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EXPERIMENTAL INVESTIGATIONS ON THE DURABILITY AND PERFORMANCE OF INDUSTRIALIZED PRODUCTS USED IN THE WOOD INDUSTRY

The woodworking industry uses a wide range of industrial items, which are subjected to severe mechanical and tribological stresses. This paper presents experimental research that examined the behavior of various essential industrial parts used in the woodworking industry, with a focus on durability, friction coefficient and wear. The performance characteristics of the materials used were determined by friction and abrasion tests, combined with microstructural analysis and mechanical measurements. The results are useful for optimizing materials and component design, which increases the efficiency and durability of industrial equipment in this field.

Keywords: Chemical composition; microindentation; friction coefficient; microstructure

1. Introduction

Band saw blades are commonly utilized cutting instruments for initial log splitting and subsequent processing tasks in the woodworking and furniture sectors. These blades are made of narrow metal strips with different widths and tooth designs, welded to a length that matches the circumference of the band saw wheels and the space between them [3]. Earlier research has indicated that blade preparation-especially the tooth profile, welding, sharpening quality, and blade tensioning is vital for cutting performance, surface quality, and tool longevity [4]. The proper choice of tooth pitch and shape significantly influences cutting efficiency, wear resistance, and the dimensional precision of sawn lumber. In recent decades, increasing attention has been paid to the efficient use of renewable natural resources, particularly woody biomass, in response to growing energy demands and environmental concerns [5]. Numerous studies have highlighted the importance of improving forest resource utilization to meet the rising demand for wood products driven by global population growth and industrial development [6-8].

Within this context, mobile mechanical sawmills have attracted growing interest from forestry and wood-processing specialists. Previous research indicates that these machines provide significant advantages in terms of flexibility and cost efficiency, as they allow wood processing directly at harvesting sites or in remote and inaccessible areas, thereby reducing transportation costs and raw material losses [9].

2. Materials and methods

This paper presents experimental research that examined the behavior of a continuous motion saw blade used in the woodworking industry [10]. The performance characteristics of the materials used were determined by mechanical tests, combined with microstructural analyses and hardness measurements. The results are useful for optimizing materials and component design, which increases the efficiency and durability of industrial equipment in this field, providing economically relevant solutions [11].

3. Determination of chemical composition by spectral analysis

Spectroscopy is the science of examining the interaction between electromagnetic radiation and matter [12]. Quantitative spectral analysis allows for the precise determination of the chemical elements in the composition of the fabric, which

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can further determine the mechanical processing required by the field of materials engineering [13]. The chemical composition determined by spectral analysis was performed on the Foundry Masters optical spectrometer located in the Laboratory: Properties of Metallic Materials, within the Faculty of Materials Science and Engineering.

TABLE 1

Chemical composition of the saw blade for cutting logs

Alloy	Chemical composition [%]						
	Fe	C	Mn	Si	Cr	Cu	Other
Saw blade	97.90	0.70	0.67	0.31	0.24	0.02	0.16

According to the analysis report obtained, we determined that the analyzed alloy falls into the category of Fe-C alloys, brand C60 (1.0601) [14].

The chemical composition of the steel used helps us evaluate its durability and wear resistance, offering an optimal balance between hardness and toughness.

4. Macro and microstructural characterization of Fe-C alloy

The performance of C60 steel is assessed following interactions with living systems, having two local aspects: macroscopic and microscopic analysis.

Macroscopic analysis is the first stage of microscopic analysis. This analysis requires minimal preparation and provides information about the type of alloy, special characteristics of the casting structure and the quality of subsequent processing [15]. The results obtained give us the final shape and properties, the type of destruction, but also its cause. [16] At the same time, plainly visible examination permits the determination of regions within the considered example, which must in this way be subjected to a point by point examination [17]. To highlight the structure, a Leica 5000DMI metallographic microscope and a Quanta 200 3D dual beam scanning electron microscope were used.

The tests required for auxiliary examination were handled by electroerosion, and as preparation methods we used grinding, polishing and highlighting the structure by chemical etching [18-20]. The tests subjected to tiny investigation have a cubic shape, with a side of 10 mm. The microstructure of metallic materials speaks to a fine development of the structure, which was highlighted employing a metallographic chemical carving with the taking after composition: 10% sodium hydroxide.

Fig. 1 shows the optical micrographs for C60 steel, which were taken in bright field, at 200× and 500× magnifications, using the BF filter, which allows obtaining micrographs with good contrast, but also with shades as close as possible to the real ones. At 200× magnification, the following can be observed:

- Ferrite: lighter, more homogeneous areas.
- Pearlite: darker, lamellar areas.

At 500× magnification, the lamellar structure of pearlite becomes more visible – cementite lamellae alternating with ferrite.

