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Research Paper

Prediction of the Tricone Rotary Bits Wear by Combining Principal Component Analysis and Regression Methods in Blast Holes of Sarcheshmeh Copper Mine

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Abstract: The first production cycle in open-pit mines is the drilling of blast holes, which is a major part of the exploitation costs. Bits are considered as one of the most important parts of drilling in operational processes due to the type of application and high costs. Examining the parameters affecting the bits wear can reduce the effect of wear, prevent wasting time and additional costs of the drilling process. Therefore, in this study, first, by determining the effective parameters based on the results of univariate regression and Principal Component Analysis (PCA), the relationship between these factors and the tricone rotary bits wear has been determined through statistical methods. Then, 100 linear and nonlinear models were examined to predict the rate of the tricone rotary bits wears during drilling, of which only 21 models, including 6 linear models and 15 nonlinear models, were approved. The performance of these models is evaluated based on the root mean square error (RMSE), coefficient of determination (R2), Variance accounted for (VAF), and mean absolute percentage error (MAPE). then the priority of each method is determined based on performance evaluation and prioritization strategies. In this research, three strategies of prioritization, the Rank average method, the Borda method, the Copeland method, and finally the Aggregate of these methods have been used. The ranking results show that the best model for predicting the tricone rotary bits wear is the regression model with independent variables of Weight on Bits (WOB), Uniaxial Compressive Strength (UCS), and Geological Strength Index (GSI). According to the results of sensitivity analysis, the Rij value of the Weight on Bits (WOB) is 0.982, which is more than the other two parameters of the final model. Therefore, this parameter has the greatest effect on the tricone rotary bits wear and it is the most important parameter of the final model.

Keywords: Drilling, Tricone rotary bits, Wear, Statistical methods, Sensitivity analysis.

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INTRODUCTION

The bits as one of the basic tools in drilling operations, responsible for breaking and crushing the rocks. The drill bits are worn during drilling due to the various parameters that are associated with it and the drilling penetration rate is significantly reduced, which leads to a loss of time and a lot of costs. Therefore, due to the high cost and importance of the drill bits in the drilling process, it is necessary to determine the correct time to replace them in order to speed up the drilling operation. Analysis of drilling bits in terms of wear can be a good step to reduce mining costs in the priority of companies and other factors related to the project. Therefore, predicting the wear of drilling bits is a fundamental step in drilling open-pit mines [1,2].

METHODS

In general, the effective parameters in the wear of drilling bits can be analyzed in three sections: rock properties, operation parameters, and management parameters. Among these parameters, operation parameters are controllable parameters or dependent parameters. Parameters related to rock properties are considered as uncontrollable parameters or independent parameters in the process of drilling bits.

in this study, among the physical properties affecting the wear of tricone rotary bits, 7 parameters are density, porosity, Equivalent Quartz Content (EQC), silica content (SIO2), alumina content (AL2O3), the average grain size (GS), and rock texture (TC) and, among the mechanical properties, there are three categories of strength parameters (Uniaxial Compressive Strength (UCS) and Brazilian Tensile Strength (BTS)), hardness indices of rock (Schmidt hammer (SH) and Mohs hardness) and abrasion indices of rock (Schmiazek F-abrasivity factor (SF-a) and Rock Abrasivity Index (RAI)) and among the operational parameters of Weight On Bit (WOB) and bit rotation speed or bit Revolutions Per Minute (RPM) has been investigated. Apart from these parameters, due to the importance of weathering and alteration of rocks and structural joints and discontinuities on the drilling process and bits wear, chemical alteration intensity index (CIA) and rock mass classification systems such as Rock Mass Rating (RMR) And Geological Strength Index (GSI) has also been studied in this study.

In this research, in order to predict of tricone rotary bits wear in Sarcheshmeh copper mine, through the weight loss of wear, 29 bits have been calculated. Then a database using laboratory studies (chemical analysis, the study of thin sections and laboratory tests), field studies and database in Sarcheshmeh Copper mine research and development center and the development of Sarcheshmeh copper mine have been created.

The purpose of investigating the physical, mechanical, structural, and measurement properties of operational parameters is to provide a model that can predict the wear rate of rotary drill bits. For this reason, first, the effect of each of the studied variables on the wear rate of the drill bits has been determined separately using the fit of univariate (univariate regression). Then the parameters affecting the wear rate are extracted based on the principal component analysis (PCA) method. In order to analyze the parameters affecting the wear of tricone rotary bits, the data are divided into two parts: training and test. Then the equations for predicting the wear rate of rotary drill bits using linear and nonlinear multivariate regression are presented. Finally, after controlling and validating the proposed models, the best model is selected based on performance evaluation and prioritization strategies, and sensitivity analysis is performed to determine the effect of input parameters on the target [3-6].

FINDINGS AND ARGUMENT

In order to develop predictive and estimating models and validate them, it is necessary to divide the database into training and test data. For this reason, based on the results of univariate regression and PCA, 10 variables affecting the wear of rotary drill bits were identified and 75% of the total data were used as training data and the remaining 25% for test data.

In this research, Rock Texture Coefficient (TC), Uniaxial Compressive Strength (UCS), Brazilian Tensile Strength (BTS), Schmidt Hardness (SH), (Schmiazek F-abrasivity factor (SF-a), Rock Abrasivity Index (RAI), Rock Mass Rating (RMR), Geological Strength Index (GSI), Weight On Bit (WOB) and bit rotation speed or bit Revolutions Per Minute (RPM) as input parameters (model independent variables) And the wear rate of the drill bits are considered as the model output.

