A METHOD TO ESTIMATE LOADING OF A MOTOR-GRADER BLADE CONTROL HYDRAULIC CYLINDERS

Cand. Eng. Sc., Associate Professor V. Shevchenko[1], Senior Lecturer Zh. Beztsennaya[2]
Department of Construction and Road Machines – Ukraine, Kharkiv National Automobile and Highway University [1]
Department of Foreign Languages – Ukraine, Kharkiv National Automobile and Highway University [2]

kaf_ptsdmo@mail.ru

Abstract: *Direct Metal Laser Sintering[1] (DMLS) is a revolutionary technology that allows a production of fully functional metal parts directly from a 3D CAD data, eliminating the investment to production tools and technologies which brings considerable cost and time savings. Metal parts made by DMLS technology are fully comparable with casted or machined parts. A range of application of DMLS technologies is very wide – from prototypes, through short-run production to final products. Advantages of DMLS technology are arising along with complexity of parts – more complex geometry of parts (in terms of shape and occurrence of the detail) make DMLS technology even more economically effective.*

Keywords: TITANIUM ALLOY, DMLS, LASER SINTERING, 3D PRINTING, MICROSTRUCTURE

1. Introduction

One of the most widely used machines in road-building is the motor-grader. Due to the specialized work attachment - the main blade, the grader can perform a great number of work operations. The distinctive feature of the machine is that the work attachment is controlled by means of space system of three cylinders, each of them having its individual drive (Fig.1).

The complex hydraulic suspension of the main blade at different modes of external loading in some cases can cause decreasing reliability index of the control system, premature failure of its elements.

2. Analysis of publications

The known technologies of motor-grader design include simplified approaches to calculation of the main attachment hydraulic drive [1]. For example, calculation and choice of hydraulic cylinders are made on the basis of static estimated positions corresponding either to average level of normal work effort at digging soil or loss of the machine stability as a result of its front axle losing the contact with the support surface.

Despite of the fact that the blade lift and drawbar shift cylinders are arranged into asymmetric space construction, there considered two-dimensional design models not taking into account distribution of forces among them.

With the purpose of simplifying the calculations the authors accept that the blade lift hydraulic cylinders are positioned vertically when the drawbar shift ones are positioned horizontally. The latter does not correspond to real constructions. Furthermore, for swing hydraulic cylinders the angle of their rotation in the horizontal plane has a significant impact on the axle load [2]. In the case of the main grader blade suspension, changing the length of only one of the cylinders leads to a change in the rotation angle of the other two ones and therefore to a change in the axle loads.

All the above mentioned confirms the discrepancy between the existing calculation methods of the blade control hydraulic drive of a motor-grader and the real space pattern of its loading.

The work objective

The purpose of the article is determining patterns of loading the blade control hydraulic cylinders of a motor- grader taking into account their interaction and angle of alignment in relation to the working attachment.

The research results

In drawing up the design scheme of application to the working attachment of digging forces F_x, F_y, F_z and axle loads $R1, R2, R3$ in the hydraulic cylinders of the main blade suspension (Fig. 1) there were accepted the following assumptions and simplifications: the deformation of the metal construction is negligible; the working fluid is incompressible; connecting hoses are not deformed; there are no gaps, counting of efforts is conducted for the construction preloaded by its curb weight.

To estimate the load of hydraulic cylinders in the space scheme Cartesian coordinate system $Oxyz$ with the origin in the center of the spherical hinge connecting the drawbar and the main frame was used. In such geometric interpretation the whole system has three degrees of freedom and its position is unequivocally determined by angles of rotation of the drawbar in the horizontal plane α, β, and γ.

