elastic deformation of the cable; later on the load remainder acts on the stem making an event of Snag.

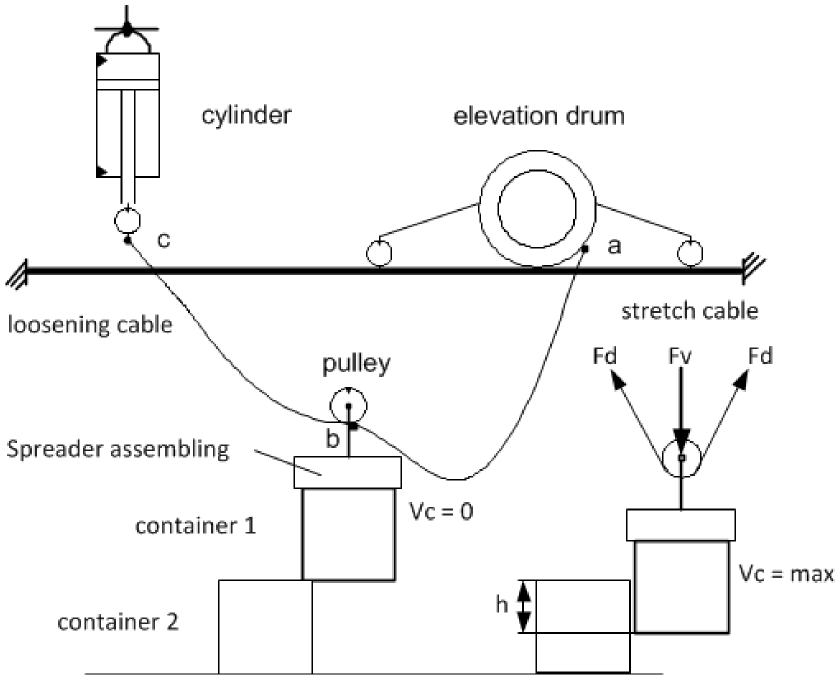

Fig. 5. Fall free of the container

Suppose the force Fv (originated by the free fall) is distributed equally among each brunch of the cable Fd, with two components: one to deform the cable Fdc and the other one for interaction axially in the stem's end Fdv [N]. It is supposed that:

$$Fdv = 0.3 \cdot Fv \quad (3)$$

Applying the impulse law and quantity of movement, also, the principle of energy conservation, referred to figure 5 and substituting in (3), it is:

$$Fdv = 0.424 \cdot \frac{m_{unitaria} \cdot \sqrt{g \cdot h}}{\Delta t} \quad (4)$$

The $m_{unitaria}$ [Kg] is the mass associated to the most loaded cable, it is the sum of the mass of the sprider support, that of the sprider and the one of the container to full load divided by the number of cylinders and multiplied by the coefficient k = 1.2; keep in mind the eccentricity of the load in the container. g[m/s^2] is gravity, h[m] is the distance made by the container in the free fall and Δt [s] the time in the free fall.

$$munitaria = \frac{k(mps + ms + mc)}{8} \quad (5)$$

3. Event Snag

The event Snag a consequence of the effect of the compressibility of the hydraulic oils, the force is Fdv it makes to the piston pump (see figure 6) generating a deformation X, which implies a variation of the volume of oil ΔV and the emergence of a pressure pd according to (6), in [9].

$$pd = -E\frac{\Delta V}{V} \quad (6)$$

The pressure pd and E: module of elasticity [Pa ΔV: variation of volume [m^3].
The pressure spreads from the inferior face of the piston of the cylinder A to its homologous d. The effect of the pressure on the piston of the cylinder B causes the deformation ΔX_1, does this deformation generate the pressure pd1, if when arriving to the point **f**it takes a superior value to the acceptable one for the valve **V1** this collapses. Otherwise it creates a damped harmonic movement between the points **a** and **f**.

