ZĘBY WYMIENNE DO CZERPAKÓW KOPAREK WIELONACZYNIOWYCH KOŁOWYCH

EXCHANGEABLE TEETH FOR BUCKET WHEEL EXCAVATORS

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Podano przyczyny podjęcia prac badawczych, których celem było opracowanie nowej konstrukcji i technologii produkcji zębów do koparek kołowych eksploatowanych w kopalniach odkrywkowych węgla brunatnego. Sformułowano założenia konstrukcyjne budowy zęba i technologii jego produkcji. Przedstawiono opracowaną konstrukcję zębów wymiennych. Opisano korzyści wynikające z zastosowania powyższej konstrukcji zębów i technologii ich produkcji. Zaprezentowano rezultaty badań eksploatacyjnych nowych zębów i efekty techniczno-ekonomiczne wynikające z badań. Wskazano na możliwość uzyskania dalszego wzrostu trwałości opracowanych zębów.

Słowa kluczowe: *koparki wielonaczyniowe kołowe, zęby wymienne, konstrukcja, technologia produkcji, trwałość, napawanie, automatyzacja.*

The reasons for initiation of research works aimed at developing a new construction and production technology of exchangeable teeth for BWEs operating in open cast lignite mines were given. Design assumptions for the construction of teeth and the technology of their production were formulated. The developed construction of exchangeable teeth was presented. The advantages of using the developed construction of teeth and technology of their production were described. The results of exploitation tests of the developed teeth and the technical and economic effects resulting from the tests were presented. The possibility of obtaining a further increase in the durability of developed teeth were indicated.

Keywords: *bucket wheel excavators (BWEs), exchangeable teeth, construction, production technology, durability, pad welding, automation.*

Introduction

In BWEs operating in domestic lignite open pit mines, buckets with fixed teeth were used on a large scale. The teeth were welded to the bucket knife and composed a fixed unit (Fig. 1). That is why after wearing or breaking some teeth, the buckets were dismounted and were undergoing a regeneration consisting in the replacement of teeth and faxing new knives, in the case of their wear out or damage. Regeneration was not possible on site, therefore the buckets had to be transported to workshops and then transported back to the excavator and mounted, which resulted in increased exploitation costs [1].

As the situation led to the increase in digging resistance and furthermore, a whole range of negative phenomena such as: the increase in dynamic loads having impact on the load bearing structure and mechanisms of excavator, the decrease in efficiency or higher energy consumption, it was necessary to exchange the buckets frequently. Thus the excavator exploitation costs increased considerably as well (average time of bucket set exchange requires about three hours of the excavator stoppage, not to mention the cost connected with servicing and transportation of buckets, which is not simple, especially when the working levels are not easily accessible). Moreover the necessity to exchange the buckets so often was caused by the fact that after wear out or damaging of teeth at particular buckets, the whole set had to be removed because otherwise the same slice thickness could not be ensured, which led to the increase in digging resistance and above mentioned negative effects.

These negative effects resulted in the research undertaken in Poltegor-Institute, with the objective of improving the situation.

