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TOMASZ CICHOŃ
KRZYSZTOF PYREK
KRYSTIAN RATUSZNY
PIOTR KALINOWSKI
PAWEŁ KAMIŃSKI

A milling machine used for groove making in a tubing inter-rib niche

The sealing of shaft cast iron tubing within a tubing Inter-rib niche is often needed during overhauls and repairs of a shaft lining. Leakages or scratches and fractures can occur within the area of individual tubing of the shaft lining. The Przedsiębiorstwo Budowy Szybów S.A. developed special method for the sealing in question. Around the sealed area, a closed circumference groove of a depth smaller than the tubing thickness is made in the inner shaft lining. The sealing element is placed in this groove and then tightened with a spatial insert, with a hole for the injection of the sealing medium. A specially designed milling machine is used for groove making in the tubing lining of the mine shaft. The milling machine is composed of: power transmission system, special construction for mounting the milling machine to tubing and advance mechanism. The milling machine is driven by a battery drill-driver, and the whole device is mounted to the tubing with the use of specially designed guides with handles.

Key words: *tubing milling machine, shaft lining repairs, tubing lining*

1. INTRODUCTION

Tubing lining is used as the final lining of shafts sunk in complex hydro-geological conditions, and it is composed of a cylinder made of separate rings. Individual rings are composed of separate, equal segments called tubings. Tubings can be built of reinforced concrete, cast iron and steel. Steel tubings, having dimensions depending on the shaft diameter, have the form of a metal pipe [1].

1.1. Reasons and examples for tubing lining damages

Leakages, scratches, and fractures can occur within the area in individual tubings of the excavation lining and this damage to the shaft lining must be repaired. Material faults and hydro-geological conditions occurring in the rock body are the most common reason for the occurrence of such damage.

In the region of the Upper Silesian Coal Basin, tubing lining is used sporadically because of economic aspects. Mining shaft sections with steel tubing lining are more often observed in the KGHM within Legnica-Głogów copper district. The first damage to iron tubing segments were observed in the 1990's in shafts of the LGOM, in the shaft L-II of the Lubin Mine. The damage comprised segments of the tubing lining, in the ring of upper and lower picotage gap, at the depth of 295.8 m (~50 m over floor of the Tertiary beds). The damage comprised a break to the horizontal flange directly neighbouring the picotage gap [2, 3]. Damage to the segments are shown in Figures 1 and 2.

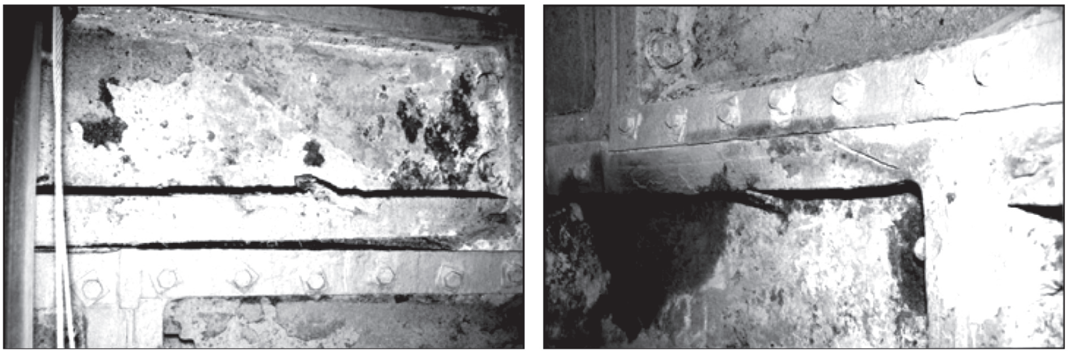

Fig. 1. Damage of the tubing segments of the picotage gap No. 8 in shaft L-II of the Lubin Mine [2]