In this study, the final model is a combination of operational, structural, and inherent variables of rock. Based on this, all the models that can be studied have been investigated and tested. Based on tests related to regression models, out of 100 created models, only 21 linear and nonlinear regression models have been approved.

In order to evaluate the performance of each of the selected models, test data sets are used. Based on this, using four performance indices, Root Mean Square Error (RMSE), Coefficient of Determination (R^2), Variance Accounted For (VAF), and Mean Absolute Percentage Error (MAPE) have been used.

Then, using three prioritization strategies including the rank average method, Borda and Copeland's method, aggregate methods have been introduced to prioritization of models [7].

The results of the rankings show that three linear models and two nonlinear models presented below are the final five models with higher priority than the other models.

$$BW = -4.009 + 0.108\ WOB + 0.035\ RAI + 0.103\ GSI \quad (1)$$

$$BW = -3.121 + 0.122\ WOB + 2.706\ TC + 0.058\ GSI \quad (2)$$

$$BW = -2.495 + 0.11\ WOB + 0.124\ \text{SF-a} + 0.071\ GSI \quad (3)$$

$$BW = 10^{-2.911} \times WOB^{0.417} \times UCS^{0.153} \times GSI^{1.591} \quad (4)$$

$$BW = 10^{-2.156} \times WOB^{0.406} \times SF - a^{0.15} \times GSI^{1.236} \quad (5)$$

Among these models, the best model for predicting the wear rate of the drill bits is the nonlinear regression model in which the independent variables include Weight On Bit (WOB), Uniaxial Compressive Strength (UCS), and Geological Strength Index (GSI) because they have a better ranking in the evaluation indices and are available in most databases. Figure 1 shows the sensitivity analysis of the input parameters on the wear rate of tricone rotary bits.

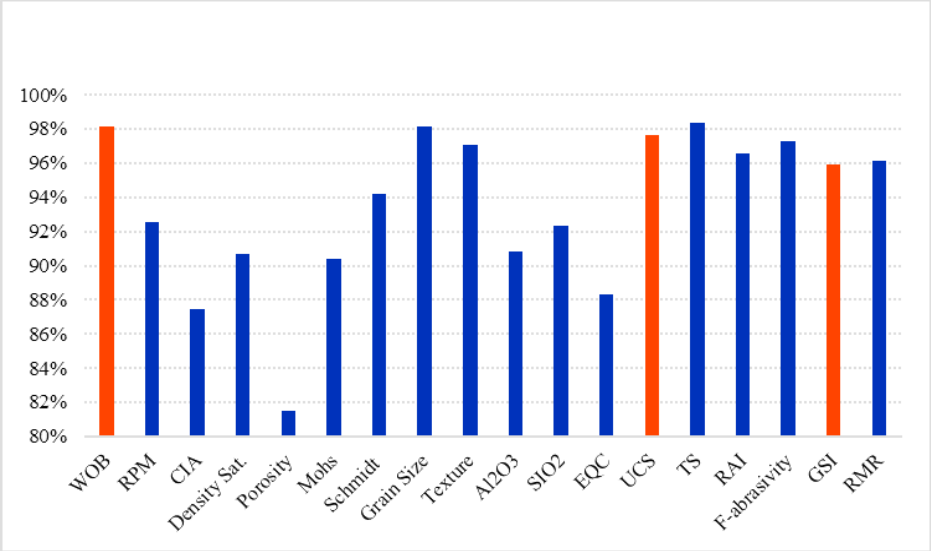

Figure 1. Sensitivity analysis of input parameters on the wear rate of drilling bits

It is worth mentioning, according to the results of sensitivity analysis, the Weight On Bits (WOB) has the greatest effect on the tricone rotary bits wear and it is the most important parameter of the model.

CONCLUSIONS

Drilling of blast holes is the first stage of the production cycle in open-pit mines, which accounts for a

large part of the exploitation costs, and it is necessary for every miner and a relevant specialist to know the drilling parameters. Bit wear is an important parameter for estimating the efficiency of drilling equipment in mining projects. For this reason, using the study of various scientific sources, essential and influential parameters on the wear of rotational taper heads have been determined and Eventually, the final effective parameters based on the results of univariate regression and Principal Component Analysis (PCA) has been determined.

In this study, the final model is a combination of operational, structural, and inherent variables of rock. Therefore, in order to develop predictive and estimating models and validate them, it is necessary are divided the database into training and test data. Based on tests related to regression models, out of 100 created models, only 21 linear and nonlinear regression models have been approved. In order to evaluate the performance of each of the selected models, four performance indices, Root Mean Square Error (RMSE), Coefficient of Determination (R2), Variance Accounted For (VAF), and Mean Absolute Percentage Error (MAPE) have been used. Then, using three prioritization strategies including the rank average method, Borda and Copeland's method, aggregate methods have been introduced to prioritization of models.

The ranking results show that the best model for predicting the tricone rotary bits wear is the regression model with independent variables of Weight On Bits (WOB), Uniaxial Compressive Strength (UCS), and Geological Strength Index (GSI). According to the results of sensitivity analysis, the Weight On Bits (WOB) has the greatest effect on the tricone rotary bits wear and it is the most important parameter of the model.

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