Angle impact on drill life during hole drilling land mine explosion at Quangninh area, Vietnam

Dinh Van Chien\textsuperscript{1}, Nguyen Khac Linh\textsuperscript{1,2} and N S Golikov\textsuperscript{2}

\textsuperscript{1} Ha Noi University of Mining and Geology, 18, Pho Vien Street, Duc Thang Ward, Bac Tu Liem District, Ha Noi, 90000, Vietnam
\textsuperscript{2} Saint-Petersburg Mining University, 2, 21st Line, St Petersburg 199106, Russia

E-mail: khaclinhhum@gmail.com

Abstract. Rock drilling and blasting holes created during construction of underground mining in general and in Quangninh are the interaction of the drill into the rock. Drilling efficiency and productivity depend on many parameters such as power dam, the rock solidity and the rotational speed of drilling and geometric parameters of the drill head. These parameters determine and affect the durability of the drill head. In this report, the authors present the results of experimental studies of the influence of sharp angles on the durability of the cross drill head during the drilling process and blasting rock in the Quangninh coal region. According to the results, it is established that the wear intensity $f$ varies positively with firmness $i$ and inversely with the sharp angle of the drill head in the range of studied sharp angles. Nevertheless, the variation of wear intensity with regard to the change in sharp angles is not significant compared to the variation of wear intensity according to the rock strength. Research results can be used to calculate, design and choose appropriate drill rock quarry that increases the productivity and efficiency of drilling, contributing to reducing product costs.

1. Introduction
In this report, the author presents experimental results that determine the effect of sharp angle on the life of drill bit of the boring machine to drill blasting holes in underground coal mining in Quangninh. The dam drill is used to break up rock and soil to form a drill hole. The drill bit is made of tool steel carbon with carbon content from 0.7 to 1\% by forging and then sharpening. When the blade section is fitted with a hard alloy, the drill bit can be made by casting. When drilling, the drill is worn with a blade and the diameter due to friction with the rock and soil, the diameter becomes smaller, the sharp angle becomes obtuse, without grinding or replacing the new drill, it cannot continue to drill. The wear of the drill depends on many parameters such as: sharp angle, solidity of rock and soil, impulse, rotation angle after each dam, drill material, dam frequency of drill bits has scientific and practical significance to increase productivity, lower drilling costs and contribute proactively in the planning of production, maintenance and repair of drilling equipment [1-8].

Among the parameters mentioned above, sharp angle is the parameter that most affects the drill head wear and drill life. Therefore, in this report, the author delves into the effect of sharp angle $\alpha$ on tip life.
2. Research content

2.1. Basic structure of dam drill
The tool of the drill is the tip of the drill bit and the drill bit is made of special steel, one end is used to break the rock called the tip of the drill, and the other end is fitted with a machine called a tail ring. The casing has a hole to guide compressed air or water to the drill head to blow chips. The body of the cylinder is on duty: The axial transmission force includes thrust and thrust to the drill head; Orientation for drill holes; Exit Chips. There are two types of drill rigs [9]:

Instant drill bit: Made from special steel with a drill bit tip attached to the shaft as shown (Figure 1).

![Figure 1. The drill bit has a cross-shaped drill bit](image)

Including 3 parts: A - Drill head; B - Drill core body; C-Tail

2.2. Drills with removable drill bits:
It is made of special steel including a drill bit head (Figure 2), which is manufactured separately from the shaft. The drill bit is connected to the stem by means of a thread or taper (Tapered angle 3°30'). Hard-alloy drill bits. Depending on the strength and texture of the rock, we choose the tip of the drill with the sharp angle as follows: To drill soft rock, the sharp angle of the blade is $\alpha = 90^0$, medium hard rock $\alpha = 100^0 + 110^0$ and hard rock $\alpha = 120^0$.

