



**OPERATION-ORIENTED METHOD FOR TESTING THE ABRASIVE WEAR OF MINING  
CHAIN WHEELS IN THE CONDITIONS OF THE COMBINED ACTION OF DESTRUCTIVE FACTORS**

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**Abstract:**

This paper presents a general characteristic of a rig for chain wheel testing in the conditions reproducing the actual operating conditions of conveyor elements in the rolling and sliding motion. This test rig allows performing wear tests in the presence of an abrasive material, corrosive factors and additional dynamic excitations in the form of steel beaters. The paper also describes a methodology of abrasive wear tests of chain wheels that allows determining the value of the linear wear of chain wheels and presents the test results for the materials typical of armoured face conveyors.

*Key words:* wear, chain wheels, maintenance

**INTRODUCTION**

Despite a continuous development of the manufacturing technology and the material science, a premature degradation of elements and assemblies of machines working in harsh operating conditions takes place due to the impact of the surrounding environment. Chain wheels are often used in tension member transport systems in underground mines and in coal handling systems of coal-fired power plants. The factors limiting the durability of such chain wheels [1, 2, 4, 7, 9] include primarily: stone dust or stone and coal dust, significant moisture content in the environment contributing to surface corrosion, numerous start-ups of the machines, as well as overloads caused for example by excessive loads and blockages. The impacts of the aforementioned factors include first of all a significant abrasive wear of mating surfaces of chain wheels and chains, which is intensified by the action of loose and hard abrasive. The value of the abrasive wear of mating elements depends on the properties of the materials used, the chemical and fractional composition of abrasive particles, their hardness, unit pressures, the rubbing speed, and the operational factors.

In the conditions of the combined action of destructive factors, an abrasive material, a dynamic load and corrosive agents, their destructive effect is strengthened. The negative synergism that occurs in such a case significantly reduces the durability of elements operated in the actual conditions.

The abrasive wear should be tested under conditions typical for the entire tribological system, but this requires a carefully designed test system, in which mating elements will be subjected to processes similar to those occurring in real conditions. The test rig in terms of reproduction of operating conditions of chain wheels should take the following into account:

- the synergy of the action of destructive factors: abrasive material, dynamic load and corrosive agents,
- rolling-sliding motion of the chain wheel and the chain,
- impact of the abrasive and crushed particles of the abrasive.

In most test rigs designed for testing the wear of materials the impact of the abrasive on the mating surfaces takes place only in the presence of sliding motion [3, 5] or only in the presence of a rolling motion [6]. Test equipment for testing the combined impact of an abrasive material and corrosive agents [8] in the conditions of a sliding motion is also known.

The test rig presented in this study enables a faithful reproduction of the working conditions of chain wheels operated in harsh environmental conditions, taking into account the synergistic impact of destructive factors, the conditions of the rolling and sliding form of contact, and impact of the crushed abrasive. This study also presents a method of determining the parameters characterizing the linear wear of chain wheels.

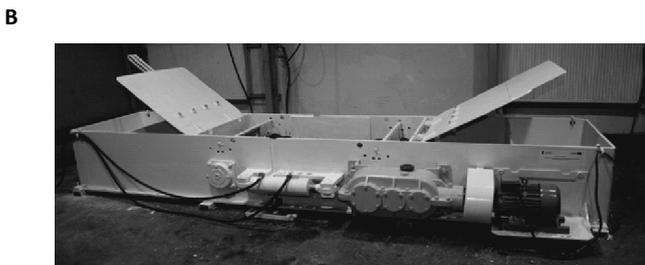
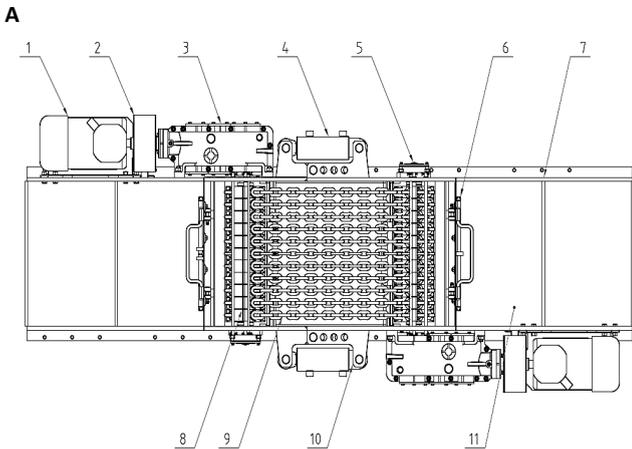
**CHARACTERISTICS OF THE TEST RIG**