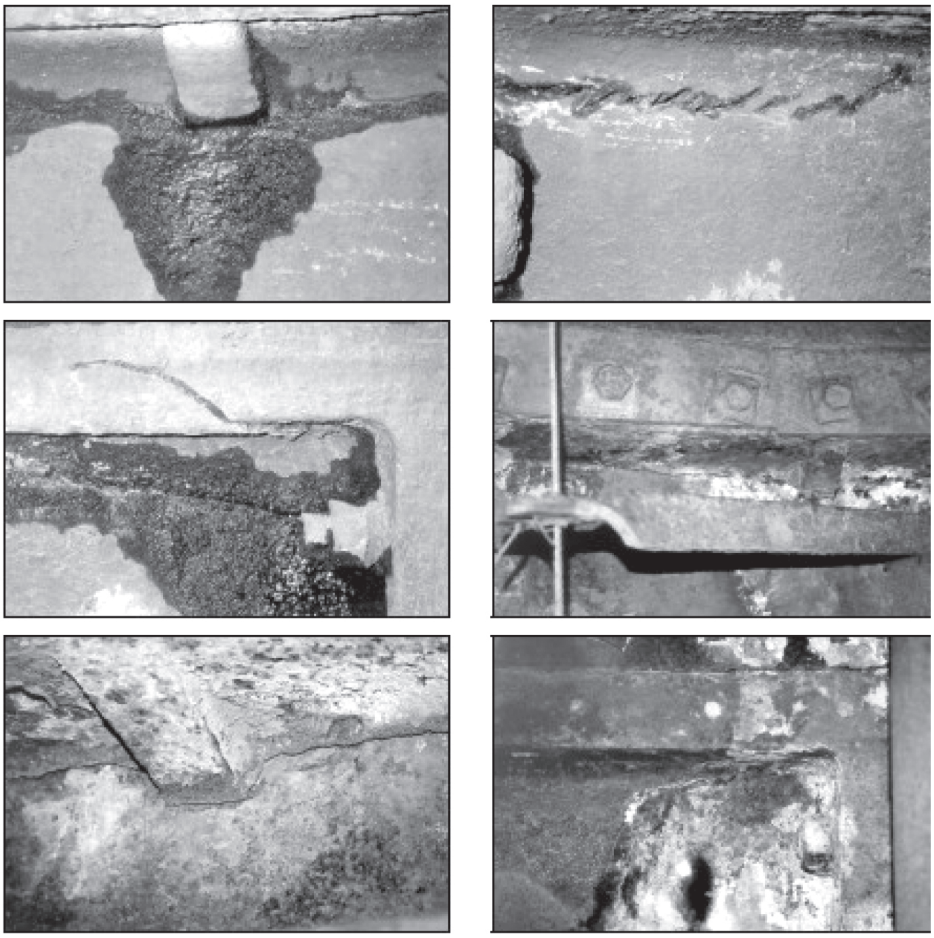

Fig. 2. Damages of tubing segment within area of picotage gaps [2] in the LGOM regions

More or less dangerous damages of the shaft lining were proved during numerous inspections of the shaft lining pipe conducted in the mines of the KGHM. Examples of damage are shown in Figure 2.

On the basis of observation and analyses of the damage, it was proved that the following factors accompany the damage in question:

– occurrence of damage in the majority of tubing rings installed directly on picotage gaps,
– in most cases, the first damage in a given shaft is related to tubing segments within picotage gaps located in the floor of Tertiary beds,
– an increase in the number of damaged tubings within the area of a given ring, with time,
– tendency of the segment damage occurrence on neighbouring picotage gaps,
– lack of tubing segments fractures on picotage gaps within areas with cohesive rocks,
– in almost all cases, the tubing damage was not related to material faults, with the exception of one single case [2].

Problems related to the damage of tubing linings, particularly within tubing inter-rib niche, refer not only to mines and shafts belonging to KGHM. Cases of damage to the tubing lining are found in hard coal mines, for example shaft VII of the hard coal mine "Chwałowice" the retention reservoir in the Bogdanka Mine, and the northern shaft of the Ruda Halemba II mine etc. [4–6].

1.2. Methods of tubing lining protection

Damage to the shaft tubing lining are directly dangerous for the shaft operation because damage, like fractures for example, are accompanied with more or less intensive water inflow into the shaft. The safety of mining excavations is considered dangerous, because the devastation of the lining usually comprises a bigger zone, and the possibility of more intensive water leakage related with rock mass movements is quite realistic.

1.2.1. Protection methods

An analysis of lining damages and deformations of the shaft should be made. Deformation of the rock mass can result in changes to the stress state within the lining and its deformation, and in consequence the destruction of the lining, independent of its material defects.

