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Experimental Analysis Upon Rotating Wheel Operating Loading of the Bucket Wheel Schrs 650/5*24

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ABSTRACT: The results of dynamic tests carried out on the bucket wheel SchRs 650/5*24 built by Krupp GmbH, which is in service in Kosovo's largest opencast mine Dobro Selo, Obilić, are discussed. The values of the specific excavation forces are given; these values are calculated by indirect methods on the basis of the recorder power input figures for the drive system of the bucket wheel and the recorded variable output. Based on tensometric measuring methods and on the calibration of the measuring arrangement by mean of external forces that are known, an analysis of the actual loading which occur in specially selected, typical steel structure cross sections of the superstructure under dynamic working conditions of the dredge is carried out. The relations between the engaged power for working wheel driving and corresponding hourly production of the entire excavation resistance which constitutes stress on the bucket wheel are determined. Forced and own vibrations in the bucket wheel boom and counterweight boom system then have been analyzed.

1 INTRODUCTION

Size, form and the construction of the bucket wheels mainly depend on requested capacity, method of material loading and specific excavation site conditions (stability of work site, strength of rock massive, allowable loading of soil). Respecting these facts a number of bucket wheel dredge types are developed nowadays, that differ mutually by the working wheel diameter, number and shape of buckets on the working wheel and the length of the working arrow.

Loading of the bucket wheel dredge structure reliable parts and elements can not be expressed in the form of common mathematical function, in other words, it can not be presented by the model in which variables or parameters change uniformly in operating conditions, because such model has to predict a number of approximations which are caused by the real manufacturing and exploitation conditions.

For that reason, only examinations of structure in operating conditions and databases enable total assessment of its status. Necessary data for quality comparison and assessment of machines and structures, for the assessment of single parts and elements spatial work influence to capacity, and also for the determination of cooperative work of the driving devices and structures are acquired in this way.

2 BASIC TECHNICAL AND TECHNOLOGICAL CHARACTERISTICS OF BUCKET WHEEL

Basic technical and technological characteristics of KRUPP's bucket wheel SchRs 650/5*24 /4/, which is presented on Fig. 1 are:

- theoretical capacity	Q_t = 4212 [m³/h]
- driving power of working wheel [2*450 kW]	N = 900 [kW]
- diameter of bucket wheel	D_r = 10.2 [m]
- length of working arrow	l = 24 [m]
- number of buckets	z = 21
- volume of buckets including amount of empty space	W_{kof} = 650 [l]
- number of bucket shaking out	n_s = 36 [min^{-1}]
- specific cutting force per knife length	k_L = 109.6 [kN/m]
- machinery efficiency overall coefficient	η = 0.935
- cutting speed	V_r = 2.78 [m/s]

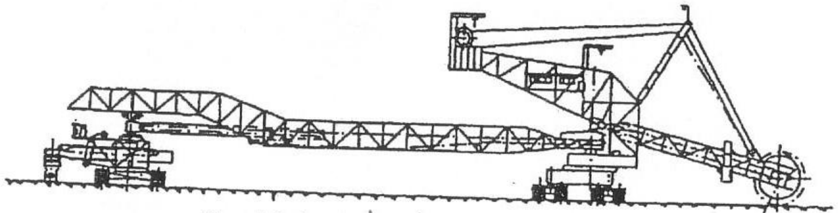


Figure 1 Bucket wheel SchRs 650/5x24

3 EXCAVATION RESISTANCE AND FUNKTIONAL CHARACTERISTICS OF BUCKET WHEEL

Determination of external loading due to wheel excavation resistance appears as basic demand in designing and in exploitation of bucket wheels. Numerous parameters which define resistances in the process of excavation by using of bucket wheel are classified in three groups: parameters of rock massive, geometrical parameters of excavation and structural-kinetic characteristics of bucket wheel as working machine.

3.1 Theoretical basis

Wheel should overcome bucket cutting resistances, elevation of excavated material, buckets loading, friction between the material of soil and the material of bucket, which depend on cutting resistance and the characteristics of the environment. Mentioned resistances, more or less precisely, can be determined by using of adequate methods. However, common situation in practice is demand for the determination of overall resistances, because they are relevant for the regular selection and the dimensioning of wheel /1/.

