Development of a Test Rig for Determining Wear Resistance Based on a Modified “Disk–Abrasive Fluid With Free Rotation of Specimens” Method

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***Abstract*—Abrasive wear is responsible for hundreds of tonnes of metal loss in the mining, cement and brick industries. This necessitates the development and testing of wear resistant materials (alloys). Samples of these alloys are tested in conditions that mimic working conditions as closely as possible. The test rig developed enables the assessment of wear resistance between different materials.**

***Keywords*— abrasive wear, bench, high alloy white cast iron, relative wear resistance.**

I. Introduction

During the extraction and processing of ore, coal, cement raw materials, stone, and others, hundreds of thousands of tons of metal are consumed due to abrasive wear [1]. This necessitates the development and study of wear-resistant materials (alloys). These alloys are tested (their behavior is observed) under conditions that closely imitate real working environments.

High-alloy white cast irons, with their specific structure, often represent an irreplaceable structural material for machine and apparatus components used in such industrial operations.

Wear is a complex process in which, in addition to abrasion, corrosion and cavitation effects are often involved. The process itself is ambiguous – it may involve micro-cutting or fatigue of the metal surface as a result of repeated impacts [2].

II. Research Methodology

In wear studies, the main factor influencing the wear process is typically identified, and a material (alloy) suitable for the specific working conditions is selected, while also accounting for the influence of other contributing factors.

To evaluate the wear resistance of materials, various types of test rigs based on different methodologies are used [3, 4, 5, 6, 7]. To date, there is no universally accepted methodology for testing alloys under abrasive wear conditions.

A significant number of white cast iron components operate at attack angles up to 30°, under which the dominant wear mechanism is micro-cutting. For such conditions, the KM-1 test rig has been developed to investigate wear resistance.

In the KM-1 rig, the tested specimens (dimensions Ø30×340 mm) undergo wear while rotating in a circular path within a “cup” filled with a mixture of quartz sand and water in a 2:1 ratio, with a total solution volume of 30 liters. The relative velocity of the specimens with respect to the abrasive medium is 8 m/s. The specimens—two made from the tested alloy and two reference specimens—are mounted on a rotating disk (Figure 1).

The working chamber is enclosed in a jacket with a flow of cooling water to control the temperature of the abrasive mixture (sand and water), which heats up due to friction between the abrasive particles and the specimen surfaces. Quartz sand grade 016, in accordance with ISO 3262-21, is intended for use in the tests. The microhardness of the sand grains under load is 1000–1200HV. As a reference material, specimens made from unalloyed white cast iron in as-cast condition will be used.

To evaluate wear resistance, a relative wear resistance coefficient K is defined, representing the ratio of the worn volume of the reference specimen to the volume loss of the tested specimen:

$$K = \frac{\Delta \mathrm{V_{et}}}{\Delta \mathrm{V_{sa}}} = \frac{\Delta \mathrm{m_{et}} . \rho_{\mathrm{et}}}{\Delta \mathrm{m_{sa}} . \rho_{\mathrm{sa}}} \tag{1}$$

where, $\Delta \mathrm{V_{et}}$, $\Delta \mathrm{V_{sa}}$ - change in volumes of the reference and test specimen, $\Delta \mathrm{m_{et}}$, $\Delta \mathrm{m_{sa}}$ - mass loss, ρ_{et} and ρ_{sa} - density of the reference and test specimen.

A Kern EMS 6K1 analytical balance accurate to ± 3 g was used to record the change in mass of the samples before and after the test.

III. Design Solution

Fig. 1 shows an overview of the proposed design solution, and Fig. 2 shows, in exploded view, the individual functional modules and details. The main modules of the structure are the stand 1, the high torque motor 4 the working rotor 6 and the cup 8. The stand module is made as a welded gantry shaped structure. It supports the high torque electric motor 4 and the sleeve 2 used for bearing the Work Rotor Module 6.

A section in the bearing area is shown in Fig. 3. In addition to the sleeve 2, a set of support washer and nut 5 are used to support the shaft of the impeller (Fig. 2). Securing the nut against self loosening and ensuring axial play is done, by means of a stop screw. The type of central shaft bearing is adapted to the relatively low speed of the impeller and the nature of the load forces.

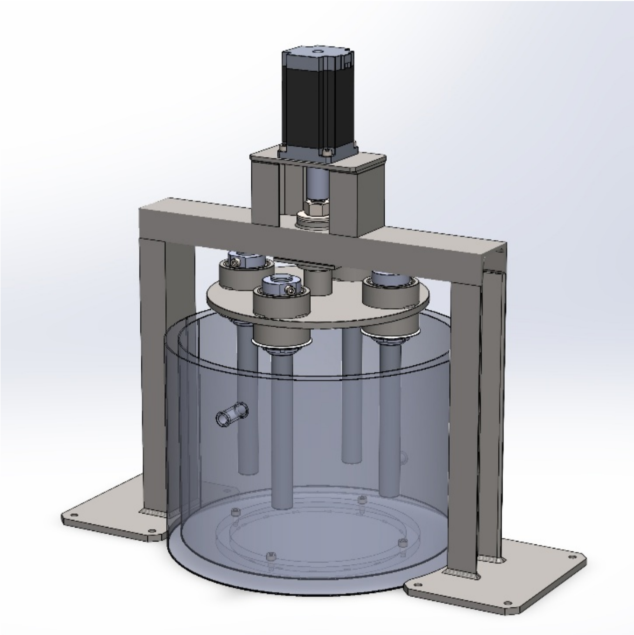

Fig. 1. General view of the bench for determination of wear resistance by the modified method "Disc - abrasive fluid, with free rotation of test specimens"