Therefore, the application of preventive activities which can reduce number and size of lining damage is important. The main preventive activities comprise:

- selection of a suitable exploitation system near the borders of protective pillars;
- preparation of the tubing column should ensure safe operation independent of the exploitation conducted. For that purpose, the following solutions are realised:
  - reinforcing of the lining in shafts in the vicinity of picotage gaps via infilling inter-rib niches with reinforced material near the picotage gap,
  - making access to tubing columns on the picotage gaps via drilling holes in the wooden gap sealing. According to safety regulations, the length of the boreholes cannot be bigger than the flange thickness [5].

1.2.2. Methods of tubing lining sealing – Polish patent descriptions

On the basis of the published patents, three methods of mine shaft tubing lining reinforcement can be distinguished. Polish patent P.361415 describes the method of repairing damaged segments of tubing lining where furnishing cages are installed. Such a prepared tubing inter-rib space is filled with reinforcing material.

Another solution is presented in the description of the patent PL 179822 B1, where a method for repairing mine tubings with an inter-rib niche is described. According to this method, first the sealing medium is injected into the leakage occurrence zone, which should stop the water leakage. When the leakage is stopped, a glue layer is put on the inner tubing surface, and then a metal insert is pressed into the glue layer. The metal insert has an outer shape which is the mirror image of the tubing niche and, independently of the gluing process, the insert is additionally screwed to the tubing ribs and flange. Basically, the arc length of the insert corresponds to the niche arc length between the ribs of the tubing segment, however it is not obligatory. However, the length of the insert is always such that is ensures the requisite water-tightness and structural strength.

2. A NEW METHOD OF TUBING LINING SEALING

As mentioned before, the need to seal shaft tubing lining made of iron tubing with an inter-rib niches often appears during shaft renovation and repairs. For such sealing, the Przedsiębiorstwo Budowy Szybów S.A. uses a sealing method by making a closed circumference groove around the sealed area in the internal shaft wall, whereas the groove depth must be smaller than the tubing depth. Then the sealing element is placed in the groove and pressed with spatial insert closed in the top side and having a hole for the injection of the sealing medium. In the next stage, the insert is mounted to the lining and then the sealing medium is injected in. When the process is finished, the insert hole is closed.

A specially designed milling machine is used for making grooves in shaft tubing lining. The milling machine is composed of the power transmission system and a construction for tubing and advance mechanism mounting. A battery drill-driver is used as the milling machine driving system, and the whole device is mounted to the tubing with the use of specially designed guides with handles. A model of the tubing milling machine is shown in Figure 3.

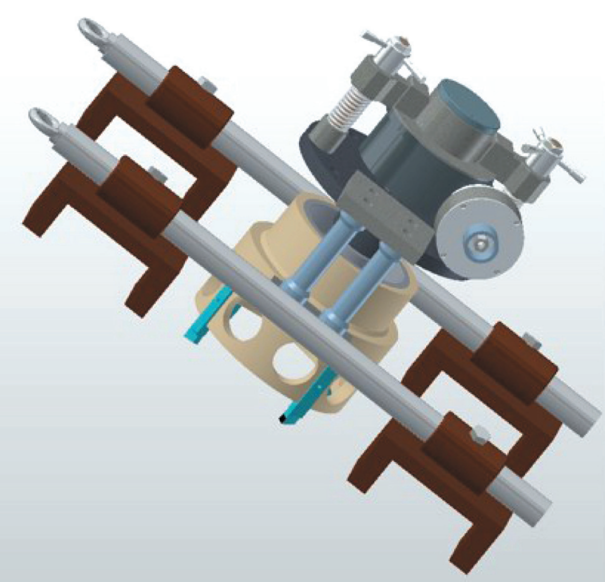

Fig. 3. Model of the tubing milling machine

2.1. Tubing milling machine

2.1.1. Performance and technical data

The described device is designed for shaft tubing lining and is used during the renovation and repairs of shafts, particularly for the needs of the mining industry. Use of the milling machine allows the solution of technical problems occurring during repairs to the iron tubing lining of the shaft made of cast iron tubings.

The application of the milling machine allows the development of the new method of tubing shaft lining, comprising suitable stages for mounting the sealing insert in the tubing and the injection of the sealing medium. The new method comprises milling a closed circumference groove in the internal shaft lining, whereas the groove depth must be smaller than the tubing thickness. Then the sealing element is placed in the groove and pressed with a spatial insert with a hole for the injection of the sealing medium. In the next stage, the spatial insert is mounted to the shaft lining and then the sealing medium is injected to the sealed area via a hole in the spatial insert, before the insert hole is corked. A method for mounting the milling machine to the tubing is shown in Figure 4.

