Determination of resistances to coal reclaiming at bridge-type stacker-reclaimer with bucket chain booms

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One of the basic stages in design of bridge-type stacker-reclaimer with bucket chain booms is identification of external loads caused by resistances to reclaiming process. In its nature, it is both dynamic and stochastic. In this paper it an original model is presented for calculating such loads, which, along with developed softwares, enables fast and accurate identification of its dynamic and stochastic characteristics. High accuracy, along with no sensibility for variation of constructive parameters and operating stages, presents main advantage of this model respected to other models in literature. This paper analyzes, on a real model, effects of some structural and operating parameters upon character and magnitude of loads caused by resistance to reclaiming process. It presents comparative analysis of output results obtained by this model and others that are given in literature. Finally, based on loads defined in this paper, it is possible to perform a static and dynamic behaviour simulation of structure and mechanisms of bridge-type stacker-reclaimer with bucket chain booms.

***Key words**: bridge-type stacker-reclaimer, bucket chain booms, kinematics of coal reclaiming process, resistances to coal reclaiming*

1. INTRODUCTION

Reclaimers are a basic link of bulk transportation system in thermal plants. They are generally categorized according to their functional and constructional characteristics. Within the class of bridge-type equipement with blending effect, the type of specially designed bridge-type stacker-reclaimer with bucket chain booms is shown in fig.1.

Figure 1 – Bridge-type stacker-reclaimer; Power plant "Kolubara" – Veliki Crljeni

Capability for changing the position of reclaiming bucket chain booms and central belt conveyor, along the bridge, enables such machine to have 4 working regimes:

- reclaiming the coal from tranches and transportation to the main belt conveyor (which goes in to the plant), fig. 2(a)

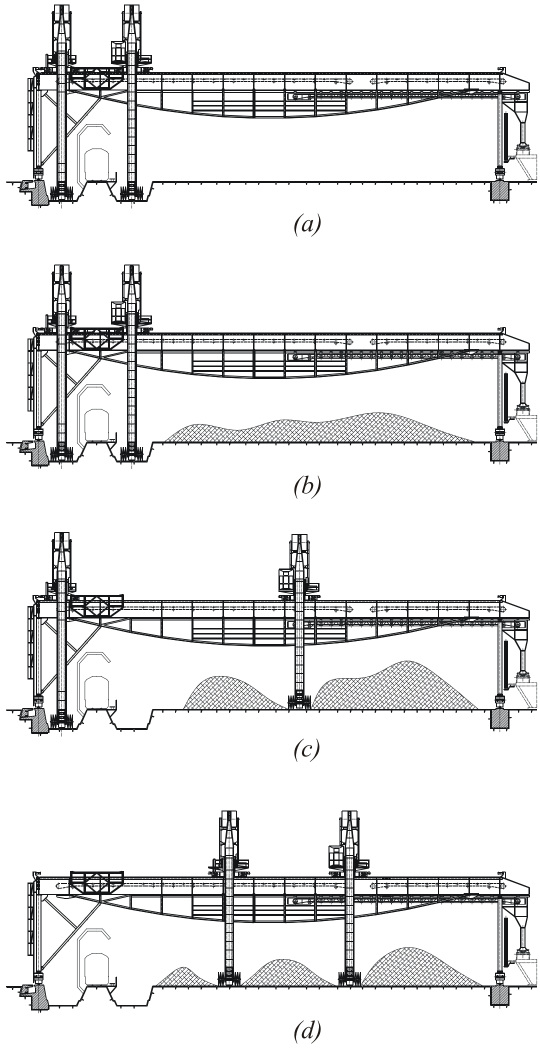

Figure 2. Working regimes of bridge-type stacker-reclaimer [6]

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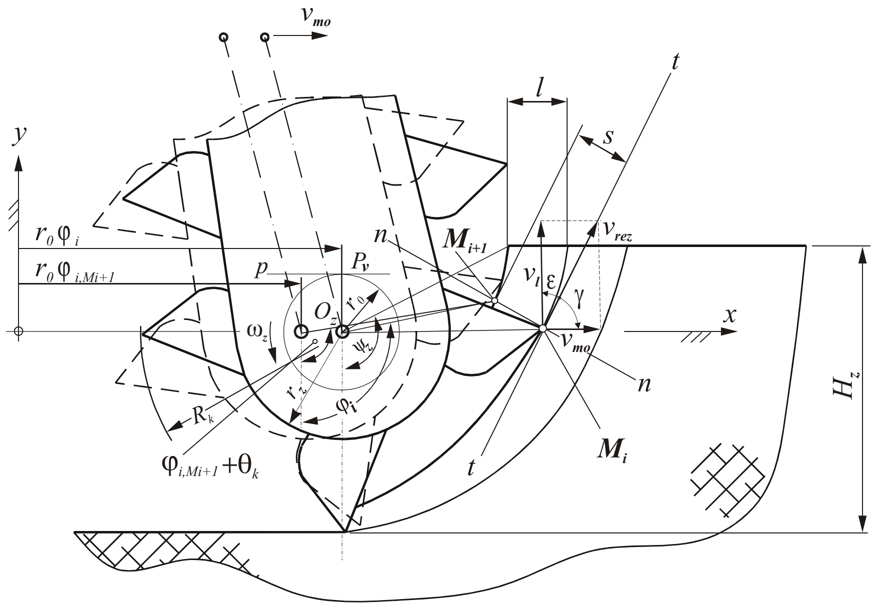


Figure 3. Scheme for determination of cutting depth [6]

- reclaiming the coal from tranches and stacking on stockyard, fig. 2(b)
- reclaiming the coal both from tranche and from stockyard and further transportation to the main belt conveyor, fig. 2(c)
- reclaiming the coal from stockyard and transportation to the main belt conveyor, fig. 2(d)

External loads acting upon structure of bridge reclaimer which are caused by resistances to coal reclaiming process are dynamic loads, unlike other loads. Identification of such loads, as at wheel excavating machines, considers the problems related to: ship section, specific resistance to digging and position of components of force resisting excavation.

