KNIFE SIZING FOR THE SRS 4000 BUCKET WHEEL EXCAVATOR

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ABSTRACT: This article focuses on determining the dimensions of a specific knife of the SRS 4000 bucket wheel excavator. The calculated scheme chosen is in the form of a broken spatial frame. It is supported by four inclined rods and its two ends are fixed. Most of the frame lies in one plane. The load on the teeth of the knife is asymmetric. It is divided into two groups. The first group includes transverse forces and moments, lying in the plane of the frame. The second load group is composed by forces lying in the plane of frame and moments perpendicular to it. Both load groups lead to the solution of two tasks. In the first task, the frame is subjected to the first load group. The calculation scheme is frame supported by four vertical rods and clamped at both ends. The solution is described in previous articles. The current article solves the second problem. The frame is loaded with the second load group. The components of the reactions in the inclined rods lying in the plane of the frame are added to this load group. To determine the internal moments, the force method is used. The solution is illustrated by a numerical example. For a specific frame, first the reactions of the inclined rods loading the frame are determined. Then, a force method is applied and the reactions at both ends of the frame and the internal moments are obtained. Finally, the dimensions of the knife are calculated.

Key words: bucke knife, stresses, force method.

ОРАЗМЕРЯВАНЕ НА НОЖ НА КОФА ЗА РОТОРЕН БАГЕР SRS 4000

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РЕЗЮМЕ: Статията е фокусирана върху оразмеряване на нож на кофа за роторен багер SRS 4000. Избрана е изчислителна схема с форма на начупена пространствена рамка. Тя е подпряна с четири наклонени пръта и е запъната в двата края. Голяма част от рамката лежи в една равнина. Натоварването върху зъбите на ножа е несиметрично. То се разлага на две групи. Първата група включва напречни сили и моменти, лежащи в равнината на рамката. Втората група натоварване се състои от сили, лежащи в равнината и моменти перпендикулярни на нея. Двете групи натоварване води до решаване на две задачи. В първата задача рамката е подложена на първата група натоварване. Изчислителната схема е рамка, подпряна с четири вертикални пръта и е запъната в двата края. Решението е описано в предишни статии. Тази статия решава втората задача. Рамката е натоварена с втората група натоварване. Към него са прибавени компонентите на реакциите в наклонените пръти, лежащи в равнината на рамката. За определянето на вътрешните моменти се прилага силов метод. Решението е илюстрирано с числен пример. За конкретна рамка първо са определени реакциите в прътите, натоварващи рамката. След това е приложен силов метод и са получени реакциите в двата края на рамката и вътрешните моменти. Накрая са изчислени размерите на ножа.

Ключови думи: ножа на кофа, напрежения, силов метод.

Introduction

The dimensions of a bucket knife for the SRS 4000 rotary excavator are determined on the basis of technical calculations. They start by choosing a calculation scheme. The bucket knife is replaced with the broken frame supported by four inclined rods. The load on the teeth is asymmetric and decomposed into two types. The first type includes transverse forces and moments lying in the plane of the frame. The second type of load consists of forces lying in the plane of the frame and moments perpendicular to it.

The first type of loading leads to the solution of a special broken frame described in previous works of the authors (Vucheva et al., 2017, 2018, 2021). The frame is supported by vertical rods. Their reactions determine the reactions in the inclined rods.

The main purpose of this paper is to describe the solution of the framework resulting from the action of the second type of load.

Methods

1. Formulation of the problem

The frame is clamped at both ends (A_*, B_*) and is supported by rods at points K, I, A_3, and C (fig.1). The components of the rods are determined by the dependences given in (Dinev et al., 2016b). They involve the vertical reaction of the support rods, the result of the solution of the first problem (Vucheva et al., 2021). To these components of the rods are added the forces (P_i^{**}), the bending moments (M_{zi}), applied in points A_i ($i = 1 \div 4$) (Dinev et al., 2016a, 2016b).