![Figure 2. Geometric shape of the dam head](image)

1) and 2) The tip of the drill has the most blade shape
3) and 4) The drill bit has a cross-shaped blade

Depending on the strength and structure of the rock, people use drill bits of different shapes as (Figure 2). The most common type of drill bit has a cross (+) blade (figure 2(3)) and most words (-) (figure 2(1)). The drill bit has the largest blade to ensure maximum drilling speed in dense, less cracked
rock. The drill has a cross-shaped blade used to drill cracked rock. Removable drill bits include the following diameters: 28, 32, 36, 40, 42, 44, 46, 52, 60, 65, 75, 85 mm, according to [9].

During the drilling process, the tip of the drill is easy to wear the blade and wear the diameter, the diameter becomes smaller, the sharp angle becomes obtuse, can be restored by grinding but must ensure to keep its geometric parameters and to create in front of the appropriate wear area of about 0.2 mm.

![Figure 3. Shape of dam tip](image)

2.3. Research factors
- Drilling equipment and heads [8]:
  + Pneumatic drills, mounted on drilling racks with electrical control devices, hydraulic equipment and measurement equipment (see Figure 4);
  + Cross-shaped pneumatic drill head (Figure 3b);
- The original parameters
  + Rocks in Quangninh area, of sandstone type often have hardness f = (6 ÷ 8). Stone samples were analyzed according to Appendix 4;
  + Drilling machine: pneumatic pressure p = (0.4 ÷ 0.48) MPa, beating frequency (1880÷2000) times / minute, drilling speed (360 ÷ 600) rpm; thrust (80 ÷ 90) kN;
  + Drill diameter d = 42mm; sharp angle α = (100 ÷ 120) degree.

2.4. Experimental models and how to proceed
To test and evaluate the influence of technology parameters on the efficiency and service life of drilling tools, the authors designed and manufactured testing equipment using air compressors as a power source. The specific gas distribution element is the distribution valve, it is responsible for distributing compressed air flow to the working device, which is the power cylinder and drilling machine. One-way valve is used to guide the flow of air in one direction and block the flow in the opposite direction, the distribution valve for the pneumatic path to the cylinder in certain direction and other compressed air elements (air tank compression system; pipeline system; control valves; safety valves and gauges). Set of drilling parameters (converters, trip sensors, measurement signal processors, computer monitors) and load, all installed on a sturdy steel frame [10, 11, 12].

The purpose of designing and manufacturing a system of equipment to measure the impact force, compressed air pressure and rock drill journey, in order to study and determine some parameters of rock drilling machine.

The test equipment consists of the main components: dam drill mounting equipment, dam parameters measurement system and control software, data collection and processing.
Figure 4. Drilling test device

1- Bolts; 2- bolts; 3- Bolts; 4- bolts; 5- The upper surface; 6-Cylinder Rod; 7 - Cylinder; 8- Moving axis; 9- Electric control box; 10- The moving block; 11- Cylinder cushion; 12- Support bar; 13 - Bolts; 14- Bolts; 15- bolts; 16- Left support post; 17- Bolts; 18- Wheel; 19- The middle bracing; 20- Vertical bracing; 21- Sliders; 22- Leg support; 23- Horizontal bracing; 24- Bolts; 25- Bolts; 26. Turning hand control; 27- Tamarind screw; 28- Leg support; 29- Tamar screw nut; 30- Cushion; 31- Moving bar; 32- Stone pattern; 33- The head of a rock drill; 34- Drilling rigs; 35- Horizontal bars; 36- Right support; 37 - Drill holder clamp; 38- Impact drill; 39. Cylinder bracket.

The test device has the basic structure as shown in Figure 4 with the following main parts and details:

- Pneumatic dam 38 has a synchronous structure: has a pneumatic cylinder mechanism 7 for pressing the drill into a hole when drilling and taking the drill out of the hole; drill head mounted on drilling rig 10 guide steel structure (drilling rack and pneumatic cylinder can adjust according to actual requirements). Slide drill head assembly with drilling racks.
- Cluster head drill racks linked to the bracket with bolts, can rotate around the center line.
- All of the above-mentioned assemblies are connected with frame frames made of bolts, couplings and silver;
- The frame of equipment model is made of shaped steel box and sprayed with paint, the whole device model is moved by wheel 18.