2. KINEMATIC ANALYSIS OF COAL RECLAIMING PROCESS

Coal reclaiming (excavating) process happens within the zone of driven pulley by complex motion of buckets, fig. 3. Hence, rectilinear translation of bridge with velocity v_{mo} is transmitive motion, and bucket rotation round the center of driven pulley is its relative motion. Since bucket exits the reclaiming zone, its relative motion is rectilinear translation.

Therefore, it can be concluded that motion of reclaiming device of bridge reclaimer is fully similar to motion of reclaiming device of bucket wheel excavator. Analysis that follows is fully analogous to presented analysis in [2,3].

Bucket movement within the coal reclaiming area is plane motion, and so can be described in any plane that is normal to driven pully rotation axis. With constant bridge velocity v_{mo} and angular velocity of driven pulley, $\omega_z = v_l / r_z$, distance between the instantaneous center of driven pulley and its axis is also constant,

$$r_o = \frac{v_{mo}}{\omega_z} = \frac{v_{mo}}{v_l} r_z = \text{const} .$$

In that case, bucket motion within the reclaiming area can be presented as rolling, without sliding, of circle with radius r_o along the straight line p which denotes centrode, fig. 3. If the pulley rotation angle is expressed as time function ($\varphi = \omega_z t$), absolute coordinates of bucket reference point (point M), fig. 3, in relation to imovable system Oxy, become parametar equations of absolute trajectory (cutting trajectory) of that point,

$$x = r_o \omega_z t + R_k \sin \omega_z t = r_o \frac{v_l}{r_z} t + R_k \sin \frac{v_l}{r_z} t ,$$

$$y = -R_k \cos \varphi = -R_k \cos \frac{v_l}{r_z} t , \tag{1}$$

with constraint

$$y_{\max} \le H_z \le R_k (1 + \sin \psi_z) .$$

According to the structure of the equations (1), it can be concluded that absolute trajectory of any bucket point, within the coal reclaiming zone, belongs to the cycloid curve, fig. 4.

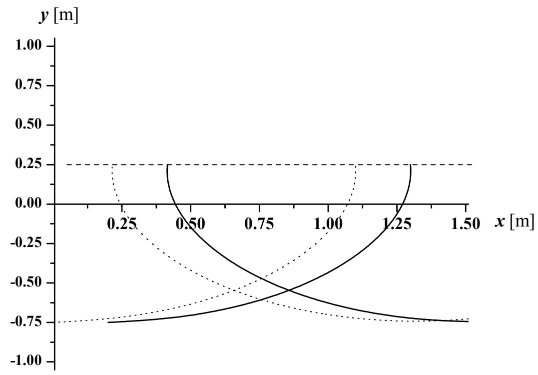


Figure 4. Absolute trajectory of reference points for two adjacent buckets [6]

With constant transmitive and relative velocity, absolute trajectory of reference point for *i*-th bucket is identical as for *i+1*-th bucket, i.e. previous bucket, but translated along the abscissa for *l*, fig. 3. Value *l* presents displacement that point O*z* makes if it moves with uniform velocity v_{mo} during an interval of time $\tau = \dfrac{\theta_k}{\omega_z} = \dfrac{r_z \theta_k}{v_l}$, i.e. $l = v_{mo} \cdot \tau = r_z \theta_k \dfrac{v_{mo}}{v_l}$, and it is called absolute trajectory pitch.

Coal reclaiming velocity, by definition, is absolute velocity of bucket reference point, fig.3. Its magnitude, $v_{rez} = \sqrt{v_{mo}^2 + v_l^2 + 2 v_{mo} v_l \cos\varphi_i}$ apparently varies from the position of selected bucket, and therefore, varying even in the case of constant magnitudes of relative and transmitive velocity.

Direction of reclaiming velocity is also varying. Slope angle, defining the direction of coal reclaiming velocity, is obtained from equation (1),

$$\mathrm{tg}\gamma = \left.\frac{\mathrm{d}y}{\mathrm{d}x}\right|_{\varphi = \varphi_i} = \frac{v_l \sin\varphi_i}{v_{mo} + v_l \cos\varphi_i} = \frac{C \sin\varphi_i}{1 + C\cos\varphi_i},$$

$$C = \frac{v_l}{v_{mo}} .$$

Angle between the relative and absolute velocity of bucket reference point, fig.3,

$$\varepsilon = \varphi_i - \mathrm{arctg}\frac{C \cdot \sin\varphi_i}{1 + C \cdot \cos\varphi_i} = \varepsilon(\varphi_i, C),$$

has, in certain cases, influence on the coal reclaiming process and on wearing of the bucket head edgeline.

3. CUTTING DEPTH

Cutting (reclaiming) depth presents offset distance of selected bucket reference point from the previous bucket along the perpendicular line to the absolute path of desired reference point. Cutting depth is variable and depends on the magnitudes of reference point relative and transmitive velocity, and bucket position, $s = s(C, \varphi_i)$ [2,3].

Therefore, cutting depth of the *i*-th bucket, fig.3, is segment on the perpendicular line of reference point absolute path, specified with points M_i and M_{i+1}. Point M_{i+1} is intersection of perpendicular line to the absolute path of the reference point from the *i*-th bucket and absolute path of the reference point from the previous bucket, i.e. *i+1*-th bucket.