The milling machine is composed of a driving system, a construction used for mounting the milling machine on the tubing and an advance mechanism.

Fig. 4. Milling machine mounted to tubing

A Bosch battery grill-driver drives the central shaft of the epicyclic gear (planetary wheel). Then the movement is transferred from the central wheel into satellites connected in a single shackle via an immobile wheel with inner teeth. The planetary gear ratio amounts to 68/11. The rotating shackle drives the worm shaft which in turn drives the worm wheel with a ratio of 40/1, whereas the worm wheel is permanently connected to a rotary mandrel on which the milling machine head will be mounted. The indicative rotation of the drill-driver on the first run amounts to a maximum of 420 rpm, and on the second run the rotation amount is 1800 rpm.

The advance mechanism comprises a mandrel with a cut metric threading of 16 mm with a lead of 1.5 mm. A single revolution of the advance mechanism knob results in a 1.5 mm jump of the milling head displacement. Maximal displacement of the milling head amounts to 25 mm. The total ratio of the milling head amounts to 247,3. The device is mounted on the tubing with specially designed handles. The construction should be covered with an anti--corrosion coating according to documentation recommendations. The total weight of the device amounts to 90.5 kg.

Driving system of the Bosch grill-driver:

- Type GSR 36 VE-2-Li.
- Catalogue No 0 601 9C0 100.
- Battery voltage 36 V.
- Max torque 100 Nm
- Rotation 0–420 rpm (run 1), 0–1800 rpm (run 2).
- Mass with battery 3.4 kg.
- Worm gear ratio 40:1.
- Planetary gear ratio 6,18:1.
- **Milling head picks** ISO 4 2012 K20 – 4 piece (ISO 7 P/L 2012 K20 – 2 piece L, 2 piece P).
- **Milling head advance mechanism.**
- Manual drive, threaded screw M16×1.5 with knob.
- Advance 1.5 mm per 1 rotation.
- **Mass of the whole machine depends on the chosen equipment version.**

Mass of individual sub-assemblies see Table 1.

2.1.2. Milling machine construction

The milling machine body comprises a main plate with bearings cooperating with a rotary mandrel. The rotary mandrel cooperating with the main plate is connected on one side with a worm gear and advance system, whereas the other side is connected with a threaded sleeve on which a milling head is mounted.

The machine is driven by a Bosch grill-driver GSR 36 VE-2-Li f-my Bosch via a planetary gear haft, and then via a reductive ring onto a worm gear. From the worm gear, rotary movement is transferred onto a rotary mandrel connected via a sleeve with a milling head. In the planetary gear, rotations are transferred from the planetary reduction gear onto satellites joined in a single shackle. The external toothed wheel is immobilised and the mine plate is immobilised with two mounting elements with guides and four handles. The handles are located on tubing ribs. The milling machine is immobilised by guide and handles. Milling machine construction is presented in Figure 5, and its individual elements are show in Figure 6.

Before machine operation, and after the milling machine is mounted with the use of guides, the machine must be protected against inertial movement by hanging the machine with the use of a chain. The chain should be led via handle ears on guides, and then the chain should be mounted to a fixed element of construction in the mine shaft.

Milling is conducted with the use of four lathe tools of the ISO 4 2012 K20 type. Alternatively, in case of increased milling resistance, two left and two right tools of the ISO 7 P/L 2012 K20 type (Fig. 7) can be mounted alternately in milling head, but only for preliminary milling. After preliminary milling the ISO 7 tools should be replaced with ISO 4 ones, and the final groove milling should be executed.

Table 1

Mass of individual sub-assemblies

Main plate with rotary mandrel, threaded sleeve, hub with pick guides with planetary and worm gears – no. 1, 3, 4, 5, 7	40 kg
Round guides with fastening devices (set 2 piece) – item 6	54 kg
Rectangular guides with fastening devices (set 2 piece) – item 6	74.2 kg
Milling head for groove ∅178–154 with tools – item 2	9.6 kg
Milling head for groove ∅220–196 with tools – item 2	10.7 kg
Milling head for groove ∅246–222 L = 190/120 with tools – item 2	12.7 kg
Milling head for groove ∅246–222 L = 250/180 with tools – item 2	16.2 kg

