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WORN CUTTER PICKS AS A SECONDARY RESOURCE FOR MANUFACTURING MODULAR CUTTING TOOLS FOR SHEARERS

Upon agreement with a Kuzbass mine's management, the worn picks of shearer JOY 4LS-20 were collected to manufacture load-bearing members of modular cutter picks. Four innovative picks were set on the cutting drum of the shearer and their performance was observed.

The mine trials proved the theoretical hypothesis on potential recycling of the worn traditional picks as a secondary scrap metal for manufacturing modular tools. Three out of four experimental picks were run for 35 days on the shearer which produced 55 Kt of broken rock mass within that space of time. Due to the inconsistency of the working coal seam thickness, the overcut of the shearer was to 0.2 m deep in the middle of the longwall floor composed of grey sandstone having the hardness factor of 5–6 on the Protodyakonov scale.

The mine managers' fears concerning attachment unreliability of the cutting modules, their falling out and expanding of screws remained unconfirmed. Only one pick was damaged with tearing-off of the attaching ring.

Inspection of the load-bearing members of the modular picks after trials exhibited their insignificant operational wear at the level of 0.5–2.5% of their initial mass. The length and the attaching diameter of the members remained nearly the same, which proves their long-term usability in a set of the modular cutter picks in underground coal cutting. The mass of the load-bearing module is 80% of the whole tool, which allows considerable reduction (to 5–7 times) in metal consumption of coal shearing with redesign and recycling of the worn tools on the ground of modularity.

Keywords: *coal shearer, cutter pick, efficiency, wear, strength, rock mass, cutting drum*
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Introduction

Cutting tools of heading machines are the research objects both in Russia and abroad. Such researches aim to reveal the effect of: diameter of carbide inserts on the rate of their wear; high-pressure water jet on the wear and dusting of a pick [1]; rock strength on the service life of the picks and heading machines [2]; number of alloying ingredients in steel on its abrasive wear [3]; uniformity of thermal treatment as well as high-temperature thermomechanical treatment of pick bodies on the rate of wear and on the service life of picks [4, 5]; shape of indenters on the endurance of the tool [6].

The energy input of rock fracture by composite bits were experimentally and theoretically studied [7, 8]. Chinese researchers investigated effect of water on penetrability and longer service life of cutter picks [9]. It was examined how the cutting tool efficiency depended on its setting angle [10, 11]. The values of the angles ensuring free cutting, least cutting efforts and low energy consumption of fracture were found [12–15].

Professor Bolobov and his colleagues tested experimentally efficiency of static and impact penetration of a rock-breaking tool in sandstone [16]. The load applied to the picks and transmissions of the cutting heads of heading machines in cutting hard dirt rocks in coal seams or in switching operating modes is analyzed in [17, 18]. Indian scientists investigated types of wear of cutter picks by the X-ray spectroscopy, with identification of cracks, voids and polishing effect [19].

Australian researchers found how the unit and cyclic bending loading influences fracture of a pick body in a series of tests on a special bench tester at CSIRO's laboratory [20]. They also performed the same tests with the thermally stable diamond composite (TSDC) tipped picks which were considered as a replacement for the tungsten carbide cobalt tipped picks in hard rock cutting. It is found that owing to high hardness of TSDC at low fracture toughness, the major type of failures of TSDC tipped picks in rock cutting are random failures due to excessive bending force applied to the cutter picks [21].

The currently advanced improvements of rock-cutting tools of underground heading machines include design engineering of modular cutter picks [22, 23]. The studies are carried out both theoretically, in the field of development of promising designs and their substantiation, and experimentally, by means of testing functional capabilities of new designs and their efficiency when used on mining machines [24].

Design of a modular cutter pick includes a load-bearing member and an attached cutting head [25]. The length of the latter is 15–25% of the total length of the pick. The developed attachments and their validated parameters ensure a strong and effective structure. Such tools were manufactured and tested in mines, which made it possible to reveal that the load-bearing members are durable up to 9–12 replacements of the cutting heads [24].

The analyses of the nature, causes and size of wear of the current tangential rotary picks allowed a hypothesis on potential recycling of the scrapped parts. Many scrapped parts preserve the unworn length sufficient to enable using them as semi-finished products for manufacturing load-bearing members. Conversion of metal junk into tools may offer an opportunity of manufacture of a nonexpendable load-bearing member. It is expected that such load-bearing member takes 70–80% in the mass of a pick, which allows anticipating an essential reduction in metal consumption in rock cutting. The aim of this study is to check the theoretical conclusion on re-use of worn pick as holders of cutting heads on cutting drums of underground heading machines in coal mines.

