New design of cutters for coal mining machines

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Annotation. The author designs an up-to-date rock cutter for mining machines and presents a matrix to determine its service life depending on the strength of the rock being broken. The dependence of the cutter service life on the strength of the rock being broken is proved. Advanced designs of rock cutters by the leading companies are described. The author develops an original design of a rock cutter which provides greater cutting surface, increased strength and prolonged service life. Pilot samples of the cutters ready to the test run are presented.

Introduction

Rocks breaking in mines during the mining and clearing activities is conducted by special coal mining machines; their working bodies are equipped with cutters. The cutters are placed on the coal mining machines in the amount of 38-96 pieces, depending on the design of the executive body (Fig. 1).

Figure 1. Working element of coal mining machine with cutting tools

In 2011 134 coal mining machines operated in Russian mines, 108 of them being produced in Ukraine, Poland, Germany and the USA [1]. Coal mining machine cutting tools play a key role in mining technology. If a rock cutter is out of order the whole complex of mine machines has to stop work as far as coal cutting is impossible. An average coal mine in Kuzbass spends 15,000 – 18,000 rock cutters per year which increases the cost of mining. In this view improving strength and prolonging service life of rock cutters are important.

Research Results

Currently coal mining machines are equipped with swivel tangential cutter which is designed as a cylinder swing holders made of high strength alloy steel and hard-tipped with hard-metal nose (Fig. 2).

Figure 2. Swivel tangential cutter of coal mining machine

The nose is made of strong wear-resistant tungsten-rhenium alloy and is joined to the holder by means of brazing. The efficiency of rock braking depends on the depth and the speed of penetration into the rock, strength and abrasiveness of the rock, cutter wear resistance, a rock breaking technique, mining machine driver's skills and some other factors.

Mechanical characteristics such as rock strength and cutter strength are crucial for effective coal breaking. Both the rock and the cutter can have high, average and low strength. Various combinations of these properties define different rate of reciprocal destruction of the rock and the cutter. Rock cutter wear rate is stipulated by different variations in strength ratio. (Fig.3).

Low strength cutters have limited applications and can be used only with coal and soft rock. Using such cutters with average and high strength rocks leads to quick wear out and inefficient performance. Soft and average strength rocks can be effectively cut by an average strength cutter. When using high strength cutters with strong rocks, their reciprocal impact matches. If a rock becomes softer wear rate of a high strength cutter decreases, which provides wide application field of such cutters.

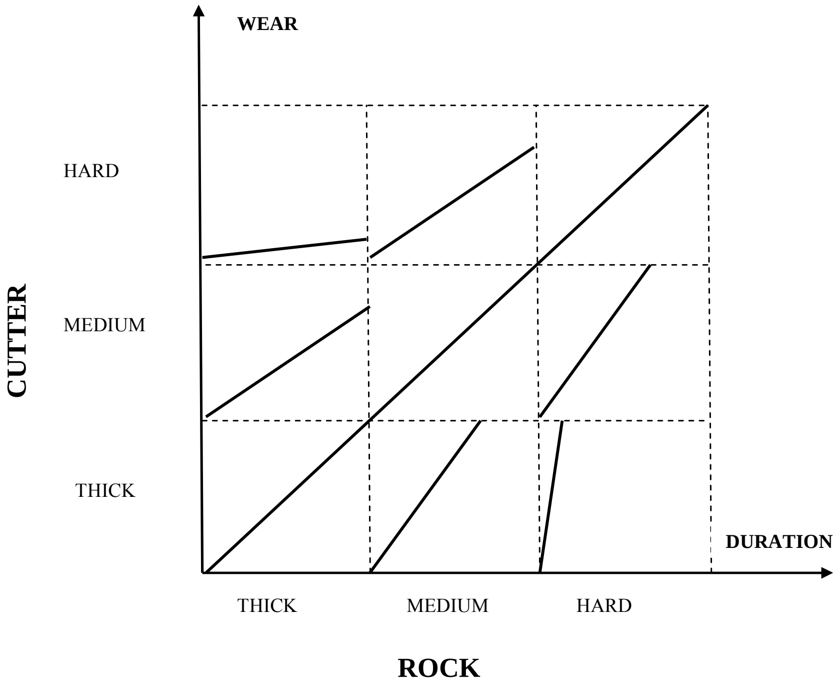

Figure 3. Rock cutter wear rate matrix depending on the strength of destroyed rock

Strength of the rock being destroyed influences rock cutter durability as well as coal mining machine service life. The dependence in Fig. 4 build up according to data [2] shows that as rock strength rises from 30 to 80 MPa, coal mining machine service life is shortened and it is 80 % worn out and needs general overhaul after breaking 55,000-60,000 m^3 in average instead of 10,000-12,000 м^3.