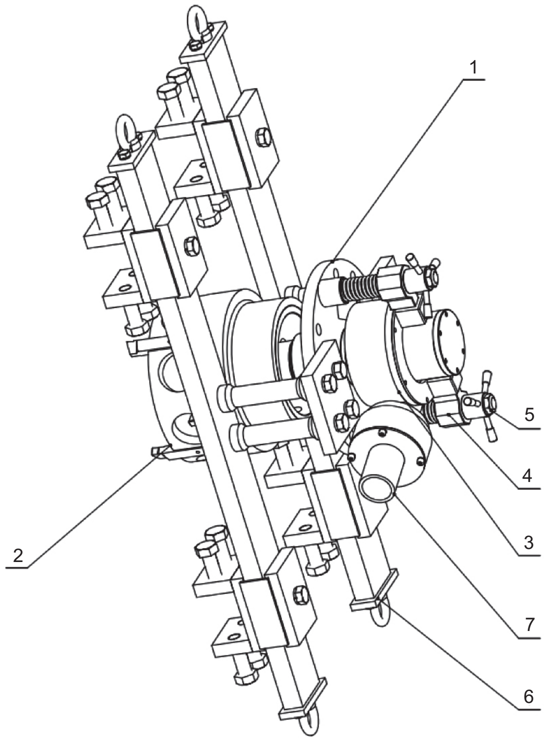

Fig. 5. Milling machine construction: 1 – main plate with mandrel and threaded sleeve; 2 – milling head – depending on the chosen option: • for groove ∅178–154 for seal ∅176/∅156, • for groove ∅220–196 for seal ∅218/∅198, • for groove ∅246–222 for seal ∅244/∅224 L = 190/120, • for groove ∅246–222 for seal ∅244/∅224 L = 250/180; 3 – worm gear, 4 – hub with guides and mounting device, 5 – mounting to main plate device, 6 – guides with mounting – depending on the chosen option: • round for mounting milling machine with handles, • rectangular for mounting the milling machine with handles; 7 – planetary gear with driving system housing

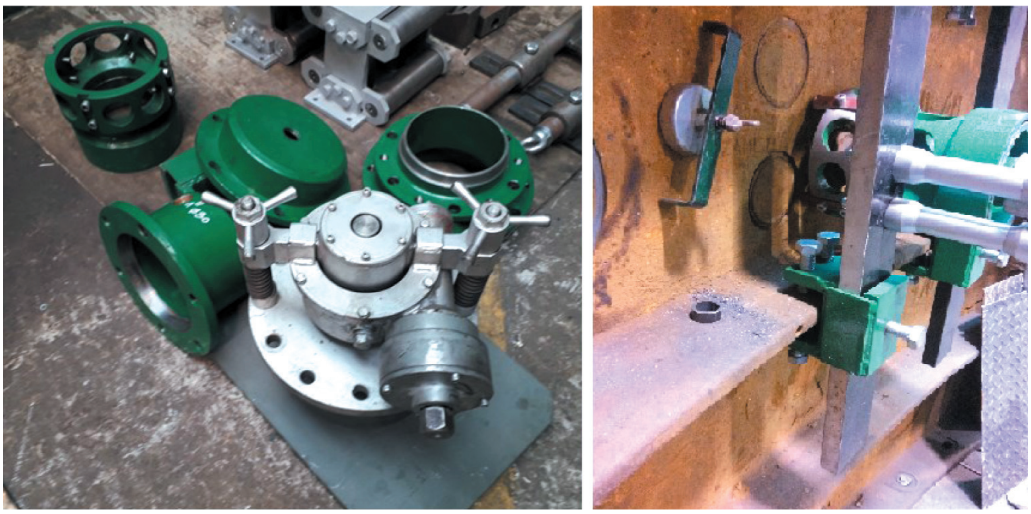

Fig. 6. Elements of milling machine

Nóż Tool Резец	ISO 243 ISO 514 (PN-93/M-58355)	PN-91 M-58352	DIN	F	Gost
	ISO4	NNPd	4976	304	2120
	ISO7	NNPa-c	4981	307	2130

Fig. 7. Tools mounted in the milling head

2.1.3. Exemplary technological process

An example of the groove making process in the tubing shaft lining is described below:

