Gabriel NIEMCZYK

STABILITY OF A TRUCK CRANE WITH HYDRAULIC SUSPENSION

1. Introduction

Various solutions of hydraulic systems may be applied in truck cranes' suspensions. These solutions involve both the selection of hydraulic cylinders and the way their work is controlled. That answers for diversity of hydraulic systems of crane suspensions. The control of hydraulic suspension involves crane ride and weight lifting, either supported or unsupported. The paper deals with the conditions the suspension has to meet when the crane is to be used for weight lifting whilst on wheels.

The control of crane suspension in hydraulic system is effected by means of hydraulic distributors. Depending on the working conditions, appropriate circuits are activated. For crane operation while on wheels the suspension rigidity must be increased – that is achieved when the accumulators are cut off and liquid flow from cylinders is hindered. Proper hydraulic connections between the suspension cylinders may improve the working conditions.

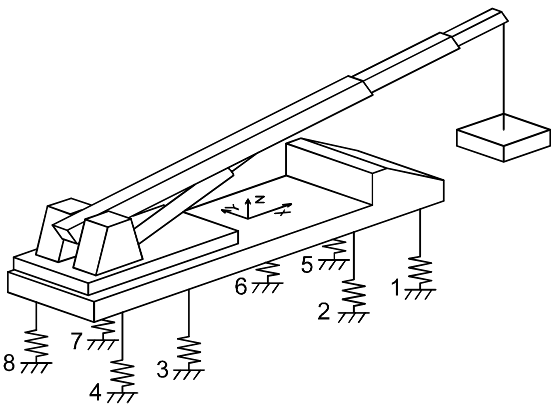

Fig. 1. Model of crane body support

2. Model of the System

Let us consider here a four-axle crane. Because of elasticity of the hydraulic system the support is modelled as elastic, see Fig 1. Hydraulic cylinders may be connected in various manners. Fig 2 presents the cylinders being the subject of this study and the way they are connected.

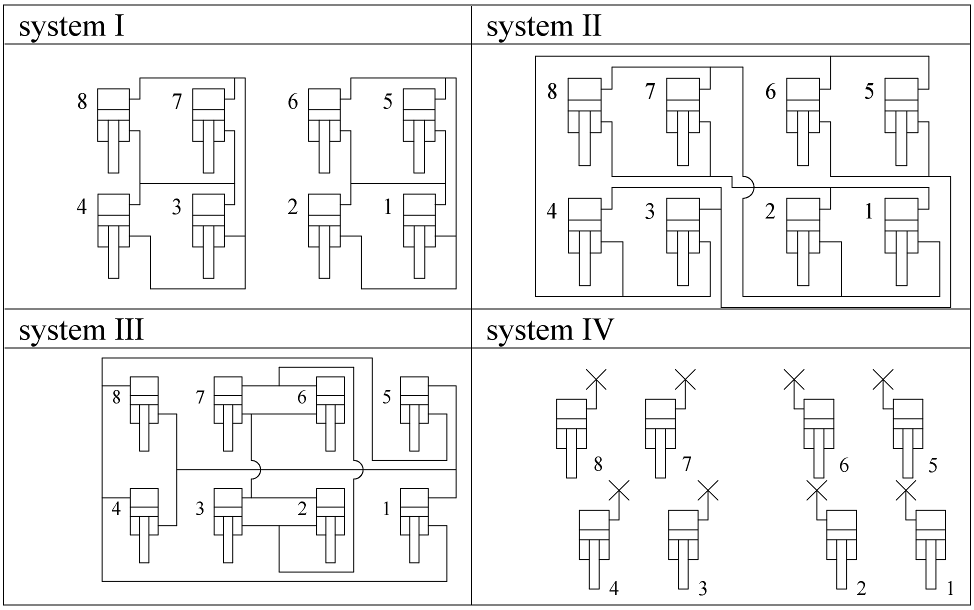

Fig. 2. Case of systems

These connections are described using matrix notation. The following symbols were used: $\boldsymbol{P}_{GG}$, $\boldsymbol{P}_{DG}$, $\boldsymbol{P}_{DD}$, $\boldsymbol{P}_{GD}$– matrices of connections between cylinder chambers; G - piston end, D - piston rod end; $P_{ZL\,i}$ - vector determining whether the i-th piston rod chamber is connected with the return line ($P_{ZL\,i} = 0$) or not($P_{ZL\,i} = 1$). Assuming that if the piston rod end is not connected with any piston end it will be connected with the return line; accordingly on the basis of $\boldsymbol{P}_{GG}$, $\boldsymbol{P}_{DG}$ it is possible to determine $\boldsymbol{P}_{DD}$, $\boldsymbol{P}_{GD}$ and the vector $\boldsymbol{P}_{ZL}$ basing on the following relationships:

$$\boldsymbol{P}_{GD} = \boldsymbol{P}_{DG}^{T}$$
$$P_{DD\,i,j} = \begin{cases} 1, & [\exists\, k = 1..8 : (P_{GD\,k,i} = 1) \wedge (P_{GD\,k,j} = 1)] \vee (i = j), \\ 0, & [\forall\, k = 1..8 : (P_{GD\,k,i} = 0) \vee (P_{GD\,k,j} = 0)] \wedge (i \neq j) \end{cases} \tag{1}$$
$$P_{ZL\,i} = \begin{cases} 1, & \exists\, k = 1..8 : P_{GD\,k,i} = 1, \\ 0, & \forall\, k = 1..8 : P_{GD\,k,i} = 0 \end{cases}$$