Equation of the perpendicular line to the absolute path of reference point for the *i*-th bucket, through point M_i, with coordinates $x_{Mi} = r_o \varphi_i + R_k \sin\varphi_i$, $y_{Mi} = -R_k \cos\varphi_i$ is [2,3]:

$$y = -\frac{r_0 + R_k \cos\varphi_i}{R_k \sin\varphi_i} x + r_0 \left(\frac{r_0 + R_k \cos\varphi_i}{R_k \sin\varphi_i} \varphi_i + 1 \right). \quad (2)$$

Coordinates of the point M_{i+1} also satisfy the previous equation,

$$x_{Mi+1} = r_o \varphi_{i,Mi+1} + R_k \sin(\varphi_{i,Mi+1} + \theta_k), \quad (3)$$

$$y_{Mi+1} = -R_k \cos(\varphi_{i,Mi+1} + \theta_k). \quad (4)$$

Substituting (3) and (4) in the equation (2), after series of transformations, it is obtained [1]

$$A\varphi_{i,Mi+1} + D \sin\varphi_{i,M+1} + E\cos\varphi_{i,Mi+1} + C = 0, \quad (5)$$

where

$$A = r_o \frac{r_o + R_k \cos\varphi_i}{R_k \sin\varphi_i},$$

$$B = R_k \frac{r_o + R_k \cos\varphi_i}{R_k \sin\varphi_i},$$

$$C = -r_o \frac{r_o + R_k \cos\varphi_i}{R_k \sin\varphi_i},$$

$$D = B\cos\theta_k + R_k \sin\theta_k \quad \text{and}$$

$$E = B \sin\theta_k - R_k \cos\theta_k .$$

Angle of pulley rotation *($\varphi_{i,Mi+1}$)*, that defines the position of the point M_{i+1} is gained by numerical solving the transcendental equation (5). Afterwards, based on (3) and (4) coordinates of the point M_{i+1} can be determined, along with cutting depth, following the next expression

$$s = \sqrt{(x_{Mi} - x_{Mi+1})^2 + (y_{Mi} - y_{Mi+1})^2} . \quad (6)$$

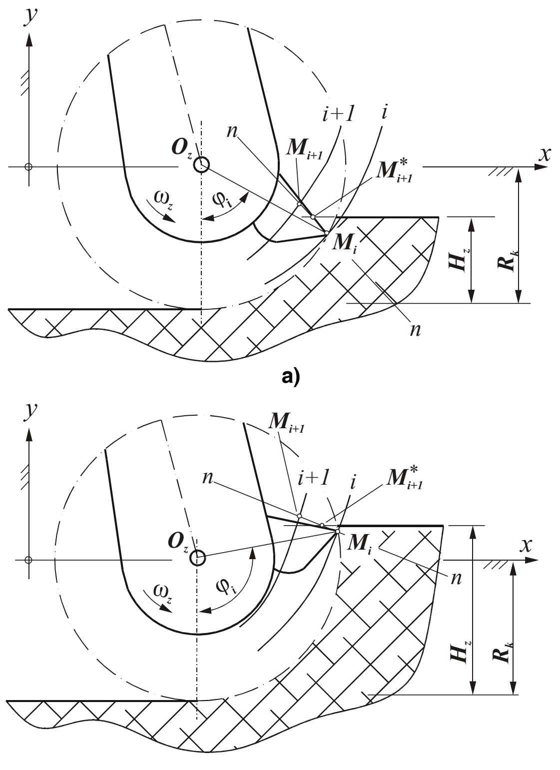


Figure 5. Exit of buckets from the reclaiming zone[6]: a) $H_z < R_k$; b) $H_z > R_k$.

Within the exit zone of bucket from the reclaiming zone, fig. 5, at $y_{Mi+1} > H_z - R_k$, coordinates of the point M^*_{i+1} should be substituted in the expression (6), instead of the coordinates of the point M_{i+1},

$$x^*_{Mi+1} = -\frac{R_k \sin\varphi_i}{r_o + R_k \cos\varphi_i}(H_z - R_k) + r_o\left(\frac{R_k \sin\varphi_i}{r_o + R_k \cos\varphi_i} + \varphi_i\right)$$

$$y^*_{Mi+1} = H_z - R_k ,$$

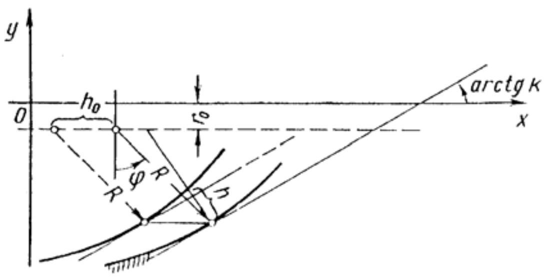
which presents intersection of perpendicular line (2) and line $y = H_z - R_k$ [6].

Vetrov [8], Volkov [11] and other authors give aproximate expressions for cutting depth, starting from the successive cutting trajectory pitch.Thereat, Vetrov expresses the influence of the current position of bucket reference point with angle that its absolute velocity makes with abscissa, fig. 6 (*a*),

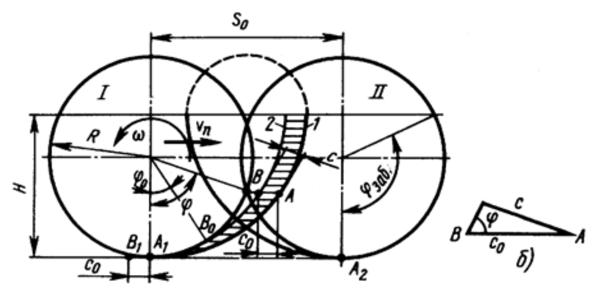
$$h \approx h_o \sin(\mathrm{arctg}\, k) = h_o \frac{k}{1+k^2} = s_1 , \qquad (7)$$

and Volkov, fig. 6 (*b*), with bucket positioning angle

$$c = c_o \sin\varphi = s_2 . \qquad 8)$$



(a)



(b)

Figure 6. Determination of cutting depth, according to: (a) Vetrov [8]; (b) Volkov [11]

Determination of cutting depth, according to expression (6), does not have aproximate character. Gained error is strictly numerical and consequence of solving the equation (5). Accuracy is so high that cutting depth, obtained from the expression (6), can refer as nominal. According to this fact, if mentioned cutting depth is taken as nominal, there can be defined relative errors gained by appliances the of Vetrov (7) and Volkov (8) expressions,

$$e_{ri} = \frac{s_i - s}{s} \cdot 100 \ [\%] , \ i = 1,2 .$$

Fig. 7 shows graphs of relative errors that are gained by using the expressions (7) and (8) for calculating the cutting depth. Results are gained by developed software [4].

