DETERMINING THE DIAGRAMS OF INTERNAL FORCES IN A KNIFE ON AN EXCAVATOR BUCKET

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ABSTRACT. The article examines the internal forces in a specific knife on the bucket of an excavator. The knife is modelled as a broken planar and spatial frame. The load on the teeth of the knife is asymmetric. It is located on the local axes of the sections of the frame. The case studied here is of loading that is composed of concentrated forces and moments. The former are transverse to the frame, the latter lie in its plane. The two ends of the frame are cramped. Furthermore, it is supported by four-point rods. To determine the internal forces in the undefined frame, a method of forces is used.
For a particular knife, the basic frame is selected. It consists of fifteen sections. The basic frame is then loaded both with concentrated single forces and moments applied in the places of redundancy, as well as with a load from the teeth of the knife. The torsions and the bending moments at the border points of each section are obtained. The coefficients of unknown reactions in the equations of the selected method are calculated through the energy methods of the resistance of the materials. The results obtained are only part of the developed methodology by which the internal forces in a bucket knife are determined.

Keywords: bucket knife, internal forces, spatial frame.

ОПРЕДЕЛЯНЕ НА ДИАГРАМИТЕ НА ВЪТРЕШНИ СИЛИ В НОЖ НА КОФА НА БАГЕР

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РЕЗЮМЕ. В статията се изследват вътрешните сили в конкретен нож на кофа на багер. Ножът е моделиран като начупена равнинно-пространствена рамка. Натоварването върху зъбите на ножа е несиметрично. То е разположено върху локалните оси на участъците на рамката. Тук се разглежда случай на натоварване, състоящо се от съсредоточени сили и моменти. Първите са напречни на рамката, вторите лежат в нейната равнина. Двата края на рамката са запънати. Освен това в четири точки тя е подпряна с напречни прътове. За определяне на вътрешните сили в неопределената рамка се използва силов метод.
За конкретен нож е избрана основна система, която се състои от петнадесет участъка. Системата се натоварва последователно както със съсредоточени единични сили и моменти, приложени в местата на излишните връзки, така и с натоварване от зъбите на ножа. В граничните точки на всеки участък са получени стойностите на огъващите и усукващите моменти. С енергетичните методи на съпротивление на материалите са изчислени коефициентите пред неизвестните опорни реакции в уравненията на избрания метод. Тези резултати са само част от етапите на разработена методика, чрез която са определени вътрешните сили в ножа.

Ключови думи: нож на кофа, вътрешни сили, пространствена рамка.

Introduction

The model of a knife of the bucket of the SRS 4000 excavator is described in (Dinev et al., 2016). The dimensions of the concrete computational scheme and the load on the teeth for this model are obtained in the same article. A possible case of loading of a knife is considered in (Vucheva et al., 2017). It includes concentrated forces transverse to the plane of the frame and moments lying in its plane. The algorithm for determining the internal force at the border points of each section of the frame is described in detail. It includes the figures and analytical expressions of the internal forces. The purpose of this work is to obtain and analyse the numerical values of the internal moments at indicated points in the frame.

Methods

1. Application of the problem

The broken spatial frame is tilted at two ends (A , B_*). It is supported by four vertical rods at points K , I , A_3 , and C (Fig.1). On the one hand, the load includes the forces (P_i^*) parallel to the axis and, on the other hand, the bending and torsion moments (M_{yi} , M_{xi}), which lie in the $y_* z_*$ plane. These concentrated forces and moments are applied at points A_i ($i = 1 \div 4$).