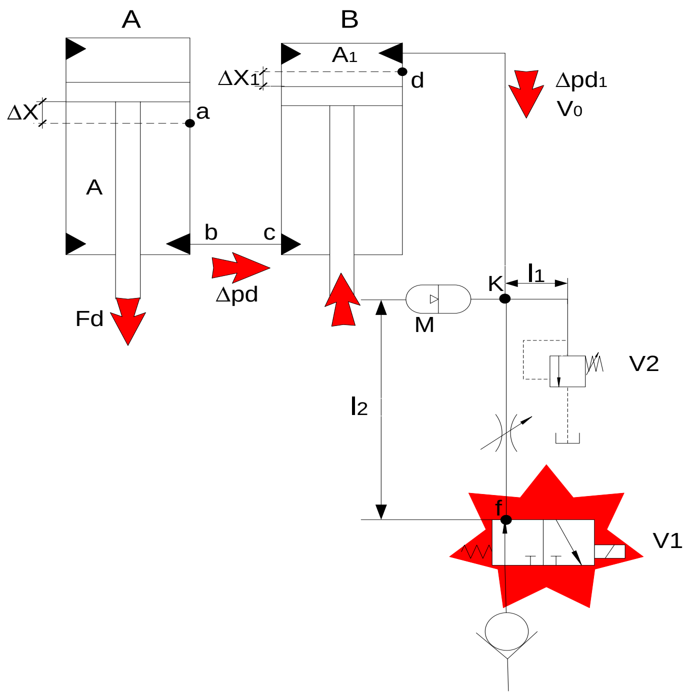

Fig. 6. Section of circuit

To protect to the valve **V1** it does intend to add a valve constrainer of pressure **V2** at a distance smaller than the point K (l1< l2) so that the wave of pressure arrives first to the valve **V2**; also, an effective method [10] of reducing the overpressure directed by the battering ram blow is the installation of hydraulic accumulators; the incorporation of both elements is the solution antisnag.
The pressure is the relationship between the force Fdv and the area of the cylinder; substituting (4) it is:

$$pd1 = 0.54 \cdot \frac{m_{unitaria} \cdot \sqrt{g \cdot h}}{\Delta t \cdot dc^2} \tag{7}$$

The flow that moves from d to f qd1 is the relationship between the ΔV [m^3] and the time of opening of the valve of security tap [s], dc is the diameter of the cylinder [m]. Clearing of (6) and substituting (7), it is obtained:

$$qd1 = 0.424 \cdot \frac{h_{aceite} \cdot m_{unitaria} \cdot \sqrt{g \cdot h}}{tap \cdot \Delta t \cdot E} \tag{8}$$

The parameter h_{aceite} [m] is the height of the column of hydraulic oil in the cylinder and E coefficient of elasticity of the oil [Pa]. The theoretical power in the cylinder Ntc [kW] is determined for:

$$Ntc = \frac{pd1 * qd1}{1000} \tag{9}$$

4. Results and discussion

In figures 7, 8 and 9 are shown the graphs of theoretical power, pressure and the flow of the event Snag in the section d - f of the simulated circuit starting from (7,8,9) through a program written in MATLAB with the following data: mc = 30000; ms = 1000; mps = 3000; dc = 0.1; tap =0.030; h_{aceite} = 0.5; E = 12500x10^5;Δt = (0.005... 0.03) and h = (0.05… 1.5). The units of pressure and flow were converted to coordinate with the catalogs of hydraulic elements.
The three analyzed variables have a common behavior: they are bigger while higher is the kinetic energy accumulated by the container (bigger height and smaller time of fall).