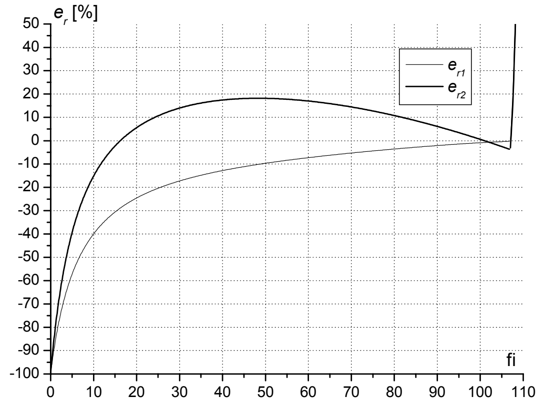


Figure 7. Relative errors for $n_k = 140$, $v_{mo} = 25$ m/min, and $v_l = 0.435$ m/s

4. SPECIFIC RESISTANCE TO COAL RECLAIMING

Reclaiming process, which goes under strict influence of soil mechanical-physical characteristics, bucket geometry and chip geometry, is fully anologous to excavating process at multi-bucket excavators. At those machines, by rule, resistances to excavating present the largest amount of the total load. Therefore, their determination has been studied by lots of researchers. Adoption of basic excavating resistance index presents place from where their aproaches differ [1].

Based on full analysis of lots of experimental results, Dombrovski [5] prefers specific resistance to excavating per unit of chip area (k_F) instead of specific resistance to excavating per unit length of cutting edge (k_L) which does not reflect the physicality of the excavating process.

According to [7,9] specific resistance k_F is recommended, especially because of its consistency at excavating the soil of the same category.

One of the basic characteristics of coal reclaiming process is its stochastic nature. Hence, regardless of which specific resistance to excavating (k_F, k_L) is taken as a basic variable of resistance to excavating, its value is a random value.

This paper considers specific resistance to excavating per unit of chip area (k_F) as basic attribute of coal reclaiming process. External loads caused by coal reclaiming process is modeling with random value generator, with Gaussian (normal) distribution, because of [10], "mathematical formulation of random values of total external loads is subjected to normal distribution".

5. COMPONENTS OF RESISTANCES TO COAL RECLAIMING

Within the coal reclaiming zone, bucket is subjected to resistance with tangent and perpendicular component, fig. 8.

According to Dombrovski [5], magnitude of tangent component of resistance to reclaiming, acting upon the bucket whose position is defined with angle φ_i, is as follows

$$R_{ti} = k_F \cdot s_i \cdot B_k \, .$$

With cutting depth less than 2.4 cm, specific excavating resistance is to be updated according to the following expression

$$k_F^{'} = k_F + \sqrt{\frac{A_I}{s_i}} \, .$$

Magnitude of perpendicular component of resistance to reclaiming is calculated as $R_{ni} = k_n \cdot R_{ti}$ [5].

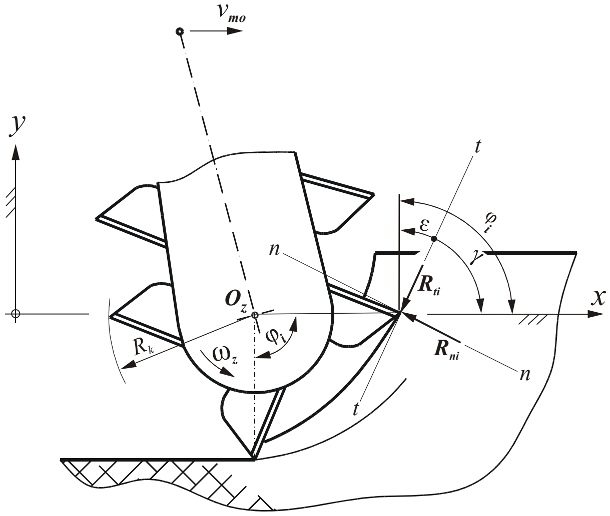


Figure 8 [6] – Components of resistance to coal reclaiming

6. BOOM LOADS CAUSED BY RESISTANCE TO COAL RECLAIMING

One of the basic characteristics of working process of elevator is periodic entrance and exit of bucket at reclaiming zone. Consequently, the number of buckets varies in the reclaiming zone. Average minimal and maximal number of buckets in reclaiming zone can be calculated as follows [1]

$$m_{k,\mathrm{sr}} = \frac{\psi_k}{\theta_k} \, ,$$

$$m_{k,\min} = \mathrm{int}(m_{k,\mathrm{sr}}) = \mathrm{int}(\frac{\psi_k}{\theta_k}) \, ,$$

and

$$m_{k,\max} = m_{k,\min} + 1 \, .$$

Let the selected bucket enter the zone at time t=0 and let the driven pulley be rotated for angle φ ; the number of buckets in reclaiming zone are defined as [1]

$$n_{\theta_k} = \mathrm{int}(\frac{\varphi}{\theta_k}) \, .$$

Current number of buckets in reclaiming zone is determined by [1]:

$$m_k = m_{k,\max}$$

for $n_{\theta_k}\theta_k \le \varphi \le \psi_k + (n_{\theta_k} - m_{k,\min})\theta_k$

and

$$m_k = m_{k,\min}$$

for $\psi_k + (n_{\theta_k} - m_{k,\min})\theta_k < \varphi < (n_{\theta_k} + 1)\theta_k$.