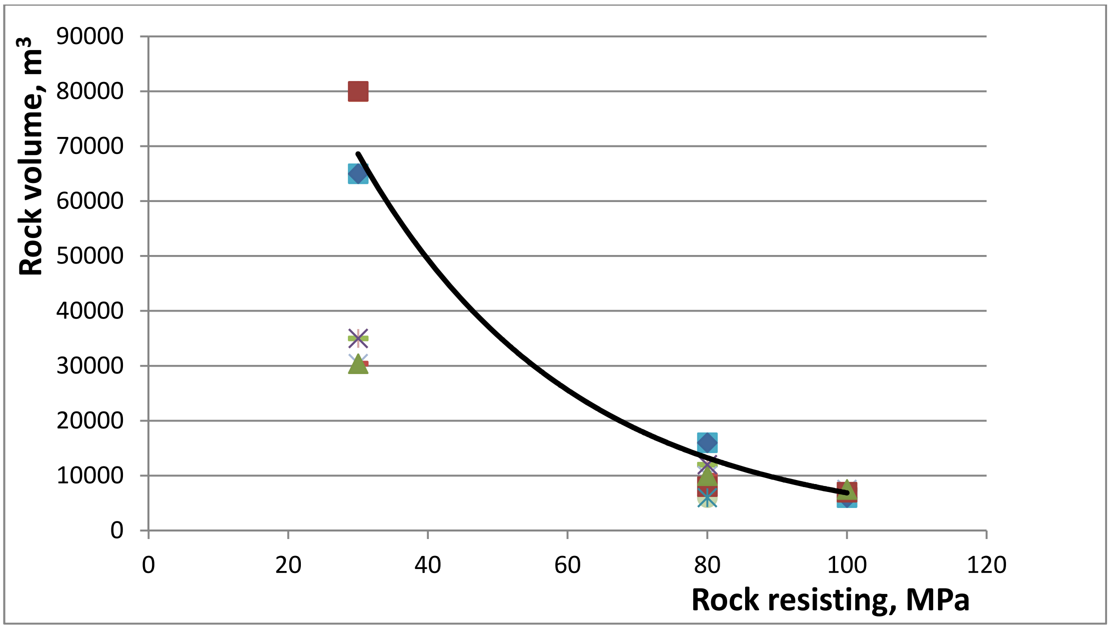

Figure 4. Influence of rock strength on coal mining machine service life

To reduce the negative influence of rocks on mining machines designers increase power of coal mining machine drives, strengthen assembly units and joint points, change operating device design. Improving rock cutting tools is an important measure to increase efficiency of rock cutting. Leading companies all over the world are concerned in designing new and better cutting tools.

Among the latest innovation by Sandvik company there are ribbed cutter heads to provide easy rotation and uniform wearing [3]. The cutter heads has four ribs longwise (Fig. 5a).

a

b

Figure 5. Sandvik cutters with ribbed heads (a) and protecting ring (b)

Kennametal company adopted cutter heads of similar shape. Cutters U83K 3.1 48,UR118 3.5 12.5NB, AM512FG have longwise ribs on their heads.

Another promising design by Sandvik company is equipped with TriSpecTM carbide ring to protect the area where the nose is fastened to the head body (Fig. 5b) [3]. The ring entrains about the front part of the cutter head where the nose is brazed-in and prevents the steel body from early wearing, thus prolonging service life of the carbide insert. Kennametal company offers a similar design of rings U119HF 80 16 and AM521HF 74 with protecting ring on the head nose.

Some designers suggest using a hard steel insert (for example X12MΦ) as a cutting element in order to uniform the rate of wearing of cutter body and insert. Work tests of such cutters showed their efficiency and uniform self-sharpening [4]. There are a number of researches aimed at improving design and increasing strength of cutters in various ways [5-8].