Basic component of excavation resistance is tangential force Ft, kN, defined as the product of specific linear excavation resistance kL, kN/m and the sum of the average lengths of knife cutting edges in the capture Lsr, m, or the specific surface excavation resistance k_A, kN/m² and the sum of the average cross-section areas of cuts Asr, m², depending on the number of buckets z on the bucket wheel and the angle of excavation φ:

$$\Phi_{\text{т}} = \begin{Bmatrix} \kappa_{\text{Л}} \text{Л}_p ; \text{Л}_p = \frac{3}{2\pi} \int^{\varphi} \text{Л}(\varphi) \text{д}\varphi \\ \kappa_A A_p ; A_p = \frac{3}{2\pi} \int^{\varphi} \text{Л}(\varphi) \text{д}\varphi \end{Bmatrix} \qquad (1)$$

Overall excavation resistance F_k is spatial load which comprise three components: tangential force F_t, normal force F_n caused by the wheel rotation, and the lateral force F_b, caused by the rotation motion of the dredge superstructure together with the bucket wheel and the arrow:

$$\Phi_{\text{к}} = \sqrt{\Phi_{\text{т}}^2 + \Phi_{\text{н}}^2 + \Phi_{\text{б}}^2} \qquad (2)$$

Average values of the normal component F_n and the lateral component F_b of soil resistance are determined on the basis of tangential component F_t:

$$\Phi_{\text{н}} = \psi_{\text{н}} \Phi_{\text{т}} \qquad (3)$$

$$\Phi_{\text{б}} = \psi_{\text{б}} \Phi_{\text{т}} \qquad (4)$$

where ψ_n and ψ_b are experimental proportionality coefficients, which values depends on the environmental conditions.

Nominal excavation power N, kW, which depend on the efficiency of driving electromotors η, can be defined as the sum of power necessary for excavation and the power for the elevation and the loading of excavated material Nh.

$$\text{Н} = \frac{1}{\eta}(\text{Н}_{\text{к}} + \text{Н}_{\text{х}}) \qquad (5)$$

On the basis of the single bucket excavation resistance $Fi_{(\varphi)}$, as a random function of excavation angle, it is possible to pass to statistical characteristic of wheel overall load, namely the rotor shaft $F_{(\varphi)}$ and the torque on the wheel shaft $T_{(\varphi)}$. Values $F_{(\varphi)}$ and $T_{(\varphi)}$ are relevant for the dimensioning of driving systems. Their exact values are obtained by the measuring on the lot of buckets, on the lot of the dredges and for many different excavation environments.

3.2 Measuring of Excavation Resistance

Measuring of excavation resistance is principally obtained in two manners: directly with excavation machinery or in the laboratory by the examination of taken specimens. Laboratory measuring of excavation resistances is obtained in many ways, but the most prominent are measuring by the cutting pendulum, measuring by the wedge, measuring by the penetrometer, measuring by the three-axial device and ultrasonic measuring. The most frequently used laboratory methods are modified methods of Orenstein & Koppel based on the Merchant's theory.

Method of wattmeter efficiency is the most frequently used method on the excavation sites in our country. Principle of this method is measuring of engaged plover on the working wheel driving gear box. On the basis of the current and voltage data measured by the wattmeter R60, engaged power on the bucket wheel driving electromotor is calculated, which is registered as the record of the power variation in the period of time. Consumption of electric energy appears as the consequence of the resistance overcoming originated in the excavation process.

Determining of the power for bucket wheel driving in dependence of accomplished capacity and the specific excavation resistance has been obtained by the using of adequate devices and the measuring and recording of current strength.

