Increase of life cycle due to application of welding as a surface coating method

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ABSTRACT

It is natural that elements of trybomechanical system (TMS) are exposed to various types of wearing processes during exploitation period. Worn machine parts, in most cases, are considered to be a disposable material that is they have been replaced with new ones. Present need for savings in every aspect of economy forces many producers to start thinking about regeneration of worn and damaged machine elements, especially with older high-priced machines. In these cases appropriate coating method can provide desired surface properties and bring machine back to work avoiding more expensive new parts.

The welding reparation method of profile wire production rolls which represents the parts of rolling stand, is presented here, as an example of effective application of coating methods in this area. The choice of the corresponding method of welding and the regulation of complete reparation technology are also considered. Results have shown that increase of life cycle is significant. Behavior of regenerated rolls showed all exploitation characteristics that had original ones.

KEYWORDS: reparation, welding

1. INTRODUCTION

Modern trends of world economy, in general, assume savings. Savings should be done in every single domain in order to reach this global aim. Therefore, in every engineering discipline exists the imperative of lowering the costs of production process. From this aspect, prolonging the life cycle of a machine element is very important and essentially reflects this requirement. If we consider the tribomechanical system and its elements, there are many solutions to this problem from the standpoint of tribology as a science and technology of friction and wear. The method of regeneration is considered in this paper.

The wearing of tribomechanical system elements is unavoidable. In recent years, machine elements that had been worn or damaged otherwise during their work time, were mostly ordered from their manufacturer, without even considering the possibility of their reparation. Nowadays, many producers start thinking about regeneration of these elements, especially with older high-priced machines. In these cases, appropriate coating method can provide desired surface properties and bring machine back to work avoiding more expensive new parts.

Machine elements' reparation can overcome problems with supply of new parts such as: difficulties with product technology, high costs of manufacturing process, long term production, large administration, if the parts are to be imported etc [1].

The reparation process economics are determined depending on many factors some of which are: ratio of a new part – regenerated part price, comparison of time needed for a production of a new element to a time needed for old one reparation and also the life cycle of a new part compared to the repaired one. Every production plant should systematically investigate possibilities of worn and damaged element regeneration within its own maintenance services, if possible. Or to look for a specialized firms who deals with the regeneration processes of machine parts.

As an example of above stated, the welding reparation method of profile wire production rolls which represents the parts of rolling stand, is presented here. Results showed the effectivity of regenerative welding, as a surface coating method, since properties of welded parts fulfilled all exploitational demands. Therefore this method can be adopted as possible in increasing the life cycle of an machine element.

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2. REPARATIONAL WELDING

Surface coating methods represent the powerful tool in improving characteristics of various metal surfaces (hardness, toughness etc), in area of thin surface layers, where tribological processes are located. The cause of machine parts wearing out, in working regime, can be of many different sources, such as: cavitation, corrosion, abrasion, erosion, increase of temperature level, dynamic loads etc. Methods of welding and metallization are the usual regeneration methods applied in cases of worn machine elements. Reparational welding method is the process of applying metal layers onto the working surfaces of some parts, in order to increase their wear resistance, resistance to impact pressure and resistance to other forms of loads. It can be successfully used to fix parts broken during work regime and also ones made with defects. It is usually applied onto the specific surfaces of working parts, which are exposed, to the greatest wear level. It is possible, sometime, to apply this method more than one time, before the old part must be exchanged for the new one.

The selection of the technology for reparational welding must include not only the weldability of the base material and additional material options, but the economics of the selected technology, as well. It should be noted that reparational welding could be done with almost every machine part and almost every material. There are some difficulties that appear with the gray iron which is unclean (remainings of sand at casting, appearing of inclusions) and with the gray iron which has its structure changed due to a long working regime with high temperature levels in organic oil environment, for example. Repaired machine parts in most cases regain their first function completely. Welding methods are powerful tool in obtaining the longer life cycle with various constructions.

In general, regenerative welding is used for [2]:

- Regeneration of machine parts and devices by applying metal onto surfaces damaged by friction, cavitation, corrosion or breakage,
- Gaining the requested physical and chemical properties for surfaces of specific elements or their segments. It can be hardness, abrasion resistance, corrosion resistance etc.