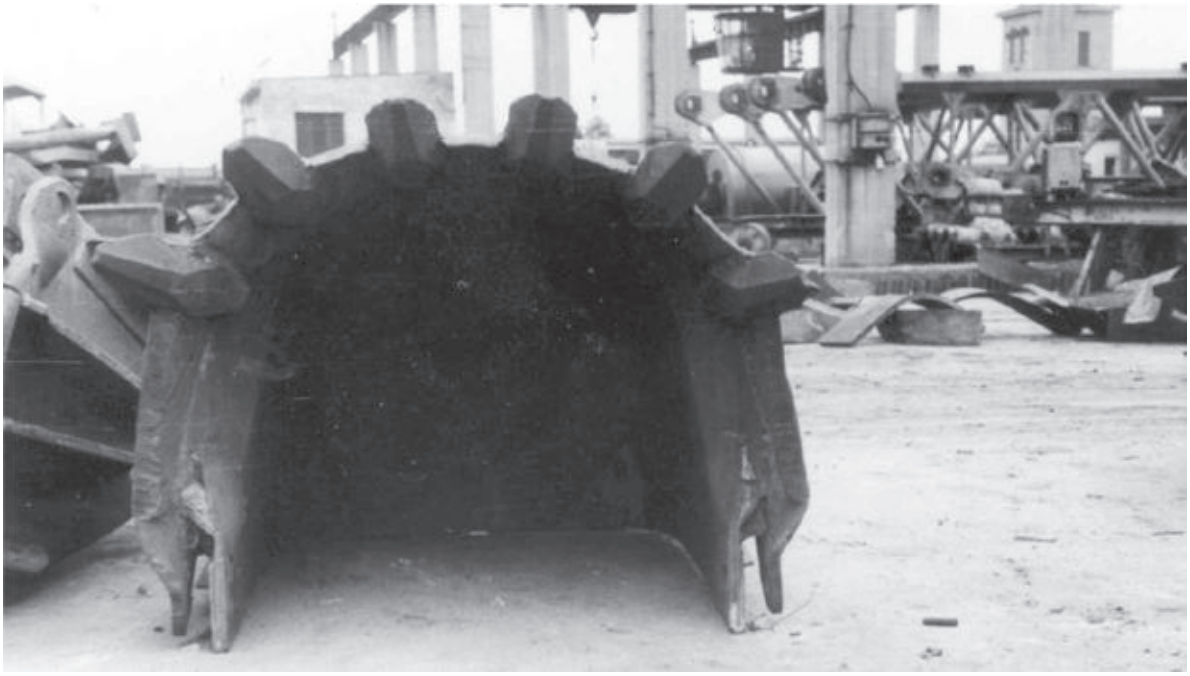

Fig. 1. Fixed teeth welded to the bucket knife
Rys. 1. Zęby mocowania stałego przyspawane do noża czerpaka

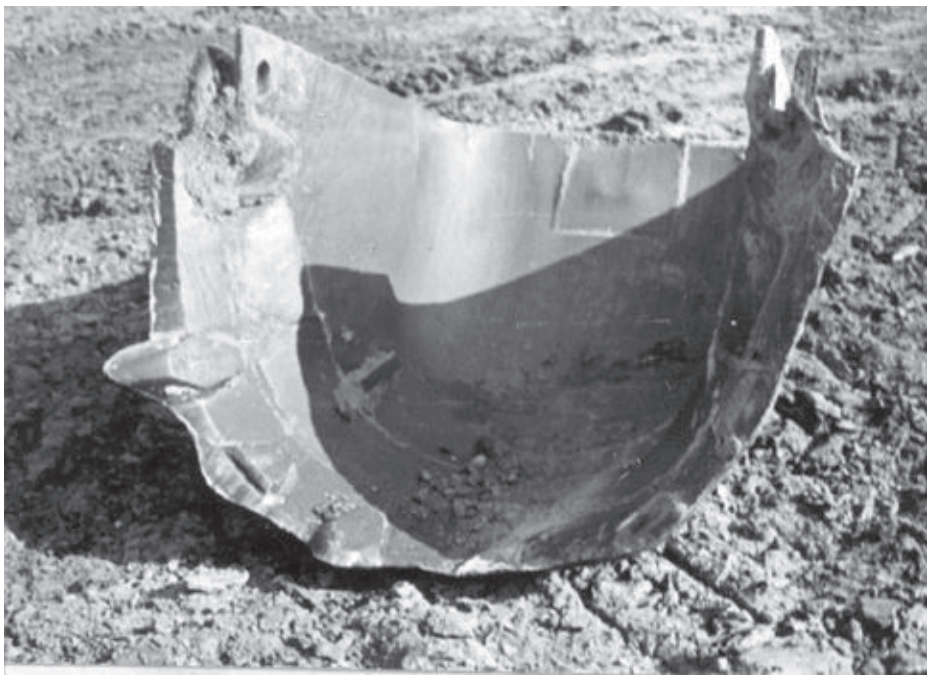

Fig. 2. Fixed teeth after wear out - broken teeth and damage to the bucket knife
Rys. 2. Zęby mocowania stałego po zużyciu - widoczne wyłamania zębów i uszkodzenia noża czerpaka

Shaping the structure of the teeth

The fixed teeth were mostly produced from low carbon alloy steels and used in normalized condition. They were characterized by low abrasion resistance and low strength, which caused fast wear out by the loss of shape geometry and frequent breaking out (Fig. 2).