Measuring are obtained the working conditions of bucket wheel in different excavation environments. This paper presents measuring results of working load on the SchRs 650/5*24 bucket wheel /9/. Fig. 2 shows one of the current strength variation records with the basic characteristics of cut, and Fig. 3 shows the record where marked points present:

- point 1 – current strength in the moment of turning on the bucket wheel driving electromotor
- point 2 – current strength in idle running of bucket wheel
- point 3 – current strength during excavation
- point 4 – maximal value of current strength in the observed range

Engaged power data have been obtained by the statistical analysis for the bucket wheel driving and the adequate hourly production Q_e (m³/h), in the cases of bucket wheel operation in different excavation environments. On the

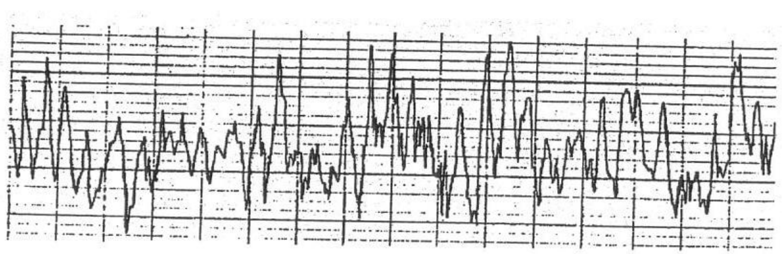


Figure 2. Review of the current strength variation record with basic characteristics of cutlet

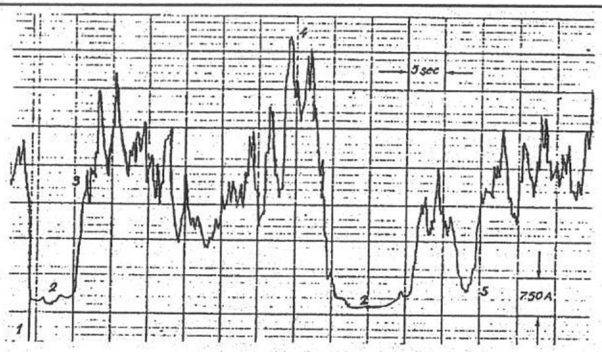


Figure 3. Review of the current strength variation record with the marked points for characteristic loadings of working whee

basis of statistical characteristics, by using the method of the least squares /2/, correlations for the regressive function $N=N(Q_e)$ have been established for the loose soil and for the grey clay, Fig. 4.

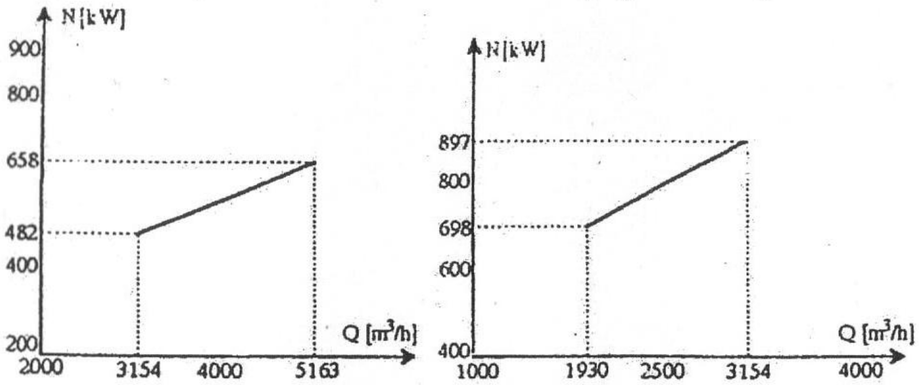
- for the loose soil

$$N(Q_e)=0.0837Q_e+229.6$$

- for the compact grey clay

$$N(Q_e)=0.1666Q_e+366.6$$

Analysis of empirical distribution histogram, of cumulative frequency functions and



a) for the loose soil

b) for the compact grey clay

Figure 4. Variation of the power in the function of hourly production

statistical characteristics has shown that normal distribution law can be used for the mathematical description of the random values of the specific excavation resistance (k_L) /3/, Fig. 5.

Normal distribution law of specific excavation resistance doesn't stand for the maximally measured loadings and for the overall measurements. These values are determined by the using of graphical methods, in order to avoid extreme values, or by using of Veyboul's distribution law. Values of normal distribution law parameters for the specific excavation resistance and the results of the acceptance verification on the basis of the variation coefficient are given in Table 1.