In order to reproduce the conditions of the actual operation of the chain wheels, it has been assumed that the design form will be identical with that of a typical tension member conveyor used in the mining industry. A diagram and a real view of the test rig are shown in Figure 1.

The test rig includes:

- 2 drive motors with a power of 22kW,
- 2 gear transmissions - type PPL 14/22,
- test rig frame with a test chamber,
- servomotors for adjusting the tension of the working tension member (chain),
- shafts for 11 chain wheels per chain with a link section of 18 mm,

- drive axle shafts assemblies,
- water spray system,
- set of beaters.



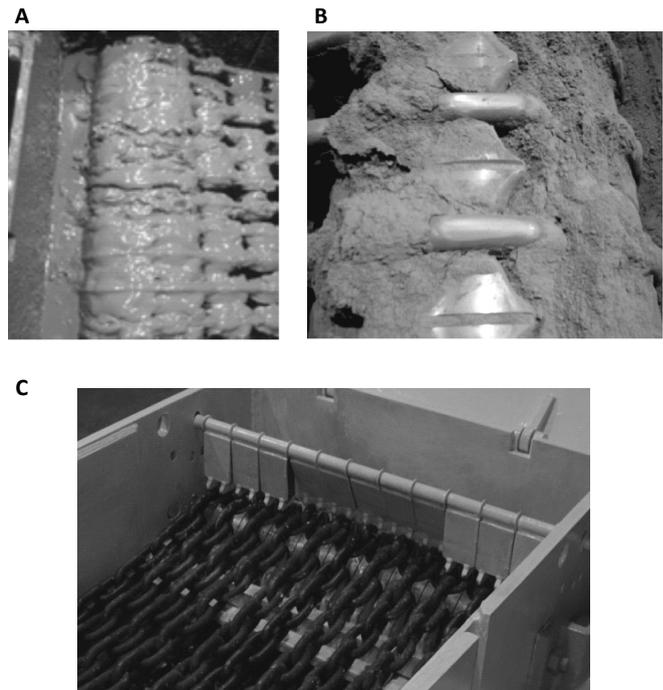
**Fig. 1 Schematic diagram of the test rig:**  
 1 - Induction motor 22 kW, 2 - Flexible coupling, 3 - Conical-cylindrical reduction gear, 4 - Hydraulic cylinder, 5 - Axle shaft, 6 - Sprinkler system for the test chamber, 7 - Body of the test rig, 8 - Test samples, 9 - Chain, 10 - Mounting bracket of the hydraulic cylinder, 11 - Additional chamber for aggregate

**THE METHOD OF IMPLEMENTING THE COMBINED ACTION OF DESTRUCTIVE FACTORS**

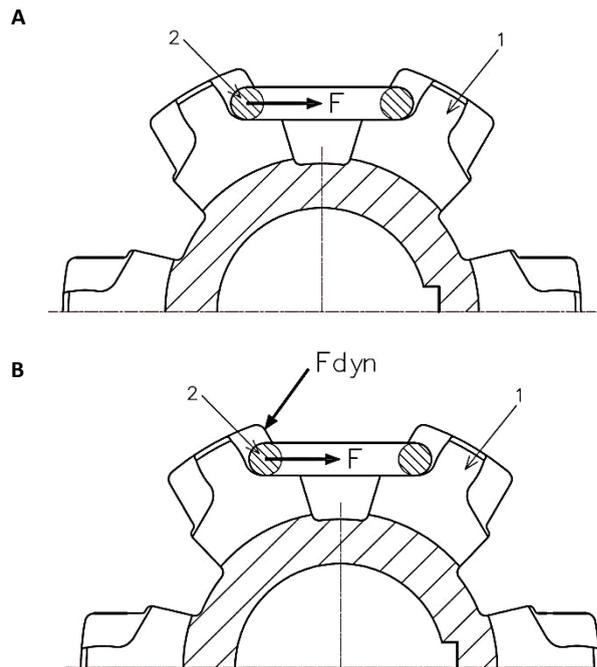
The test rig allows reproducing a combination of destructive factors:

