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Shovel Mechanism Optimisation

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Abstract: The object of this research is to find the optimal construction parameters of a front-end loader model mechanism. The projection of the mechanism comprises the choice of the optimal geometrical characteristics, those make it possible to work with reliability in any position. Optimization indicates that it is necessary to minimize during all the movement the maximum effort in the jack, element determining in the choice of the hydraulic control or to choose other criteria such as the minimal duration of the operating cycle.

Key words: Optimization of a model, mechanism of lifting, variable geometry, projection, operating cycle

INTRODUCTION

The competition between the various manufacturers trained by the requirements of the market and the changes undergone by the developments of technologies these last decades led to remarkable evolutions in the construction and the improvement of the machines performances.

The aim of this research is to find the optimal parameters of the form, dimensions, cup and the arrow, the determination stable normal speeds as well as the general questions of the theory and calculation of the hydraulic control mechanisms with the constant reduced mass are largely mentioned, among this work, in particular those of Bachta (1972), Preissman and Mischke (1968) which initiated the principal contributions on the models of construction. This research is conducted in the laboratory and confirmed in the field.

MODEL CONSTRUCTION

The front-end loader mechanism can be presented like a hydrodynamic system provided with two independent mechanisms; lifting and the cup.

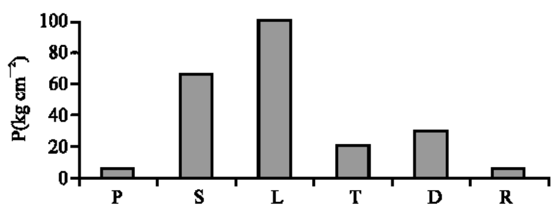

Fig. 1: Hydraulic system pressur

The lifting and arrow process is essential and occupies 25% of the operating cycle time. The pressure of the system depends on the kinematics of the mechanism and reached its maximum when the cup is charged (Fig. 1)

Where,

P : Penetration of the cup
S : Separation of the load
L : Lifting of the arrow
T : Translation of the loader
D : Unloading of the cup
R : Return of the arrow

The movement of the arrow which orders the cup is ensured by a back and forth pass of a jack being articulated in its turn on the frame.

In various working methods from the machine, the mechanism takes a multitude of positions. The study of this last relates to the optimization of various component parameters of the mechanism. The goal is to fond the minimum effort operating the hydraulic actuating cylinder of the arrow and the time of its shortest operating cycle.

From the points of fixing on the frame and the arrow, the masses of the various elements and their relative positions, it can be determined the position of the mechanism according to φ or X to Fig. 2.

The relationship between the co-ordinates of entry and exit expresses the generalized report/ratio

$$i = X/\varphi$$

the expression of the arrow movement is

$$M = M\,st + M_D$$

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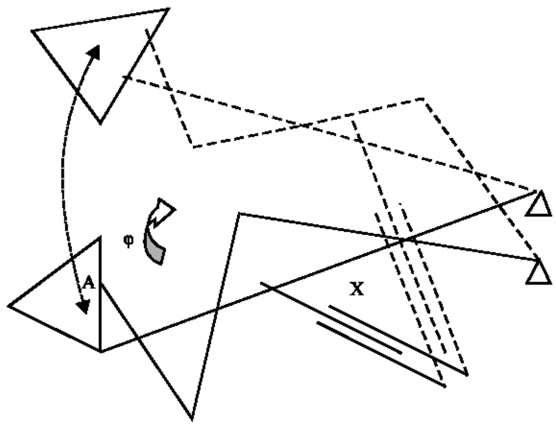

Fig. 2: Diagram of the mechanism calculation

its value changes with the variation of the steering angle

$$Mst = \sum_{i=1}^{n} Msti - F(\varphi)$$

$$MD = \omega^2 \frac{dl}{dt} + J\frac{\alpha\omega}{dt}$$

In the general case

$$l = J_B i^2 + J_0$$

J_B : Moment of inertia of the valve block
J_e : Moment of inertia of the element with to reduce

For a valve block to alternative action the driving couple is determined by:

$$M = (P_p.S_p\text{-}P_tS_t)\ i.\eta$$

P and Pt are the pressures of the liquid work in the room of the piston and the stem Sp and St sections of the piston and the stem η is the friction characteristic of the coefficient

$$\eta = f(d\varphi/dt)$$

is a function the speed of the element to reduce. The determination of J and dI/dφ rests on the analysis of the kinematics mechanism Fig. 1 and by using the theorem of the cosine there is the following expression:

$$X^2 = K^2 + p^2 - 2Kp\cos\varphi$$

while replacing

$$dt = d\varphi/\omega \quad ; \quad \omega = d\varphi/dt$$

one has

$$\frac{dx}{d\varphi} = \frac{kp\sin\varphi}{\sqrt{k^2 + p^2 - 2kp\cos\varphi}}\omega$$