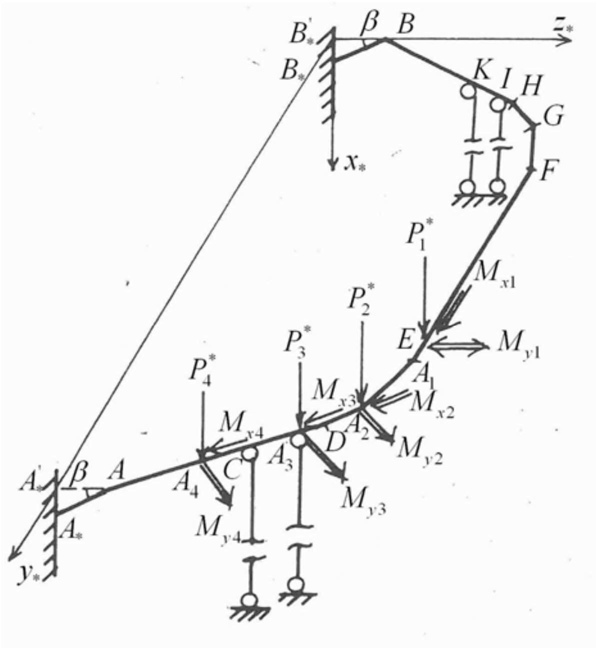

Fig. 1. Computational scheme

The frame is undetermined. For determining the reactions in the connections, a force method is used. According to it, the reactions at points B_*, K, I, A_3, and C are extracted and then the basic frame is obtained. It is tilted to point A_*. The reactions in the supports are determined by two sets of equations: for equilibrium and for deformations (Kisyov, 1978). The former equations are written for an undetermined frame. The latter set of equations has two kinds of coefficients. The first are obtained through moments as a result of the actions of the concentrated forces and the moments of magnitude one in basic frame. The other kind of coefficients is determined by using the values of moments by an external load in the same frame.

2. Diagrams of the moments

2.1. Diagrams of unit forces

The methods of the resistance of the materials are used here (Valkov, 2011; Trifonova-Genova et al., 2017). Each of the diagrams results from the consistent application of forces, equal to $1kN$, applied at points B_*, K, I, A_3, and C of the basic frame. The moments M_y^j and M_x^j are projections of the moment M_k^j (Fig.2). The latter is equal to the distance d_k^j between point k of a given section and the applied point of force j (Valkov, 2004; Valkov et al., 2013). The angle δ_k is calculated by the slope β_k of the distance d_k^j and the slope α_i of section i by axis y_* (Vucheva et al., 2017).

The local moments in section AA_* are obtained by expressions (Fig.3):

$$M_x = M_{x'} \cos\beta \, ; \; M_z = M_{x'} \sin\beta \, . \qquad (1)$$

The moment $M_{x'}$ lies in the $y_* z_*$ plane, but axis x' is parallel to z_*.