1. groove diameter must be chosen and then a suitable milling machine head selected and mounted to the machine;
2. milling machine is mounted on guides;
3. handles with guides and milling machine are mounted (Fig. 8);
4. milling machine is positioned in a suitable location;
5. screws blocking the rotation of guides are loosened (refers only to round guides);
6. turning the guide distances of opposite blades according to the tubing surface (refers only to round guides);
7. bolts blocking the rotation of guides in the handles are screwed in place;
8. the milling machine mounted to the tubing lining is positioned at a distance of 2–5 mm from its surface with the use of bolts M16×1.5;
9. suitable run of the drill-driver (run 1 is recommended), rotation direction and value of torque (Maximal value is recommended) are set;
10. drill-driver GSR 36 VE-2-Li is connected with a planetary gear shaft and then the drill-driver rotation is switched on;
11. with the use of the milling machine head, the groove in the tubing lining is milled to the target depth with the use of a manual advance system, turning the knob M16×1.5; (to assure the proper operation of the tools, the adjustment should be made by turning the knobs simultaneously);
12. after grooving is finished, the drill-driver should be switched off – and the drill-drives should be disconnected from the milling machine;
13. after checking that the groove dimensions are suitable, the milling machine with guides and handles should be dismounted from the tubing lining. If the groove dimensions need to be corrected, the procedure described above should be repeated.

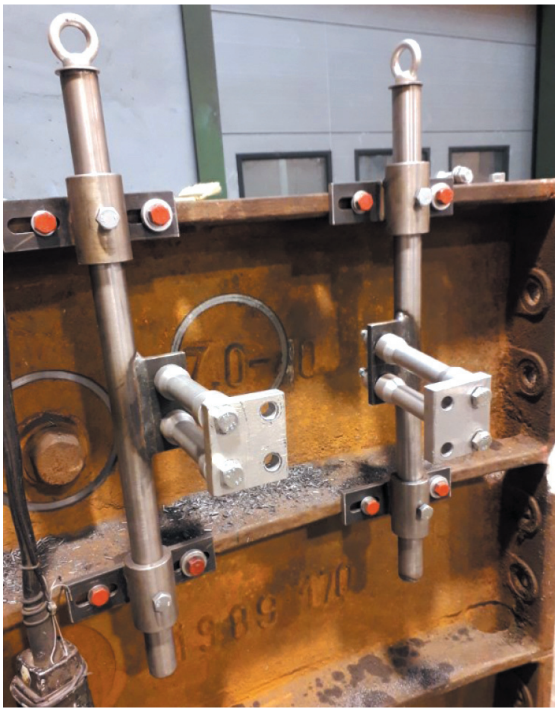

Fig. 8. Handles and guides

When the grooving is finished, mounting holes with a depth smaller than the tubing thickness are drilled at its external side with the use of a special matrix (the shape of the matrix is tailored to the shape of the groove in the tubing). Then the holes are threaded (a matrix having a shape tailored to the shape of the groove in the tubing can also be used for exact threading). A previously prepared lead seal is placed in the groove. The mounting procedure of the milling machine during tests conducted on the surface is shown above (Figs. 9 and 10).

When the seal is placed in groove, a spatial insert in form of closed at the top cylinder with a mounting flange with holes and a special hole for the injection of the sealing medium are mounted to the tubing. The lower part of the cylinder is inserted into the groove milled in the tubing in order to press the seal. The cylinder (Fig. 12) is mounted to the tubing with bolts inserted into the boreholes and then screwed in place. When the cylinder is screwed to the tubing, a sealing medium infilling the internal space of the insert is injected into the tubing in order to seal the fracture. When the sealing medium injection is finished, the injection hole is corked.

In order to assure the proper operations of the milling machine, it should be transported in a horizontal position on a transport pallet, with the use of a fork lift. In the case of machine transport with the use of the hosting crane, special transport handles should be screwed to the guides. Each time, all of the elements of the milling machine must be protected against damage.