Table 1. Parameters of normal distribution law for the specific excavation resistance

	Normal distribution		$\Phi=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{\kappa_L \kappa_L^{*}}{\sigma}\right)^2}$	
	Average value	Standard deviation	Variation	Extreme values verification
	k_L^* (kN/m)	σ	$V=\sigma/k_L$	$k_L^*-3\sigma$
For maximally measured loadings	86.3	23.2	0.27	satisfactory
For overall measurements	68.2	19.1	0.28	satisfactory

Specific excavation resistances established by measurements, for certain working environments, can be used by the designers for the verification of the driving elements and the parts of the mechanisms calculations, and for the invention of satisfactory solutions.

4 ANALYSIS OF THE OWN AND FORCED OSCILATIONS

Rotary connection between the upper rotational and the foot part of the bucket wheel, in the comparison with working arrow, reloading arrow and the counterweight, presents insufficient basis for the stability of entire structure in operation conditions. Due to this fact dredges can relatively easy be took in the oscillatory state. Induced oscillations of the supporting structure produce dynamic strains in structural elements.

The most of assemblies and the elements of bucket wheel during exploitation are exposed to complex dynamic loadings, which depend on the exploitation conditions and own oscillations. Oscillatory motions of supporting structure elements of dredge appear in both cases: stationary and non-stationary working regime of bucket wheel driving system and they can be very complex and can appear in wide frequency range.

This paper presents results of the theoretical and experimental analysis of the own and forced oscillations of bucket wheel supporting structure, in different exploitation conditions.

In the case of time coincidence of own structure oscillations and oscillations induced by the periodical action of the loading, case of the resonance can appear, and as a consequence produce failure of the tensest sections. Respecting this fact, frequency of forced oscillations must not lie in the vicinity of the own frequency oscillations of supporting structure.

4.1 Theoretical analysis

On the basis of the technical documentation and structural elements of the working arrow of the bucket wheel, calculation of forces and node displacements of working arrow spatial lattice has been obtained. Masses and rigidity coefficients for single bars and nodes have also been calculated.

In the frame of the dynamical endurance analysis it is necessary to carry out calculation of working arrow own oscillations by using of Finite-storrelemente /4/, for plane lattice model.

Mass displacement of every bar and every node make overall mass displacement of all bars. In the calculation of own oscilations frequency concentrated masses in nodes have been taken as rigid elements, and elastical elements have been positioned in convergent streams of lattice model bars, as it is shown on Figure 9. Frequency of own oscilations is given in the following equation:

$$\det(XK=f^2M)=0$$

where: XK - matrix of system rigidity

M - matrix of masses,

Matrix XK and M are of 26th rank.

Approximative values of own oscillations frequencies recalculated in this way for working arrow of the dredge give out f_{min}=4,58 Hz and f_{max}=195.0 Hz.

4.2 *Oscillation examinations and measurement results*

Mechanical oscillations of bucket wheel supporting structure are characterized by the straight line or rotary motion of single point in the section, i.e. their distance from the neutral position, which is variable in time Y=y(t).

Obtaining of experimental examination, which is consisted of measurement program, measurement performing and determination of measured values, requires measurement devices system which comprises characteristic oscillatory properties of the dredge supporting structure. Function of the measurement devices system is in essence the processing of the signal.

Measurements of the vertical and horizontal displacements, speeds and the accelerations on the bucket wheel supporting structure have been performed for the aim of the own and the forced oscillations analysis.

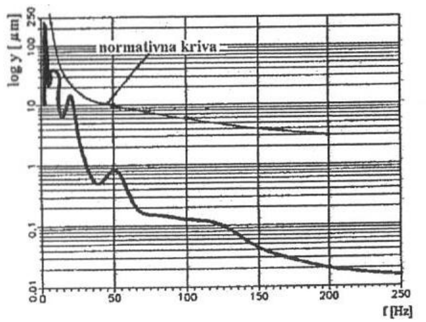
Measurements of the vertical and horizontal displacements, speeds and the accelerations have been obtained by the using of vibration method, in the middle of the supporting columns and in the middle of the upper zone main girder, by the noise and vibrations analyzer General Radio Company, for the different phases of dredge operation in hardly workable environments, when strong strike loading appear. In the frame of strain measurement on the supporting structure of bucket wheels, measurements of the vertical displacements in the middle of the upper zone main girders on the working arrows has also been performed.

