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NEW TRENDS IN DISINTEGRATING PROCESS CONTROL WITH GPS APPLICATION
IN THE CASE OF GIANT MACHINES

NOVÉ SMĚRY ŘÍZENÍ ROZPOJOVACÍHO PROCESU VELKOSTROJŮ S APLIKACÍ GPS

Abstract

For disintegration process control we need a quantity that respects objectively rock-disintegrating tool interaction with the elimination of human factor. From this, basic requirements for the evaluation quantity given below follow:

- available in advance or at the moment of disintegration,
- minimises the influence of human factor on the resultant effect,
- objectively evaluates the disintegration process

A measure of efficiency of any disintegrating process is the consumption of energy usually related to the unit volume of disintegrated rock, and on the basis of analysis of done theoretical and practical researches orientated towards the disintegration processes and the verification of objectivity when used in situ (in drilling and tunnelling), minimised specific volume energy is the most objective evaluation quantity at present. This quantity has a general validity for dispersion processes, and thus its use even for the evaluation of diggability on the digging wheel of excavator has a rational basis.

Abstrakt

Pro řízení rozpojovacího procesu potřebujeme veličinu, která objektivně respektuje interakci mezi horninou a rozpojovacím nástrojem s eliminací lidského činitele. Z toho plynou základní požadavky na hodnotící veličinu:

- k dispozici v předstihu nebo v okamžiku rozpojování,
- minimalizuje vliv lidského činitele na výsledný efekt,
- objektivně hodnotí rozpojovací proces..

Mírou efektivnosti jakéhokoliv rozpojovacího procesu je spotřeba energie vztažena obvykle na objemovou jednotku rozpojované horniny a na základě analýzy realizovaných teoretických i praktických výzkumů orientovaných na rozpojovací procesy a prokázání objektivity při použití in situ (při vrtání a tunelování) je v současné době neobjektivnější hodnotící veličinou minimalizovaná měrná objemová energie. Tato veličina má obecnou platnost pro dispergační procesy, a proto její využití i pro hodnocení rozpojitelnosti na kolese rypadla má racionální podklad.

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1 SPECIFIC VOLUME ENERGY AS A CRITERION FOR DIGGABILITY

If we subject the methods used for the diggability determination, which concerns digging resistance as well, to the analysis of objectivity, we shall find that they do not take into account, to a more or less extent, the whole set of affecting factors, and thus their informative ability concerning the real disintegrating process diminishes. What remains debatable is the quantification of evaluation quantity as well. The basic question is, for the benefit of which we are in need of absolute value of diggability (cutting resistances, drillability, digging resistances, etc.). The wheel diggability then will be defined as “the amount of energy needed for the disintegration of unit volume of rock per unit time and for breaking down other wheel resistances; mode parameters being regulated to ensure the minimisation of this specific energy” [1]. Diggability defined in this way is quantified in $J \cdot m^{-3}$. Diggability thus formulated differs markedly from “digging resistances”, i.e. evaluation quantity used at present.

A general equation for specific volume energy is given as follows:

$$w = \frac{P}{V_{ij}}, \quad (1)$$

where:

w - specific volume disintegration energy [J.m⁻³],
 P - power brought to the disintegrating tool [W],
 V_{ij} - the volume of rock disintegrated by the wheel per unit time [m³.s⁻¹].

For digging by the excavator wheel, the volume of rock taken by the wheel per unit time will be as given below:

$$V_{ij} = s \cdot h \cdot v_o$$

s - the depth of cut [m],
 h - the height of cut [m],
 v_o - the velocity of revolution (of digging-wheel boom at max. radius) [m.s⁻¹].

The velocity of revolution (circumferential) v_o of non-extensible machine depends merely on the revolutions of superstructure and the pitch of boom:

$$r_o = l_v \cdot \cos \alpha + a + R_k, \quad (3)$$

where:

r_o - the radius of wheel rotation in the horizontal plane (approx.) [m],
 l_v - the length of digging-wheel boom (from joint axis to wheel axis) [m],
 α
 a - a distance between the joint of digging-wheel boom and the excavator axis [m],
 R_k - the wheel radius (including buckets) [m].

$$v_o = \pi r_o \cdot n_o = \pi (l_v \cdot \cos \alpha + a + R_k) n_o$$

n_o - superstructure revolutions [s⁻¹].