Work life for many machines and devices are limited due to a wearing of their specific parts only. Therefore, for machine elements, different materials have been chosen in order to obtain approximately the same life cycle for all of them. Until now, this was done by improvement of working surface quality, by thermal treatment (quenching, cementation, and nitriding) and lately reparational welding successfully replaces some of these processes. Advantage of welding is the fact that the metal used for welded layers can be of different chemical composition than the one for the base material. Therefore, desired properties of working surfaces can be obtained by depositing thin layers of expensive materials onto the less expensive base material, thus saving good quality materials and lowering the final price of a machine part at the same time. The thickness of welded zone is usually up to 3 mm. For bigger thickness required, it should be performed with several passes.

Experience in welding technique application encourages for its use in a various branches of manufacturing. With today's level of its development, it is more economic to organize special welder's workshops, while cutting down the production of new spare parts. Investigations of many welded parts showed that they had bigger wear resistance than new ones, and their price was lower at the same time.

3. PROFILE WIRE PRODUCTION ROLLS - DESCRIPTION, WORKING CONDITIONS, CONSTRUCTION

Profile wires production rolls, which represents the parts of rolling stand [3], is presented in Figure 1. Manufacturer of these parts is "Marshal Roberts" – England, and it is installed in Factory "Kablovi", Jagodina, SR Yugoslavia. Machine has been primarily used for cooper profile wire production, but it can also be used for production of steel ones. The motion of the rolling stands is due to a power supply from electromotors of 15 KW power.

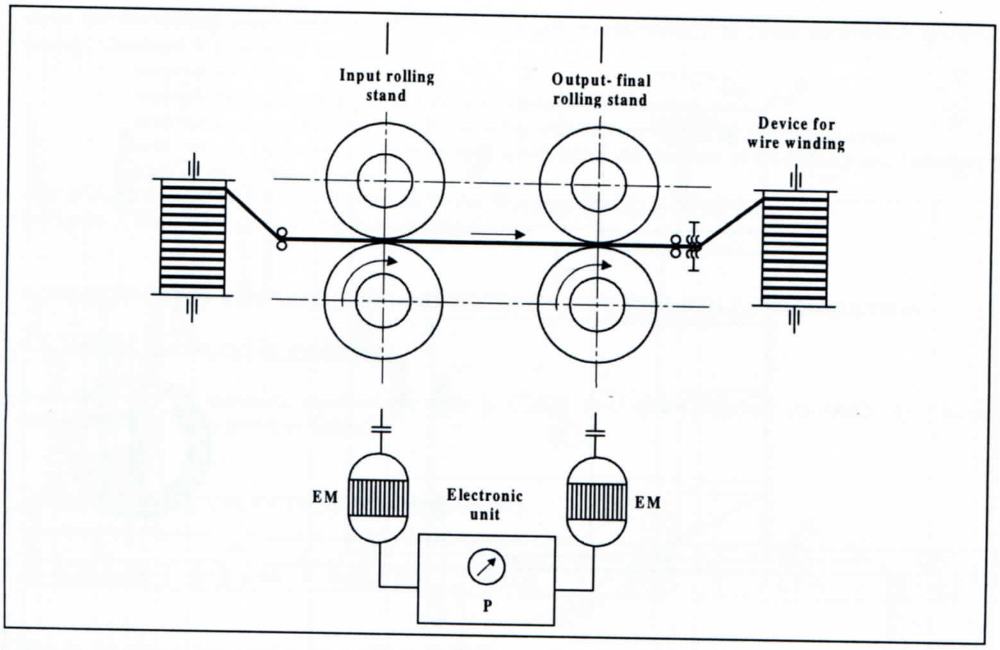

Figure 1: Schematic representation of rolling of profile wire

Synchronization, that is, regulation of rolled wire, is done by changing the revolution number of rolls through the potentiometer P and electronic unit that acts onto the direct current motor drives. Stretching of rolled wire must not be larger than 30 %, in this operation. Revolution number of rolls is from 0 – 225 °/min. Working temperature is below 100°C, for rolls. During its lifetime, in order to minimize friction, rolls are lubricated by industrial grease.

Rolls must be of the same diameter (D1 = D2), in order to achieve the good quality of produced wires. Rolls' surfaces must be very fine, that is, highly polished surfaces and of hardness of 60 HRc.