From where one can write

$$\frac{dx}{dt} = \omega.i_x \ ; \ \frac{dx}{d\varphi} = \omega^2.t_x$$

rod data base ensures the plane movement in the relative movement. This last is determined by linear velocity V and that angular ω1

$$V = \omega(i_\psi - i_y)r.\sin\mu$$

$$\omega_t = \frac{\omega(i_\psi - i_Y)r\cos\mu}{i}$$

during the phase shift of rotation of the arrow of the initial value φ0 with a step Δφ the length of the stem is that of the jack

$$X = X_0 + \Delta\varphi.\ i_x$$

and for the angle

$$v = v_0 + \Delta\varphi.i_x$$

elements LD, dB, BA turn with the arrow in the direction of drive with angle Δφ and in the relative movement each element turns with an angle:

$$\beta = \beta_0 + \Delta\varphi.\ i_\beta$$

$$\lambda = \lambda_0 + \Delta\varphi.\ i_\lambda$$

$$\varphi_g = \varphi_{g0} + \Delta\varphi.\ i_g$$

$$\mu = \mu_0 + \Delta\varphi.\ i_\mu$$

indeed element dB moves linearly in the direction of the movement by having linear displacement

$$X_B = \Delta\varphi\ (i_\psi\text{-}i_y)\ r.\sin\mu$$

and turns around D so that its angle formed with the arrow will be;

$$\delta = \delta_0 + \Delta_\varphi \frac{\omega(i_\psi - i_Y)r\cos\mu}{1}$$

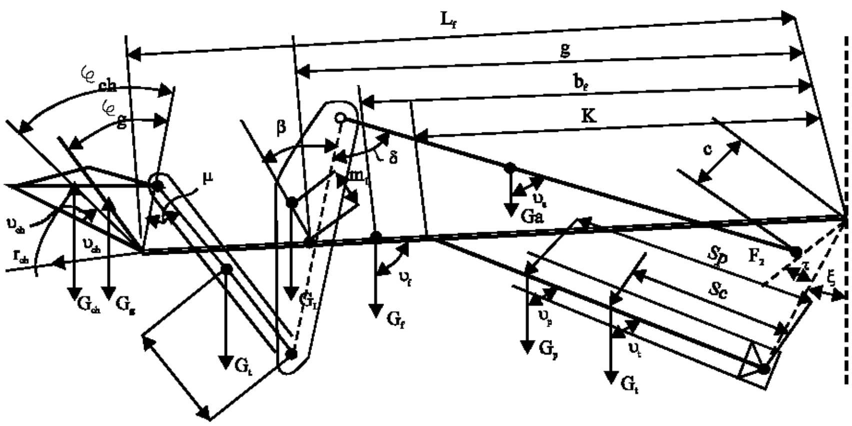

Fig. 3: Scheme of calculation

Table 1: Expressions for the calculation of I

Triangle	Functions
KOU	$X^2 = K^2+p^2-2K\ p\ \cos\varphi$
KUO	$X^2 = K^2+p^2-2X\ p\ \cos\upsilon$
COM	$n^2 = q^2+p^2-2\ qc\ \cos(\varphi-\tau)$
CML	$\Delta = \text{arc.cos}\frac{n^2+f^2-m^2}{2fn}$
CLM	$\delta = \text{arc.cos}\frac{m^2+f^2-m^2}{2mf}$
CML	$\beta = \text{arc.cos}\frac{m^2+n^2-f^2}{2mn}$
ACD	$W^2 = a^2+d^2-2ad\cos\beta$
ACD	$\gamma = \text{arc.cos}\frac{w^2+d^2-a^2}{2wd}$
ABD	$\psi = \text{arc.cos}\frac{r^2+w^2-l^2}{2wr}$
ABD	$\mu = \text{arc.cos}\frac{r^2+l^2-w^2}{2rl}$

One can achieve the similar transformations for all the angles and variable dimensions of the mechanism and consequently the report/ratio generalized for each element (Fig. 3).

In Table 1, we recapitulate the basic expressions corresponding to the various angles for the determination of the various generalized reports/ratios

MODEL OPTIMIZATION

For the mechanisms with variable geometry the reduction in the instantaneous center of rotation of the static couples of the the separate elements weights is carried out using the generalized transmission ratios (Heping, 2005).