The velocity of revolution v_o determines the width of cut b . In this manner, basic dimensions of cut taken and a relation for the volume of bucket are determined:

$$V_k = s.b.h.k_n \quad (5)$$

where:

k_n - the coefficient of bulk increase [-].

The coefficient of bulk increase k_n is a variable depending upon rock properties (especially tectonic conditions) and the geometry of wheel (above all the number of buckets). For the first approximation, it will be possible to consider the coefficient $k_n = 2$. After introducing into specific conditions of operation, the specification of coefficient will be necessary.

The relation for excavator wheel diggability will have the final form as follows:

$$w = \frac{P}{s.h.v_o} \quad (6)$$

The above-mentioned relation determines unambiguously the quantities that must be, in the course of excavation operation, measured to determine values of diggability:

- input power to wheel drives [W],
- the depth of cut in the horizontal plane [m],
- the height of cut in the vertical plane [m],
- the velocity of revolution [m.s⁻¹].

2 SPECIFIC VOLUME ENERGY AND DIGGING RESISTANCES

If we consider the case of wheel diggability analogously to digging resistance determination according to the norm ČSN 27 7013 *Opencut mining machinery* [2], neither power required for disintegrated rock uplift into the point of unloading, nor power corresponding to resistances at the idle run of wheel can be considered.

To determine the digging resistance defined by specific volume energy (henceforth referred to as digging resistance), the power required to lifting the disintegrated rock to the point of unloading will not be taken into account, because its quantity is directly proportional to the theoretical extracted quantity, i.e. the size of cut taken by crowding, and does not depend on the power for disintegration.

We shall express the digging resistance by the following relation:

$$w_R = \frac{P_{Kstř} - P_{ZDV} - P_0}{V_{ij}} \quad (7)$$

where:

w_R - digging resistance expressed by specific volume energy [J.m⁻³],
 $P_{Kstř}$ - the mean value of measured input power [W],
 P_0 - no-load power [W].

Thus, the relation for digging resistance would have the following final form:

$$w_R = \frac{P_{Kstř} - P_{ZDV} - P_0}{b.s.h.k_n} \quad (8)$$

The above-mentioned relation expresses unambiguously the quantities that must be measured to determine the value of digging resistance in the course of excavator operation. Up to now, the determination of cut height has only been done by estimation according to the number of buckets engaged. However, continuous monitoring the evaluation quantity requires accurate measurement.

The issue why power losses should be deducted remains controversial. A wheel is a disintegrating tool as a whole, and forces acting on it are various and change with time. The elimination of them to individual components is practically impossible. Therefore, it is more objective and simpler to consider specific volume energy as evaluation quantity according to relation /6/.

3 MEASURED QUANTITIES

Measurements of wheel motive power, measurements of cut depth and measurements of velocity of revolution (cut width) are taken on excavators at sufficient accuracy and continuously. What is still a problem is the height of cut. Here, a satellite navigation system of global positioning (GPS) is available. Several land stations define a co-ordinate system. The stations measure distances to satellites by means of electromagnetic waves. Then, the unknown co-ordinates of any point can be determined from the known positions of satellites and measurements of distances between this point and the satellites. At present, the quality of GPS signal receivers achieves the accuracy of $\pm 2\text{cm}$ even in the z axis.

The placement of GPS receiver on the excavator wheel will enable the observation of wheel movement in the horizontal and vertical planes. This makes it possible to measure the depth of cut and the height of cut at sufficient accuracy, and the observation of excavator travel into a new working position can be removed.

Another advantage of GPS application is the better formation of horizontal plane at the bench toe even if the excavator does not stand in the ideal plane.

4 CONCLUSIONS

Here, new opinions on the control of excavation process of giant machines with a completely different conception of evaluation quantity – specific volume energy w are presented. The application of GPS will enable the observation of w in the whole duration of disintegrating process and will simplify the measurement of cut depth and height. The system that will markedly influence the economics of excavating process and decrease the energy demand of excavation of unit volume of soil is offered here.

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