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REVERSE ENGINEERING ON A COUPLE "CUTTING BLADE AND SHEARBAR" USED IN THE TEXTILE INDUSTRIES

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Abstract. *This work has the purpose of indicating the composition and thermal treatments of tool steels used in the textile industry and to point out possible materials for new cutting blades and shearbars. For this, samples of each material were prepared and, later submitted to characterization techniques. During the experimental procedure were developed chemical analysis – Energy Dispersive Spectrometry and X-Ray Fluorescence (EDS and XRF), microstructural analysis – Scanning Electron Microscopy and Optical Microscopy (SEM and OM) and also mechanical analysis – Hardness Test. The literature match analysis indicates that the specimen are tool steels AISI D and it is probably of the series 3, i.e., AISI D3.*

Keywords: *Tool steel, Textile industry, Cutting blade, Microstructural analysis, Chemical analyzes.*

1. INTRODUCTION

The Brazilian textile sector demonstrates that existed and still exists a process of change. Brazil is experiencing an invasion of imported products. In the history of the textile sector, technology can be highlighted as a strategic factor for changes and development that currently requires adherence to the technological complexity due to the need to assimilate new artistic and cultural tendencies for a continuous re-signification of culture and even of individuality.

Brazilian imports of textile and clothing machinery and equipment grew 28.7% from January to April 2017, compared to the same period in 2018. According to data from the Brazilian Association of the Textile and Apparel Industry (ABIT, 2019), the amount invested was US \$ 152,687,514.

The replacement of imported parts and machinery entails exorbitant costs in replacing it in case of damage or failure. This type of expense for a company's financials are unexpected as well as having a delivery service that can slow down the entire industrial process.

In the textile industry, there are machines that is widely used, which are the cut-fabric. They are essential parts of the productive process of textile pieces, since, the cut of the weave of fabric is done constantly, and due to its using condition, they are tools that suffer considerable wear. When it is necessary to fix or replace this type of tool, the machine manufacturer is requested, however, it is usually located in other countries and this can affect significantly the production process due to a time-lapse created by the slow logistics.

In order to solve this problem and reduce cost and time, replications can be made, but for this to occur it is necessary to first know the constitution of the material, using microstructural analysis techniques.

It is very important to know the components present in the materials used in this type of system, since from this knowledge it is possible to determine important characteristics for its operation. One of the ways to obtain this information is through the characterization techniques, since these use instrumental techniques of analysis aiming at the understanding of different aspects related to the composition (molecular mass, number of oxidations, etc.) and structure

(chemical bonds, crystalline phase, etc.) of materials that are directly linked to their chemical and physical properties (Gomes, 2015).

Soon after the characterization, the materials are sized and taken to the manufacture. This methodology can be called Reverse Engineering (RE).

Commonly described as the reversal of the traditional approach of product development, reverse engineering is a putative concept of the field of engineering that has found numerous applications in diverse fields. Reverse engineering can be used to capture a three-dimensional product or model in digital form, remodeled, and exported for rapid prototyping/tooling or rapid manufacturing. A salient feature of reverse engineering approach is the ability to speed up the manufacturing process, as the production is typically based on prototypes that have already been manufactured and undergo desired modifications (Bhatti and John, 2017).

This article aims use the reverse engineering on a couple "cutting blade and shearbar" used in the textile industries in order to determines the microstructural components of these two parts, commonly used in machines of such industries, in the interesting of the reproduction observing the same material composition and properties configuration which will be used for corrective or preventive maintenance.

2. MATERIALS AND METHODS

In order to develop this work, samples of the following cutting tools (Figure 1) were produced:

- Cutting blade
- Shear bar

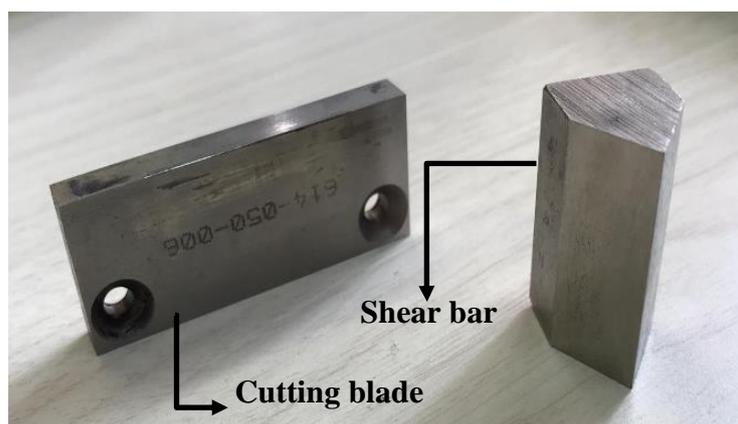


Figure 1. Cutting tools examples before of the tests

2.1 Metallography

Initially, to perform the analysis of the materials, metallography techniques were used to prepare the samples, in order to improve the analyzes that will be described next. The two samples were prepared by cutting using Isomet 100, Bueller precision cutter with diamond cutting disc, with constant rotation of 700 rpm, lubricated in a mixture of oil and water and then hot embossing with resin of Bakelite. Sanding and polishing were performed in Metaserv 250 automatic polishing machine, Buehler, using grit sizes # 360, # 400, # 600, # 1200. The polishing was done in a suspension of diamond of 1 μm and suspension of alumina of 0,05 μm , in the same equipment. Soon after the preparation was made the chemical attack with Nital 5% for the development of microstructure

2.2 Main analyzes

In order to know the elements that make up the material, the following analyzes were used: Dispersive energy spectroscopy (EDS), X-ray fluorescence (XRF), Scanning Electronic Microscope (SEM) coupled detection equipment and the microstructure of the material was analyzed using Optical Microscopy (OM), SEM and also Electron backscatter diffraction (EBSD).

