

ENERGETIC ANALYSIS OF THE EFFICIENCY OF HYDRAULIC DRIVE OF CABLE SHAKER

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Summary. The paper is focused on the theoretical research of the efficiency of hydro-drive of the cable fruits-shaker with the system of accumulated power. Analytical formulas for determination of torque and power on the shaft of vibro-driver of the shaker vibrations are suggested. Regularity of the alteration of hydro-engine's useful power during its interaction with the tree are discussed.

Key words: torque, shaker, hydro-drive, power, pneumo-hydraulic accumulator (PHA), pressure.

INTRODUCTION

Hydraulic drive of a cable fruit-shaker with power accumulation [Krupych and others, 2003] has the pump of separative and aggregate hydraulic system which is put into operation by an internal combustion engine of the energetic type and one or more parallelly connected serial [Mashinostroenie, 1998] pneumo-hydro-accumulators switched on the road of feeding of the hydro-engine of the driver of shaker's vibration through a throttle.

When moving the fruit-picking device from one tree to another, one switches on the supply of working liquid to charge the accumulators. After changing the place and occupying the tree, one sets the nominal regime of operation of the energetic device engine and the shaker's drive is switched on. The total stream of the working liquid from the hydro-pump and accumulators reaches the hydro-engine. After getting the ω_{str} velocity of the vibrations driver, allowing securing of agrotechnically perfect fruit-picking, the shaker's drive is switched off.

Conditions of vibro-driver vibrations of the modernized cable shaker [Patent MPK 7 A 01/Д 46/26] depend on the parameters and regimes of the operation of elements of its hydraulic system and hardness and damping abilities with dimensions and mass parameters of fruit-trees. The hydraulic system will secure the operation of vibro-strike driver of vibrations in the optimally frequent regime in the case of the working liquid supply to the hydro-engine under pressure. This creates the torque on the shaft of hydroengine M_{he} , which exceeds the consequent moment on resistance M_{str}

METHODS OF RESEARCH

Coming from the conditions of the shaker's operation, the torque of resistance on the hydroengine's shaft, security and technological quality of fruit-picking can be determined by the following formula:

$$M_{str} = \frac{N_{str}}{\omega_{sh}}, \quad (1)$$

N_{str} – is the power for tree-shaking, kWt;

ω_{sh} – angular velocity of the driver's shaft of shaker's vibrations (frequency of tree-shaking), c⁻¹.

Methods of determining the power directed to the drive of the shaker is described in the research works [Shevchyk R.S., 2004; Shevchyk R.S. and others, 2005]:

$$N_{str} = N_{sh} + N_j, \quad (2)$$

N_{sh} – power expenditures for the shaker's drive in the constant regime. Thus, when the constant angular velocity of the vibrations driver, kWt;

$$N_{sh} = M_{sh}\omega_{sh} = Fr\omega_{sh}\sin\omega_{sh}t, \quad (3)$$

N_j – power expenditures for the alteration of velocity of tree and shaker vibrations, kWt;

F – power of cable stretching, H;

r – radius of the centre of vibro-driver of the shaker vibrations, m.

$$N_j = I_{sum} \frac{d\omega_{sh}}{dt} \omega_{sh}, \quad (4)$$

I_{sum} – converged to the hydro-engine shaft moments of inertia of a fruit-picking unit as the vibration system, kg·m².

$$\text{Since:} \quad \frac{I_{sum}\omega_{sh}^2}{2} = \frac{m\dot{q}_k^2}{2} + \frac{m_1\dot{q}_1^2}{2} + \frac{m_2\dot{q}_2^2}{2}, \quad (5)$$

m, m_1, m_2 – accordingly: mass of tree, loop-delight and power mean with fastened vibrodriver of vibrations, kg, according to the formula (4) we will get:

$$N_j = \left(m\dot{q}_k^2 + m_1\dot{q}_1^2 + m_2\dot{q}_2^2\right) \frac{\dot{\omega}_{sh}}{\omega_{sh}}. \quad (6)$$

Taking into consideration (3) and (6), the formula (1) will get the following form:

$$M_{str} = \left(Fr \sin \omega_{sh}t + \left(m\dot{q}_k^2 + m_1\dot{q}_1^2 + m_2\dot{q}_2^2\right) \frac{\dot{\omega}_{sh}}{\omega_{sh}^2}\right). \quad (7)$$

The torque on the shaft of hydro-engine is grounded by the parameters of hydro-system and is determined by the condition [Lovkin Z.B., 1990]:

$$M_{he} = \frac{q_m p_l \eta_{he}}{2\pi}, \quad (8)$$

q_m – expenditures of the working liquid which are consumed during one hydro-engine's rotation; frequency of its shaft's rotation is n_e ;

p_l – pressure in the system of hydro-drive of the shaker, MPa,

η_{he} – hydroengine efficiency.

