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ACCURACY RESEARCH OF WORKING MECHANISM POWER SHOVEL ACTUATOR WITH CONSIDERING DYNAMIC CHARACTERISTICS

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ABSTRACT

When performing works on improvement in the city line, a variety of road and construction machines are used, however, in case of inaccurate operation of such machines, previously laid communications can be damaged, which leads to disturbances in the operation of urban systems affecting thousands of people. In this article estimation of the accuracy of the position of the cutting edge of the bucket is given taking into account the temperature expansion of the links, the variable cutting forces, the delay of the hydraulic drive, gaps and elastic deformations in kinematic pairs. Based on the calculations carried out, recommendations are proposed for developing methods to improve the accuracy of digging.

Keywords: shovel excavator, mathematical model, automatic control system, temperature expansion, resistivity to cutting, precision.

INTRODUCTION

When performing works on improvement in places of historical and cultural value, or when carrying out work in the city, there is a need to perform a significant part of them using construction equipment. If these works are not accurately carried out, it is possible to damage the cultural layer or previously laid communications.

LITERATURE REVIEW

One of the most versatile construction machines is a single bucket shovel excavator. The task of investigating the accuracy of production and the search for possible ways to improve accuracy is important for the developers of such machines [1, 2]. According to the building codes and rules in force in Russia, the deviation of the marks when working with a single bucket excavator is allowed not more than 0.05 m [3]. Modern excavators are equipped with a control system that allows you to quickly assess the position of the cutting edge of the bucket, the initial and processed profiles of the ground surface and inform the operator of errors

in operation [4, 5]. However, most modern systems operate in automatic mode only on finishing operations, while untimely embedment of the cutting edge is possible not only on the finishing operations, which can lead to the breakage of existing communications.

METHODOLOGY

The purpose of this work is to analyze the accuracy of the possible production of excavation works, produced by single-bucket excavators. The position of the working mechanism, as well as the initial and processed profiles of the ground surface, are characterized only by the coordinates along the x and y axes, with the rotation of the working mechanism relative to the caterpillar base not considered because at that moment no longitudinal profile of the bottom of the trench. Kinematic diagram of the working mechanism of the caterpillar excavator Chetra EGP-230, produced by the Cheboksary enterprise "Chetra - Industrial Machines", is presented in figure 1.

The position of the cutting edge of the excavator bucket can be described by the function f=f(s1, s2, s3) of the generalized coordinates of the input action, where s1, s2, s3

– linear coordinates characterizing the displacement of the rods of hydraulic cylinders [3, 6, 7].

The mathematical model of the working mechanism on the basis of structural-kinematic relationships makes it possible to study the characteristics of the kinematic chain of the working mechanism, to evaluate the influence of each of the links on the position of the cutting edge of the bucket, and to estimate the accuracy of the position of the cutting edge as a function of the input generalized coordinates s1, s2, s3.

DATA ANALYSIS

For the compiled mathematical model, errors in the valve cylinders were taken into account, which has a significant effect on the position of the cutting edge of the bucket of the excavator [8]. The distribution of possible errors in the service area is shown on figure 2.

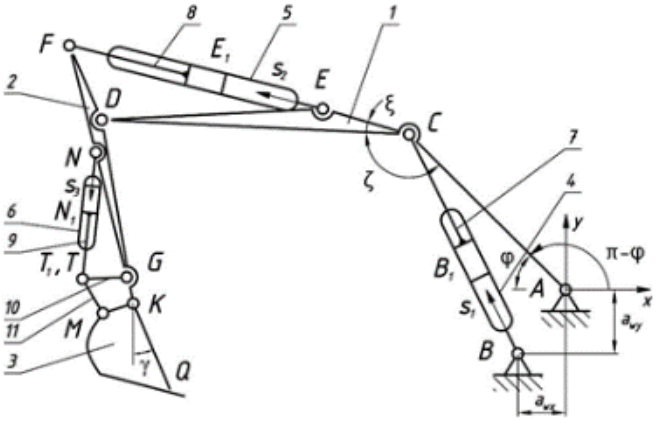

Figure 1 – Kinematic scheme of the working mechanism, where 1 – boom; 2 — handle; 3 — bucket; 4, 5, 6 — cylinders; 7, 8, 9 — valve cylinders; 10 — rocker; 11 — thrust

The trajectory of the cutting edge of the bucket of the working mechanism is simulated in the temperature range from minus 30 to plus 50 ° C when the generalized coordinates of the input action

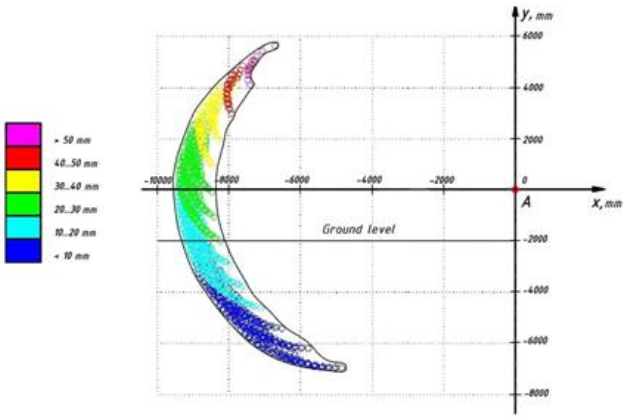

Figure 2 – Distribution of possible errors in position of the cutting edge of the bucket in the service area

In addition, the accuracy of the position of the cutting edge is affected not only by the geometric characteristics of the links, but also by the possible effect of temperature. The use of technology only in Russia suggests a wide range of possible ambient temperatures. To specify the temperature range for the middle zone of Russia: from minus 30 to plus 30°C. However, in the warm season at an ambient temperature of plus 30°C under direct sunlight, additional heating of the links of the working mechanism up to 50°C can occur.