During rolling, wire has to be without internal defects, as porousness and macro and micro-cracks.

Maximum width of the rolled profile is equal to the rolls' width, but the limiting factor is the power of drive motors, also.

Profiles are mostly of the types showed in Figure 2 with characteristics given in Table 1.

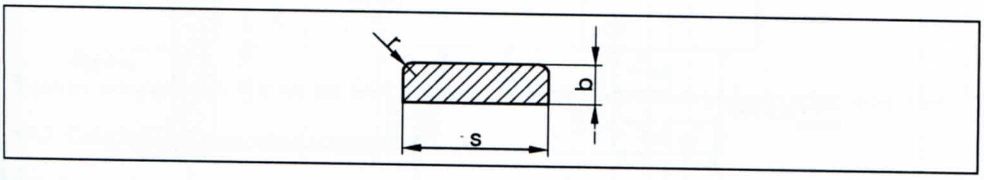

Figure 2: Profile type

Table 1. Profile characteristics

b (mm)	s (mm)	r (mm)
5.6 ± 0.02	2.12 ± 0.015	0.80 ± 0.06
6.7 ± 0.035	2.5 ± 0.015	
7.1 ± 0.035	2.5 ± 0.015	
8.0 ± 0.035	2.5 ± 0.015	

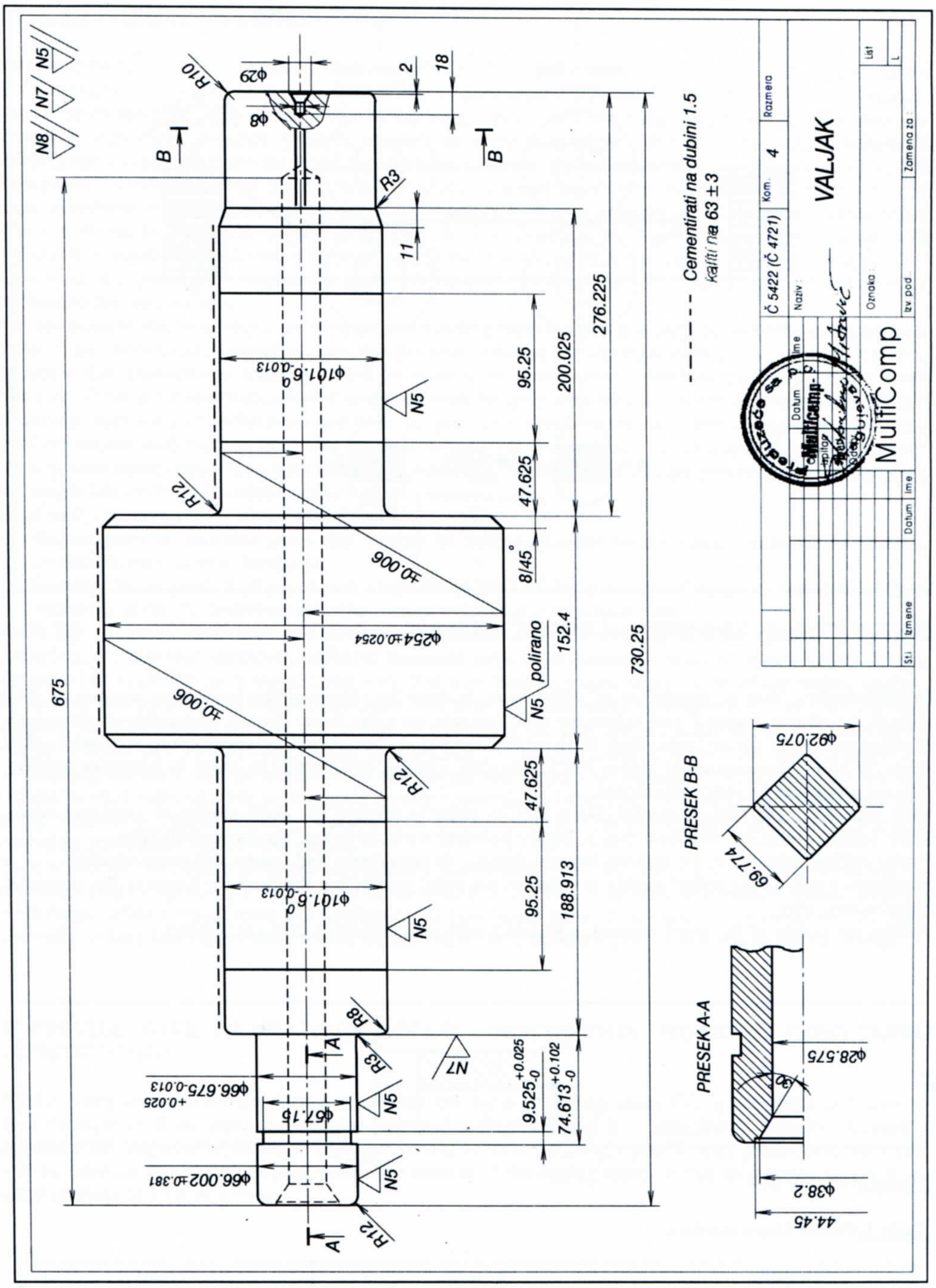

Figure 3: Drawing of a roll

Rolls on the rolling stand must fulfill some important characteristics in order to achieve good wire quality. Obtained wire surface must be [1]:

- smooth and clean,
- without dirt or remainings of pull-out material,
- without surface defects as cracks, scaling, inclusions of metal or non-metal origin
- without any other surface defects that could affect the process of lacquering and therefore the quality of the produced wire.

Any of these defects on the rolled wire can be the first sign of rolls wearing out.
In Figure 3, dimensions of one roll are presented.

4. SELECTION OF PROCEDURES AND TECHNOLOGY FOR ROLLS REPARATION

4.1. Material of rolls and its weldability

According to JUS standard, material for rolls is C7421 steel (DIN standard 25 MoCr 4). Chemical composition (in %) is given in Table 2.

Table 2. Chemical composition for rolls' material (%)

C	Si	Mn	P_{max}	S_{max}	Cr	Mo
0.23-0.29	0.15-0.40	0.60-0.90	0.035	0.035	0.4-0.6	0.4-0.5

Tensile strength of this steel is from 400 to 490 MPa, and hardness is 217 HB.