Bright field microscopy is the most widely used in metallography for the qualitative and quantitative analysis of the structure of metallic materials [21]. In the case of C60 steel, the structure consists of pearlite as the basic metallic mass and secondary white cementite distributed at the boundary of the former austenite grains.

From the analysis of the microstructures obtained on the electron microscope (Fig. 2), a fine ferrite-pearlitic structure can be observed, with an unoriented distribution of the constituents.

5. Determination of the hardness of C60 steel

Hardness measurements highlight the strength of the saw blade for cutting logs and provide information on its behavior in forestry (reduction of wood losses) where they are subjected to various mechanical stresses (compression, torsion, wear) [22]. For a saw blade for cutting logs, a high hardness is sought to ensure high wear resistance, but sufficient toughness to prevent cracking.

We used the Rockwell method for hardness identification tests using a Wilson Wolpert universal hardness tester, model 751 N. Equipment located at the Department of Materials Pro-

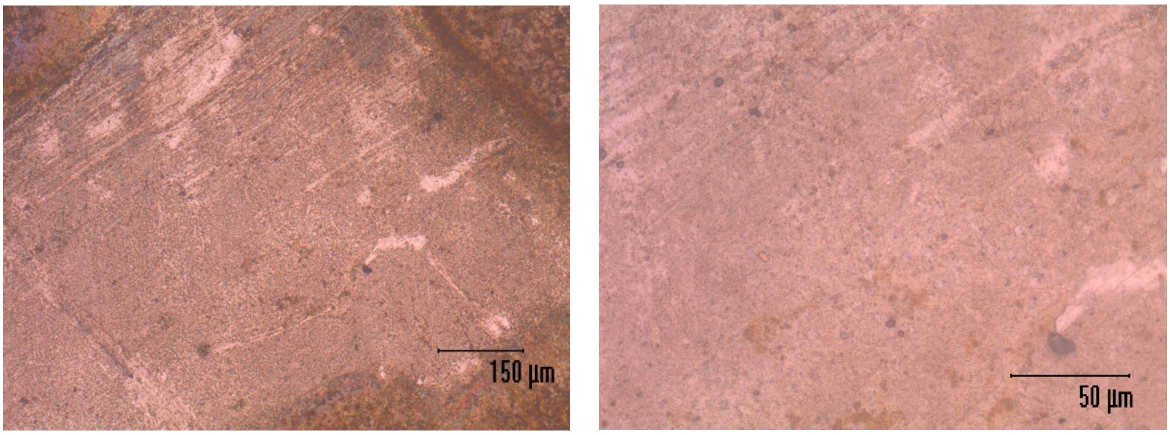

Fig. 1. Microstructures of C60 steel at 200× and 500× magnifications

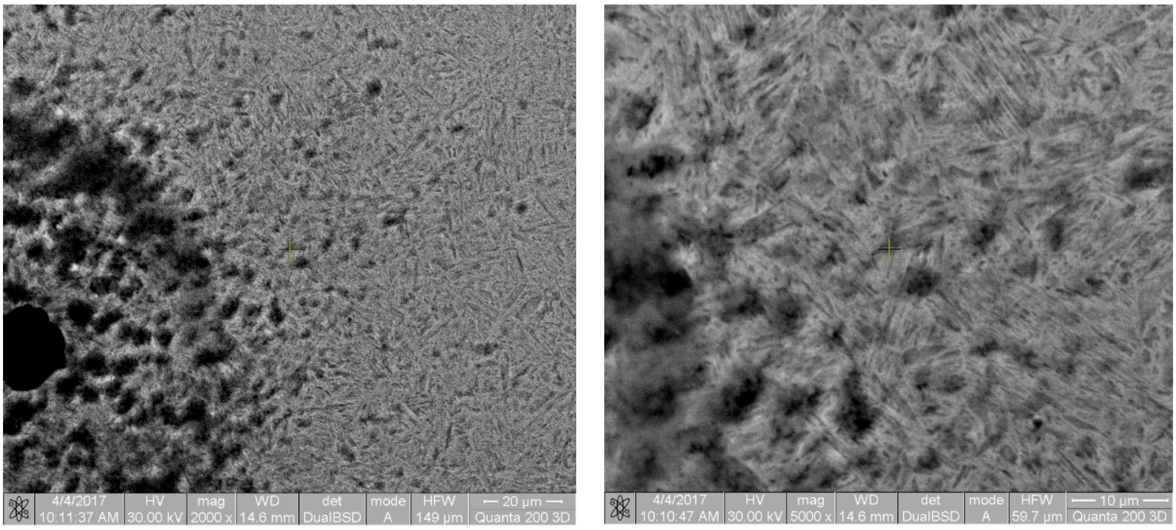

Fig. 2. Microstructures of C60 steel at 2000× and 5000× magnifications

cessing Technologies and Equipment, Faculty of Materials Science and Engineering.