- A. Abrasive wear in the presence of loose quartz abrasive; the occurrence of this process was achieved through the possibility of filling the test rig box with dry abrasive (Fig. 2B).
- B. Abrasive wear in the presence of loose quartz abrasive with a simultaneous impact of dynamic forces; the occurrence of this variant was achieved through the possibility of filling the test rig box with dry abrasive and installation of steel beaters (Fig. 2C).
- C. Abrasive wear in the presence of loose quartz abrasive combined with corrosive processes; the occurrence of this variant was achieved through the possibility of filling the test rig box with dry abrasive and systematic addition of water (Fig. 2A).
- D. Abrasive wear in the presence of loose quartz abrasive combined with intensified corrosive processes; the occurrence of this variant was achieved through the possibility of filling the test rig box with dry abrasive and systematic addition of water and technical salt NaCl.

Figure 3 shows diagrams of the chain drum load in the presence of the quartz abrasive only (Fig. 3A) as well as in the presence of the abrasive together with the action of an external dynamic force (Fig. 3B).



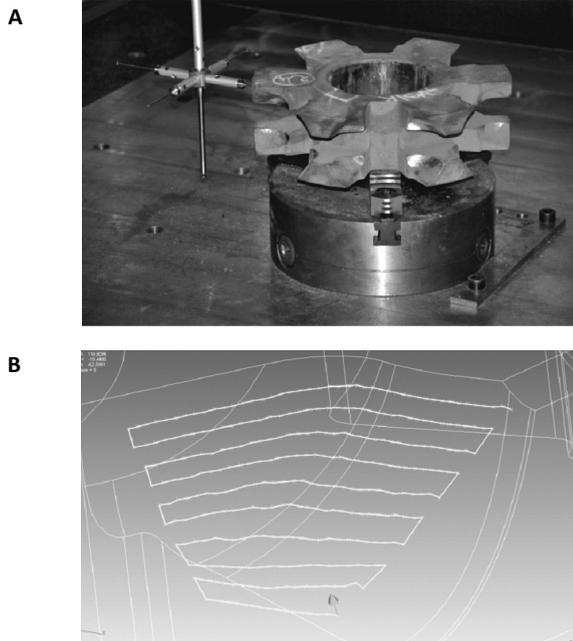
**Fig. 2 A view of the test ring during the tests in the presence of quartz abrasive and water (A), in the presence of quartz abrasive only (B), adapted to tests with an external dynamic load (C); designations: chain wheels (1), chains (2), beaters (3).**



**Fig. 3 Diagram of the chain drum load; A - in the presence of the abrasive, B - in the presence of abrasive and an external dynamic force; designations: 1 - chain wheel, 2 - chain,  $F$  - driving force,  $F_{dyn}$  - external dynamic force obtained by the use of beaters**

**METHODOLOGY FOR DETERMINING THE LINEAR WEAR OF CHAIN WHEELS**

In order to determine the linear wear of the chain wheels, the geometry of all mating surfaces between the chain wheel and the chain is measured before and after the wear test using the coordinate measuring machine (Fig. 4A). The area of mating between the chain wheel and the chain is represented by a route composed of 10 main lines (Fig. 4B). Approx. 300 points along the predefined route of the machine's measuring head is read and recorded during the measurement.