At moving forward rods of the hydraulic cylinders, the position of the drawbar as to the coordinate origin (point O) changes and, consequently, coordinates of fixing the cylinders to the drawbar change as well, which results in changing of levers of axle loads in hydraulic cylinders relative to the coordinate axes. The rotation of axes is determined by the rotation matrices.

$$M_\alpha = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos(\alpha) & -\sin(\alpha) \\ 0 & \sin(\alpha) & \cos(\alpha) \end{pmatrix};$$

$$M_\beta = \begin{pmatrix} \cos(\beta) & 0 & \sin(\beta) \\ 0 & 1 & 0 \\ -\sin(\beta) & 0 & \cos(\beta) \end{pmatrix}; \qquad (1)$$

$$M_\gamma = \begin{pmatrix} \cos(\gamma) & -\sin(\gamma) & 0 \\ \sin(\gamma) & \cos(\gamma) & 0 \\ 0 & 0 & 1 \end{pmatrix}.$$

If the initial coordinates of fixing points of hydraulic cylinders to the drawbar are determined by vectors $\overrightarrow{T_{01}}, \overrightarrow{T_{02}}, \overrightarrow{T_{03}}$ as a result of the rotation they will change and be equal to

$$\begin{aligned} T_{11} &= M_\alpha \cdot M_\beta \cdot M_\gamma \cdot T_{01}; \\ T_{21} &= M_\alpha \cdot M_\beta \cdot M_\gamma \cdot T_{02}; \\ T_{31} &= M_\alpha \cdot M_\beta \cdot M_\gamma \cdot T_{03}. \end{aligned} \qquad (2)$$

