Türkiye 14 Madencilik Kongresi / *NthMmmg Congress of Turkey,* 1995 , ISBN 975-395-150-7

A REGRESSION MODEL OF THE BUCKET-WHEEL EXCAVATOR OUTPUT

P. Zlatanov
Department of Opencast Mining, University of Mining and Geology - **Sofia**

ABSTRACT: In the existing methods used to forecast the **bucket-wheel excavator output** (hourly, shift, monthly), the variability of the geological and mining conditions is **estimated by means of** different coefficients. In fact it is a function of the interaction between 3 real systems, viz. **the excavator as a productive** machine, the rock mass (overburden or mineral) and the labour management, **as a result of which its** values are random variables.

Regression analysis was applied in the short-term forecast **of the bucket-wheel** excavator output at Troyanovo-Sever Mine. The analytical dependence describing **the output is represented** by a Chebyshev polynomial This approximation is convenient because the **polynomial coefficients are** not interdependent When it is necessary to raise the polynomial degree, the initially **detennmed coefficients are** preserved and the new ones are calculated and added. The calculations of the **forecast bucket-wheel excavator** output performed by using Chebyshev polynomials yield results of high accuracy.

The regular coal output from Troyanovo-Sever Mine in Bulgaria is a necessary condition for the normal operation of the connected thermo-electric power station. Throughout the year this output undergoes considerable changes depending on the season. The autumn-winter season is characterized by higher power consumption resulting in a maximum coal output. The opposite tendency can be observed in summer when the individual power station units are repaired and the coal output decreases. For shorter periods of time within the given ranges the factor "season" does not have a significant effect on the excavators output. In these cases the labour management, the technical condition of the excavators and the heterogeneity of the rock mass have more weight. Each the factors mentioned above can be viewed as a real system. The interaction between these systems, whose elements are mostly random variables, determine the excavator output also as a random variable.

The excavator output forecast (hourly, shift, monthly) and its comparison with the scheduled output are of practical interest for the real time control of the production process. Regression analysis can be successfully used for the short-term forecast. **The construction of the** forecast model is reduced **to finding such an equation of** regression as **to reflect the studied process in the** best way, Le. to have **a mmitmim dispersion.** In mining practice this **equation is usually determined** by the least squares **method.**

Observation data t = **n** (n - No. of observation) on 11 **consecutive shifts (Table 1,** column 1) were used for **the forecast model of the hourly output of** a **bucket-wheel excavator** Rs 1200 operating in the **mining area. The average value of the hourly output** y **(Table 1, column 2) were** calculated for each shift **The model was constructed** by using Chebyshev's method **(Ralston, 1976).** This model can be **represented in the form of** a polynomial

$$y = a_0 + a_1x + a_2x^2 + ... + a_mx^m \qquad (1)$$

In the case under discussion, when all values of the factor **feature (work** shift) are equidistant (the observations **were** carried out at an interval of h= 12 hours), **the** variable x from equation (1) is substituted for t according to the formula

$$t = \frac{x_a - (x_1 - h)}{h} \qquad (2)$$

Table 1. Auxiliary calculations for finding the coefficient a,,,

No. of observation (t)	y_t, t/h	$P_1(t)$	$y_t P_1(t)$	$P_2(t)$	$y_t P_2(t)$	$P_3(t)$	$y_t P_3(t)$
1	2	3	4	5	6	7	8
1	1060	-5	-5300	15	15900	-3.6	-38160
2	1150	-4	-4600	6	6900	7.2	8280
3	1200	-3	-3600	-1	-1200	26.4	31680
4	1290	-2	-2580	-6	-7740	27.6	35604
5	1400	-1	-1400	-9	-12600	16.8	23520
6	1580	0	0	-10	-15800	0	0
7	1700	1	1700	-9	-15300	-16.8	-28560
8	1800	2	3600	-6	-10800	-27.6	-49680
9	2080	3	6240	-1	-2080	-26.4	-54912
10	2210	4	8840	6	13260	-7.2	-15912
11	2500	5	12500	15	37500	36.0	90000
E	17970	0	15400	0	8040	0	1860

Thus the actor feature t is represented by the natural sequence of numbers.