**Fig. 4** A view of the chain wheel during the measurements on the Acura Zeiss measuring machine. The shape of the measuring path superimposed on a solid model of the chain wheel

In order to determine the value of the linear wear, there was used the difference in the distance  $\delta_i$  between the  $i$ -th measuring point, measured before and after the tests. It is expressed by the following dependence:

$$\delta_i = \sqrt{(x_{i,1} - x_{i,2})^2 + (y_{i,1} - y_{i,2})^2 + (z_{i,1} - z_{i,2})^2} \quad (1)$$

where:

- $x_{i,1}$  –  $x$  coordinate of the  $i$ -th point before the test,
- $x_{i,2}$  –  $x$  coordinate of the  $i$ -th point after the test,
- $y_{i,1}$  –  $y$  coordinate of the  $i$ -th point before the test,
- $y_{i,2}$  –  $y$  coordinate of the  $i$ -th point after the test,
- $z_{i,1}$  –  $z$  coordinate of the  $i$ -th point before the test,
- $z_{i,2}$  –  $z$  coordinate of the  $i$ -th point after the test.

Based on the determined values of wear  $\delta_i$ , the maximum value for the test surface  $\delta_{i,MAX}$  can be determined.

$$\delta_{i,MAX} = MAX\{\delta_i\} \quad (2)$$

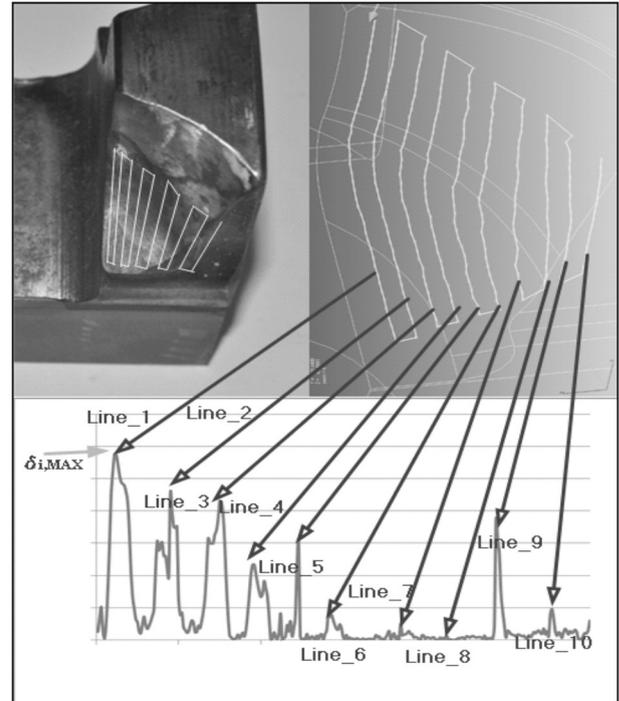
The  $\delta_{i,MAX}$  values determined for all 24 surfaces measured for a given wheel will be averaged further.

$$\delta_{AVR,MAX} = \frac{\sum_1^n \delta_{i,MAX}}{n} \quad (3)$$

where:

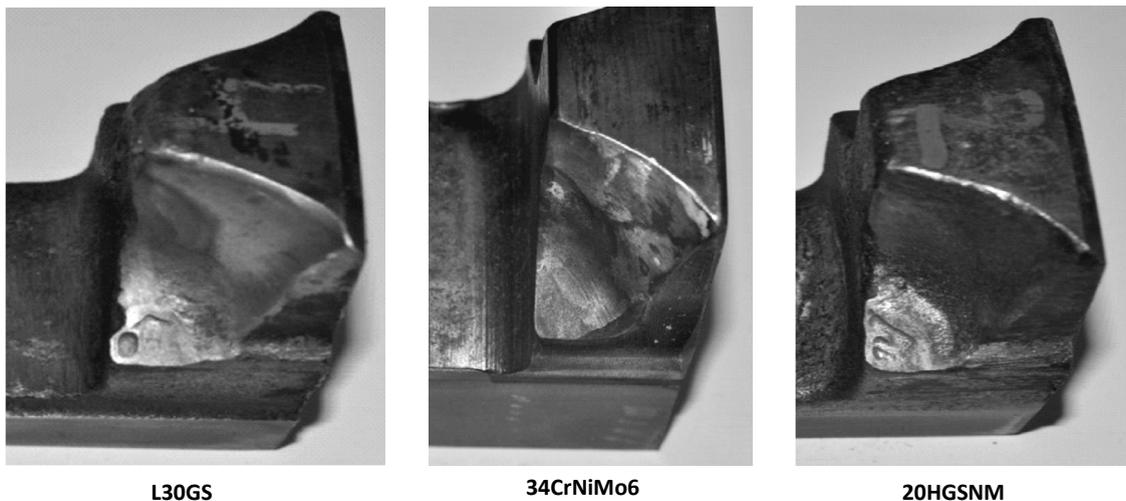
$n$  – the number of surfaces of the seats of a given chain wheel ( $n = 24$ ).

