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Synthesis and identification of parameters of regenerative device for reversing link with increasing speed

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Abstract. The article shows the problem of modeling the flow of fibrous suspension in the working bodies of mixing machines. A mathematical model describing the motion of a suspension with fibrous inclusions in a wet-type disintegrator, depending on the design of the accelerating unit and the operating device is obtained.

1. Introduction

One of the features of many working machines is a developed mechanical system that simultaneously performs transport and technological operations. At the same time, the movements of the working bodies is relative to the movements of the base because of an inertial effect [1].This causes additional energy loss, which, as a rule, affects the productivity of the whole machine. To ensure this, in such cases, it is necessary to increase the engine power, which in turn changes the weight of the entire machine [2, 3].

Therefore, to increase the energy efficiency of such working machines, it is advisable to use special devices - energy recuperators that accumulate energy when the link brakes at the end of each phase of the motion and returns it during acceleration in the next phase [4-6].

Features of the organization of such recuperative system are related to the laws of motion of the links determined according to the conditions of the functioning of the machine [7-9]. In some cases, they exclude the possibility of energy recuperation or lead to cumbersome constructions [10].

Thus, in the initial stages of design of transport-technological machines with a regenerative actuator fixed to the movable base, it is necessary to analyze the principle scheme of energy recovery and assessment of its impact on the energy efficiency of the working machine.

2. Synthesis of the principle scheme of work

In most cases, energy recuperators consist of two elastic elements (for example springs) located on the body of the mechanism in front and behind the reversed link in places corresponding to its extreme positions. Such design can be used if the conditions of the link movement at each phase are the same (that is, the reverse does not change its mass or velocity). If after the reversal of the link, its speed increases, then the energy stored in one elastic element will be insufficient, and in another one it will be redundant to provide the given motion.

Therefore, the construction of the energy recuperator should be different. Its main distinction lies in the fact that the elastic elements must provide the possibility of redistribution of useful energy among themselves according to the conditions movement of the link. On the basis of this, it is possible to imagine a general principal scheme of the operation of an energy recuperator (Figure 1). Link 1 makes oscillatory movements relative to the housing under the action of the drive. Changing the direction and speed of the link occurs when it interacts with storage devices 2 or 3. The energy stored in them during braking (at the points of cycle D or B) can be transferred to additional elements 4 or 5 and used in the future when overclocking the link (at points A or C, respectively).

In this case, two options for the redistribution of energy in the cycle of the link movement are possible. The first of them is the fact that the only part of the energy stored, for example, in storage devices 2, is transferred to element 4, and the remaining - serves to overclocking the feet on next phase A. The energy stored in element 4 is used to accelerate the link at point C (since there is not enough energy of accumulator 3), while element 5 can be excluded from the general scheme. A concrete realization of the work under this scheme can be carried out on the basis of various storage devices, the possibility of their application being determined by their ability to differentiate stored energy and redistribute it. The use of such storage devices, for example, with compression springs, requires a special ratio of the speeds of the reversible link of the special adjustment of the elastic elements, and therefore can not be used in variable modes of motion.

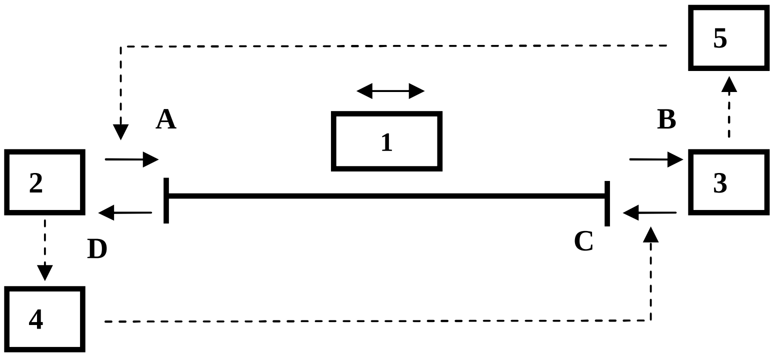

Figure 1. A principle scheme of the operation of the recuperative device with reverse link with increasing speed.