As it was revealed in the exploitation tests, teeth had the major impact on the bucket work quality and durability [2][3]. Thus the studies were focused on the issues connected with the choice of their shape, the ways of fixing and ensuring the required durability, especially abrasion resistance [4][5]. As a consequence of the studies, the teeth construction assumptions were formulated:

- shape and construction ensuring the minimal digging resistance for the whole range of their wear,
- sure and easy fixing and the possibility of fast exchange on the bucket,
- high resistance to abrasive wear on tooth blade,
- high bending strength and resistance to cutting forces,
- recycling of the tooth part left after wear,
- the length of the tooth blade should be equal to or slightly greater than its width,
- the length of the tooth cylindrical body should be slightly different from the blade length,
- the tooth blade angle should be as low as possible however due to strength aspects and also abrasive wear it should be with the range 24° - 30°.

Next, after several tests and exploitation studies on the experimental solutions, a new kind of exchangeable teeth was elaborated. The tooth structure is shown in Figure 3 [1].

Tooth consists of two parts: cylindrical body part 1 and blade part 2. The blade part in the shape of a strait wedge with a recess on a clearance surface is welded to the body part. The blade part is covered with padding weld 3. The body part is put into the pocket 4 welded into the bucket knife 5 and is protected from slipping out by key-bolt 6. Half-rings 7 and 7a are welded to the pocket edge and to the tooth to prevent the tooth from turning in the pocket. A stop plate 8 is welded to the lower part of the pocket to carry the loads action on the tooth during cutting.

New type tooth production technology

On the basis of the tooth structure presented above, the technology of its production was developed [4]. The technological assumptions are presented below:

- to harden the tooth blade part we should use an automatic submerged arc pad welding with electrodes made of self-shielding flux cored wires,
- the chemical composition of self-shielding flux cored wires should ensure high abrasion resistance and satisfactory resistance to impact loads of the padding welds,
- during the pad welding operation, the established technology must be strictly adhered to, especially the value of the arc current and the pad welding rate,
- teeth should be manufactured from low carbon materials,
- teeth production technology should be fully automated.

Choice of padding weld

The requirements for padding welds were presented in the technological assumptions [4]. These requirements are met by the padding weld with the following characteristic:

- its structure is characteristic and typical for determined chemical composition. In surface and medium layers it is composed of dendrite areas of alloy ferrite (α) and mixture [α + $(Fe, Cr)_7C_3$+$(Fe, Cr)_3C$] (Fig. 4). The amount of mixture (α + carbides) decreases towards the fused zone (padding weld - blade part material). In this areas there is a narrow alloy ferrite zone with a small amount of carbides placed both inside the grains and on their outlines (Fig. 5). The fused zone does not show any macro or microscope disadvantages. Although the ferrite matrix is not hi-