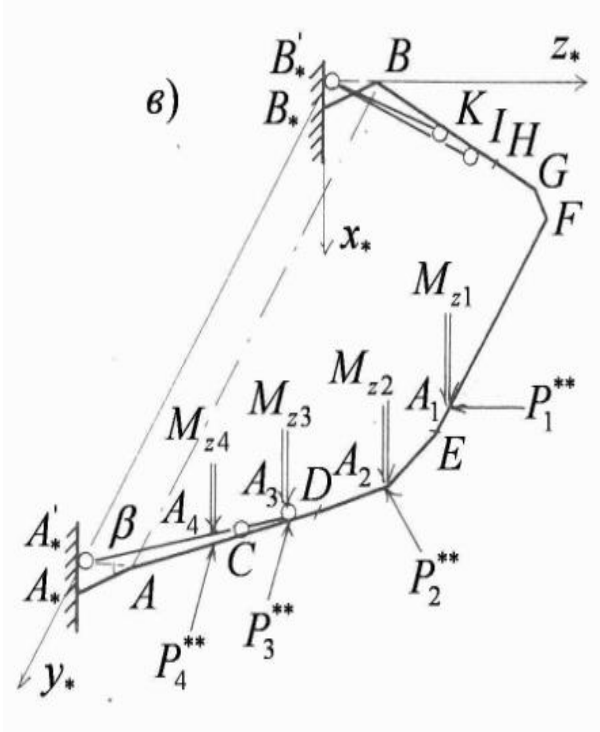

Fig. 1 Calculation scheme

2. Internal moments in the frame

The frame is clamped on both sides and has three unnecessary connections. The forces method (Kisyov, 1978; Vulkov, 2011) is used to determine the reactions in it.

2.1. Reactions in the supports

When choosing a basic system, the reactions in support B_* are considered redundant. The main system is a frame clamed at end A_*. The system of equations of the method is compiled. These equations express the equivalence conditions for the basic and for the given system:

$$[A]\{X\} = \{B\}, \tag{1}$$

where

$$\{X\}^{-1} = \{X_1 \quad X_2 \quad X_3\}^{-1};$$
$$\{B\}^{-1} = \{B_1 \quad B_2 \quad B_3\}^{-1};$$

$$[A] = \begin{bmatrix} \delta_{12} & \delta_{12} & \delta_{13} \\ \delta_{21} & \delta_{22} & \delta_{23} \\ \delta_{31} & \delta_{32} & \delta_{33} \end{bmatrix}.$$

The elements of matrix $[A]$ and vector $\{B\}$ of equation (1) are determined by expressions given in a previous works of the author (Vucheva et al., 2021).

The main system is loaded successively by an external load and by unit forces and moment applied to support B_*. For each load, the corresponding diagrams of the internal moments are obtained.

The system of linear equations (1) is solved by the Gaussian method. The other reactions in support A_* are determined by equilibrium equations (Vulkov et al., 2013).

2.2. Internal moments

The formulae for the internal moments in the frame of figure 1 are given the above-cited authors’ work.

3. Stresses

To determine the dimensions of the cross section in the frame, the strength condition is used:

$$\sigma_{eq}^{III} \le \sigma_{adm}, \tag{2}$$

where

σ_{adm} is the allowable stress for a given material;

σ_{eq}^{III} is the equivalent stress according to the third strength theory.

The expression of stress is given in a previous work by the authors (Vucheva et al., 2021). It involves the internal and resistance moments to three axes in the endangered sections. The cross section is rectangular. The unknown dimensions are two: width and height. Therefore, the width is considered known. The resistance moments are expressed by the unknown height. After simple operations, a fourth degree equation is reached. Its roots are determined by the chord method (Petrova-Deneva et al., 1977).

4. Numerical example

The vertical components of the inclined rods in the frame were obtained in a previous work of authors (Vucheva et al., 2021). They are given in the second column of table 1. The other components of the rods are listed in the next two columns of the table.

Table 1. *Components of the rods, kN*

S_i	x_*	y_*	z_*
S_K	3.42	0.45	1.49
S_I	-313.17	-41.55	-136.75
S_3	-120.34	-15.97	-52.55
S_C	379.23	50.31	165.60

The main system is subject to the action of external forces and moments. From the solution of this problem, the internal moments in Table 2 are obtained.

Table 2. *Internal moments in main system by external load, kNm.*

point	M_x	M_y	M_z
I	0	0	-0.17
H	0	0	10.36
G	0	0	32.75

F	0	0	63.33
A_1	0	0	149.48
E	0	0	160.72
A_2	0	0	181.22
D	0	0	196.90
A_3	0	0	200.23
C	0	0	202.15
A_4	0	0	207.98
A	-80.45	189.55	205.92
A_*	-74.97	176.64	191.89

The internal moments in the main system, which is loaded with single forces and moment, are also obtained. They participated in the expressions for elements in the matrix $[A]$ and the vector $\{B\}$. Ready-made tables (Trifonova-Genova et al., 2017) are used in their calculation. The results are given in Tables 3 and 4.