Difference of the second variant of redistribution of energy is that overclocking link in each phase is at the expense of energy accumulated when braking in the same phase. In this case, storage devices 2 gives to element 4 all the energy stored by the braking of the link at point D, and the acceleration of the link at point A is due to the energy of element 5 stored in the previous cycle of motion.

An obvious advantage of this scheme of operation of the energy recuperator is the simplicity of organizing redistribution of the required amount of energy under any conditions without special adjustment of the elements of the system. The proposed drive of such device is shown in the figure.

Link 1 makes oscillatory movements relative to the housing under the action of rodless pneumatic cylinder 2. Resistance to movement is overcome by constant gas pressure in magistral 3. For the reversals of link 1 with increasing speed, it is proposed to include two three-line distributors 4, 5 and two storage tanks 6 and 7 for storing energy in the traditional scheme pneumatic cylinder control circuit.

Let us consider the operation of this device (Figure 2). The authors denote all the events associated with changing the speed of link 1 by letters A, B, C and D. Figure 2 shows the drive status of the drive state with energy recovery turned off, and letters represent the positions of the valves, which should be linked cavity of pneumatic cylinder 2 with storage tanks 6 and 7 at the time of occurrence of a given event.

Event A corresponds to the beginning of the movement of the link from the extreme left position. The speed of the link is determined by the energy reserve in tank 6.

In the extreme right position, event B occurs. The deceleration of link 1 is accompanied by compression of the gas in tank 6. The energy accumulated in this case will remain until the occurrence of event A.

Event C corresponds to the beginning of the movement of the link from the extreme right position. The speed of link 1 is determined by the energy reserve in tank 7.

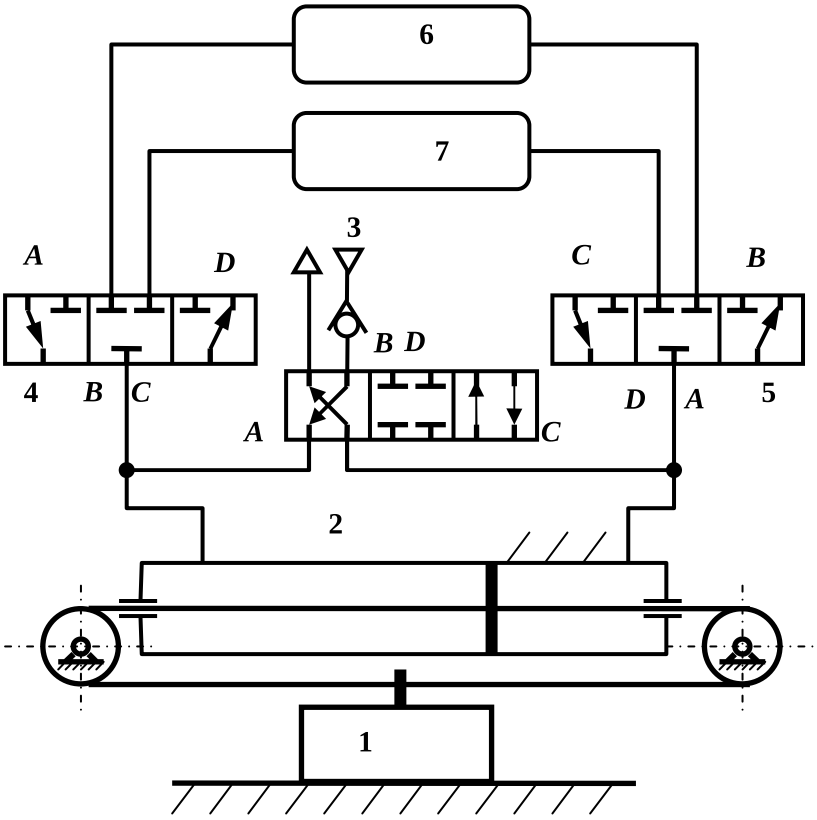

Figure 2. A principle scheme of a pneumatic energy recuperator with reverse link with increasing speed.