It is Mo-Cr cemented steel with higher level of carbon. This steel is in the group of poor weldable steels, so it is necessary to do preheating and then apply more complex scheme of welding technology, than for the steels of good weldable status.

4.1.1. Weldability evaluation

As base criteria for evaluation of welding for this steel, so called chemical equivalent carbon CE, is used, and it is calculated by:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \%$$

$$CE = 0.29 + \frac{0.90}{6} + \frac{0.60 + 0.50}{5} = 0.66$$

It can be seen from this, that for the steel of such a chemical composition, preheating has to be done.

4.1.2. Calculation of preheating temperature

Seferijan method of calculating the preheating temperature, has been applied:

$$|C| = |C|_H + |C|_D \ (\%)$$

$$T = 350\sqrt{|C| - 0.25} \ °C$$

where:

$|C|$ - total equivalent carbon
$|C|_H$ - chemical equivalent carbon
$|C|_D$ - equivalent carbon of thickness D [mm]

Calculation of equivalent carbon, chemical equivalent carbon and equivalent carbon of thickness D is done by formulas:

$$360\ |C|_H = 360C + 40\ (Mn+Cr) + 20Ni + 28Mo$$

$$360\ |C|_H = 360 \cdot 0.29 + 40\ (0.90+0.60) + 28 \cdot 0.50$$

$$360\ |C|_H = 0.496$$

$$360\ |C|_D = 0.005 \cdot s\ |C|_H$$

$$360\ |C|_D = 0.005 \cdot 250 \cdot 0.496 = 0.620$$

$$360\ |C| = 0.496 + 0.620 = 1.116\ \%$$

$$T = 350\sqrt{1.116 - 0.25}\ \ °C$$

$$T = 325\ °C$$

This way calculated preheating temperature, considers the worst possible case, that is when the construction is big and material preheating is done only in specific area of welding. However, in this case roll is heated through the whole across section and the criteria for temperature calculation can be somehow changed. With including this criteria, preheating temperature is T = 250°C. This results in large amounts of saved energy compared to calculated level of T = 325°C.