By Cheby&hev's method polynomial (1) is replaced by the equation

$$y = a_0P_0(t) + a_1P_1(t) + a_2P_2(t) + \ldots + a_mP_m(t) \quad (3)$$

The approximation polynomial is constructed in the form of sums with incremental degrees (m). The new degrees added do not change the earlier calculated coefficients. The new added polynomial has the form- a^Pg^Ct) in which Pm+iM is calculated by the general formula

$$P_{m+1}(t) = P_1(t)P_m(t) - \frac{m^2(n^2 - m^2)}{4(2m-1)(2m+1)}P_{m-1}(t) \quad (4)$$

where $P_0(t) = 1$;

$$P_1(t) = t - \frac{n+1}{2};$$

$$P_2(t) = t^2 - (n+1)t + \frac{(n+1)(n+2)}{6} \text{ etc.}$$

In equation (3) coefficients am are determined by the expressions:

$$a_0 = \frac{\sum y_t}{n};$$

$$a_1 = \frac{\sum y_t P_1(t)}{\sum P_1^2(t)}; \quad (5)$$

$$\ldots\ldots\ldots\ldots\ldots\ldots$$

$$a_m = \frac{\sum y_t P_m(t)}{\sum P_m^2(t)}$$

The numerators are directly determined whereas the denominators are calculated by the expressions:

$$\sum P_1^2(t) = \frac{n(n^2-1)}{12};$$

$$\sum P_2^2(t) = \frac{n(n^2-1)(n^2-4)}{180}; \quad (6)$$

$$\sum P_3^2(t) = \frac{n(n^2-1)(n^2-4)(n^2-9)}{2800} \text{ etc.}$$

In the approximation of the data from the observations, residual dispersion *(D^)* is used as a criterion for discontinuing the calculations.

$$D_m = \frac{S_m}{n-m-1} \qquad (7)$$

In order to calculate S_m, first we find S_0

$$S_0 = \sum(y_t)^2 - \frac{\left[\sum(y_t)\right]^2}{n}, \qquad (8)$$

then we use the relationship

$$S_m = S_{m-1} - a_m^2 \sum P_m^2(t) \qquad (9)$$

Immediately from the table 1 we obtain $a_0 = 1633.63$; $\sum P_1^2(t) = 110$. «ı = 140, which enables us to write the following approximate first-order equation:

$$y_u = 1633.63 - 140(t - 6) \qquad (10)$$

The variance of this approximation is Dj = 9406. For the regression equation set with a H-degree parabola we calculate $a_2 = 9.37$ and obtain the following relationship:

$$y_n = 1633.63 - 140(t - 6) + 9.37(t^2 - 12t + 26) \qquad (11)$$

with variance $D_2 = 1165$. Since D, > D_2, then the n-degree equation obtained is a better approximation of the results for the average hourly output. For a Hi-degree equation, by the data from Table 1, we find $a_3 = 0.3$ and $D_3 = 1253$. It is obvious that $D_2 < D_3$. This means that the transition to a Hi-degree equation will deteriorate the forecast data. We assume that equation (11) is the mathematical model of the forecast hourly output. The narrow range of the relationship obtained is estimated by the correlation $K = \sqrt{1 - S_2 / S_1} = 0.936$. There is a strong correlation. In order to establish the accuracy of the forecast model, we assume that only the first 7 observations have been carried out (the remaining 4 can be used for checking the results). By the described method we obtain a model of the form:

$$y_7 = 10\,t^2 + 26.43\,t + 1034.28 \qquad (12)$$

with variance $D_2 = 473.48$ and $K = 0.9033$. This equation serves to calculate the average hourly output with 4 shifts in advance, Le. at $t = 11$. We obtain y_u = 2535 t/h at an observed value y_n = 2500 t/h. The error made is about 1.4%.

The final results obtained enable us to draw the following conclusions:

1. When we use Chebyshev polynomials for processing experimental data, we obtain high accuracy results by performing a smaller number of calculations. For constructing a Hi-degree polynomial we have to solve, by the classical method, 4 equations with 4 unknown quantities. By using Chebyshev polynomials, for the same polynomial we need to calculate only $P_3(t)$ and a_3 according to the described formulae.

2. The use of computers equipped with the proper software (by the mine dispatcher) would allow to enter the excavator output data for each shift and to perform the necessary forecast calculations. The comparison of the forecast data with the scheduled data will help improve the real time control.

3. The conditions under which the excavators operate on the overburder are quite varied. In case of a subsequent moving of the excavator onto sections having mining-geological environment similar to the one for which the model has been constructed, it will be possible to plan more accurately the respective output.

REFERENCES

Ralston, A. 1972. *A first course m numerical analysis.* Nauka i Izkustvo, Sofia.