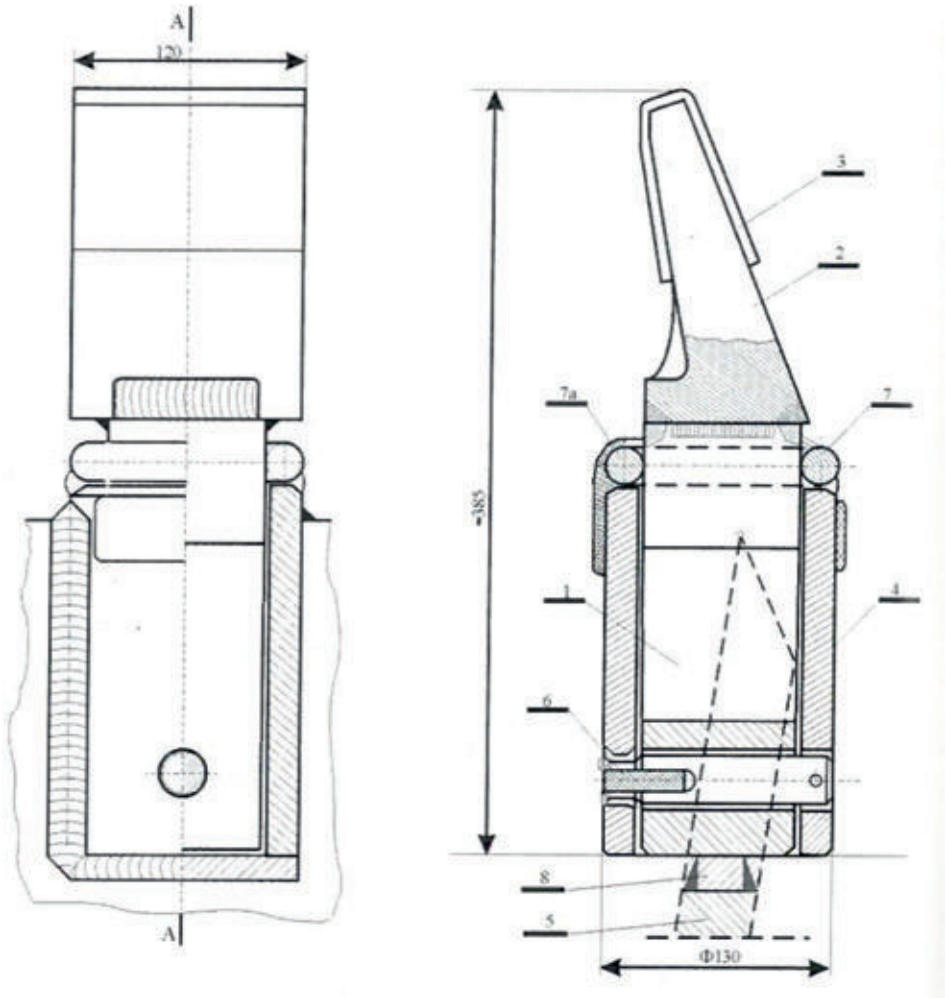

Fig. 3. Design of an exchangeable tooth with a pad welded blade part
Rys. 3. Konstrukcja zęba wymiennego o napawanej części ostrzowej

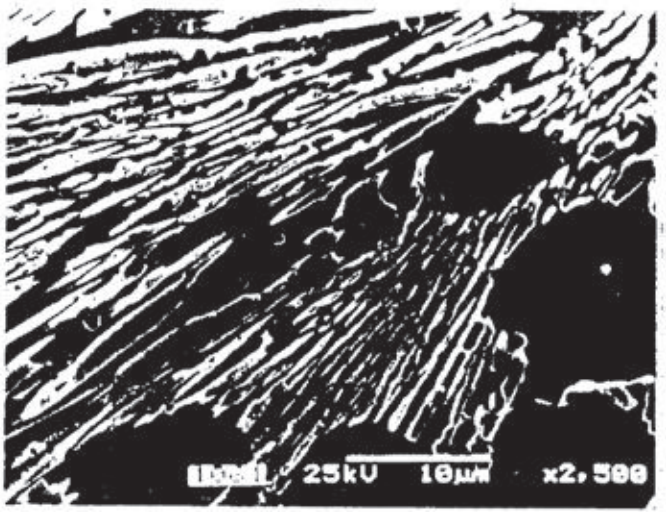

Fig. 4. View of the padding weld structure. Scaning microscope. Magnification 2500 times
Rys. 4. Obraz struktury napoiny. Mikroskop skaningowy. Powiększenie 2500x

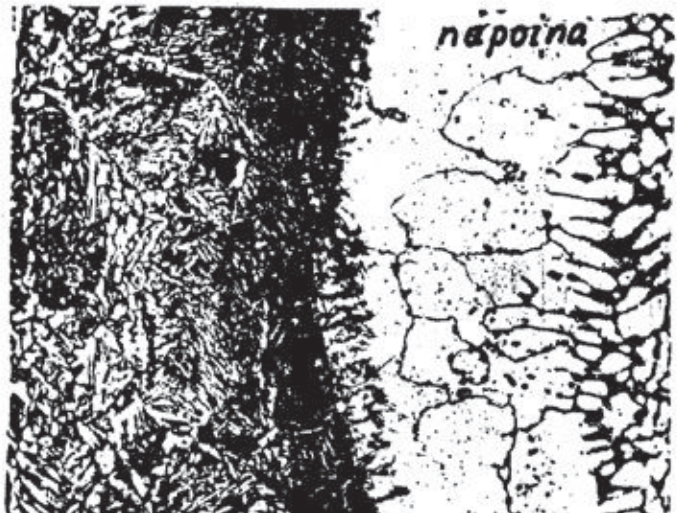

Fig. 5. Fusion zone between the blade material and the padding weld. Scaning microscope. Magnification 200 times
Rys. 5. Strefa wtopienia pomiędzy materiałem ostrza a napoiną. Powiększenie 200x

Fig. 6. Automatic pad welding of the tooth blade parts
Rys. 6. Automatyczne napawanie części ostrzowych zębów

ghly resistant to abrasion but it ensures good fixing of carbides with the matrix and satisfactory ductile properties in the case of impact loads and large surface impact. This padding weld is characterized by uniform distribution of the hardness lowering towards the fused zone. The maximal hardness of the padding weld equals c. 55HRC.