In mines of Kuzbass region some tests have been carried out to study the degree and the pattern of cutters wearing. The tests showed that the upper tapered section of the cutter head undergoes intensive wear. Fig. 6 shows a cutter which has lived its lifespan on KP-21 coal mining machine.

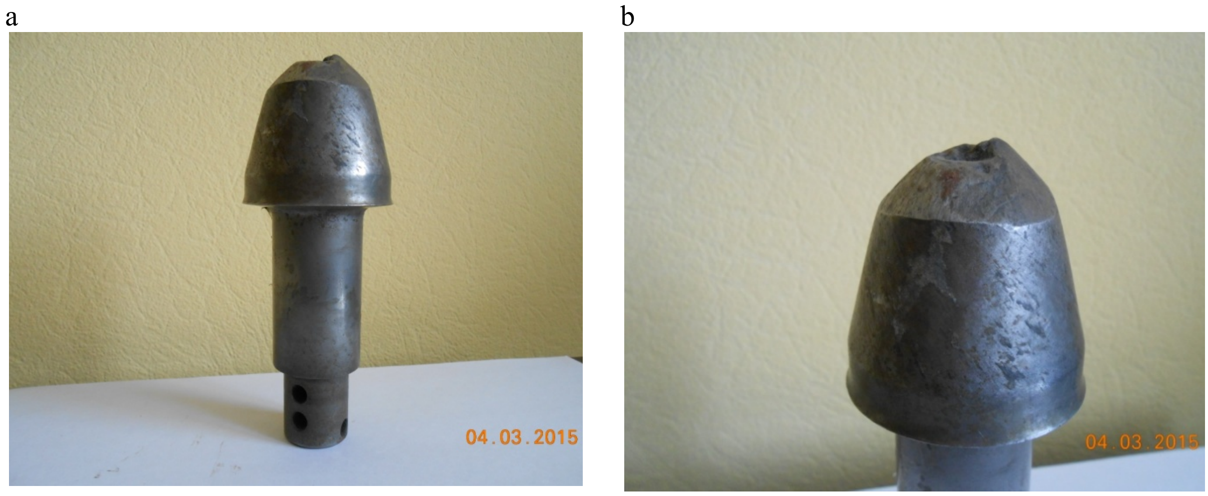

Figure 6. Worn out coal mining machine cutter (a) and its head (b)

We can see that the tapered area of the cutter head is uniformly worn out by 36 %. The rest of the head is not changed except for surface wear as deep as about 1mm.Wear rate (reducing head length) can be estimated with the help of graphs in Fig. 7, where curve 1 shows reducing head length from initial 70mm, and curve 2 shows an aggregate wearing of the head in per cent on a cumulative total.