In addition to the parameter  $\delta_{AVR,MAX}$ , the standard deviation and the average standard deviation are calculated in order to determine the scatter of the results. The manner of interpreting the results of measurements on the coordinate measuring machine is presented in Figure 5.



**Fig. 5** The manner of interpreting the results of measurements on the coordinate measuring machine

The abrasions in the area of mating between the chain wheel and the chain after the wear tests in the presence of loose quartz abrasive (lasting 100 hours for each direction of motor rotations) for 3 sample materials are shown in Figure 6. Figure 7 presents sample plots of linear wear  $\delta_i$  for the materials tested. These plots provided a basis for determining the parameter  $\delta_{AVR,MAX}$  (Table 1).



**Fig. 6** Examples of the abrasion in the area of mating between the chain wheel and the chain

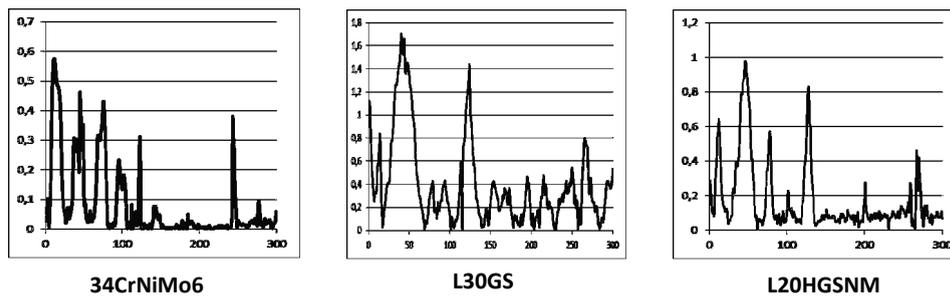


Fig. 7 Plots of the linear wear  $\delta_i$  for the materials tested

Table 1  
Determined values of the parameter  $\delta_{AVR\_MAX}$ , standard deviation  $S_{\delta}$  and average standard deviation  $S_{\delta x}$ .

Grade of steel or cast steel	$\delta_{AVR\_MAX}$ , mm	$S_{\delta}$ , mm	$S_{\delta x}$ , mm
34CrNiMo6	0,62±0,13	0,31	0,06
L30GS	1,601±0,039	0,28	0,02
L20HGSNM	0,890±0,095	0,23	0,05

## SUMMARY

The problem of improving the durability of chain wheels operated in harsh operating conditions is important for practical applications. It requires extensive studies that take into account the specific character of a given industry. However, it is very difficult to measure the wear in real conditions and therefore there are no clear results concerning the synergism of destructive processes.

This study presents a test rig for testing the wear of chain wheels and a methodology for determining the parameters characterizing the abrasive wear, which enable simultaneous performance of wear tests in the presence of an abrasive material, corrosive agents (water and salt) and additional dynamic excitations in the form of steel beaters. Thus it is possible to study the synergistic effects of destructive processes that affect the chain-drive drum system. The research method described above enables a full determination of the effects accompanying the operation of chain wheels.

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