Manufacture of modular cutter picks from waste

In the spring of 2022, management of a mine in Kuzbass agreed to test cutter picks manufactured from metal junk. With his end in

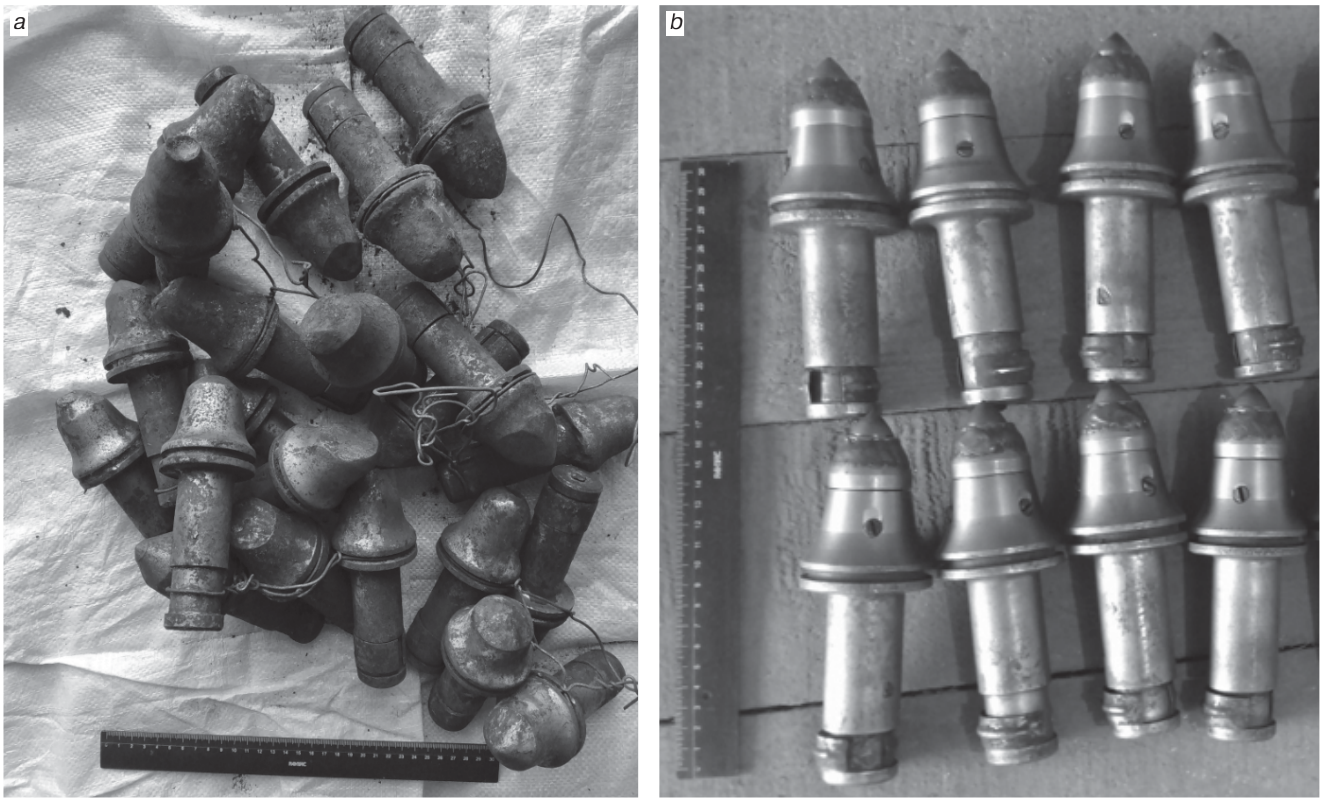

Fig. 1. Worn picks RSH 35-95L90/19 (*a*) and modular picks manufactured from them (*b*)

view, operators of shearer JOY 4LS-20 collected worn picks RSH 35-95L90/19 of traditional one-piece construction (**Fig. 1a**).

After inspection of the size and nature of wear of the worn picks, some picks were discarded and the other picks were selected as a secondary serviceable material. The selected picks served as a feedstock for manufacturing load-bearing members the actual mass of which in the final product was 80% (**Fig. 1b**).