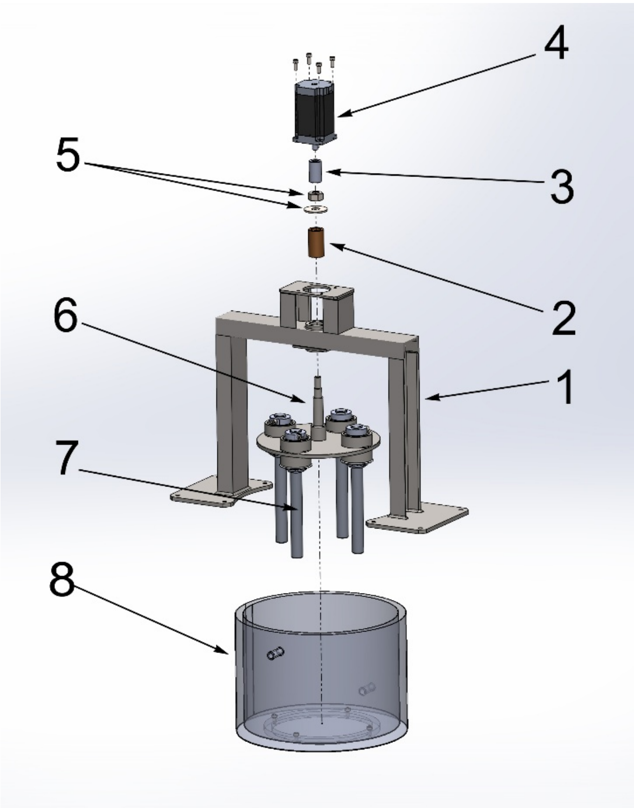

Fig. 2. Modules and functional elements

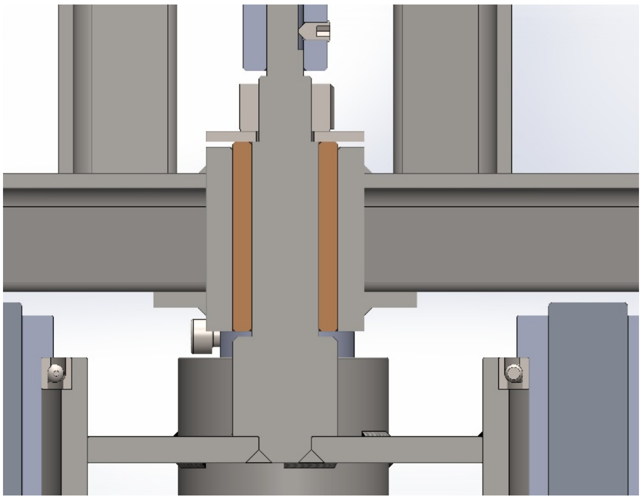

Fig. 3. Bearing of the module Working rotor

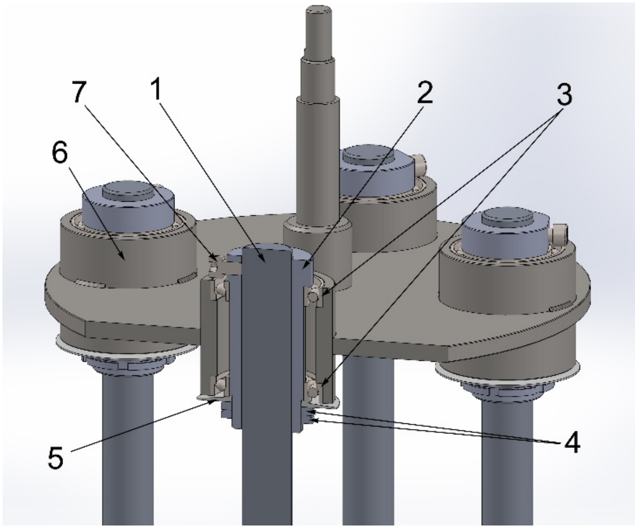

Fig. 4. Module Working rotor

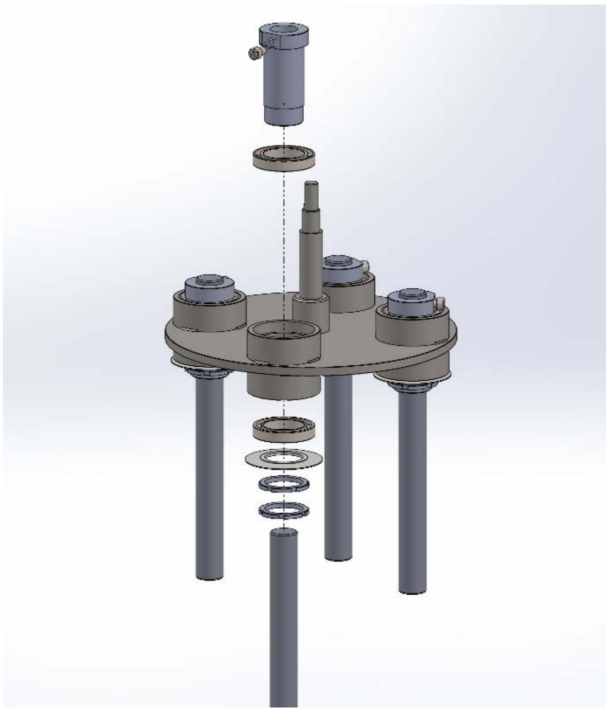

Fig. 5. Working rotor module, exploded view

Fig.4 and Fig.5 show the arrangement of the Working Rotor module. On the support body, 6 four identical bearing beds are provided for the assembly of the bearings 3 ensuring the free rotation of the bushings 2. The test and reference specimens 1 are seated in the bushings 2 and fixed, by means of the screws 7. The bearings selected are of the radial-axial type. The nuts 4 are used to adjust and maintain the axial play. The washer 5 protects the lower (in the figure) bearing from moisture and abrasive particles

The carrier of the working rotor is shown in Fig. 6. It has a composite structure of welded parts including a central shaft - 1, a disc - 2 and four bearing beds - 3. The locations and type of welds are visible from the figure.

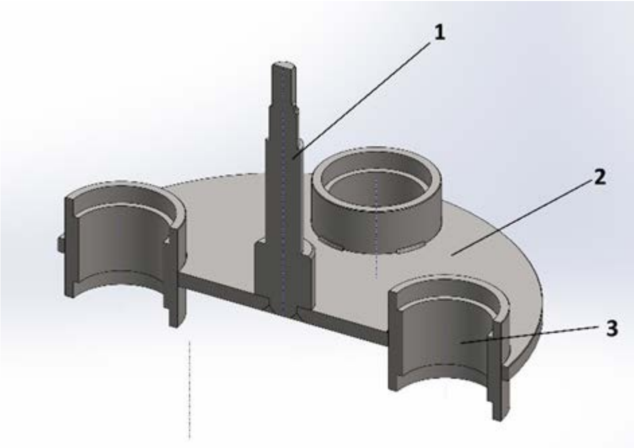

Fig. 6. Work rotor module support body

The design of the Cup module is shown in Fig. 7. For ergonomic reasons, when servicing the bench, it is designed as a detachable unit and consists of two concentric vessels - inner 1 and outer 2. A ring 3 is used to distance