3. Experimental research results

In order to assess the impact of sharp angle and rock solidity on drill bit wear intensity, a test was conducted to determine the abrasive strength of the bit tip when changing the sharp angle of the bit tip at 5 values degrees, corresponding to 21 test rock samples with a f-strength of 6 to 8 [8, 13]. Each test is performed 05 times, after filtering out abnormal values, values The measurement is averaged over
the measured values. Summarize the results of measuring the wear intensity of the drill corresponding to the sharp angle values and \( f \) as in Table 1.

**Table 1. Intensity of wear \( i_h \) (%) of drill bits with sharp angle \( \alpha \) and strength \( f \)**

| Sharp angle \( \alpha \) (Durability \( f \)) | 100\(^0\) | 105\(^0\) | 110\(^0\) | 115\(^0\) | 120\(^0\) |
|--------------------------------------------|---------|---------|---------|---------|---------|
| 6.0                                        | 0.1312  | 0.1350  | 0.1412  | 0.1480  | 0.1531  |
| 6.1                                        | 0.1315  | 0.1355  | 0.1415  | 0.1485  | 0.1535  |
| 6.2                                        | 0.1320  | 0.1360  | 0.1420  | 0.1490  | 0.1540  |
| 6.3                                        | 0.1325  | 0.1365  | 0.1425  | 0.1495  | 0.1545  |
| 6.4                                        | 0.1330  | 0.1370  | 0.1430  | 0.1500  | 0.1550  |
| 6.5                                        | 0.1335  | 0.1375  | 0.1435  | 0.1505  | 0.1555  |
| 6.6                                        | 0.1340  | 0.1380  | 0.1440  | 0.1510  | 0.1560  |
| 6.7                                        | 0.1345  | 0.1385  | 0.1445  | 0.1515  | 0.1565  |
| 6.8                                        | 0.1350  | 0.1390  | 0.1450  | 0.1520  | 0.1570  |
| 6.9                                        | 0.1355  | 0.1395  | 0.1455  | 0.1525  | 0.1575  |
| 7.0                                        | 0.1360  | 0.1400  | 0.1460  | 0.1530  | 0.1580  |
| 7.1                                        | 0.1365  | 0.1405  | 0.1465  | 0.1535  | 0.1585  |
| 7.2                                        | 0.1370  | 0.1410  | 0.1470  | 0.1540  | 0.1590  |
| 7.3                                        | 0.1375  | 0.1415  | 0.1475  | 0.1545  | 0.1595  |
| 7.4                                        | 0.1380  | 0.1420  | 0.1480  | 0.1550  | 0.1600  |
| 7.5                                        | 0.1385  | 0.1425  | 0.1485  | 0.1555  | 0.1605  |
| 7.6                                        | 0.1390  | 0.1430  | 0.1490  | 0.1560  | 0.1610  |
| 7.7                                        | 0.1395  | 0.1435  | 0.1495  | 0.1565  | 0.1615  |
| 7.8                                        | 0.1400  | 0.1440  | 0.1500  | 0.1570  | 0.1620  |
| 7.9                                        | 0.1405  | 0.1445  | 0.1505  | 0.1575  | 0.1625  |
| 8.0                                        | 0.1412  | 0.1450  | 0.1523  | 0.1582  | 0.1631  |

Let us develop an empirical regression equation that reflects the influence of sharp angle and hardness of the rock on the strength of the drill bit tip wear.