For the precision of the comes about, three determinations were made for C60 steel with certain estimation conditions. The hardness assurance was performed on tests with two parallel plane surfaces, one of the surfaces being arranged by grinding on abrasive paper.

Experimental conditions:

- samples with plane-parallel surfaces;
- the surface on which the test was performed was sanded with 180 and 320 grit abrasive paper;
- temperature: 28°C (reference temperature 23 ± 50°C).
- humidity: 62%.
- conical diamond indenter with a 136° tip angle.

6. Microindentation method

In order to obtain information related to the modulus of elasticity, hardness and stiffness of the Fe-C alloy at the surface level, the microindentation method was used. This method consists of penetrating the sample surface with a conical tip probe at a certain force.

To carry out this test, it was necessary to use the CETR UMT-2 microtribometer equipment from the Faculty of Mechanics, Tribology Laboratory.

During the microindentation test, the values of the loading forces were recorded in relation to the depth of penetration of the indenter into the material layer.

The tests were carried out in dry conditions. A Rockwell diamond indenter was used, with an indenter cone angle of 120° and a spherical tip with a radius of 200 µm, applying a force of 15 N.

For a more precise determination, three determinations were made for the Fe-C alloy. After completing the work stages and recording them by the UMT 2 device software, the imprint curves were drawn by the VIEWER program.

Fig. 3. shows the variation curve of the penetration force in relation to the indentation depth after performing the microindentation test.

TABLE 2

Hardness measurements, HRC 150 kg

<table>
<tr><td rowspan="4"></td><th colspan="4">Measured point values</th><th>Average value</th></tr>
<tr><td></td><th>Point 1</th><th>Point 2</th><th>Point 3</th><td></td></tr>
<tr><th>HRC</th><td>55.40</td><td>57.20</td><td>59.30</td><td>57.30</td></tr>
<tr><th>HB</th><td>577</td><td>596</td><td>614</td><td>595</td></tr>
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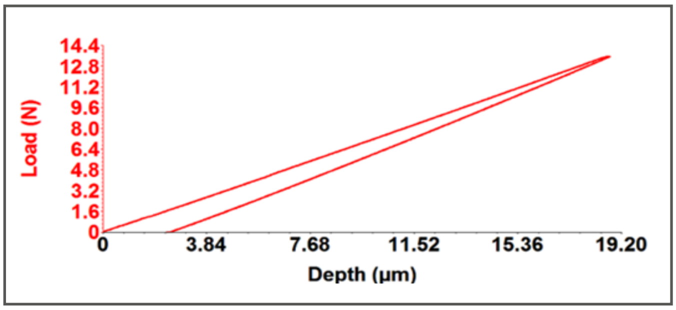

Fig. 3. Microindentation test variation curve

The modulus of elasticity may be a exceptionally imperative measure that underlies the choice of metallic materials utilized in in forestry. The value of the modulus of elasticity for the Fe-C alloy resulting from the indentation test is E = 7.554 GPa. The Fe-C alloy has a major advantage, combining strength with elasticity, the modulus of elasticity giving the alloy good deformability.

7. Determining the coefficient of friction in dry conditions

The friction force Ff acts on the flexible lamella of the sensor and the information procurement from the force sensor is done with a Vishay P3 strain gage and the recording is done on the computer, utilizing an suitable computer program. The estimation framework was calibrated utilizing loads extending from 0.5 grams to 5 grams (5 mN to 50 mN). The measurement accuracy is 0.2 mN. Ff, the friction force is determined directly during the experiment and the friction coefficient is determined as the ratio between Ff and the normal load G.

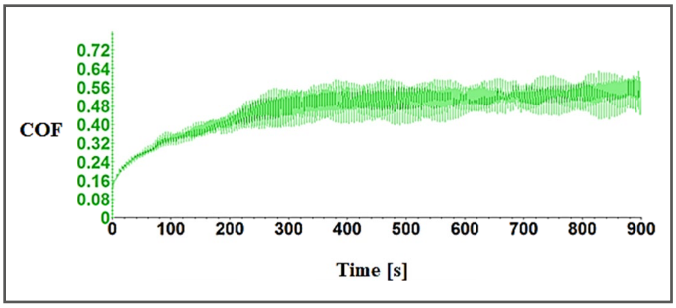

Fig. 4. The coefficient of friction for a load of 10 N

Fig. 4 shows the variation of the friction coefficient with respect to time for the sliding speed v = 10 mm/s, steel pin, for the normal load (10 N). The test duration was 15 minutes, and the friction coefficient shows stabilization around the value 0.5.