Position of i-th bucker is defined with positioning angle [1]

$$\varphi_i = \varphi - (n_{\theta_k} + 1 - i)\theta_k \, , \; i = 1, 2, \ldots, m_k \, .$$

After the identification of number and position of buckets at reclaiming zone, magnitudes and position of components of resistances to reclaiming, coordinates of forces and moment of external loads can be determined in relation to adopted coordinate system. If cutting depth is defined according to equations (6) and (7), coordinates of forces and moment can be calculated according to the following expressions

$$F_x = -\sum_{i=1}^{m_k} (R_{ti} \cos\gamma_i + R_{ni} \sin\gamma_i) \, , \tag{9}$$

$$F_y = \sum_{i=1}^{m_k} (-R_{ti} \sin\gamma_i + R_{ni} \cos\gamma_i) \, , \tag{10}$$

$$M_z = R_k \sum_{i=1}^{m_k} [-R_{ti} \cdot \cos(\varphi_i - \gamma_i) + R_{ni} \cdot \sin(\varphi_i - \gamma_i)] \, , \tag{11}$$

but, with equation (8) for cutting depth, coordinates of forces and moment are to be calculated according to the following expressions:

$$F_x = -\sum_{i=1}^{m_k} (R_{ti} \cos\varphi_i + R_{ni} \sin\varphi_i) \, , \tag{12}$$

$$F_y = \sum_{i=1}^{m_k} (-R_{ti} \sin\varphi_i + R_{ni} \cos\varphi_i) \, , \tag{13}$$

$$M_z = -R_k \sum_{i=1}^{m_k} R_{ti} \, . \tag{14}$$

Results of calculation of load components $R_x = |F_x|$, $R_y = |F_y|$ and $M_k = |M_z|$, gained by software [4], for variety of input parameters:

- *case I*: $n_k = 70$, $t_k = 500$ mm, $B_k = 680$ mm, $H = 1.0$ m, $v_{mo} = 20$ m/min, $v_l = 0.87$ m/s, $k_F = 1.0$ daN/cm^2 i $k_n = 0.4$
- *case II*: $n_k = 140$, $t_k = 250$ mm, $B_k = 340$ mm, $v_l = 0.435$ m/s, other data are same as for case I
- *case III*: $v_{mo} = 25$ m/min, ... same as for case II
- *case IV*: $n_k = 140$, $t_k = 250$ mm, same as for case I

are shown in figures 11,12, 13, ...,17 and 18 and in tables 1,2,3,....7 and 8 (Note: Index '1' refers to values obtained from equations (7),(9),(10),(11); index '2' refer to (8),(12),(13),(14); values without index refers to equations (6),(9),(10),(11)).

Software [4] also enables stochastic simulation of coal reclaiming process, fig.19.