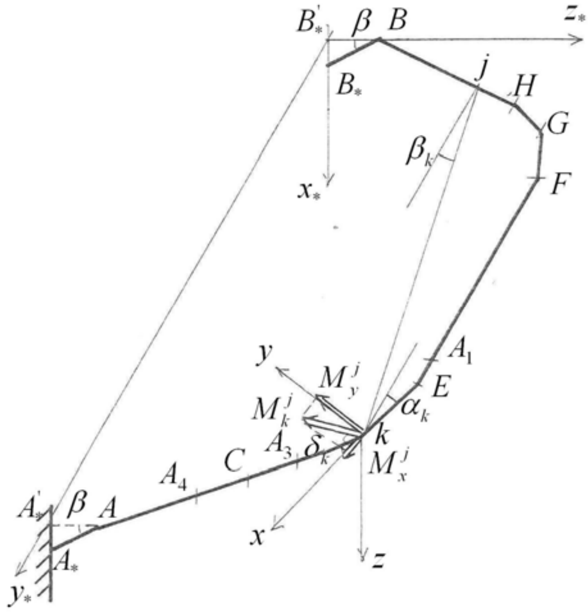

Fig. 2. Basic frame

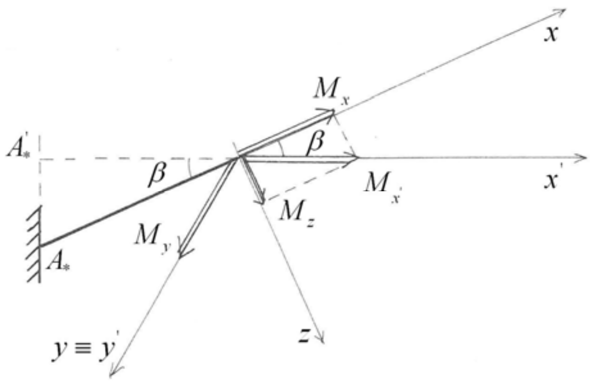

Fig. 3. Local moments in section AA_*

2.2. Diagrams of unit moments

The moments with a volume of $1kNm$ are successfully applied to the direction of reactions $M_{B_* z_*}$ and $M_{B_* y_*}$. The local moments $M_{x,2}$, $M_{x,3}$, $M_{y,2}$, and $M_{y,3}$ are expressed by the trigonometric function of the slope α_i of each section in the chosen coordinate system.

2.3. Diagrams by external load

The basic frame is loaded by forces parallel to axis x_*, and by bending and torsion moments (Fig.4). To obtain the values of the moments, and consequently the operation of forces, the approach described in 2.1 is applied. The concentrated moments are projected to the local axis of the section. Finally, the values of the two types of moments are summed up.

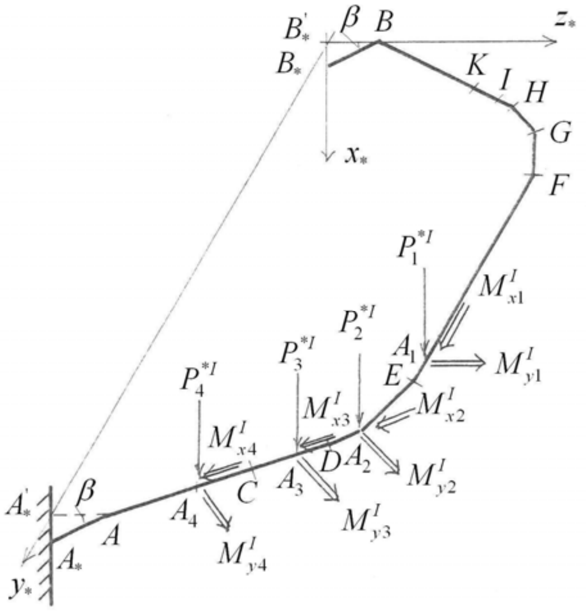

Fig. 4. External load on the basic frame

3. Numerical example

The frames in Figures 1, 2, and 4 have the dimensions taken by (Dinev et al., 2016). The load in Figure 4 can be seen in the same article.

The basic frame is loaded with three kinds of load: forces equal to $1kN$, moments equal to $1kNm$, and external load. The results of the first load are given in Tables 1, 2, and 3. These forces are loaded at points B_*, K, I, A_3, and C.

The results of the second kind of load are given in Table 4. These values correspond to the group of points which are explicated in Table 5. For Table 4, it is typical that some values are negative. These are the values of $M_{x,3}$ from point K to point F and the values of $M_{y,2}$ from point E to point A.

The third kind of load is taken from Tables 3 and 4 of the work of (Dinev et al., 2016). Thus, the values in Table 6 are obtained.

4. Key findings

The described algorithm for determining the values of the internal moments is applied to a concrete broken planar and spatial frame. It is the generalisation of a known solution for a rectangular plane-space frame (Kisyov, 1978). It can easily be adapted for other form of a frame. The values in the tables will be used to calculate the coefficients in the equations of deformation (Vucheva et al., 2017).

All values in the tables will be used for calculating coefficients δ_{ij} and Δ_{iP}. Their formulae can be seen in the work by (Vucheva et al., 2017). They are part of a system of equations whose solution is the subject of a future work.

Table 1.

