



POSSIBILITIES OF INCREASING THE WEAR RESISTANCE OF STEEL CHAIN WHEELS AS A RESULT OF CHANGES IN THEIR MANUFACTURING PROCESS

A. N. Wieczorek

Silesian University of Technology, Institute of Mining Mechanization, Gliwice, Poland
andrzej.n.wieczorek@polsl.pl

ABSTRACT

The paper describes the problems of the operation of chain wheels of armoured face conveyors and the related assurance of the required wear resistance. An analysis of the current methods of manufacturing the chain wheels used in armoured face conveyors has also been performed. It has been found that a dynamic surface treatment can be used in the process of manufacture of these elements. As a part of the study, the results of wear tests for the standard and modernized variants of chain barrels have been presented, which confirmed the validity of the changes made in the process.

Keywords: wear, shot peening, chain wheel, armoured face conveyors

1. INTRODUCTION

Chain drums, especially those for armoured face conveyors are operated in very harsh operating conditions. An example view of an armoured face conveyor is shown in Fig. 1, while a view of the chain drum installed in the conveyor is presented in Fig. 2. Despite the changes in materials and technology over recent years, there still occurs premature degradation of such drums as a result of the impact of the mine environment and intensified mining operations. Destructive factors include primarily stone dust or stone and coal dust getting to the area of mating between drums and the chain, the moisture contributing to formation of corrosion on drum surfaces, numerous successful and unsuccessful conveyor start-ups, as well as overloads caused, inter alia, by overloading and blocking of the conveyors.



Figure 1. Example view of an armoured face conveyor

The impacts of the aforementioned factors [1] include:

- significant abrasive wear of mating surfaces of drums and chains, which is intensified by the action of hard abrasive (Fig. 3A).
- plastic deformations of mating surfaces of drums (Fig. 3B).
- chipping of teeth in chain drums (Fig. 3C).
- fractures of teeth at the base – of ad-hoc or fatigue nature (Fig. 3D).



Figure 2. Chain drum installed in an armoured face conveyor

Abrasive wear has a particularly significant impact on the durability of chain drums. Destructive processes, especially the abrasion wear, can be counteracted by the use of appropriate technologies. As it appears from the analyses of damage to chain drums of armoured face conveyors [1], the materials and technologies used so far do not prevent the occurrence of abrasive processes to a satisfactory degree and therefore alternative methods of manufacture should be considered in order to improve the wear resistance of materials used in the manufacture of chain drums.



A



B



C



D

Figure 3. Examples of damage to the teeth of chain drums: A - abrasive wear of surfaces of drums intensified by the action of hard abrasive, B - plastic deformations of teeth, C - chipping of tooth tips in chain drums, D - teeth fractures of ad hoc nature.

2. CURRENT METHODS OF MANUFACTURING CHAIN DRUMS OF ARMOURED FACE CONVEYORS

In the current practical solutions, split and non-split cast or forged drums are used. Different production technologies are used for individual manufacturing variants.

A. In the case of the split cast variant, it is necessary to make casting from wear-resistant cast steel, clean it, carry out volumetric heat treatment and then quality control (Fig. 4A). The next step involves the treatment of the drum parting surface, drilling holes for connecting bolts (Fig. 4B), machining the inner hole, correcting the shape of the teeth (Fig. 4C), chiselling a key, surface hardening of sockets, and final quality control.

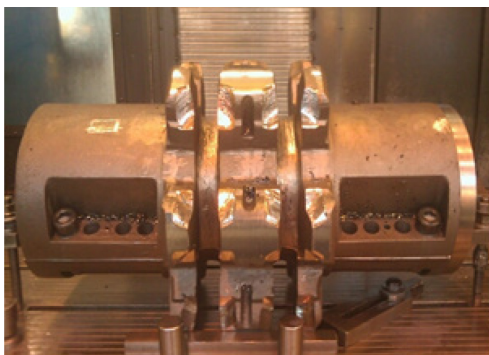
B. In the case of the non-split cast variant, it is necessary to make casting from wear-resistant cast steel, clean it, as well as carry out volumetric heat treatment and then quality control. The next step involves the treatment of the inner hole and faces (Fig. 4D), correcting the shape of the teeth, chiselling a spline, surface hardening of sockets, and the final quality control.



A



B



C



D

Figure 4. Selected stages of production of the cast chain drums: A - view of split drum casting during the acceptance inspection; B - view of split drum casting after the treatment of the parting surface and drilling of holes, C - view of a split drum when milling the tooth sockets, D - view of a non-split drum after the inner diameter and faces have been turned.

C. In the case of the forged split variant it is necessary to make forging of steel for quenching and tempering, carry out volumetric heat treatment and then the quality control. The next step involves the treatment of the drum parting surface, drilling holes for connecting bolts, joining both halves (Fig. 5A), machining the inner hole, milling the shape of the teeth (Fig. 5B), controlling the shape of the teeth, chiselling a key, surface hardening of sockets, and final quality control.

D. In the case of the forged non-split variant it is necessary to make forging of steel for quenching and tempering, carry out volumetric heat treatment and then the quality control. The next step involves the treatment of the inner hole and faces (Fig. 4C), milling the shape of the teeth, controlling the shape of the teeth (Fig. 5D), chiselling a spline, surface hardening of sockets, and the final quality control.