Values of the own frequency basic oscillations have been established by the analysis of the bucket wheel own loadings, namely by the recording of the oscillation during transport and working moves out of the excavation process, in dependency of bucket wheel type (working arrow length), and they are:

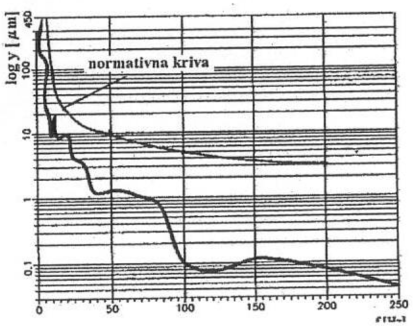
- vertical oscillations 1.0 -3.2 Hz,
- lateral 0.5 - 0.7 Hz and
- longitudinal 0.4 - 0.5 Hz.

In addition to that, it has been established that logarithmic decrement of the suppression, p is up to 0.5 which presents relatively low power and indicate to possibility of resonance appearance.

Frequency analysis, with regard to theoretical indicators has been obtained for the case of harmonic oscillations in the frequency range from 2.5 up to 250 Hz with the step from 1/3 octave (third octal analysis). Frequent spectrums of vertical oscillations in relation to normative curve for the measuring points where maximal vertical displacements have been registered, are shown on Fig. 6.



Measuring point 3
(on the opposite side from the driving)



Measuring point 4
(on the side of the working wheel driving)

Figure 6. Frequent spectrum of vertical oscillations on the working arrow supporting structure

Maximal vertical oscillations have been recorded on the working arrow main carriers in the domain of frequency analysis from 2.5 up to 5.0 Hz. Oscillations in the domain of frequency analysis from 25 up to 250 Hz, that are believed to be dangerous if they are conceived by the considerable amount of the displacements authors like Goldman, Zeler, Andrejeva-Golinina, oscillations can be neglected on the basis of these examinations.

In some of later examinations on the working arrows of the bucket wheels, with tensometric measurement of strains aimed to establish working stresses, i.e. loading spectrum /3/, vertical, lateral and longitudinal oscillations have been measured. Frequency examination results have shown that vertical oscillations during the bucket wheel operation appear as a double amplitude in the interval from 2 up to 3 sec. These results confirmed that danger of the oscillation appearance exists in the low-frequency region.

Analysis of the own and forced oscillations show that the possibility of resonance appearance is greater in the working arrow structure then in the supporting columns whilst strictly in the low-frequency region.

Frequency analysis for the different phases of bucket wheel operations shows that all oscillations are in allowable limits, but with rapid changes. Rapid oscillation changes are the consequence of the strike loadings.

Resonance that originates by the coinciding of the structure own oscillations and the oscillations which are induced by the effect of periodical loading in the horizontal and vertical plane of the working arrow, doesn't claim to be dangerous for the structure if soil has character of strong suppression, while in opposite case can result with rapid damages of the tensest sections.

Taking into account that these examinations haven't comprise marginal loadings which appear during the income of bucket wheel to the petrified rock massive, when due to strike loadings wheel practically come to a stand during the working process, limit of useful loading can't be determined.

5 CONCLUSION

Results presented in this paper and realised research /5, 6/ offer great capabillities in the extensive analysis of relevant parts and elements and the bucket wheel dredge supporting structures behaviour aimed to establish changes in mechanical properties of constructive materials while numerous factors are variated, resulting in more reliable structures or in deminishing of some undesirable effects to tolerable size, i.e. to realize stisfactory constructive solution of bucket wheel dredge as a whole.

Quick and reliable solution of supporting structure relevant parts and elements is achievable only if create database and as a basis for the development of software. Following software packages would enable more efficiently usage of database, analysis of single influential factors, improvement techniques, possibilities to prevent destruction, and search for the variable solutions in all phases of designing and development of bucket wheels.