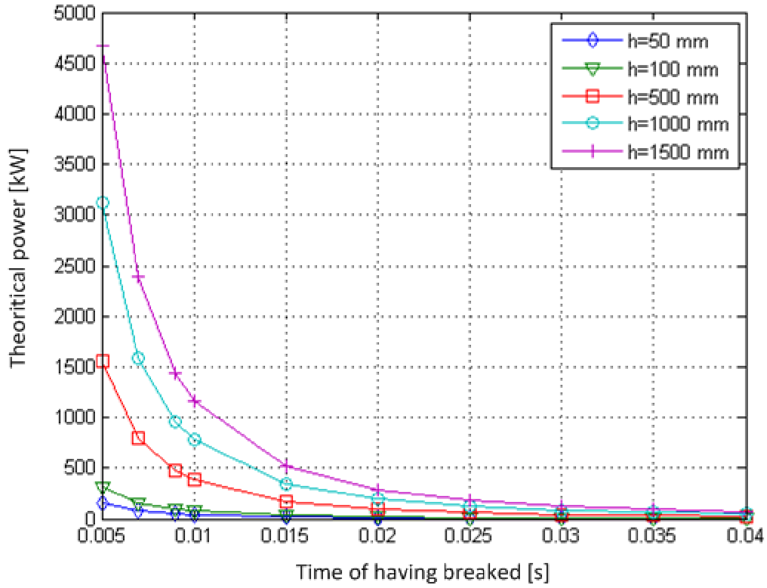

Fig. 7. Behavior of the theoretical power

Figure 7 allows determining the interval of time to protect the hydraulic circuit from fallen free of containers to full capacity of same heights or smaller than meter and half. In [pamphlet of TCH] "the theoretical power reached by the cylinder is superior to 600 Kw." Fixing the limit in 1000 kW, the interval of time for the biggest analysis is 10 milliseconds.
The remaining figures allow determining the values of the necessary parameters for sizing the elements of the antisnag starting from interval of defined time (bigger at 10ms). In figure 8 the value of the pressure pd1 of 1000 bar is determined in the accumulator to plane the picks of pressure. In figure 9 the value of the flow qd1 of 600 l/min is determined for the valve logical constrainer of pressure.

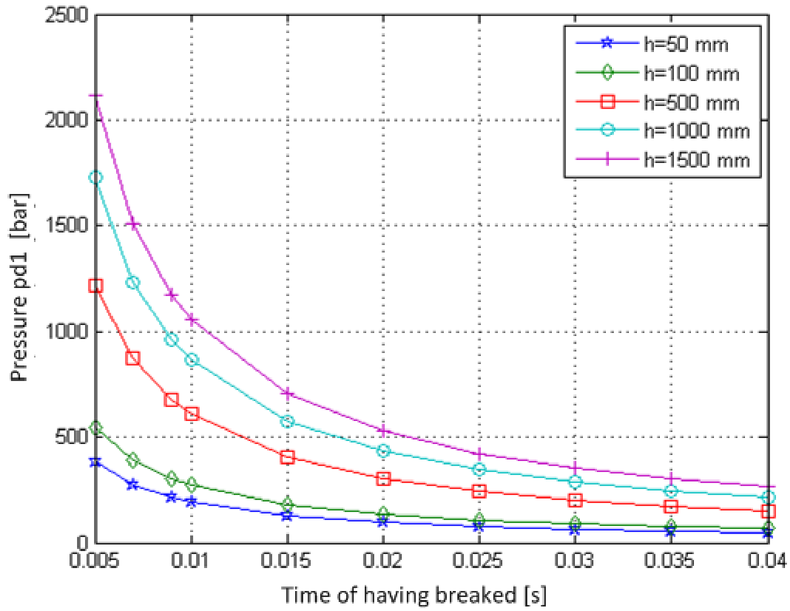

Fig. 8. Behavior of the pressures

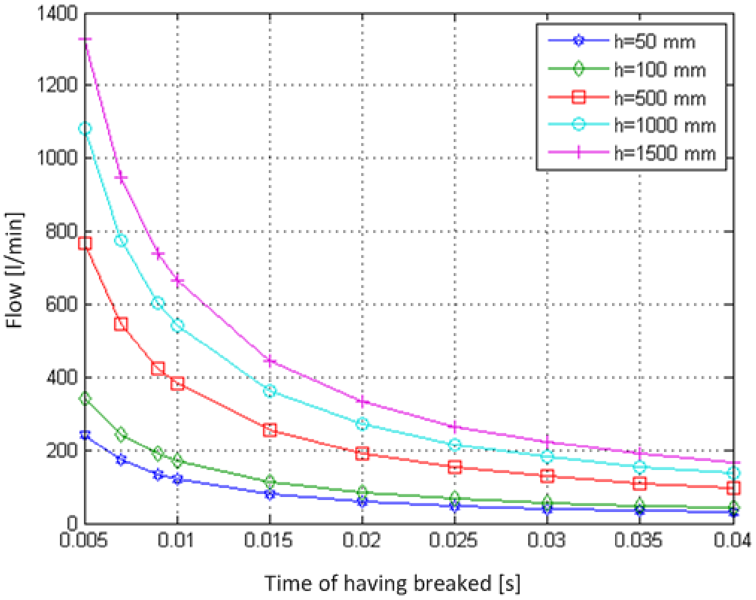

Fig. 9. Behavior of the flows

The knowledge founded during this investigation allowed to propose a modification to the original circuit (see figure 3), for the necessary correction, they intend two sub circuits and in each one to install a valve logical constrainer of pressure and an accumulator to plane the picks of pressure, uncoupled of the rest of the circuit with valves check like sample the outline of the circuit, figure 10.