When the coordinates of support points of suspension cylinders on the plane XY are designated as x_i, y_i, they can be written as:

$$\boldsymbol{W}_K = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 & x_8 \\ y_1 & y_2 & y_3 & y_4 & y_5 & y_6 & y_7 & y_8 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \tag{2}$$

Positions of the centres of gravity of the crane undercarriage, body, the boom and the lifted weight can be represented as:

$$\boldsymbol{W}_P = \begin{bmatrix} x_P & x_N & x_W & x_L \\ y_P & y_N & y_W & y_L \\ 1 & 1 & 1 & 1 \end{bmatrix} \tag{3}$$

The condition of equilibrium (balance of the moments of force with respect to X and Y axis and the sum of force projections onto the Z-axis) for the system can be given as:

$$\boldsymbol{F}\boldsymbol{W}_K^T - \boldsymbol{G}\boldsymbol{W}_P^T = \boldsymbol{0} \tag{4}$$

where: $\boldsymbol{F} = [F_1, F_2, F_3, F_4, F_5, F_6, F_7, F_8]$ - forces acting on the wheels from the ground; $\boldsymbol{G} = [G_P, G_N, G_W, G_L]$ - mass of undercarriage, body, the boom and lifted weight.

Assuming that the inertia forces acting upon the wheels are zero, the force acting on the wheel from the direction of the ground is equal to the force acting on the piston rod. Balancing the forces acting on the piston rod, we get:

$$\boldsymbol{F} = A_G \boldsymbol{p}_G - A_D \boldsymbol{p}_D \tag{5}$$

where: A_G - effective area of the piston; A_D - effective area of the piston on the piston rod end; $\boldsymbol{p}_{G,D}$ - pressure inside the cylinder at the piston end and piston rod end, respectively.

Assuming that liquid volume at the atmospheric pressure is V and the apparent bulk modulus is found to be B', the relation between the pressure and volume can be written as:

$$p = \frac{\Delta V}{V} B' \tag{6}$$

The volume of oil in cylinder chambers is based on the geometric relationship:

$$\boldsymbol{V}_{SG} = A_G \boldsymbol{h}_T, \quad \boldsymbol{V}_{SD} = A_D(h_S \boldsymbol{I} - \boldsymbol{h}_T), \quad \boldsymbol{h}_T = \boldsymbol{U}\boldsymbol{W}_K - \boldsymbol{h}_N + \boldsymbol{u}_K \tag{7}$$

where: :$\boldsymbol{U} = [\sin a_y, \sin a_x, z_0 + \Delta z]$ - matrix determining the undercarriage position; $\boldsymbol{h}_T$ - piston rod protrusion; h_S - cylinder stroke; $\boldsymbol{h}_N$ - height of terrain unevenness; $\boldsymbol{u}_K$ - wheel deflection.

The deflection characteristics is assumed to be linear.

For thus obtained solution the authors checked the forces acting upon the wheel from the terrain, pressure in the hydraulic system and piston rod protrusion $\boldsymbol{h}_T$. The height of terrain roughness being taken as a parameter, the boundary values were determined at which the wheels are lifted from the ground, that is when the values of F are negative. Parameters of the crane body position: $\Delta z, \sin a_y, \sin a_x$ were determined.

3. Results

The boundary values of unevenness height h_{Ngran} at which the wheels are lifted from the ground were computed. In the case of the systems considered here the allowable pressure was not exceeded nor was the cylinder stroke maximally protruded before the wheels are lifted from the ground.

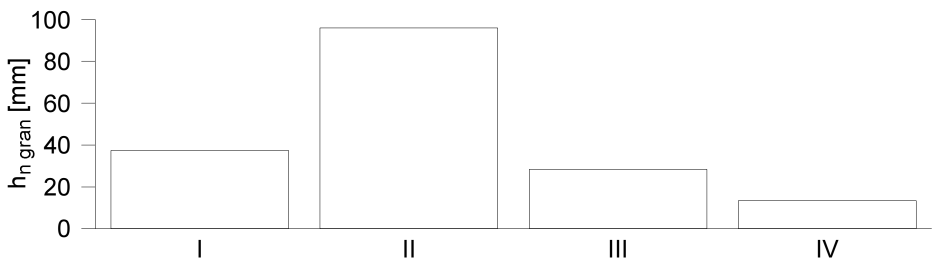

Fig. 3. Boundary values of ground unevenness at which one wheel is lifted from the ground

4. Conclusion

The paper presents the analysis of how the structure of a hydraulic suspension impacts on crane stability while it is moving on wheels. The linear and angular displacement of frame were examined when the crane moved over uneven terrain. The distribution of wheel pressure on the ground and piston rod protrusion were investigated, it was demonstrated that the way the hydraulic cylinders are connected may improve crane stability and reduce platform sloping when the crane moves over uneven terrain.

BIBLIOGRAPHY

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