The essential characteristic of the mechanism is the transmission ratio generalized which on the one hand depends on the report/ratio of the reducer i_r and on the other hand parameters geometrical on the mechanism, in this condition for a concrete diagram one carries out a

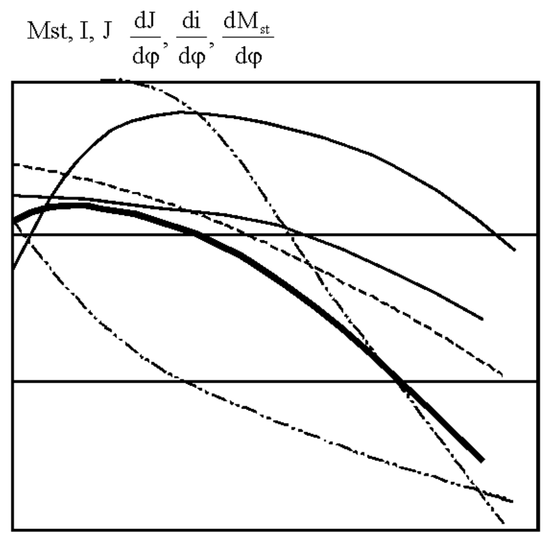

Fig. 4: Parameters of the mechanism

diagram on the scale. Then one varies the angle of φ0 with φmax with a step Δφ (Preissman and Mischke, 1968) one finds Mst, J, I and while deriving one obtains their intensities $\frac{dM_{st}dJ}{d\varphi\,d\varphi}$ and $\frac{di}{d\varphi}$

By examining these curves (Fig. 4) one can trace the ways of reduction of the time of movement of the mechanism or of the force of pushed mechanism.

Thus for a given whole of constructive parameters of the mechanism one finds the velocity angular of the element to be reduced according to displacement, then one can find the speed of any point of the mechanism and the time of his movement (Qingxin *et al*., 2005; Heping *et al*., 2005). Such an approach of the problem allows the optimization of the parameters of the mechanism, (points of catch of hydraulic actuating cylinders, angles of the levers, angles initial and their development.

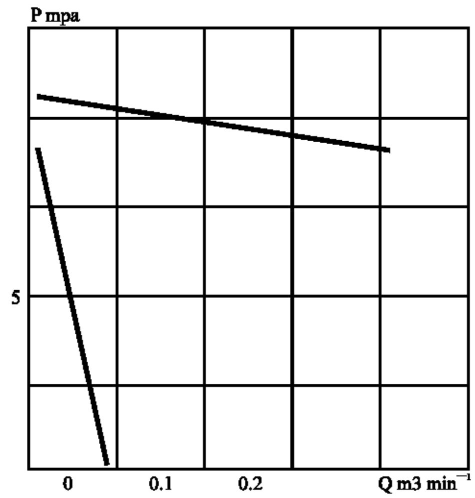

Fig. 5: Characteristic of the valve block

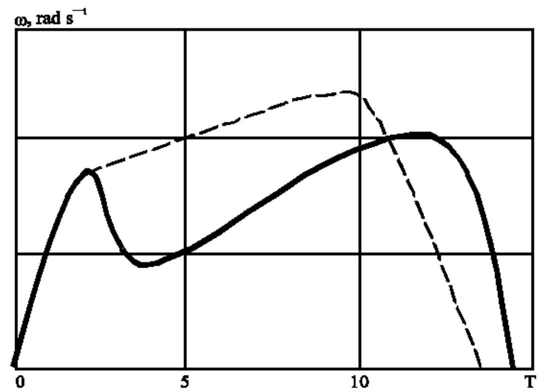

Fig. 6: Speed of the cup according to time

One can see that optimization can be obtained using $I\frac{di}{d\varphi}$, $\frac{dJ}{d\varphi}$

While varying the initial values of position (points of catch of hydraulic actuating cylinders, angles of the levers, angles initial and their development) for the same valve block (Bachta, 1972) (Fig. 5) one can optimize the parameters according to the criterion of the minimum of time of movement. The results obtained carried out on a rocker shovel show the similar behaviour of Mst and I but the increase J to Fig. 6.

On Fig. 6 is shown a dependence speed of lift of the cup according to time, the presence of the collar (difference between the theoretical curve dotted and that experimental testifies to the presence of a reserve which makes it possible to reduce of advantage the cycle time of the mechanism.

The comparison shows a good agreement between results calculated and those experimental what explains the fidelity of the elaborate model. This last makes it possible to analyze the influence of the geometrical parameters in particular the fixing of the centers of arrow rotation and the jacks compared to the speed of movement. In other words allows the optimization of the mechanism according to a criterion chosen like minimal speed or the driving force.

CONCLUSION

We developed, in this research a mathematical model which makes it possible to find the optimal construction values and the influence of the geometrical parameters on the optimality of the mechanism by taking account various criteria that the decision maker will retain according to is priorities.

Indeed the manufacturers are constantly confronted on, one hand to raise the design of the machines that to set up a valid base of the machines construction theory and on the other hand have a constant concern of the improvement of their performances imposed by the question of competition between them. The step suggested as well as the results which result from this can be justified by their integration in an industrial step. The optimal values were validated in the field with various constructed equipments.

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