4.2. Selection of welding method and regime

As the welding method of reparation of rolls the electric arc welding under powder has been chosen (EPP).

Welding under powder has often been used in practice because of its high productivity and good quality of welded surfaces. Only massive parts in horizontal position is welded under powder and additional material can be in a form of a wire (one or two) or a ribbon.

Above stated form of welding is mostly applied in case of cylindrical surface regeneration, like steel rolls of a big diameter. Welding can be done along generating line of roll or circles, and the process itself can be automated with rotative motion of roll and transitive motion of welding head along the roll's axis. Welded layers in most cases have bigger hardness and wear resistance than the base material.

This welding regime is adopted taking into account two opposite requirements:

- for larger productivity the current intensity should be as big as possible;
- for mixing rate, smaller current intensity is required.

Depending on the practice case, the optimal solution is selected.

Welding velocity is from 10 to 30 kg/h, and the welding thickness is 4 mm.

4.3. Welding parameters

Welding cylinder reparation has been done with following parameters:

I_z = 680 – 700 A - welding current
U_z = 32 – 34 V - stress
V_z = 40 cm/min - welding velocity
d_e= 5 mm - electrode diameter

4.4. Additional material

Additional material has been chosen in combination with covering powder. Considering the fact that there is small offer for domestic additional material, welding is done with electrode wire EPP Cr 6 and covering powder OP 100, which are products of steel factory "Jasenica" from Slovenia.

Chemical composition of additional material is given in Table 3:

Table 3. Chemical composition of additional material

C	Si	Mn	Cr	Ni	Mo
0.1 %	0.25 %	0.7 %	7.0 %	0.35 %	0.55 %

However, direct applying of this material onto the roll's base material C 7421 steel, showed some negative consequences like crack appearance. Therefore we decided the first layer to be of additional material EPP 2 in combination with EP 45 powder, and other layers with EPP Cr 6 wire.
Combination:

- base material C 7421 steel;
- layer EPP 2 with powder EP 45;
- layers EPP Cr 6 with powder OP 100

showed the best possible working conditions and so it was adopted for reparation process.

4.5. <u>Welding technology</u>

Reparation process for rolls consists from five phases:

1. Surface preparation;
2. Preheating;
3. Welding;
4. Thermal treatment (annealing)
5. Final machine treatment (scraping, grinding and polishing)

The first reparation phase is the degree of rolls' damages determination and then preparation of the surfaces that is to be welded. The number of passing that should be applied onto the base material depends on a depth of these damaged layers. Surface preparation consists from two steps:

- Smoothening of rolls, that is removing of base material layers by appropriate machine treatment until all the cracks vanish and
- Surface cleaning from corrosion.

EPP welding is done with starter plates as a method of prevention of end cracks. With rolls, starter plates are substituted by pipes, which are welded at the rolls' ends and has been taken off during the final machine treatment.
The second phase is the preheating of rolls. This process is carried out in a burning kiln made by fire resistant bricks, right next to the welding equipment (Figure 4). The heating is done with prophan – butane burners. The preheating temperature should be kept at the constant level during the whole process of welding.

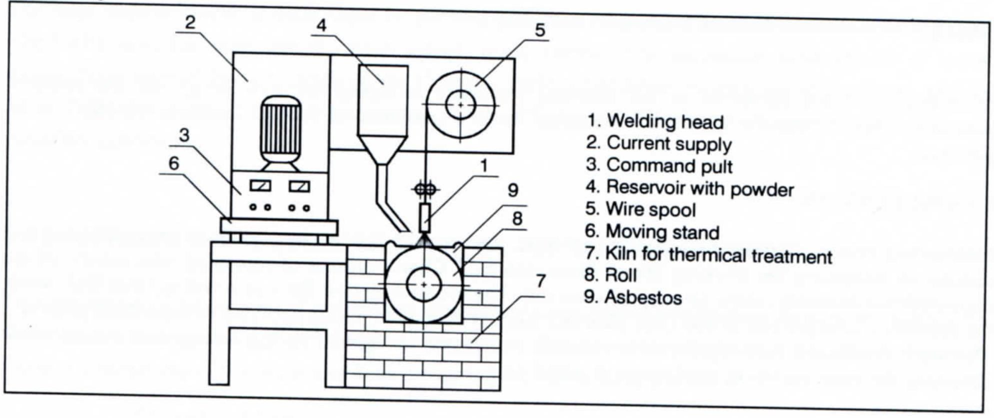

Figure 4: Preheating of rolls

As soon as the preheating temperature is reached, the welding is performed. In this phase the potential danger are deformations that could appear on the roll. Therefore, it should be noted that the order of welded layers is important. The following layer is put to a diametrically opposite place than the one preceding, as in a Figure 5. This phase continues until reaching the required rolls' dimensions.