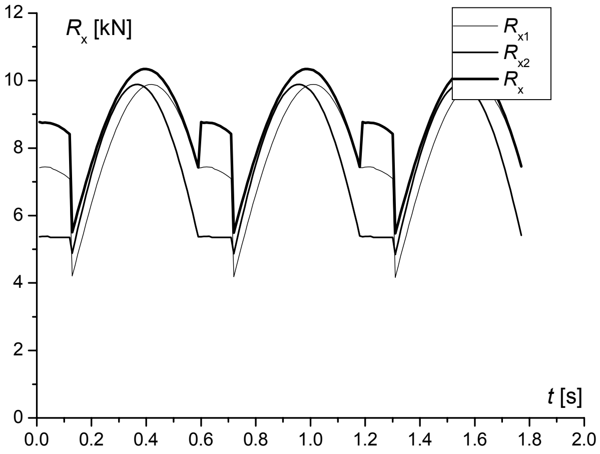


Figure 11. Time plot of R_x – case I

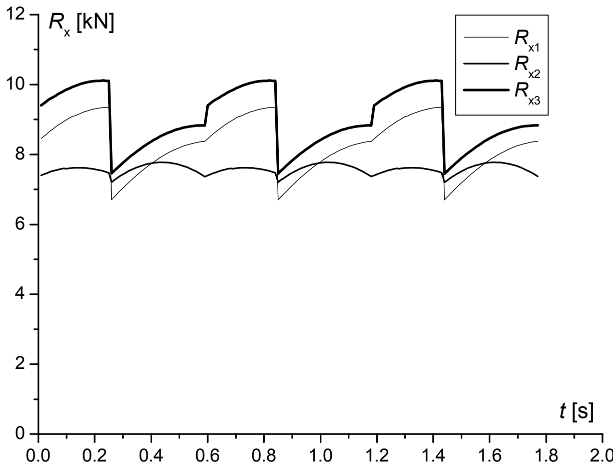


Figure 14. Time plot of R_x – case II

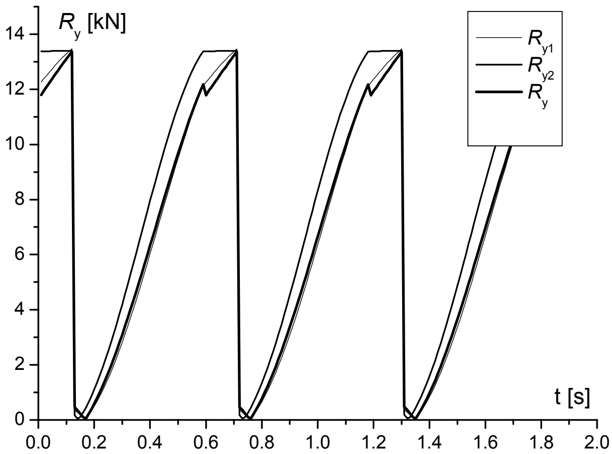


Figure 12. Time plot of R_y – case I

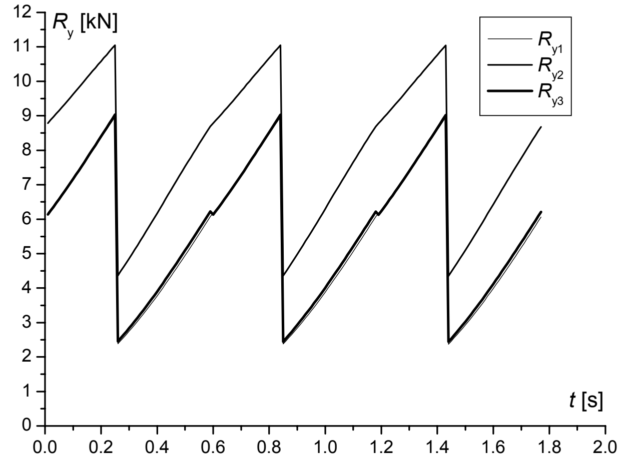


Figure 15. Time plot of R_y – case II

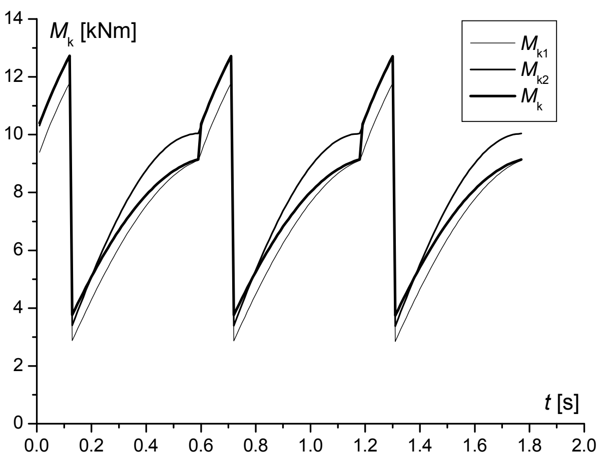


Figure 13. Time plot of M_k – case I

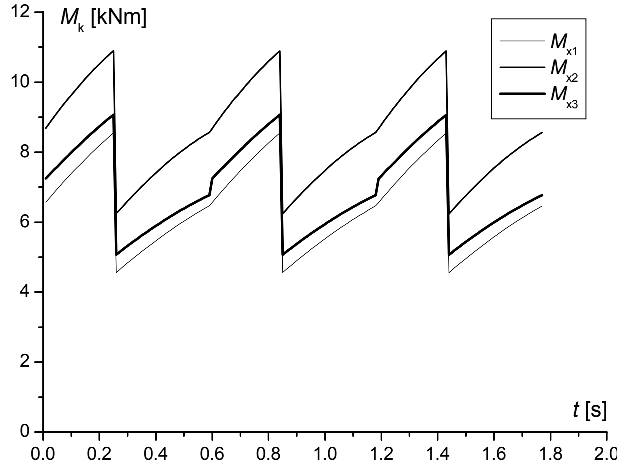


Figure 16. Time plot of M_k – case II

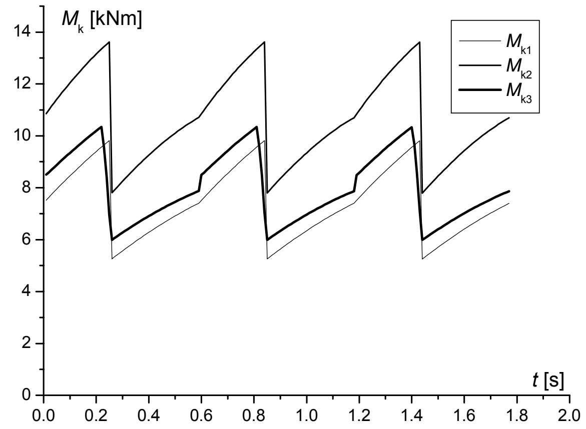


Figure 17. Time plot of M_k – case III

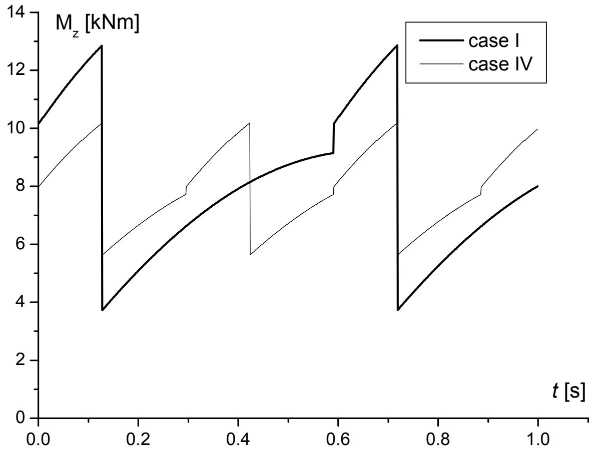


Figure 18. Time plot of M_k - cases I i IV

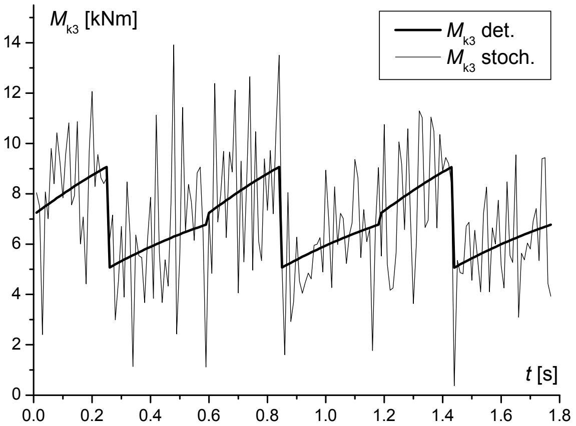


Figure 19. Time plot of M_{ks} (case II) as stochastic function

Table 1. Basic characteristics of R_x – case I

R_x	R_{x1}	R_{x2}	R_{x3}
Maximum value [kN]	9.9	9.9	10.3
Minimum value [kN]	4.2	4.8	5.5
Irregularity ratio	2.4	2.1	1.9