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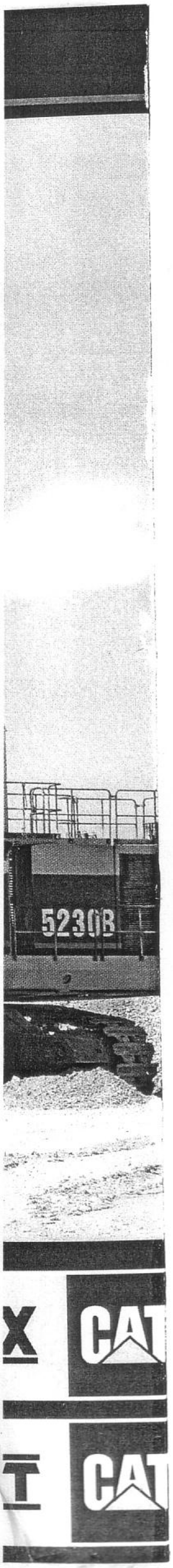

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81 EXPERIMENTAL ANALYSIS OF BUCKET WHEEL DREDGER SCHRS 650/5X24

Miodrag Arsić, Vujadin Aleksić, Zoran Anđelković

The results of dinamic tests carried out on the bucket wheel dredger SchRs 650/5x24 built by Krupp GmbH, which is in service in Kosovo's largest opencast mine Dobro Selo, Obilich, are discussed. The values of the specific digging forces are given; these values are calculated by indirect methods on the basis of the recorder power input figures for the drive system of the bucket wheel and the recorded variable output. Based on tensometric measuring methods and on the calibration of the measuring arrangement by mean of external forces that are known, an analysis of the actual stresses which occur in speciallly selected, typical steel structure cross sections of the superstructure under dynamic working conditions of the dredger is carried out. The relations between the tangential, lateral and radial components of the entire digging resistance which constitutes stress on the bucket wheel are determined. Force the natural vibrations in the bucket wheel boom and counterweight boom system are then analysed.

82 DIAGNOSTIC OF BEHAVIOUR BUCKET WHEEL'S CONSTRUCTION ON THE BUCKET WHEEL EXCAVATOR

P. Jovančić, M. Tanasijević

This article marks the weak points at the most commonly used constructions of the bucket wheel and at the same time, highlights those among them which are best suited to the conditions at the Serbian lignite open pits. Conclusions are based on theoretical analyses of constructions of the bucket wheel on the side and relevant indexes on certain constructions, on the other side. Work presents parameters which are the basis for identifications diagnostically situation of bucket wheel construction, and with the great assurance determinates next activities at bucket wheel's constructions. Identification of construction's situation (diagnostic), can influenced on badly behavior of constructions apropos on cause that behavior, not on the effect of this. Based on that, it cans determinate remained term of life of bucket wheel's construction.

Key words: Bucket wheel excavator, Bucket wheel, Diagnostics.

83 DEVELOPMENT OF OPENPIT COAL MINE UGLJEVIK

Tomo Benović

Thermo-energetic development in the Republic of Srpska is based on significant brown coal reserves in area of Ugljevik coal basin. Therefore, expected perspective mainly depends on exploration-development activity in mining. Openpit coal mine Bogutovo Selo, coal supplier of the First phase on Thermo Power Plant Ugljevik, goes into last third of operation (approximately 10 years, I.750.000 tons of coal per year) with quite uncertain progress direction. Because of that is necessary urgent decision about Ugljevik-East openpit coal mine opening, which is also source of coal for Second phase on Thermo Power Plant Ugljevik, with reconsideration of common investment. Exploitable coal reserves to 2014. are 18.860.459 tons with overburden ratio Ko=4,38 m^3/t. For future building of thermo-energetic blocks and reconstruction and modernization of TE Ugljevik I, together with Bogutovo Selo mine, available coal reserves are 267.499.000 tons. Open pit mine Ugljevik-East was planed for providing TPP Ugljevik II by coal, with capacity of 1.800.000 tons per year.