A



C



B



D

Figure 5. Selected stages of the production of forged chain drums; A - view of a split drum after joining the two halves, B - view of a split drum after the teeth have been machined, C - view of a non-split drum when milling the teeth, D - view of a non-split drum during inspection of the teeth shape.

3. ANALYSIS OF THE POSSIBILITY OF USING THE SHOT-PEENING TREATMENT IN THE PROCESS OF CHAIN DRUMS MANUFACTURE

Shot peening is a long-known method for increasing the durability of machine elements exposed to the action of a construction notch or for compensating for the adverse effects of other processes making up the industrial process, but it is not used for shaping the performance characteristics of the mining elements. An example of a possible application of this treatment are toothed components [2,3] used in highly-loaded industrial power units of mining machines. The dynamic action of shot during the shot-peening process [4] substantially modifies the stress distribution in the surface layer, increases the surface hardness, and leads



to the transition of residual austenite into martensite under the influence of stresses. As a result of the plastic deformation of the surface, in the surface layer of the materials treated there occur also compressive stresses, the value of which depends on the properties of the metal treated and shot peening parameters. A positive effect of the shot peening process is an increase in the resistance of teeth at the base against fatigue fracture as well as a delay in the formation of cracks in the carburized and hardened surface layers of toothed wheels [5,6,7]. The essence of the modification proposed is that the areas of mating with the link chain are additionally subjected to the dynamic surface treatment near the areas of mating with the link chain and at the bases of the chain drum teeth (Fig. 6). In the modified process cycle the shot-peening stage will take place after the surface treatment and hardening of chain drums.

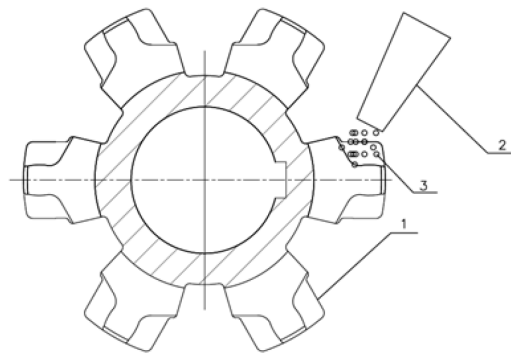


Figure 6. Diagram showing the process of shot peening of chain drums; 1 - the area of mating of the chain drum, 2 - the nozzle of the shot-peening machine, 3 - shot.

4. OPERATIONAL VERIFICATION OF THE PROCESS CHANGES

In order to confirm the usability of the process changes made, tests of wear properties were carried out in the conditions similar to the real ones. The tests of wear properties of 34CrNiMo alloy steel subjected to quenching and tempering were carried out on a test rig designed especially for that purpose, which allows reproducing the real operating conditions of the chain wheels. Details concerning the test rig and the method of determining the abrasive wear are presented in [8,9].

Two identical chain wheels made of steel subjected to quenching, tempering and surface hardening were used in the wear tests. As regards the shot-peened chain wheels, they were subjected to a dynamic heat treatment (Almen intensity: 0.32 mmA, coverage: 2x100%) in the area of contact between the wheel and the chain. Shot peening was conducted with the use of cut and rounded shot with the diameter of 0.6 mm and the hardness of approx. 54 HRC. As a result of this process, no increase in the hardness of the surface was found (the hardness was 555 HB). During the wear tests, there occurred relative movement of the mating surfaces of the wheel and the chain, which resulted in dislocation and crushing of abrasive grains in the mating area. The movement of the abrasive was accompanied by micro-cutting of the wheel surface.

After the completion of the wear tests, the test wheels were subjected to measurements in the area of wear using a coordinate measuring machine in order to determine the measure of abrasive wear (δ_{AVR_MAX}). Tab. 1 presents the values of the measure of abrasive wear (δ_{AVR_MAX}) of the chain wheels tested in the presence of the abrasive material as well as the measures of the dispersion. Tab. 2 summarizes the values of the relative difference in the wear ($\Delta\delta_{AVR}$) of shot-peened chain wheels and non-shot-peened ones. When comparing the results of the wear tests in terms of the impact of the shot-peening treatment, it can be noticed that the values of wear for the shot-peened variant were lower by 5.8%.



Table 1. The determined parameters characterizing the abrasive wear δ_{AVR_MAX} of 34CrNiMo steel for the materials considered; SP - the variant subjected to shot peening

Tested steel	δ_{AVR_MAX} , mm	S_{δ} , mm
34CrNiMo	0,623	0,041
34CrNiMo (SP)	0,587	0,020

Table 2. Values of the relative difference in the wear ($\Delta\delta_{AVR}$, %) of the shot-peened and not shot-peened chain wheels

Tested steel	$\Delta\delta_{AVR} = (\delta_{AVR_MAX_SP} - \delta_{AVR_MAX}) / \delta_{AVR_MAX}$
34CrNiMo	-5,77%

5. SUMMARY

The paper presents the possibility of modifying the current technology of manufacturing the drums by the introduction of an additional dynamic treatment of the surface – shot peening. On the basis of the operational tests conducted, it has been found that shot peening of the surfaces mating with the chain resulted in a reduction of the abrasive wear by 5.8%. The reason for the increase in the wear resistance was probably an increase in internal stresses in the surface layer of the chain wheels, which prevented the propagation of cracks (initiated by micro-cutting with crushed abrasive) to the inside of this layer.

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