Bending moments by units of force at points B_*, K, and I

point	$M_{y,1}$	$M_{y,4}$	$M_{y,5}$
B_*	0		
B	18.6		
B	17.11		
K	53.61		
K	53.63	0	
I	68.13	14.4	
I	68.34	14.4	0
H	80.31	26.5	12.0
H	74.80	25.33	11.42
G	93.84	44.43	30.58
G	64.06	33.63	24.03
F	80.40	49.98	45.57
F	41.48	35.58	37.46
A_1	121.42	107.09	101.48
A_1	121.39	107.09	101.48
E	129.13	114.84	109.20
E	90.90	94.23	93.20
A_2	107.25	110.58	109.50
A_2	20.69	52.05	58.81
D	39.80	71.17	86.90
D	1.92	29.26	50.20
A_3	2.05	41.32	51.63
A_3	2.16	44.71	54.80
C	16.6	59.14	69.22
C	14.55	57.50	67.70
A_4	29.12	72.08	82.26
A_4	34.67	75.71	85.39
A	55.57	97.61	107.58
A	18.600	33.59	46.90
A_*	0	52.20	65.50

Table 2.

Moments by units of force applied at points A_3 and C

point	$M_{x,6}$	$M_{x,7}$	$M_{y,6}$	$M_{y,7}$
A_3	0	-	0	-
C	0	-	14.1	-
C	0.17	0	14.4	0
A_4	0.17	0	29.0	14.6
A_4	0.06	0.37	29.0	14.6
A	0.58	0.58	51.0	36.5
A	18.34	13.16	46.95	33.58
A_*	18.33	13.16	65.54	52.18

Table 3.
Torsions moments by units of force at points B_*, K, and I.

point	$M_{x,1}$	$M_{x,4}$	$M_{x,5}$
B_*	0		
B	0		
B	7.28		
K	7.28		
K	5.99	0	
I	7.08	0	
I	5.43	0.35	0
H	5.43	0.35	0
H	29.75	7.78	3.67
G	29.93	7.77	3.68
G	74.82	30.05	19.27
F	74.74	30.02	17.47
F	101.66	44.57	31.27
A_1	96.81	44.59	31.29
A_1	97.45	44.59	31.30
E	96.82	44.61	31.30
E	133.36	79.37	64.95
A_2	133.32	79.34	64.95
A_2	169.85	125.76	113.01
D	169.89	125.76	106.30
D	174.48	141.51	127.79
A_3	173.88	140.46	131.42
A_3	173.88	140.46	130.13
C	173.91	140.46	130.13
C	174.09	141.14	130.93
A_4	174.08	141.16	130.89
A_4	173.27	139.27	128.40
A	173.30	139.19	128.77
A	166.66	153.4	148.30
A_*	166.61	153.46	148.29

Table 4.
Moments by units of concentrated moments at point B_*

Group of points	$M_{x,2}$	$M_{x,3}$	$M_{y,2}$	$M_{y,3}$
I	1	0	0	1
II	0.95	0.32	0.32	0.95
III	0.63	0.77	0.77	0.63
IV	0.37	0.93	0.93	0.37
V	0.39	0.91	0.91	0.39
VI	0.38	0.93	0.93	0.38
VII	0.40	0.92	0.93	0.40
VIII	0	O.92	1	0
IX	0.39	-0.92	0.92	0.39

Table 5.
Explication of Table 4

Group of points	points
I	A_1, E
II	G, F, E, A_2
III	G, H, A_2, D
IV	H, I, D, A_3
V	I, K, A_3, C
VI	C, A_4
VII	A_4, A
VIII	B, B_*, A, A_*
IX	B, K

Table 6.
Moments by external load

point	$M_x^{P,M}$	$M_y^{P,M}$	$M_z^{P,M}$
A_1	-4.13	-0.61	
E	107.60	-0.61	
E	324.88	115.35	
A_2	339.39	39.79	
A_2	459.10	374.71	
D	1 374.93	224.98	
D	1 533.06	726.06	
A_3	1 949.20	635.56	
A_3	2 119.73	706.74	
C	3 324.14	595.40	
C	3 498.67	712.04	
A_4	4 703.08	634.28	
A_4	5 009.25	651.64	
A	7 600.77	563.59	
A	6 940.19	3 359.75	1 430.27
A_*	9 230.73	3 560.33	1 511.16

Conclusion

The values of the internal moments at points on a plane-space frame are presented in this article. They are the result of two types of load. The first type of load is by forces and moments with value one. The second type is external load. These loads are applied on the basic frame.

The results will allow to calculate the coefficients of basic system of equations with the method of the forces, as well as to determine the unknown reactions.

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