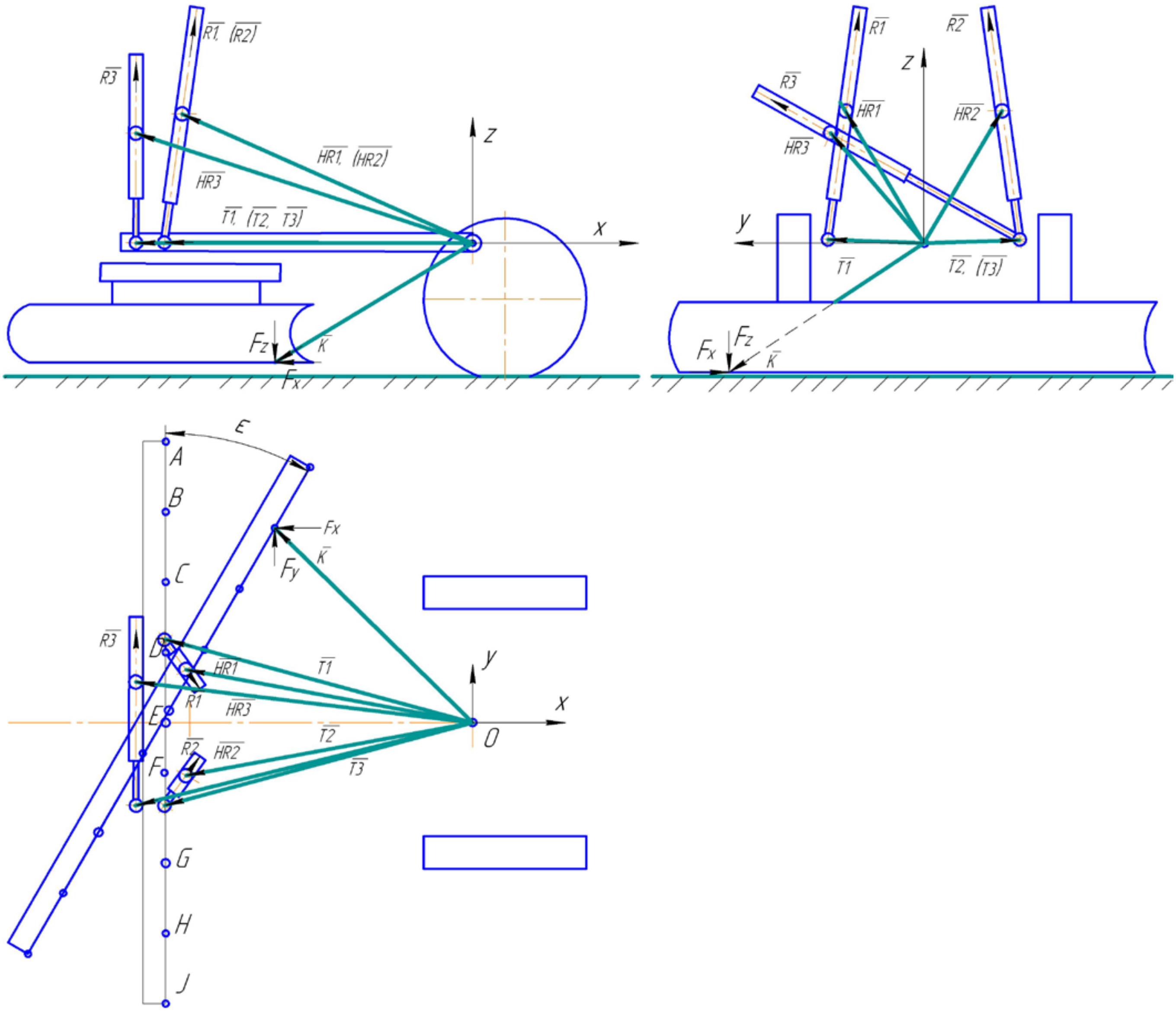

Fig. 1 *3-dementional scheme of applying forces to the motor-grader working attachment*

The preset point $K\left(K_x, K_y, K_z\right)$ of digging effort after the drawbar rotation will have the coordinates

$$\left(K1\right)=\left(M_x\right)\left(M_y\right)\left(M_z\right)\left(K\right) \tag{3}$$

The drawbar equilibrium is described by the equation of the digging effort moment and vectors of moments of efforts $R1, R2, R3$ in the hydraulic cylinders:

$$\overrightarrow{M_{R1}}+\overrightarrow{M_{R2}}+\overrightarrow{M_{R3}}=\overrightarrow{M_F} \tag{4}$$

where $\overrightarrow{M_{R1}}=\begin{pmatrix} R1 & R1 & R1 \\ T1x & T1y & T1z \\ \cos 1x & \cos 1y & \cos 1z \end{pmatrix}$

$\cos 1x, \cos 1y, \cos 1z$ – directional cosines of the effort vector in the left hydraulic cylinder.

The moments of efforts in the right cylinder ($R2$) and the cylinder of the drawbar shift ($R3$) $\overrightarrow{M_{R2}}$ and $\overrightarrow{M_{R3}}$.

In the matrix form the equilibrium state of the drawbar can be written as follows:

$$\left(M\right)\left(R\right)=\left(M_F\right) \tag{5}$$

where $\left(M\right)=\left(\overrightarrow{M_{R1}}\right)+\left(\overrightarrow{M_{R2}}\right)+\left(\overrightarrow{M_{R3}}\right)$

$$R=\begin{pmatrix} R1 \\ R2 \\ R3 \end{pmatrix}$$

Solving the equations (5) we obtain values of efforts in the hydraulic cylinders.

The proposed method was applied to estimate the loading of hydraulic cylinders of the main blade suspension of a real motor-grader DZk-251. When making calculations the external resistance to soil digging was simulated by three unit forces corresponding to the components F_x, F_y, F_z of the total resistance. To reveal patterns of loading the blade control hydraulic cylinders, when calculating there were used various coordinates of the point of application of unit forces to the cutting edge from 2 m to -2 m and the capture angle φ, which varied within limits of 60° clockwise to -60° anticlockwise relative to the initial position of the blade. As the external loads were simulated by the unit forces, solving the system of equations resulted in obtaining reactions in the hydraulic cylinders, considered to be force factors and can be reduced to values corresponding to the actual loading conditions by standard methods. The calculation results are presented in Fig. 2 – 4.