Table 2. Basic characteristics of R_x – case I

R_y	R_{y1}	R_{y2}	R_{y3}
Maximum value [kN]	13.5	13.4	13.4
Minimum value [kN]	0.03	0.04	0.04
Irregularity ratio	45.0	33.5	33.5

Table 3. Basic characteristics of M_k – case I

M_k	M_{k1}	M_{k2}	M_{k3}
Maximum value [kNm]	11.8	12.7	12.7
Minimum value [kNm]	2.9	3.4	3.8
Mean value [kNm]	7.5	8.5	8.0
Irregularity ratio	4.1	3.7	3.3

Table 4. Basic characteristics of R_x – case II

R_x	R_{x1}	R_{x2}	R_{x3}
Maximum value [kN]	9.4	7.8	10.1
Minimum value [kN]	6.7	7.2	7.5
Irregularity ratio	1.4	1.1	1.4

Table 5. Basic characteristics of R_y – case II

R_y	R_{y1}	R_{y2}	R_{y3}
Maximum value [kN]	9.0	11.1	9.0
Minimum value [kN]	2.4	4.4	2.4
Irregularity ratio	3.8	2.5	3.8

Table 6. Basic characteristics of M_k – case II

M_k	M_{k1}	M_{k2}	M_{k3}
Maximum value [kNm]	8.6	10.9	9.1
Minimum value [kNm]	4.6	6.2	5.1
Mean value [kNm]	6.4	8.5	6.9
Irregularity ratio	1.9	1.8	1.8

Table 7. Basic characteristics of M_k – case III

M_k	M_{k1}	M_{k2}	M_{k3}
Maximum value [kNm]	9.8	13.6	10.3
Minimum value [kNm]	5.3	7.8	6.0
Mean value [kNm]	7.4	10.6	8.0
Irregularity ratio	1.9	1.7	1.7

Table 8. Basic characteristics of M_{k3} – cases I i IV

M_{k3}	case I	case IV
Maximum value [kNm]	12.7	10.2
Minimum value [kNm]	3.8	5.6
Mean value [kNm]	8.0	8.0
Irregularity ratio	3.3	1.8

7. ANALYSIS OF RESULTS

Minimal magnitudes of load components, fig. 11,12, 13, ..., 18, occur at the moment when bucket exits reclaiming zone, that is, at the moment when number of bucket jumps from $m_{k,\max}$ to $m_{k,\min}$.

7.1 Case I

During one period, increasment of load component magnuted along x axis to its extreme, goes under curves of the same characters. Extremes of R_{x1}, R_{x2} and R_{x3} don't occur at the same moment of time, but at $0.49\,T$, $0.41\,T$ and $0.46\,T$, respectively. Decreasment after reaching the extremes also goes under curves of the same character. At $0.8\,T$ (entrance of the second bucket in the reclaiming zone) there is first kind discontinuity, with local minimal value. Afterwards, curves R_{x1} and R_{x2} first slowly increase, then slowly decrease until the exit of bucket from reclaiming zone, when minimal values of selected load occur. Opposite from that, after the occurence of singularity at $0.8\,T$, curve R_{x3} jumps to local extreme, with occurence of second singularity, and slowly fall until the exit moment, when it reaches the minimal value during one period. Maximal values of R_{x1} and R_{x2} have small variation from maximal value of R_{x3}, while minimal values variation and irregularity ratio variation are significantly bigger, table 9.

Table 9. Variation [%] of R_{x1} i R_{x2}, respect to R_{x3}

R_x	R_{x1}	R_{x2}
Maximum value	-3.9	-3.9
Minimum value	-23.6	-12.7
Irregularity ratio	26.3	9.5

Increasment of load component magnutes along y axis until the occurrence of singularity at $0.8\,T$, goes under curves of the same characters. Afterwards, curve R_{y1} increases to extreme value and at the moment when bucket exit the reclaiming zone reaches minimal value during one period. Curve R_{y2} through singularity point reaches maximal value, which remains until the moment when bucket exits the reclaiming zone and then decrease to the minimal value. Curve R_{y3}, at $0.8\,T$, reaches local extreme, then slightly decreases until next singularity occurs and increases to the maximal value. Minimal value of curve R_{y3} at in the moment when bucket exits the reclaiming zone. Maximal and minimal value of curves R_{y1} and R_{y2} slightly differs from the R_{y3}, table 3.

During one period, increasment of moment M_z, goes under curves of same the characters until the occurrence of singularity at $0.8\,T$, after curves M_{z1} and M_{z2} increase to extreme values, and then, decrease to minimum values (exit of buckets from the reclaiming zone). Curve M_{z3}, after singularity has bouncing increasment, goes through another singularity, increases to maximum value, and at the moment of bucket exit reaches minimum value. Variation of minimum and maximum values of M_{k1}, minimum values of M_{k2}, along with their irregularity ratios, respected to M_{k3}, are considerable, table 10. Maximum value of M_{k2} is equal to maximum value of M_{k3}. It is interesting that variations of mean values, in both of the curves, has equal absolute values, where curve M_{k2} gives result on the safety side, but opposite for curve M_{k1}

Table 10. Variation [%] of M_{k1} i M_{k2}, respect to M_{k3}

M_k	M_{k1}	M_{k2}
Maximum value	-7.1	0.0
Minimum value	-23.7	-10.5
Mean value	-6.3	6.3
Irregularity ratio	24.2	12.1

7.2 Case II

Maximum values of all load components are smaller, and minimum values are bigger than for case I. Consequence of this is considerable decreasment of irregularity ratio, table 1, 2, 3, and 4, 5, 6.