Table 3. *Elements* $\delta_{ij}.10^{-6}$

δ_{11}	δ_{12}	δ_{13}
49.088	18.180	-0.317
δ_{22}	δ_{23}	δ_{33}
30.367	-0.223	0.004

Table 4. *Elements* $\Delta_i^P.10^{-6}$

Δ_1^P	Δ_2^P	Δ_3^P
-3 514.060	-2 552.089	37.319

Applying the Gaussian method, the support reactions in the redundant connections of the frame are obtained. Their values are shown in Table 5.

Table 5. *Reactions in supports:* X_i

X_1	X_2	X_3
-7.701	-11.651	9 221.679

The final internal moments of the given frame of figure 1 are shown in table 6. It turns out that these values are smaller than the internal moments for first type of load. Therefore, these moments do not increase the dimensions of the cross-section obtained in a previous work of the authors.

The stresses for the spatial frame according to formula (2) are checked. The internal moments are a sum of the internal moments from this and previous work of the authors. The final dimensions of the cross section of the frame are those of the above-cited work of the authors (Vucheva et al., 2021).

4. Key finding

The article describes the second stage of an algorithm for determining the cross-sectional dimensions of a specific frame.

The results of the solution of this problem show that the influence of the second type of load on the dimensions of the frame is small. The computational work is reduced. Instead of solving a spatial frame, a planar-spatial frame is solved.

Table 6. *Internal moments, kNm.*

point	M_x	M_y	M_z
B_*	0	0	92.22
B	0	0	94.38
K	0	0	99.40
I	0	0	101.21
H	0	0	113.38
G	0	0	138.43
F	0	0	170.83
A_1	0	0	263.09
E	0	0	274.16
A_2	0	0	298.26
D	0	0	310.12
A_3	0	0	313.79
C	0	0	313.29
A_4	0	0	328.88
A	-81.37	188.94	314.25
A_*	-75.89	176.03	298.05

Conclusion

This paper presents a solution to the second problem of a method for determining the dimensions of a bucket knife for a rotary excavator SRS 4000. The following advantages can be deduced from the obtained numerical results:

1. The described method enriches the analytical methods for solving spatial frames under the action of spatial loading.
2. It uses the force method. This method is easy to apply by designers when designing a bucket knife.

References

Dinev, N., R. Vucheva, V. Trifonova-Genova. 2016a. Numerical modelling of load on the knife of bucket. - *Annual of University of Mining and Geology “St. Iv. Rilski”, 59*, Number III: Mechanisation, Electrification and Automation in Mines, 41–44 (in Bulgarian with English abstract).

Dinev, N., R. Vucheva, V. Trifonova-Genova. 2016b. Study on the stress state of knife bucket. - *Annual of University of Mining and Geology “St. Iv. Rilski”*, 59, Number III: Mechanisation, Electrification and Automation in Mines, 38–40 (in Bulgarian with English abstract).

Kisyov, I. 1978. *Saprotivlenie na materialite*. D. I. “Tehnika”, Sofia, 594p. (in Bulgarian).

Petrova-Deneva, A., V. Dimova-Nacheva, N. Stoyanov. 1977. *Vissha matematika – chast 5*. D. I. “Tehnika”, Sofia, 299p. (in Bulgarian).

Trifonova-Genova, V., M. Valkov, A. Stoyanov, S. Sezonov. 2017. *Saprotivlenie na materialite, Sbornik ot zadachi I* *metodichni ukazania*. Izd. Kashta “Sv. Iv. Rilski”, Sofia, 320p. (in Bulgarian).

Vulkov, M. 2018. *Saprotivlenie na materialite – II chast*. Izd. Kashta “Sv. Iv. Rilski”, Sofia, 268p. (in Bulgarian).

Vulkov, M., S. Pulev. 2013. *Rakovodstvo za reshavane na zadachi po teoretichna mehanika. Chast 1, Statika*, Izda. Kashta “St. Iv. Rilski”, Sofia, 133p. (in Bulgarian).

Vucheva, R., V. Trifonova-Genova. 2017. An approach for determining the internal forces in a bucket knife - *Journal of Mining and Geological Sciences*, *60*, Number III: Mechanisation, Electrification and Automation in Mines, 34–38.

Vucheva, R., V. Trifonova-Genova. 2018. Determining the diagrams of internal forces in a knife on an excavator bucket - *Journal of Mining and Geological Sciences*, *61*, Number III: Mechanisation, Electrification and Automation in Mines, 29–33.

Vucheva, R., V. Trifonova-Genova. 2021. Determining the stresses in bucket knife of SRS 4000 bucket wheel excavator - *Journal of Mining and Geological Sciences*, *64*, Number III: Mechanisation, Electrification and Automation in Mines, 143–146.