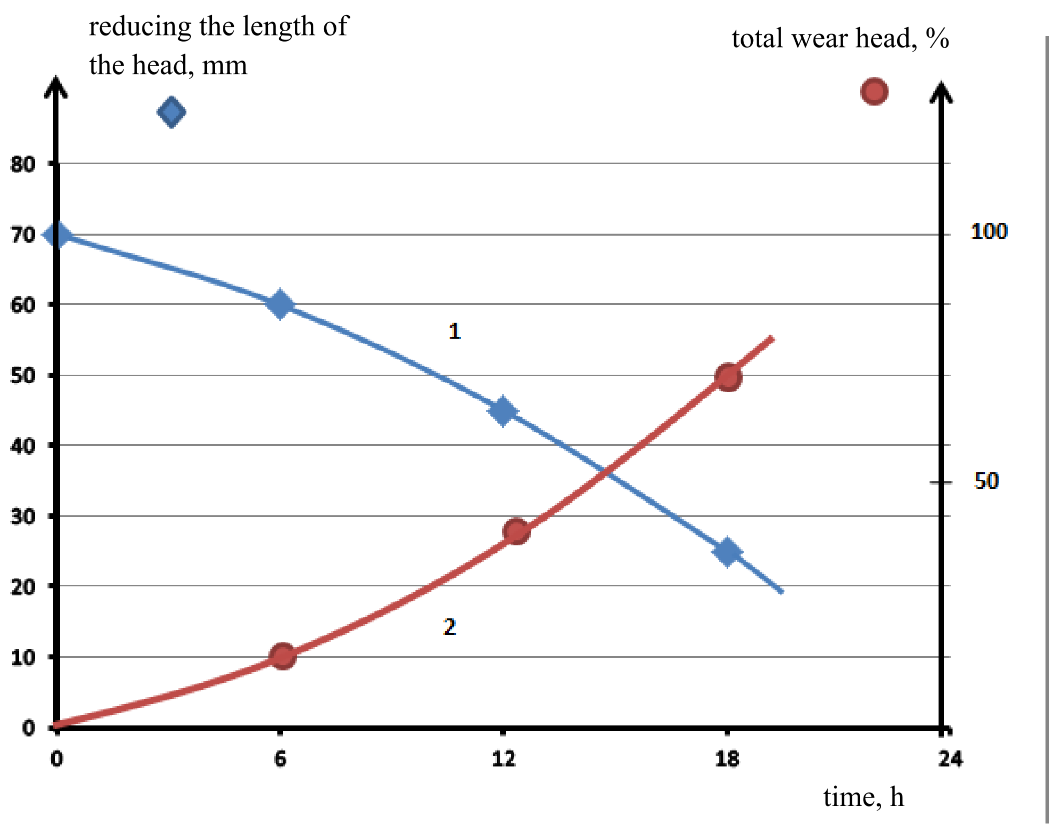

Figure 7. Rate of cutter head wearing

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It has been found out that among other factors accelerated wearing of the tapered part of the cutter head is caused by irregular hardness of the cutter material, which decreases from 55 to 42 HRD on the surface and from 50 to 35 HRC in the center in the direction from the wide part of the head to the tapered one [9].

Based on the study of the rate and the mode of wearing of coal machine cutter we have developed a new design of the cutter which has high wear resistance and efficiency. We suggest reinforcing the head with extra reinforcing elements alongside with providing it with a tampered carbide nose. We recommend using carbide blades brazed in notches along the cutter axis. The length of the blades is 30-35 mm and their thickness is 5 mm. Such design provides a larger cutting surface, higher strength and greater durability. There can be from 2 to 4 brazed-in blades. Fig. 8 shows a photo of new cutters.

Figure 8. Coal machine cutters with heads reinforced by carbide blades

The left cutter has 3 cutting blades, the right one is equipped with two blades. These cutters are innovative and we are currently arranging test runs in the mines of Kuzbass.

Carbide cutting blades improve wear resistance of cutter surface. Table 1 shows calculations of the reinforced area depending on the number of cutting blades per a head (table 1).

Table 1. Increasing reinforced area of cutter head

Reinforced area	Increasing reinforced area with different number of blades, %			
	0	2	3	4
Cutter head S=8356 mm^2	0	3,6	5,4	7,2
Working area of the head S=1885 mm^2	0	16	24	32

When 2 - 4 blades are inserted, the area protected by hard alloy increases from 4% to 7%. As for working part of the head which undergoes the greatest wearing two inserted blades increase the hardened area by 16%, with three blades this area grows by 24%, and with four blades it grows by

32%. Fig. 9 shows changes in the average hardness of the working part of the head as the number of inserted plates is increased. The graph shows that average hardness can be increased from 55 up to 60 HRC, which significantly raises cutter heads durability.

Figure 9. Changes in average hardness of cutter blade

The cutting blades serve not only to harden the holder but also to fasten the nose in the body. They prevent quick wearing of the body around the nose and its early withdrawal. The chosen length of the blades allows their inserting into the wide part of the head which does not undergo great wearing which provides reliable fastening and long service life of the cutting blades.

Increased service life of the cutters allows breaking great volumes of rock. The cost of a unit of mined coal decrease and coal mining efficiency grows.

Conclusion

Coal and rock cutting in modern mines is carried out by means of coal mining machines equipped with tangential cutters. Efficiency of their performance mainly depends on correlation of strength of a cutting metal and that of a rock.

The design of coal machine cutter reinforced by longwise cutting blades suggested in the article provides it with greater cutting surface, increased strength and longer service life. Reinforced area on the working part of the head is increased to 32%, average strength rises to 60HRC. Test samples of this design are ready for testing in the mines of Kusbass.

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