Advantages of the elaborated construction and technology

- the used method of fixing the tooth in the pocket by the key bolt enables its fast assembly and disassembly, is reliable, does not require any special equipment and does not wear out,
- the wedge shape of the blade facilitates the construction technology, enables the automation of pad welding process and the shape of a strait wedge with a recess on a clearance surface, has advantageous properties of preserving the blade geometry in the process of normal wearing out, which is crucial for the reduction of digging resistance,
- the construction of the tooth enables multiple usage of the body part of the tooth by removing the used

blade part and welding another one. In this way c. 80% of the material is reused,
- the method of fixing the pocket in the bucket knife enables fixing teeth independently of the blade surface, which makes in possible to apply them to all the types of buckets and to obtain the required tooth clearance angle and direction for each point of the bucket,
- the regeneration of the used buckets equipped with pockets consists in cutting out only the used pockets and welding the new ones in their place,
- the distance of the blade part from the fixing point is relatively small, which lowers the bending moment in the pocket and on the tooth body,
- hard surfacing of the blade part by means of pad welding with abrasion - resistant alloys, results in several times higher durability, thanks to a small amount of the pad welded expensive alloy (c. 5% of the tooth mass). The method enables also producing teeth from cheaper material (e.g. low-alloy steel, or common steel instead of high- alloy steel),
- the application of automated pad welding in the mass teeth production considerably reduces the total costs of the operation and positively influences the quality of the pad welding (Fig. 6).

Fig. 7. Exchangeable teeth after breaking the blade parts
Rys. 7. Zęby wymienne po wyłamaniu części ostrzowych

Fig. 8. Exchangeable tooth after wear out
Rys. 8. Ząb wymienny po zużyciu

Results of operational tests

The tests were carried out on BWEs digging overburden with dominant cohesive soils of highly abrasive properties (boulder clay with stones and quartz sans, silts)[5]. In the consequence of the tests it was found, that an average durability of exchangeable padded teeth is about two times higher that for fixed not pad welded teeth. The evaluation of the durability was carried basing on the observation of used blade parts of teeth and the number and ways of breaking teeth. It was found that exchangeable padded teeth did not break or bend in the blade or body. Only occasionally the teeth were broken when they met such hard material as stones. In such a case teeth got broken in the place of fixing the body with the blade without damaging buckets, which provides additional safety for buckets, mechanisms and load bearing structure of excavator against excessive dynamic loads (Fig.7)[6].

On the basis of the used blade parts it was also found that they did not show crushing out the padding weld son the active face of tooth and that they were self-sharpening (Fig. 8). This confirms the proper choice of the chemical composition and structure of the padding weld as well as the shape of the tooth.

Evaluation of technical and economic effects

The evaluation was carried out on the basis of experience from the usage of exchangeable padded teeth in BWEs working in domestic lignite opencast mines.

The technical and economic effects connected with the application of exchangeable padded teeth include:
- the number of buckets exchanges lowered by about eight times, which results in considerable reduction of servicing and transportation costs,
- the durability of the teeth increased by about two times,
- considerable material economies connected with recycling the body part of teeth,
- the lower number and time of excavators stoppage in order to exchange buckets and teeth,
- the increase in efficiency and reduction of unitary energy consumptions in excavators,

Apart from the above mentioned, there are several effects, which are difficult for direct quantitative evaluation, but they are important for the current exploitation. They include:
- the improvement in BWEs working conditions by reduction of dynamic loads in the mechanisms and load bearing structure, which results in their increased life,
- less work for mechanic service connected with renovation and transportation of buckets which enables them to go for other urgent works in the mine,
- reduced need for bucket transportation equipment within the area of the mine,
- ensuring continuous work of BWEs especially when working levels are hardly accessible.

Summary

As a result of research on increasing the durability of buckets in BWEs, a new construction of exchangeable padded teeth was elaborated.

The elaborated construction has many advantages, the most important being two times higher durability as compared to formerly used teeth and the possibility of their fast exchange without the need of buckets disassembly. The increase in durability of the tooth was achieved by optimizing its shape and selecting chemical composition and structure of the padding weld.

The application of exchangeable padded teeth in buckets enables a considerable reduction of BWEs exploitation costs.

As a result of research and exploitation tests it was found that:

- the elaborated construction of exchangeable padded teeth can be used for digging highly abrasive cohesive soils,
- it is possible to obtain a further increase in the durability of the teeth mainly trough use of new types of materials allowing to obtain padding welds with increasingly higher abrasion resistance while maintaining their satisfactory resistance to impact loads.

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Urabianie lontem w kopalni granitu