Fig. 9. Milling machine during tests made at the surface

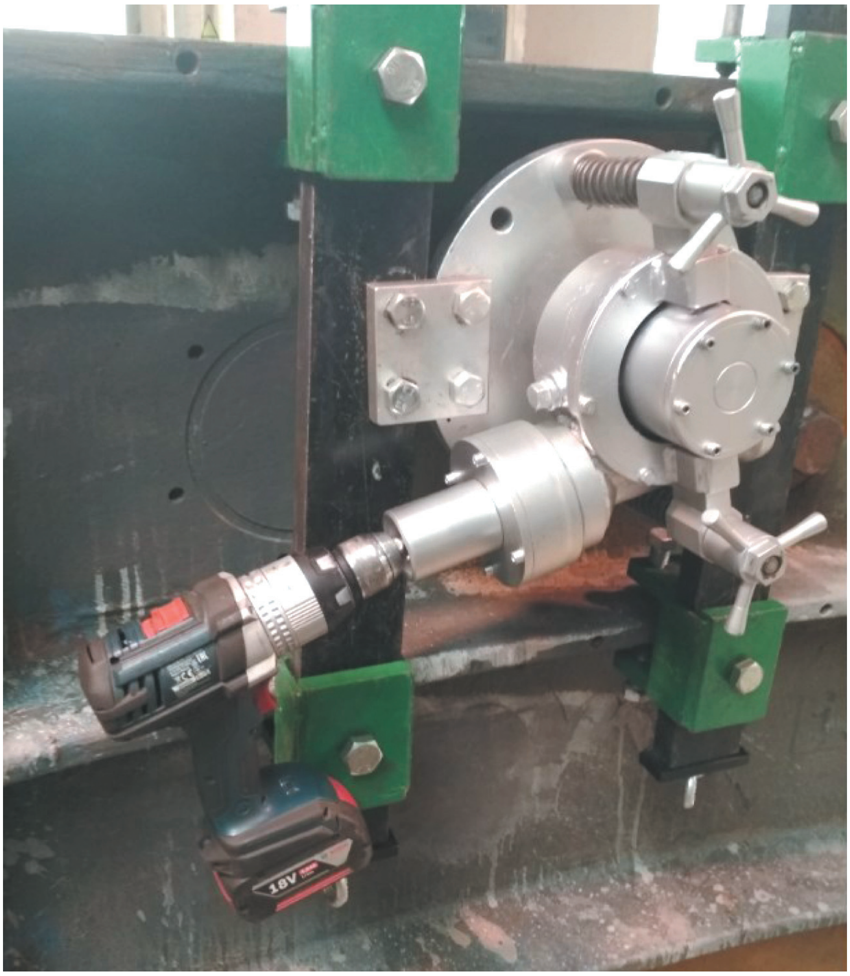

Fig. 10. Milling machine mounted to tubing lining with drill-driver driving the system

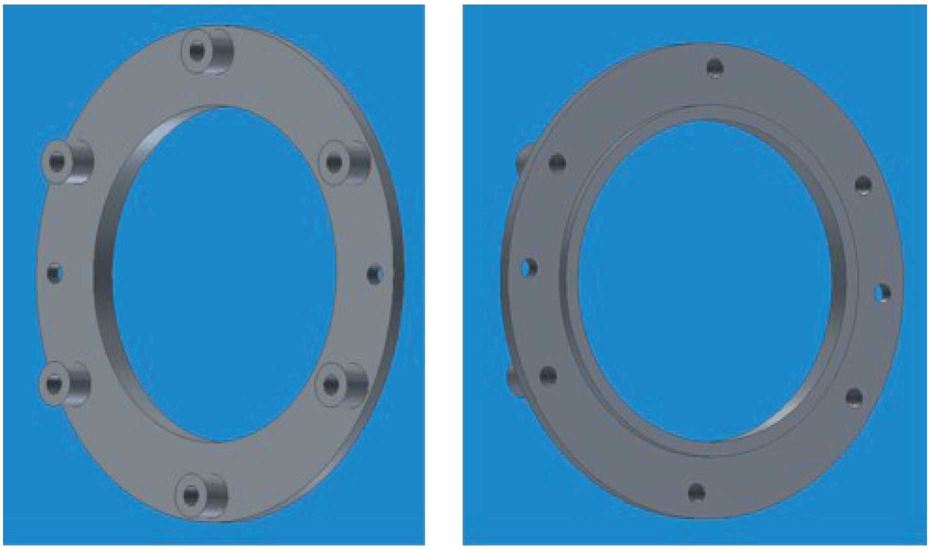

Fig. 11. Matrix used for borehole making

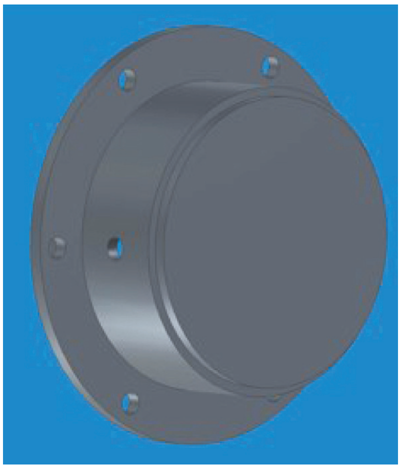

Fig. 12. Cylinder for the injection of the sealing medium

In the mine shaft, transport in a horizontal position is recommended. However, if the transport space is limited, transport in a vertical position is acceptable, taking care to maintain its stable position. The following machine subassemblies are recommended to be transported separately:

- guides with mounting elements,
- milling heads,
- main plate with rotary mandrel, threaded sleeve, hub with knife guides with mounting elements of main plate and planetary and worm gears. A transport basket should be used for the main plate transportation, as shown in Figure 13.