8. Discussions

Contemporary society demonstrates a growing interest in the effective use of renewable natural resources, especially in forestry, where productivity and equipment dependability are essential. In this scenario, portable mechanical saws are essential, and the effectiveness of their cutting components is directly affected by the material characteristics of the saw blades. This study adds to the field by offering an in-depth characterization of a log saw blade material and linking its properties to those documented in existing literature. The spectral analysis revealed that the material studied is part of the Fe-C alloy family, namely C60 steel. This classification is consistent with previous studies, which indicate that medium- to high-carbon steels (0.55-0.65 wt.% C) are commonly used for saw blades due to their high strength, good hardenability, and superior wear resistance under severe mechanical loading. Comparable material selections have been documented for industrial cutting tools functioning under abrasive and impact circumstances, where achieving a balance between hardness and toughness is crucial. Microstructural analysis performed by optical microscopy revealed a structure characteristic of hypoeutectoid steels, consisting predominantly of pearlite with secondary cementite distributed along prior austenite grain boundaries. This observation is in good agreement with previously published microstructural investigations of C60 steel subjected to conventional heat treatments, where a pearlitic matrix is associated with high wear resistance and acceptable fracture toughness. The presence of cementite at grain boundaries, as reported in the literature, contributes to increased hardness while still allowing sufficient energy absorption during dynamic loading, which is particularly important for saw blades exposed to cyclic stresses and vibrations.

The hardness value obtained experimentally (595 HB) confirms the effective hardening of the material and falls within the upper range reported for C60 steel used in cutting and woodworking applications. Comparable hardness levels have been documented for industrial saw blades designed for longitudinal wood cutting, where resistance to abrasive wear and edge degradation is a primary requirement. These findings support the suitability of the investigated steel for demanding forestry operations, where blades are subjected to high rotational speeds and prolonged contact with heterogeneous materials such as wood containing knots or mineral inclusions.

Additionally, the operational environment of log saw blades is recognized as harsh, characterized by high-speed rotational or oscillatory movement and swift longitudinal cutting of logs that can measure several meters long. Earlier research highlights that, in these circumstances, both hardness and elastic characteristics significantly contribute to avoiding early failure from fatigue or vibration-related fractures. In this respect, the experimentally determined modulus of elasticity (E = 7.554 GPa, obtained by indentation testing) indicates a rigidity compatible with the functional requirements of forestry equipment. Similar trends have been reported in the literature, where Fe–C alloys demonstrate a favorable combination of stiffness and elastic recovery, allowing them to withstand alternating stresses without excessive deformation.

Overall, the results obtained in this study are consistent with previously published data on C60 steel and comparable Fe-C alloys used in cutting tools. The combination of a pearlitic-cementitic microstructure, high hardness, and adequate elastic response confirms that this material is well suited for log saw blades operating under harsh mechanical and environmental conditions. These findings reinforce existing material selection practices in the forestry industry and provide experimental support for the continued use and optimization of C60 steel in mechanically stressed cutting applications.

9. Conclusions

This research shows that C60 carbon steel is an appropriate and dependable material for log saw blades used in severe forestry environments, owing to its advantageous blend of microstructural stability, mechanical strength, and tribological characteristics. Using a thorough experimental method, the material was analyzed regarding its chemical composition, microstructure, hardness, elastic response, and dry wear performance under conditions that mimic actual forestry activities. The microstructural analysis revealed a predominantly pearlitic matrix with secondary cementite, which directly explains the high hardness (595 HB) and the good resistance to dry abrasive wear observed during testing. These characteristics are essential for maintaining cutting efficiency and limiting material degradation during high-speed, cyclic loading. The correlation established between microstructure and tribological behavior provides a clear mechanistic understanding of wear processes in saw blades used for longitudinal wood cutting.

A key practical outcome of this work is the experimental determination of the modulus of elasticity for a forestry-grade Fe-C alloy, obtained through indentation testing. This parameter is rarely reported for such applications, yet it is crucial for CAD/CAE-assisted design, vibration control, and fatigue resistance assessment. The results confirm that C60 steel offers an effective balance between stiffness and elasticity, allowing it to withstand alternating stresses and vibrations without premature failure.

The key takeaway from this study is that a thoughtfully chosen and adequately tempered C60 steel strikes an ideal balance between hardness, wear resistance, and elastic characteristics, making it highly appropriate for rigorous forestry machinery. In addition to validating existing industrial practices, this study provides unique experimental data that can be directly applied for optimizing materials, conducting numerical simulations, and enhancing the design of saw blades. Finally, this work opens clear directions for future research, including the comparative analysis of alternative steel grades, optimization of heat treatment routes, investigation under extreme environmental conditions, and the integration of virtual simulations and circular-economy principles. Advancing these directions will contribute to extending the service life, efficiency, and sustainability of industrial equipment used in modern forestry.

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