Based on the measurement test data to determine the strength of the drill tip wear according to the rock solidity and sharp angle in Table 1, we select the experimental regression function of polynomial form of two variables. Using regression method Experimental minimum squares least squares, determining the empirical regression formula showing the relation of the wear intensity function \( i_h \) according to the strength \( f \) and sharp angles \( \alpha \) as follows:

\[
i_h = 0.06279 \cdot 7.24810^{-5} \alpha + 0.001948 f + 2.85710^{-6} \alpha^2 + 8.88310^{-5} \alpha f - 0.00051 f^2
\]

(1)

Comparing the experimental regression errors as shown in Table 2 and the coefficients in the empirical regression equation have been tested for compatibility according to Fisher standard.
| Sharp angle (°) | α  | f   | iₜ (%) | TN (%) | iₜ (%) | HQ (%) | Error Δiₜ(%)* | Sharp angle (°) | α  | f   | iₜ (%) | TN (%) | iₜ (%) | HQ (%) | Error Δiₜ(%)* |
|---------------|----|-----|--------|--------|--------|--------|--------------|---------------|----|-----|--------|--------|--------|--------|--------------|
| 100           | 6.0| 0.1312 | 0.1308 | 0.0030 | 110    | 7.0    | 0.1460       | 1465          | 0.0034 |
| 100           | 6.1| 0.1315 | 0.1312 | 0.0023 | 110    | 7.1    | 0.1465       | 1469          | 0.0027 |
| 100           | 6.2| 0.1320 | 0.1317 | 0.0023 | 110    | 7.2    | 0.1470       | 1474          | 0.0027 |
| 100           | 6.3| 0.1325 | 0.1321 | 0.0030 | 110    | 7.3    | 0.1475       | 1478          | 0.0020 |
| 100           | 6.4| 0.1330 | 0.1326 | 0.0030 | 110    | 7.4    | 0.1480       | 1482          | 0.0014 |
| 100           | 6.5| 0.1335 | 0.1330 | 0.0037 | 110    | 7.5    | 0.1485       | 1486          | 0.0007 |
| 100           | 6.6| 0.1340 | 0.1334 | 0.0045 | 110    | 7.6    | 0.1490       | 1490          | 0.0000 |
| 100           | 6.7| 0.1345 | 0.1338 | 0.0052 | 110    | 7.7    | 0.1495       | 1494          | 0.0007 |
| 100           | 6.8| 0.1350 | 0.1342 | 0.0059 | 110    | 7.8    | 0.1500       | 1498          | 0.0013 |
| 100           | 6.9| 0.1355 | 0.1346 | 0.0066 | 110    | 7.9    | 0.1505       | 1502          | 0.0020 |
| 100           | 7.0| 0.1360 | 0.1350 | 0.0074 | 110    | 8.0    | 0.1523       | 1506          | 0.0112 |
| 100           | 7.1| 0.1365 | 0.1353 | 0.0088 | 115    | 6.0    | 0.1480       | 1469          | 0.0074 |
| 100           | 7.2| 0.1370 | 0.1357 | 0.0095 | 115    | 6.1    | 0.1485       | 1475          | 0.0067 |
| 100           | 7.3| 0.1375 | 0.1360 | 0.0109 | 115    | 6.2    | 0.1490       | 1481          | 0.0060 |
| 100           | 7.4| 0.1380 | 0.1364 | 0.0116 | 115    | 6.3    | 0.1495       | 1487          | 0.0054 |
| 100           | 7.5| 0.1385 | 0.1367 | 0.0130 | 115    | 6.4    | 0.1500       | 1492          | 0.0053 |
| 100           | 7.6| 0.1390 | 0.1370 | 0.0144 | 115    | 6.5    | 0.1505       | 1498          | 0.0047 |
| 100           | 7.7| 0.1395 | 0.1373 | 0.0158 | 115    | 6.6    | 0.1510       | 1503          | 0.0046 |
| 100           | 7.8| 0.1300 | 0.1376 | 0.0585 | 115    | 6.7    | 0.1515       | 1509          | 0.0040 |
| 100           | 7.9| 0.1305 | 0.1379 | 0.0567 | 115    | 6.8    | 0.1520       | 1514          | 0.0039 |
| 100           | 8.0| 0.1412 | 0.1382 | 0.0212 | 115    | 6.9    | 0.1525       | 1519          | 0.0039 |
| 105           | 6.0| 0.1350 | 0.1360 | 0.0074 | 115    | 7.0    | 0.1530       | 1524          | 0.0039 |
| 105           | 6.1| 0.1355 | 0.1365 | 0.0074 | 115    | 7.1    | 0.1535       | 1529          | 0.0039 |
| 105           | 6.2| 0.1360 | 0.1370 | 0.0074 | 115    | 7.2    | 0.1540       | 1534          | 0.0039 |
| 105           | 6.3| 0.1365 | 0.1375 | 0.0073 | 115    | 7.3    | 0.1545       | 1539          | 0.0039 |
| 105           | 6.4| 0.1370 | 0.1380 | 0.0073 | 115    | 7.4    | 0.1550       | 1544          | 0.0039 |
| 105           | 6.5| 0.1375 | 0.1385 | 0.0073 | 115    | 7.5    | 0.1555       | 1548          | 0.0045 |
| 105           | 6.6| 0.1380 | 0.1389 | 0.0065 | 115    | 7.6    | 0.1560       | 1553          | 0.0045 |
| 105           | 6.7| 0.1385 | 0.1394 | 0.0065 | 115    | 7.7    | 0.1565       | 1557          | 0.0051 |
| 105           | 6.8| 0.1390 | 0.1398 | 0.0058 | 115    | 7.8    | 0.1570       | 1561          | 0.0057 |