the bottoms of the two vessels. It is mounted by a detachable screw joint 4 to the inner vessel and non- detachable (welded) to the outer vessel, thus facilitating the sealing of the outer vessel. The nozzles 3 are used for the supply and discharge of flowing water during operation of the stand.

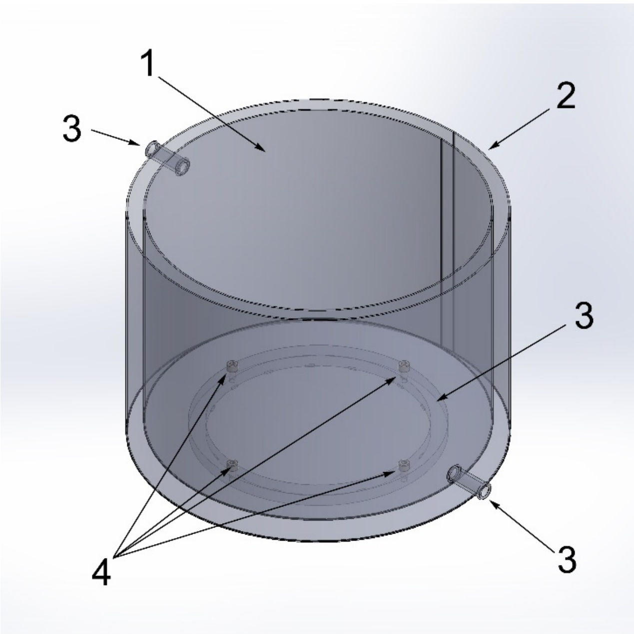

Fig. 7. Module Cup

A NEMA 34 type high motor stepper motor is used for drive. It is directly connected to the central shaft of the working rotor by means of the elastic coupling 3, Fig. 2. The stepper motor is complete with a power supply module, driver and controller/control panel allowing setting of operating modes - speed and cycle duration.

IV. CONCLUSION

1. The developed test rig is a maximally simplified design solution for evaluating the wear resistance of different materials under hydroabrasive wear conditions.

2. The parameters of the medium (fluid viscosity, coarseness, type of abrasive particles, etc.) in which the specimens are tested can be varied, which enables generalization of the results of the tests.

3. Test specimens perform complex motion (two rotations) which accelerates wear and shortens test time.

4. The proposed methodology allows to evaluate the wear resistance of different alloys in near service conditions in a simplified but efficient way.

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