Percentage variation of maximum values of curves R_{x1} and R_{x2}, respected to maximum values of R_{x3}, goes to unsafety side, where variation at curve R_{x2}, overcomes the safety levels allowed in engineering calculations, table 11.

Table 11. Variation [%] of R_{x1} i R_{x2}, respect to R_{x3}

R_x	R_{x1}	R_{x2}
Maximum value	-6.9	-22.8
Minimum value	-10.7	-4.0
Irregularity ratio	0.0	21.4

During the whole period of time curve R_{y1} almost coincides with R_{y3}, fig. 15, along with equal maximum and minimum values, table 5. Variations of curve R_{y2} are considerably bigger, table 12.

Table 12. Variation [%] of R_{y1} i R_{y2}, respect to R_{y3}

R_y	R_{y1}	R_{y2}
Maximum value	0.0	23.3
Minimum value	0.0	83.3
Irregularity ratio	0.0	34.2

Variation of all M_{k1} characteristics does not exceed levels that are tolerated in engineering calculations, but on unsafety side. Opposite to that, variations of M_{k2} are positive, but very high, table 13.

Table 13. Variation [%] of M_{k1} i M_{k2}, respect to M_{k3}

M_k	M_{k1}	M_{k2}
Maximum value	-5.5	19.8
Minimum value	-9.8	21.6
Mean value	-7.2	23.2
Irregularity ratio	5.6	0.0

7.3 Case III

Variations of M_{k1} are not so sensitive to changes in transmitive velocity, from respective variations of M_{k2}, tables 13 and 14.

Table 14. Variation [%] of M_{k1} i M_{k2}, respect to M_{k3}

M_k	M_{k1}	M_{k2}
Maximum value	-4.9	32.0
Minimum value	-11.7	30.0
Mean value	-7.5	32.5
Irregularity ratio	11.8	0.0

7.4 Cases I i IV – M_{k3}

Higher number of buckets diminish the period and maximum values, with enlargement of maximum values which decrease irregularity ratio. Mean value is the same for both cases, table 15.

Table 15. Basic characteristics of M_{k3} – cases I i IV

M_{k3}	Cases I	case IV
Maximum value [kNm]	12.7	10.2
Minimum value [kNm]	3.8	5.6
Mean value [kNm]	8.0	8.0
Irregularity ratio	3.3	1.8

8. CONCLUSION

There's been presented an original procedure for determination of external loads caused by resistances to reclaiming at bridge-type stacker-reclaimer with bucket chain booms. It is based on the fact that coal reclaiming process is fully analogous to excavating process at wheel excavators.

Based on analysis results gained by original software, review of influence of some structural and operating parametars on external loads characteristics is shown.

From this method, unlike other methods presented in literature, we can obtain results whose accuracy does not depend of machine structural and operating parameters. Developed software enables the designers to perform fast and accurate enough determination of relevant operating parameters including its stochastic characteristics. That is a base for further static and dynamic analysis of structure and mechanisms at bridge-type reclaimers.

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NOMENCLATURE

B_k	bucket width
H_z	coal reclaiming height
k_n	ratio of tangent and perpendicular components of resistance to excavating
l	absolute trajectory pitch
M_k	moment of resistance to coal reclaiming
$m_{k,\min}$	minimum number of buckets in reclaiming zone
$m_{k,ksr}$	medium number of buckets in reclaiming zone
$m_{k,\max}$	maximum number of buckets in reclaiming zone

P_v	instantaneous center of driven pulley
p	centrode
R_k	coal reclaiming radius
R_n	perpendicular component of resistance to reclaiming
R_t	tangent component of resistance to reclaiming
R_x , R_y	component of load caused by resistance to coal reclaiming
r_o	distance from instantenious center of driven pulley to its rotation axis
r_z	kinematic radius of driven pulley
s	cutting depth
t_k	bucket pitch
v_l	chain velocity
v_{mo}	bridge velocity
v_{rez}	absolute velocity of bucket reference point
γ	angle of cutting velocity respect to absciss
ε	angle of absolute and relative velocity of bucket reference point
θ_k	pitch angle of buckets within the reclaiming zone
φ_i	positioning angle of *i*-th bucket
ψ_z	coal reclaiming angle
ω_z	angular velocity of driven pulley

ОДРЕЂИВАЊЕ ОТПОРА ЗАХВАТАЊА УГЉА КОД ПРЕТОВАРНИХ МОСТОВА СА ЕЛЕВАТОРИМА

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Једну од основних етапа пројектовања претоварних мостова са елеваторима представља идентификација спољашњег оптерећења изазваног отпором копања. Оно је по својој природи динамичког, и при том, стохастичког карактера. У раду је изложен оригинални поступак одређивања поменутог оптерећења, који, уз развијену софтверску подршку, омогућава да се брзо, и довољно тачно, одреде његове релевантне динамичке и стохастичке карактеристике. Знатно већа тачност, која уз то, није осетљива на промену конструкционих параметара и параметара режима рада, представља основну предност изложеног поступка у односу на поступке који се дају у литератури. У раду је на конкретном примеру анализиран утицај неких конструкционих и радних параметара на карактер и интензитет оптерећења изазваног отпором захватања угља. Извршена је и упоредна анализа резултата који се добијају изложеним поступком и поступцима датим у литератури. Коначно, на основу оптерећења дефинисаног на начин изложен у овом раду, могуће је извршити потпуну симулацију статичког и динамичког понашања структуре и механизама претоварног моста са елеваторима.