The data obtained at performing calculations unequivocally confirm the pronounced asymmetry of loading of three control cylinders. In the process of changing the capture angle and point of application of digging resistance forces both piston (with the plus-sign «+») and rod end of the hydraulic cylinders (with the minus-sign «-») will be loaded. At that the blade lift hydraulic cylinders are loaded asymmetrically: if with the left hydraulic cylinder its head end is loaded, while with the right one its rod end is loaded and vice versa. Limits of the changes in reactions emerging in the blade control hydraulic cylinders are very broad and do not coincide due to asymmetry in the suspension construction. So the force factor for the left hydraulic cylinder varies from 60.7 to -94.3, for the right one – from -240.6 to 192.5, for the hydraulic cylinder of the drawbar shift. The minimal values of force factors correspond to the points of application of external resistance to digging nearest to the central part of the blade, when it is positioned at right angles to the direction of the grader movement.

The built graphs correspond to curved surfaces of alternating-sign curvature, which allows approximating them with the polynoms of the third degree.

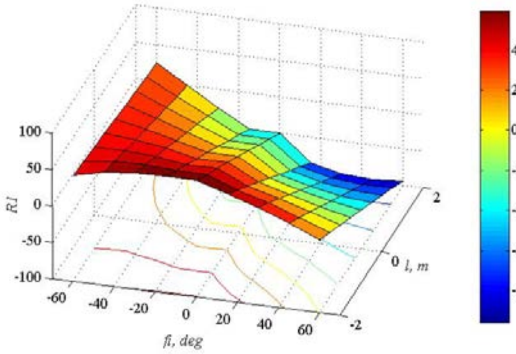

Fig. 2 *The graphic of changing the force in the left hydraulic cylinder depending on the angle of the blade position in the plane and the point of applying unit forces.*

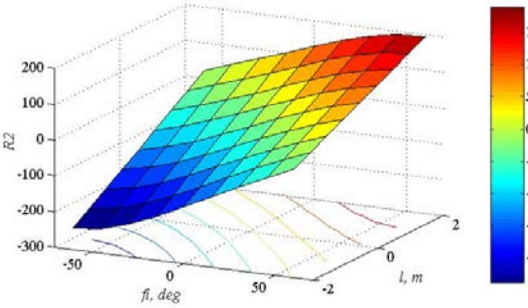

Fig. 3 *The graphic of changing the force in the right hydraulic cylinder depending on the angle of the blade position in the plane and the point of applying unit forces.*

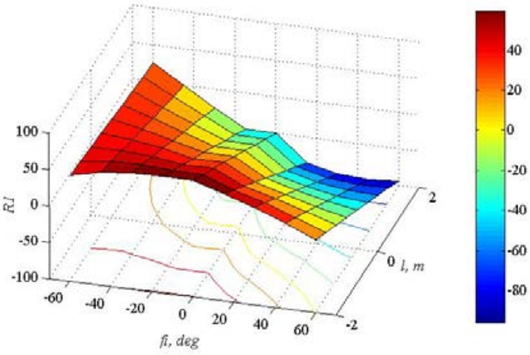

Fig. 4 *The graphic of changing the force in the hydraulic cylinder of the drawbar shift depending on the angle of the blade position in the plane and the point of applying unit forces.*

Conclusions

The proposed method of estimating the loading of the main blade control hydraulic cylinders allows taking into consideration not only asymmetry of applying the external resistance forces but variation of geometrical parameters of the suspension as well, which has not been considered by any existent calculation methods.

The obtained calculation results prove a pronounced nonlinearity and the uneven distribution of efforts between the hydraulic cylinders, consideration of which allows designing the main blade control system of a motor-grader more reasonably.

References

1. Холодов А.М., Ничке В.В., Назаров Л.В. Проектирование машин для земляных работ – Харков: Вища школа, 1986. – 272 с.

2. Кондаков Л.А., Микитин Г.А., Прокофьев В.Н. и др. Машиностроительный гидропривод. – М., Машиностроение, 1978 – 495 с.