The cutting modules were made of a new bar metal and equipped with new tungsten carbide tips manufactured by the Kirovgrad Hardmetal Works, Russia. Steel bodies of the cutting modules were coated with a protective wear-resistant material. The coating was meant to protect the area around the tips and to extend the active life of the modules.

Testing of modular cutter picks

Four modular cutter picks were set on the upper drum of shearer JOY 4LS-20 early in August 2021.The shear was used in cutting coal seam XXVII 2.0 m thick. The seam dip angle was 26 deg. The hardness factor of coal on the Protodyakonov scale was 0.9–1.0. Longwall 27 was 243 m long, and the total longwall system consisted of 162 units. Due to the inconsistent thickness of the coal seam, the overcut of the shearer was 0.2 m deep in the seam floor composed of sandstone with the hardness factor of 5–6 on the Protodyakonov scale. The coal cutting per one pass of the shearer was 0.5 m wide. The coal yield of the cutting was 500 t. The average rate of mining reached 2–3 cuttings per shift 8 hours long in the summer–autumn in 2021.

The main picks on the shearer were the picks model RSH (Novokuznetsk), and their depletion was 3–5 picks a day. **Figure 2** shows the layout of the modular cutter picks on the cutting drum.

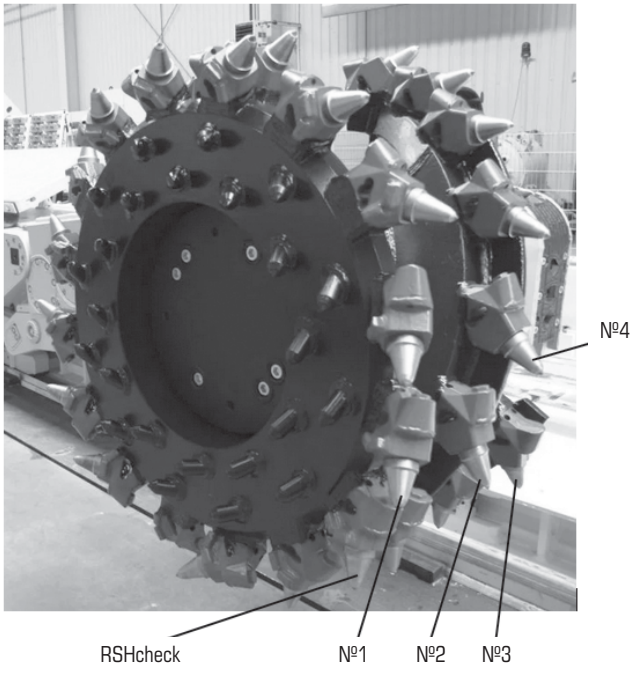

Fig. 2. Layout of modular cutter picks on shearing drum:
RSHcheck–checking pick model RSH; 1–4–modular cutter picks

Pick 1 was set on the drum blade nearest to the face heel; pick 2—on the second blade; pick 3—on the third (rearmost) blade. The picks were set along the same line relative to the face-side end of the drum. Pick 4 was set immediately behind pick 2 on the second

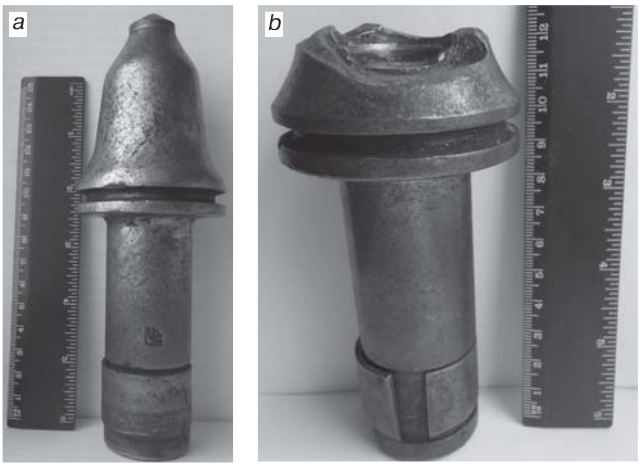

Fig. 3. Pick RSH in medium-rate wear (*a*) and damaged load-bearing module of modular cutter pick (*b*)

Fig. 4. Modular cutter picks after tests as against check pick:
K – pick in the initial condition (check pick); 1 – pick from the first shearer blade; 2 – pick from the second blade; 3 – pick from the third blade