Table 2. Compare errors and check compatibility
Table 2. Continuation

| Sharp angle ($\alpha$) (degree) | $i_b$ (%) | TN (%) | $i_b$ (%) | HQ (%) | Error $\Delta i_b$(%)* | Sharp angle ($\alpha$) (degree) | $i_b$ (%) | TN (%) | $i_b$ (%) | HQ (%) | Error $\Delta i_b$(%)* |
|---------------------------------|----------|--------|----------|--------|------------------------|---------------------------------|----------|--------|----------|--------|------------------------|
| 105                             | 6.9      | 0.1395 | 0.1402   | 0.0050 | 115                    | 7.9                             | 0.1575   | 0.1566 | 0.0057   |
| 105                             | 7.0      | 0.1400 | 0.1407   | 0.0050 | 115                    | 8.0                             | 0.1582   | 0.1570 | 0.0076   |
| 105                             | 7.1      | 0.1405 | 0.1411   | 0.0043 | 120                    | 6.0                             | 0.1531   | 0.1526 | 0.0033   |
| 105                             | 7.2      | 0.1410 | 0.1415   | 0.0035 | 120                    | 6.1                             | 0.1535   | 0.1532 | 0.0020   |
| 105                             | 7.3      | 0.1415 | 0.1419   | 0.0028 | 120                    | 6.2                             | 0.1540   | 0.1538 | 0.0013   |
| 105                             | 7.4      | 0.1420 | 0.1422   | 0.0014 | 120                    | 6.3                             | 0.1545   | 0.1545 | 0.0000   |
| 105                             | 7.5      | 0.1425 | 0.1426   | 0.0007 | 120                    | 6.4                             | 0.1550   | 0.1551 | 0.0006   |
| 105                             | 7.6      | 0.1430 | 0.1430   | 0.0000 | 120                    | 6.5                             | 0.1555   | 0.1557 | 0.0013   |
| 105                             | 7.7      | 0.1435 | 0.1433   | 0.0014 | 120                    | 6.6                             | 0.1560   | 0.1563 | 0.0019   |
| 105                             | 7.8      | 0.1440 | 0.1436   | 0.0028 | 120                    | 6.7                             | 0.1565   | 0.1569 | 0.0026   |
| 105                             | 7.9      | 0.1445 | 0.1440   | 0.0035 | 120                    | 6.8                             | 0.1570   | 0.1574 | 0.0025   |
| 105                             | 8.0      | 0.1450 | 0.1443   | 0.0048 | 120                    | 6.9                             | 0.1575   | 0.1580 | 0.0032   |
| 110                             | 6.0      | 0.1412 | 0.1414   | 0.0014 | 120                    | 7.0                             | 0.1580   | 0.1585 | 0.0032   |
| 110                             | 6.1      | 0.1415 | 0.1419   | 0.0028 | 120                    | 7.1                             | 0.1585   | 0.1591 | 0.0038   |
| 110                             | 6.2      | 0.1420 | 0.1425   | 0.0035 | 120                    | 7.2                             | 0.1590   | 0.1596 | 0.0038   |
| 110                             | 6.3      | 0.1425 | 0.1430   | 0.0035 | 120                    | 7.3                             | 0.1595   | 0.1601 | 0.0038   |
| 110                             | 6.4      | 0.1430 | 0.1435   | 0.0035 | 120                    | 7.4                             | 0.1600   | 0.1607 | 0.0044   |
| 110                             | 6.5      | 0.1435 | 0.1441   | 0.0042 | 120                    | 7.5                             | 0.1605   | 0.1612 | 0.0044   |
| 110                             | 6.6      | 0.1440 | 0.1446   | 0.0042 | 120                    | 7.6                             | 0.1610   | 0.1616 | 0.0037   |
| 110                             | 6.7      | 0.1445 | 0.1451   | 0.0042 | 120                    | 7.7                             | 0.1615   | 0.1621 | 0.0037   |
| 110                             | 6.8      | 0.1450 | 0.1455   | 0.0034 | 120                    | 7.8                             | 0.1620   | 0.1626 | 0.0037   |
| 110                             | 6.9      | 0.1455 | 0.1460   | 0.0034 | 120                    | 7.9                             | 0.1625   | 0.1631 | 0.0037   |
| 120                             |         |        |          |        |                        | 8.0                             | 0.1631   | 0.1635 | 0.0025   |