The system “hydro-engine – vibro-driver of vibrations – tree” is efficient when $M_{he} \geq M_{str}$. The minimal pressure p_{min} in the hydrosystem of the drive of hydro-engine, considering (7) and (8) will be as follows:

$$p_{min} = \frac{2\pi M_{str}}{q_m \eta_{he}} = \frac{2\pi}{q_m \eta_{he}} \cdot \left((Fr \sin \omega_{sh} t) + (m \dot{q}_k^2 + m_I \dot{q}_I^2 + m_2 \dot{q}_2^2) \frac{\dot{\omega}_{sh}^2}{\omega_{sh}^2} \right). \quad (9)$$

The useful power N_{he} which is driven to the shaft of hydro-engine is determined when:

$$N_{he} = Q_{he} p_{he} \eta_{he}, \quad (10)$$

Q_{he} – the working fluid supply which is driven to the hydroengine, l·min⁻¹;

p_{he} – pressure difference in hydr-engine, MPa.

If during the common supply of working fluid into the tank of hydro-engine from pneumo-hydro-accumulator and hydro-pump Q_{hp} of separative and aggregate hydro-system of energetic device, the pressure difference p_{he} drop to minimum ($p_{he} = p_{min}$), the useful power on the shaft of hydroengine which allows the shaker to interact with the tree will be as follows:

$$N_{he} = Q_{he} p_{min} \eta_{he} = (Q_{hp} + \dot{V}) p_{min} \eta_{he}. \quad (11)$$

Taking into consideration the working fluid supply from PHA [Nishchenko I.O. and others, 2005] and (9) the formula (11) will be the following:

$$N_{he} = \frac{2\pi}{q_{he}} \left(q_{hp} n_{hp} \eta_{hp} + \left(\frac{-a_a + \sqrt{a_a^2 + 4(b_a + b_d) \times (P_0 - F_0)}}{2(b_a + b_d)} \right) \right) \times \left((Fr \sin \omega_{sh} t) + (m \dot{q}_k^2 + m_I \dot{q}_I^2 + m_2 \dot{q}_2^2) \frac{\dot{\omega}_{sh}^2}{\omega_{sh}^2} \right), \quad (12)$$

a_a – coefficient of expenditures of the pressure of working fluid driven to pneumo-hydro-accumulator on all Z_k sites with laminar stream, MPa · c·m⁻³;

b_d – coefficient of expenditures of the working liquid pressure on the throttle, MPa · (c·m⁻³)²;

b_a – coefficient of the pressure of working liquid driven from pneumo-hydro-accumulators on all Z_k sites with turbulent stream, MPa·(c · m⁻³)²;

P_o, F_o – coefficient characterizing the fluid supply to the hydro-engine on the separate regimes of the shaker hydro-drive operation.

When PHA is absent, Q_{hp} and Q_{he} are equal, hydro-pump produces the same pressure on the pressure road as in the case of maximal charge of pneumo-hydro-accumulators, then the useful power on the shaft of hydro-engine will be the following:

$$N_{he} = Q_{hp} p \eta_{he} = (q_{hp} n_{hp} \eta_{hp}) p \eta_{he}. \quad (13)$$

Thus, the achieved theoretical relations (7)–(9), (12) and (13) allow to set analytically the main energetic parameters and regimes of operation of hydro-drive of cable shaker under different conditions of oil driving to the tank of hydro-engine of the vibro- driver of vibrations.

RESULT OF RESEARCH

Graphical interpretation of theoretical research (Fig 1) shows that the equipment of hydro-drive of cable shaker with the system of accumulating with energy allows to raise the useful power

Δ_N realized on the shaft of hydro-engine by 0,83-1,99 times compared to the hydro drive comprising of the hydro-pump of 10 cm³ working volume. The latter is able to rotate with frequency of 1500 min⁻¹. To achieve the useful power within 9,03 kWt without PHA one must use the hydro-pump with the working volume of 20 cm³.

Nevertheless, the achieved results allow to determine the main drawback in the described hydro-drive operation, i.e. the momentary supply of the fluid's stream to the tank of hydro-engine and, consequently, the rise of torque and power driven to its shaft. This phenomenon is true primarily in the first second's quarter (the general period of shaking cannot exceed four seconds). In this regime of operation of vibrations vibro-driver the frequency of tree-shaking gets maximal parameters identical with torque. When the rise of the latter is linked with the necessity of overcoming resistance during the period of making tree to shake, the momentary rise of W_c is accompanied by the intensive fruits dropping. And the fruit, when falling on the surface, may be seriously injured.

To delete these drawbacks and taking into consideration the fact that the biggest impact of the parameter of torque and power has the pressure of the previous charge of PHA with the supply of working fluid, one should implement the regulated regime of the hydro-drive's work using the multi-channel relay of time [Shevchuk R.S. and others, 2005]. These experiments need systematic approaches in solving problems with developing executive mechanisms and obligatory use of computers.

CONCLUSIONS

The conducted experiments helped to arrive at the theoretical equations (7)–(9), (12) and (13) which allow to analytically determine the basic parameters and regimes of the cable shaker hydro-drive's work under various conditions of oil drive to the tank of hydro-driver of vibrations vibro-driver. The results of research suggest that the more prospective equipment of hydro-drive is the system of energy accumulation. Its use will allow in a short time to rise by almost two times the useful power driven to the shaft of vibrations vibro-driver.

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