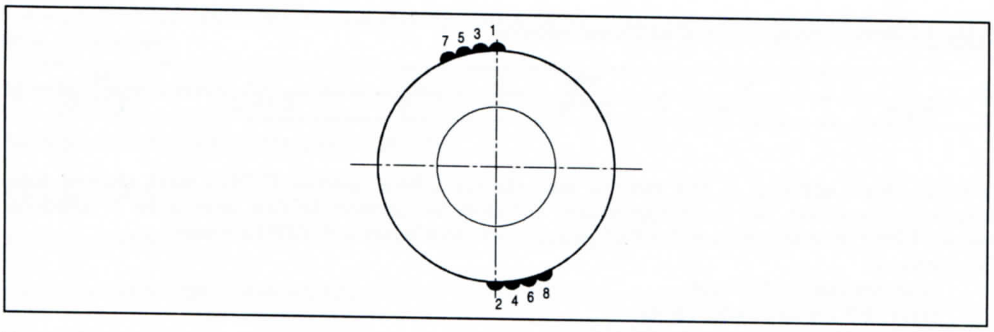

Figure 5: Order of welded layers

Next phase is the annealing which is carried out at the temperature of 650 °C in order to reduce internal stresses resulted from the welding process in previous phase. The heating is done in the same preheating kiln with prophan – butane flame. This process is schematically presented in Figure 6.

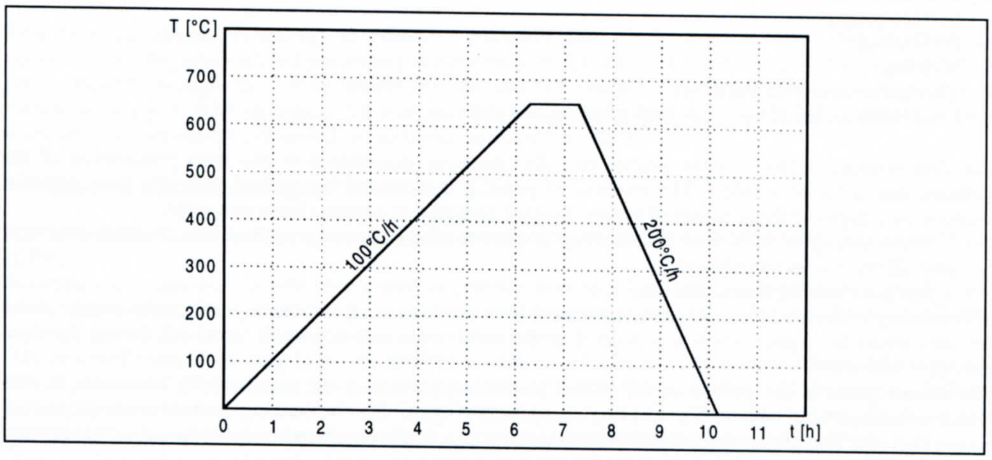

Figure 6: Flowchart for thermal treatment - annealing

After this, rolls are subjected to the machine treatment (scraping and polishing), for the required dimension (∅254) and the quality of machined surface (polished surface of hardness 60 HRc) to be achieved.

5. CONCLUSIONS

Established results of reparation method of rolls, has proved this method to be a very effective and rational in increasing the working life of these elements. Characteristics of reparated rolls satisfy all the exploitational demands, same as original ones did. The production cost for a new roll is 1800 DM, while the reparation cost per roll is 600 DM. This fact itself is enough to justify applying of reparation process.
The work conducted here represents a valuable experience in light of saving energy and money while obtaining the good results in production of rolled wire.

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