Fig. 13. Basket used for the milling machine transport

2.1.4. Certification

The milling machine, designed and manufactured by Przedsiębiorstwo Budowy Szybów, is equipped with all of the requisite certificates allowing its operations in explosion hazard environments, and machine construction is compatible with directives of the European Union – 2006/42/WE.

The identification plate of the described machine is shown in Figure 14.

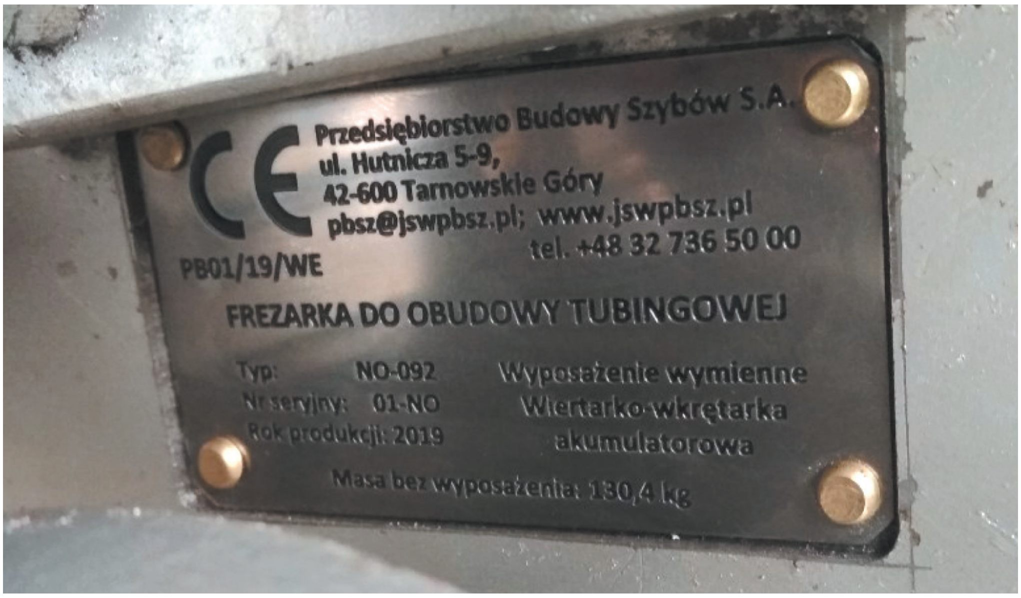

Fig. 14. Identification plate

3. SUMMARY

The sealing method of the tubing lining proposed by the Przedsiębiorstwo Budowy Szybów S.A. is an innovative solution and the application of this method facilitates the repair process, as well as solving numerous technological problems accompanying repairs of this type. In addition, this device possesses all of the required certificates assuring operational safety.

Application of the milling machine for tubing renovation (related to sealing) allows the considerable reduction of time needed for repair, also leading to shortening the time of the mine shaft technical stopover.

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TOMASZ CICHOŃ M.Sc., Eng.
KRZYSZTOF PYREK
KRYSTIAN RATUSZY M.Sc., Eng.
PIOTR KALINOWSKI M.Sc., Eng.
Przedsiębiorstwo Budowy Szybów S.A.
ul. Hutnicza 5-9, 42-600 Tarnowskie Góry, Poland
{tcichon, kpyrek, kratuszny, pkalinowski}@.jswpbsz.pl

PAWEŁ KAMIŃSKI Ph.,D., Eng.
Przedsiębiorstwo Budowy Szybów S.A.
ul. Hutnicza 5-9, 42-600 Tarnowskie Góry
AGH University of Science and Technology
ul. Mickiewicza 30, 30-059 Kraków, Poland
pkaminski@jswpbsz.pl, pkamin@agh.edu.pl