Error of abrasion intensity according to the regression function and experimental results:

$$\Delta i_b = \frac{i_bTN - i_bHQ}{i_bTN} \cdot 100,\% \quad (2)$$

From the empirical formula (1) draw a 3D graph showing the relationship of wear intensity $i_b$ at the same time solidity $f$ and sharp angles $\alpha$ as shown in Figure 5. and 2D graphs that reflect the dependence of wear strength $i_b$ at sharp angles at some different solidities as shown in Figure 6 and depending on the solidity at some different sharp angles as shown in Figure 7.
Figure 5. Graph of relationship to abrasion intensity $i_h$ with sharp angles $\alpha$ and solidity $f$.

Figure 6. Relationship graph of abrasion intensity with sharp angle when different hardness.

Figure 7. Relationship diagram of abrasion strength with strength when sharp angle is different.
From the empirical formula (1) shows, the coefficient value of the solidity $f$ is $0.001948 > 0$. means corresponding to the strength under consideration. the intensity of wear $i_h$ Variable variable with solidity $f$, ie when the strength increases, the intensity of wear increases. The coefficient value of sharp angle $\alpha$ is $-7.248 \times 10^{-5} < 0$. means that in the sharp angle range the intensity of wear is being considered $i_\alpha$, inversely variable with sharp angle, ie when sharp angle increases, the intensity of wear tends to decrease, but the absolute value of this coefficient is very small compared to the coefficient of solidity. so the decrease of intensity the sharpness of the sharp angle is negligible compared to the increase of the wear intensity with the strength of solidity. Also in the empirical formula (1), the quadratic coefficients of $\alpha$ and $f$ have absolute values that are much smaller than the absolute values of the first order coefficients. that is the degree The influence of quadratic quantities on wear intensity is negligible.

The influence of solidity and sharp angle on abrasion intensity is more clearly shown in 3D graphs in Figure 5 and 2D graphs Figures 6 and 7. Quantitatively, for each rock type soil has the most solidity. When the sharp angle increases from 100-120 degrees, the intensity of wear increases by 0.024%. As for each type of drill with a certain sharp angle. when the solidity of rock and soil increases from 6 to 8, the intensity of wear increases by about 0.022%. specifically with a sharp angle of 100 degrees, the increase is 0.019%. sharp angle of 110 degrees the increase is 0.023% and the sharp angle of 120 degrees is 0.026%. Thus. for rocky soil in Quangninh coal mine (with common solidity in the range of $6 \div 8$), it is possible to choose a drill with small sharp angle. preferably under 115 degrees.