In the extreme left position, there is event D at which link 1 is stopped due to the elastic deformation of the gas in tank 7. The energy stored in this case will remain until the occurrence of event C. Then all events are cyclically repeated.

3. Identification of parameters

In all cases, maximum performance is possible with a shortening of the working element reversal time, which corresponds to impact interaction between them and the machine hull. When using the energy recuperator, the working elements that have completed one phase of the movement partially restore the speed in the other phase due to their own energy, which allows them to represent their interaction with the hull as an elastic blow.

To determine the velocity of the hull after the blow within the dynamic model, one must known at what relative speed at that moment the working element is moving. Obviously, this movement depends on the type of energy recuperator and its construction. The solution of this problem is impossible within the framework of classical mechanics, which introduces the assumption of absolute hardness of bodies. Therefore, additional relationships are required to determine the kinematic parameters of the motion of the working member when interacting with the energy recuperator.

For this case, it is possible to use universal functions qualitatively determined by the type of energy recuperator and associated with its mass. These include, for example, the maximum coefficient useful action:

$$\eta_{рэ} = \frac{T_{к}}{T_{н}}, \tag{1}$$

where $T_{н}$ and $T_{к}$ – kinetic energy of the reversible mass, respectively before and after interaction with the energy recuperator.

Specific energy intensity is:

$$\beta = \frac{E}{m}, \tag{2}$$

where E – maximum energy, [J], which can be accumulated by the energy recuperator when the working element brakes, m – the mass of energy recuperator [kg]. Specific mass is:

$$\lambda = \frac{m}{N}, \tag{3}$$

where $N = \frac{E}{t}$ – maximum power of energy recuperator [W], t – reversing time of working element [s].

Minimum reversal time t is determined for the energy recuperator of each type from (2) and (3):

$$t = \lambda \cdot \frac{E}{m}. \tag{4}$$

It is obvious that for a given energy recuperator mass, when calculating t according to (4), one should observe condition $E/m \leq \beta$. In this case, value of energy E stored by the energy recuperator is determined as follows:

$$E = T_{нг} = \frac{1}{2} \cdot M \cdot \frac{m}{(M+m) \cdot (V_{1н} - V_{2н})^2}, \tag{5}$$

where $T_{нг}$ – initial kinetic energy calculated in a reference frame connected with the center of mass of the bodies entering each impactor pair, the working element is the hull before their interaction, $V_{1н}$ and $V_{2н}$ - absolute speeds at this time, respectively hull and working element.

Similarly, the kinetic energy after the reversal of the working element:

$$T_{kr} = \frac{1}{2} \cdot M \cdot \frac{m}{(M+m) \cdot (V_{1к} - V_{2к})^2}. \tag{6}$$

When the energy recuperator is installed on the machine hull, $T_{к} = T_{kr}$, $T_{н} = T_{нг}$, then let us combine (1), (5) and (6):

$$\eta = \frac{T_{kr}}{T_{нг}} = \left(\frac{V_{1к} - V_{2к}}{V_{1н} - V_{2н}} \right)^2. \tag{7}$$

Here the expression enclosed in parentheses is recovery coefficient k, known in the theory of impact, characterizing the amount of conservation of the normal velocity component after blow:

$$k = \left| \frac{V_{1к} - V_{2к}}{V_{1н} - V_{2н}} \right|$$

And then using (7), let us get: $k = \sqrt{\eta}$.

With k considering the working element, like the hull, by absolutely rigid bodies, considering the interaction between them such as an elastic blow, it is possible to determine all the kinematic parameters of the machine's motion after changing states. Assuming the impact impulse to be concentrated, distribution in time of the transient processes in the energy recuperator can be expressed through (4). The value of t does not change the result of the blow and should be taken into account only when calculating the cycle time.

4. Conclusion

The considered variants of the principle schemes of energy recovery with link reversals with increasing speed make it possible to find an approach to the design of the energy recuperator excluding possible energy losses during its operation.

It should be noted that the proposed parameters of the dynamic models of mechanical systems should be used only to assess the ultimate capabilities of a regenerative drive since their results can only theoretically be achieved with a minimum possible mass of the energy recuperator and its maximum possible speed.

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