The temperature influence of the environment on the links of the working mechanism affects simultaneously all the links of the kinematic chain, which affects the position of the cutting edge of the bucket. The possible change in the lengths of the links of the working mechanism of the excavator is calculated taking into account the values of the linear coefficient of temperature expansion as a function of temperature.

s2 and s3 change from the minimum to the maximum values and the constant value s1 = 0 mm, the results are shown in figure 3.

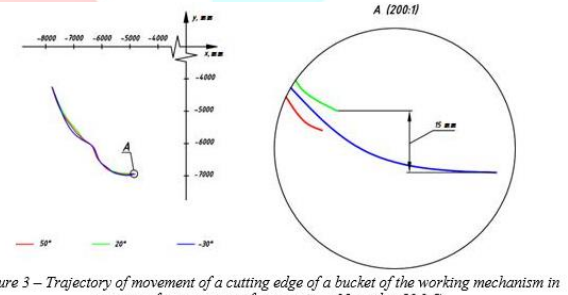

Figure 3 – Trajectory of movement of a cutting edge of a bucket of the working mechanism in a range of temperatures from a minus 30 to plus 50 ° C

Changing the lengths of links leads to a positioning error of 15 mm in the vertical coordinate in the presented case.

To assess the possible errors of digging in the construction of a mathematical model, in addition to the geometry of the kinematic chain, it is necessary to take into account the time dependence of its parameters represented by generalized coordinates that are functions of time, s1,2,3=f(t).

The greatest influence is exerted by dynamic influences from variable cutting forces, which can not be determined in advance. On the entire trench digging process, according to the cyclogram of the working process (figure 4), it is possible to distinguish the stages when the process of untimely bucket penetration is possible.

generalized coordinate	1	2	3	4	5	6	7
S_1							
S_2							
S_3							

Figure 4 – Cyclogram of the working process

The formation of the longitudinal profile of the bottom of the trench under development takes place at the stage 6, and hence the change in the generalized coordinate s3 can have the greatest effect on the introduced errors in the position of the bottom of the trench. The digging process is treated as a process with one degree of freedom, at each moment only one generalized coordinate changes. When the generalized coordinate s3 is changed, the remaining generalized coordinates do not change.

The calculation of dynamic characteristics allows us to estimate the possible deviation of the input generalized coordinate s3, which is determined by the displacement of the rod of the hydraulic cylinder of the working mechanism, from the theoretical value specified by the control action. The calculation is performed at values of the generalized coordinates s1 = 0 m, s2 = 0 m, the results are shown in figure 5.

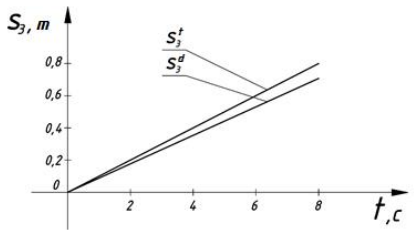

Figure 5 – Deviations of the positions of the generalized coordinate $s3^d$ with the dynamic characteristics of the working mechanism of the theoretical values $s3^t$

Calculations were made for a fixed value of the cutting resistivity, which even for one category of soil can fluctuate significantly, which can lead to unpredictable deviations in the position of the cutting edge of the bucket from the required position.

When dynamic characteristics of the working mechanism are taken into account, the difference between the set and received positions is 89.2 mm at the end of stage 6 of the work cycle, and when the random component of the cutting force is taken into account, the difference is 92.5 mm.

The accuracy of production is also affected by hydraulic drive lag, gaps and elastic deformations in kinematic pairs. The parameters presented in the literature, obtained experimentally, can be used to calculate the errors in the displacement of

the working member with allowance for retardation, gaps in the movable joints in the kinematic pairs of the working mechanism. The method of accounting for the gaps was proposed by N. Alaadin [9]. For different positions of the kinematic chain of the working mechanism, on the average, the positioning error along the vertical coordinate in the presented case is from minus 13 to plus 15 mm. In addition, it was indicated [9] that the elastic deformations of the links also lead to positioning errors, and the resulting deviations due to the presence of gaps and elastic deformations are approximately the same.

The total error in the position of the cutting edge of the bucket of the working mechanism can be determined as the sum of the errors:

$$\Delta wm = \Delta 1 + \Delta 2 + \Delta 3 + \Delta 4 + \Delta 5,$$

where Δwm – error of working mechanisms; Δ1 – dynamic component of error; Δ2 – hydraulic lag error; Δ3 – error of gaps in kinematic pairs; Δ4 – error of elastic deformations in kinematic pairs; Δ5 – technological component of error.

Taking into account the foregoing, the total error in the position of the cutting edge of the bucket of the working mechanism is 171.9 mm, which exceeds the required value of 50 mm by 3.4 times.

DISCUSSION

Inaccuracy of the position of the cutting edge of the bucket of the working mechanism can lead to the destruction of the cultural layer, as well as to the breakage of communications. To solve this problem, it is necessary to develop a methodology for making changes in the control system of the working mechanism of the excavator [10, 11].

CONCLUSION

The conducted researches allowed to draw the following conclusions:

The constructed mathematical model allows to take into account accuracy issues;

The working mechanism of the excavator has insufficient accuracy;

Requirements for the management system have been formed.

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