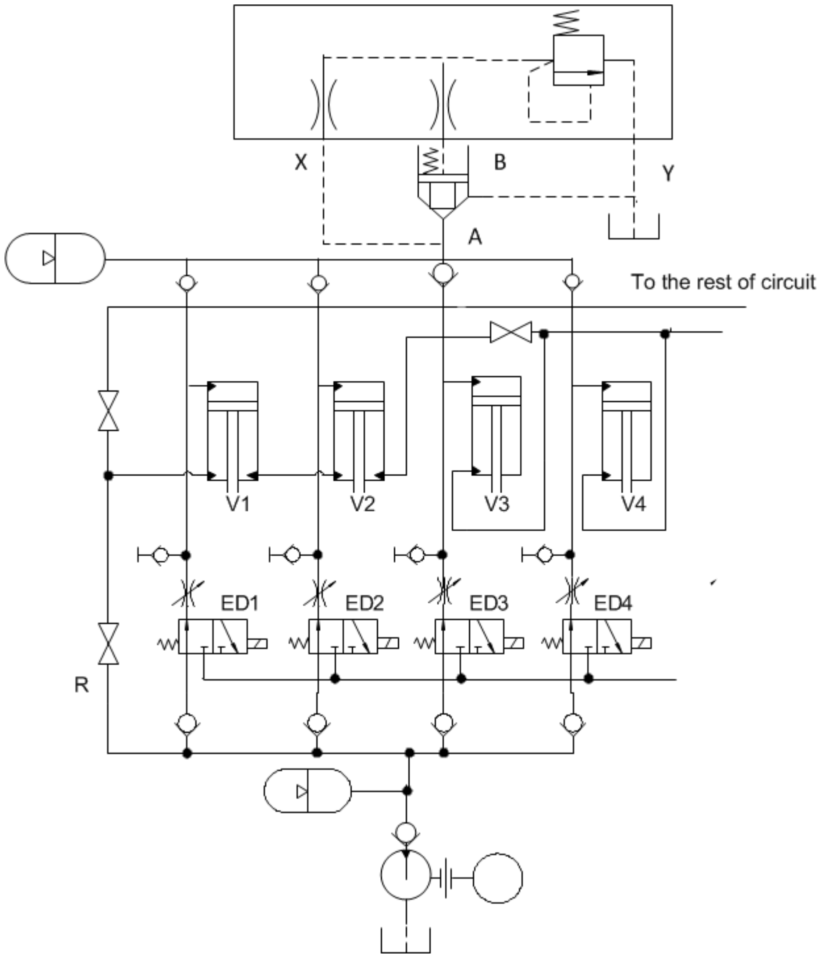

Fig. 10. Circuit modified with antisnag

Conclusions

The present work when applying the deductive-inductive method has been diagnosed the causes of the mishaps, the dynamic loads generated by an event Snag caused by the fall free of the container by an erroneous manipulation, also, the hydraulic circuit doesn't possess antisnag protection since the valves of security are not of fast response, neither the distance of location of the elements allows the protection.

A methodology has been developed based on the mathematical modeling and simulation to evaluate the event Snag caused by the fall free of the container in a crane transtainer, type Rail Mounted Gantry in a terminal container support; you can use this methodology in many other applications.

The simulation allows obtaining the values of the variables for sizing the components of the antisnag solution proposed to correct the circuit and to protect it before fallen free of containers to full load capacity and same heights or smaller than meter and half.

The weak points of the work are: the time to calculate the flow of the Snag the same as that of opening of the valve and to fix the limit of the theoretical power in 1000 kW.

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