Comparing with the fair value area of sharp angle according to the stable condition of cutting edge and the body of drill bit defined [14], the adjacent sharp angle area of 110 degrees has been determined to be perfectly reasonable. not only ensure the durability but also ensure the longevity of the drill bit in solid rock condition ($6 \div 8$) in Quangninh coal mine.

4. Conclusion
The aforementioned results showed the influence of sharp angle and hardness of stone on the intensity of drill bit wear.

With the above-mentioned research results, it is possible to calculate, select and determine the wear tip of the drill bit in the direction of increasing the durability. ensuring that the drilling equipment works according to the requirements set out when drilling and blasting holes in service digging basic kilns in construction and mining in Quangninh region. In order to increase productivity. it is necessary lower costs and contribute proactively in production planning and repair of drilling equipment.

References
[1] Yungmeyster D A and Urazbakhtin R Yu 2017 Rescue complex for coal mines IOP Conference Series: Earth and Environmental Science 87 092032
[2] Nguyen K L Gabov V V Doan V G Pham V T 2019 Study of the influence of structure and parameters of loading and transporting devices of a cleaning combine on the efficiency of coal loading Journal of Physics: Conference Series (JPCS) 1384 012036
[3] Osman Hekimoglu 2017 A pick force calculation method suggested for tool lacing of mechanical excavators employing drag tools International Journal of Mining, Reclamation and Environment 10.1080/17480930.2017.1317946
[4] Bolobov V I and Le Thanh Binh 2018 Influence of deep cryogenic treatment on structure and wear resistance of materials of hydraulic breaker chisels. IOP Conference Series Materials Science and Engineering 327 042016
[5] Nasonov M Yu. Lykov Yu V. Do Duc Trong 2020 The study of the resource and durability of metal structures of excavators after the expiration of the service life Ugol’ 2 13-17
[6] Aleksandrov A N. Rogachev M K. Thang Nguyen Van. Kishchenko M A. Kibirev E A 2019 Simulation of organic solids formation process in high-wax formation oil Topical Issues of Rational Use of Natural Resources 2 779-790
[7] Zhang Qianqian, Han Zhennan, Zhang Mengqi and Zhang Jianguang 2015 Prediction of tool forces in Rock cutting using discrete tlement vethod EJGE 20 1607-1625
[8] Gabov V V, Zadkov D A and Nguyen Khac Linh 2019 Features of elementary burst formation during cutting coals and isotropic materials with reference cutting tool of mining machines Journal of Mining Institute 236 153
[9] John P M and Khamis Y H 1988 Probe-hole drilling: high-stress detection in coal (Pittsburgh Pa.: U.S. Dept. of the Interior, Bureau of Mines)
[10] Skryabin R M and Timofeev N G 2016 Development of an innovative shneko-heat-sink boring shell for drilling of shurfo-wells in the conditions of a kriolitozona Eurasian mining 1 33-36
[11] Daolong Yang, Jianping Li, Liping Wang, Kuidong Gao, Youhong Tang and Yanxiang Wang 2014 Experimental and theoretical design for decreasing wear in conical picks in rotation-drilling cutting process. The International Journal of Advanced Manufacturing Technology 75 3-11
[12] Bochkov V, Bolobov V and Chupin S 2017 About increasing wear resistance of rock-breaking tool to abrasion by using mechanical and thermo-mechanical treatment International Review of Mechanical Engineering 11 301-304
[13] Gabov V V and Zadkov D A 2016 Energy-saving modular units for selective coal cutting. Eurasian mining 1 7-40
[14] Le Quy Chien 2015 Researching and determining some reasonable parameters of drill bit heads to drill blasting holes in underground mining in Quang Ninh