Parameters of modular picks before and after testing

Parameter	Modular picks			
	Check pick	1	2	3
Cutting module length without shank, mm	36.40	24.50	26.40	29.10
Wear, mm (%)	0.00	11.90 (33)	10.0 (27)	7.30 (20)
Cutting module mass, g	329.85	228.15	247.55	271.30
Wear, g (%)	0.00	101.70 (31)	82.30 (25)	58.55 (17)
Load-bearing module mass, g	1205.15 (with narrow ring)	1214.25 (with wide ring, initial mass 1246.00 g)	1194.40 (with narrow ring)	1198.80 (with narrow ring)
Wear, g (%)	0.00	31.75 (2.5)	10.75 (0.9)	6.35 (0.5)

Fig. 5. Load-bearing members of worn picks as against check pick (K)

blade of the drum. In front of pick 1, new RSHcheck pick was set to monitor the wear rate of the traditional tool.

In August 2021, the shearer produced 50 Kt of broken rock mass. The longwall services reported wear of 90 picks RSH. A pick RSH having the medium rate of wear in a week-long operation is shown in **Fig. 3a**. The advanced wear of the steel head and the core exposure is visible. The checking pick RSH had the average service life of 15 days.

By the third testing day, experimental modular cutter pick 4 suffered breaking out of its head walls and was removed from the shearing drum (**Fig. 3b**). A probable cause of the failure might be high quenching of metal in this batch of picks and, consequently, their high fragility. In combination with the high cuttability of the seam floor rocks, this could lead to the tear-off of the sides of the module from the mating ring.

The rest three picks operated on the shearer for 35 days without replacement of their heads. The shearer produced 55 Kt of broken rock mass for that time. Then the picks were removed from the shearer to inspect their wear rate in laboratory. **Figure 4** demonstrates the picks in comparison with the check pick in the initial condition.

Inspection of the three picks removed from the shearer showed that the picks remained serviceable. The cutting modules had minor wear. The screw holes on the heads kept their initial condition and were unexpanded. No signs of metal preload in the holes were detected. The screws were unscrewable with no effort. The mine's managers' anticipations of such problems appeared to be invalid.

The further lab-scale tests of the wear rate of the cutting and load-bearing modules of the modular cutter picks show that the length of the check module without the shank is 36.4 mm, while the picks after testing in mine are 24.5–29.1 mm long without the shank. The length of three test cutting modules reduced by 11.9 mm, 10.0 mm and 7.3 mm, respectively (**Table**). The wear rate of the picks was 33, 27 and 20% (Table).

The initial mass of the cutting module is 329.85 g. The mass loss after testing on the shearer is 101.7 g, 82.3 g and 55.7 g, or 31, 25 and 17%, respectively. On the whole, the average wear of all cutting modules in terms of their length and mass is 25%, and they preserve an essential service life.

The mass of the modular cutter pick as a set is 1535–1575 g depending on the size of the ring on the shank. The load-bearing module in the initial condition reaches 80% of the pick mass. Inspection of the load-bearing members of the modular picks after testing exhibited their insignificant wear. Their lengths and the attaching diameter kept nearly the same after 35 days of operation (**Fig. 5**).

Friction of the modules in rotation almost unaltered their attaching planes. They preserved their initial condition. So did the diameters

of the attaching rings of the load-bearing modules. The mass of the load-bearing modules 1, 2 and 3 decreased by 2.5%, 0.9% and 0.5%, respectively. The minor change of the surfaces and masses of the load-bearing modules means their further long-term usability.

Conclusions

1. The mine trials confirmed the theoretical hypothesis on recycling of metal junk of traditional cutter picks in capacity of a secondary resource for manufacturing modular tools. The tests show an insignificant wear of the load-bearing module made of a worn pick, which proves its long-term serviceability in a set of a modular pick in underground coal cutting. The mass of the load-bearing module is 80% of the whole tool, which allows considerable reduction (to 5–7 times) in metal consumption of coal shearing with redesign and recycling of the worn tools.

2. Three out of four experimental picks were run for 35 days on a shearer which produced 55 Kt of broken rock mass. Only one pick was damaged with tear-off of the attaching ring. The mine management's fears concerning attachment unreliability of the cutting modules, their falling out and expanding of screws remained unconfirmed.

3. After serviceability of the modular picks made of junk metal of the worn cutting tools has been proved, the further research goal is to assess service lives of various-geometrics load-bearing modules and retrofittable modular cutter picks on different-type shearers and in different geological conditions.

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