EDS technique is implemented for microanalysis; the sample region is chosen under the microscope and can analyze the entire area of the chosen region or choose a single point. This equipment also allows mapping of the selected elements present in the region.

To determine the chemical composition of the material using X-ray fluorescence (XRF) it is assumed that every chemical element has a characteristic radiation that is emitted when it is excited. A higher energy electron then fills in

the space left, and this causes the fluorescence of energy in the form of an X-ray photon. This detached energy has a wavelength characteristic of the element, and each detected wavelength provides the information of the elements present in the sample.

Optical Microscopy (OM) is a technique that uses an optical equipment and its operation occurs through the refraction of light coming from various lenses, to enlarge and regulate structures invisible (or difficult to see) with the naked eye. It is used to visualize surface morphology such as cracks, grain contours and so on.

In order to visualize in much smaller scales, the Scanning Electronic Microscope (SEM) Hitachi TM3000, unlike the opticians, use electrons to form an enlarged image, with the main advantage of allowing higher resolutions. Imaging is basically done by using a thin beam of electrons to "sweep" the surface of the sample successively, point to point, the detector signal being transmitted to a screen and synchronized with the sweep of the incident beam. SEM is normally used for surface inspection of solid samples. Since the SEM allows to obtain three-dimensional images and with greater detail, it is easier to analyze these surfaces in this type of equipment than in the MO (Dedavid, Gomes and Giovanna, 2007; Vicente, 2007). Electronic Backscatter Diffraction (EBSD) is a technique that the SEM uses to generate the image.

To obtain more accurate results, the samples were submitted to hardness tests; later the obtained data were confronted with the literature.

Figure 2 depicts sequences of various activity involve in the process of reverse engineering on a couple "cutting blade and shearbar" used in the textile industries in order to determines the microstructural components of these two parts

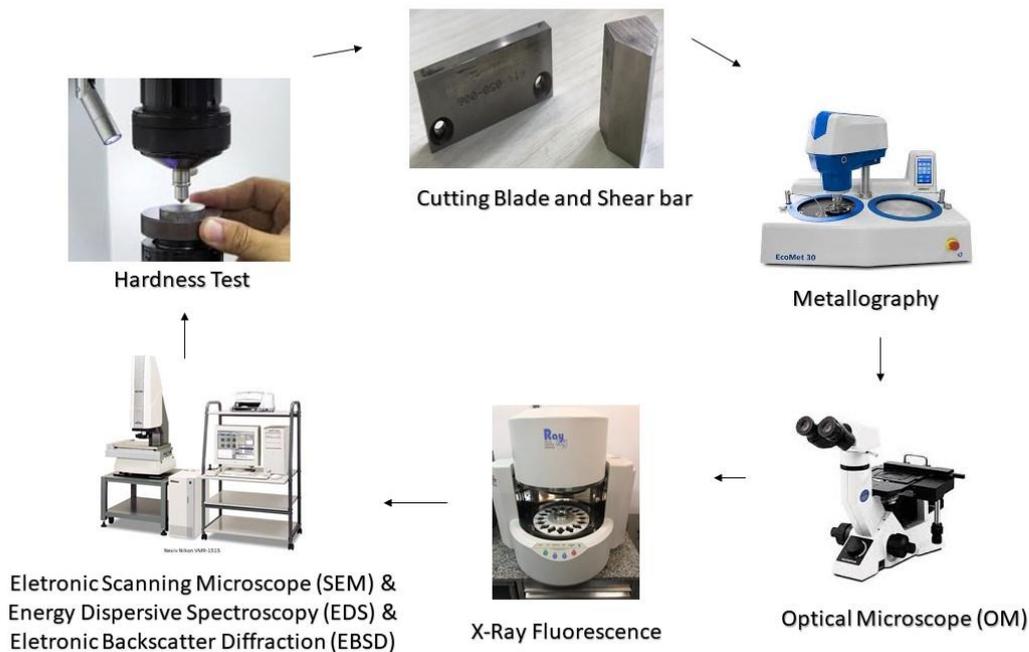


Figure 2 - Sequences of activities involve in the process of reverse engineering on a couple "cutting blade and shearbar" used in the textile industries

3. RESULTS AND DISCUSSIONS

According to what was described in Section 2 of this paper, it was possible to obtain the results related to the chemical and mechanical properties of the analyzed specimen.

Using the X-ray Fluorescence (XRF) method, it was possible to find out the chemical composition of the material, which indicated for the cutting blade a large amount of Fe and Cr, besides S, Cu and Mo with negligible values. While for the shearbar a large amount of the Fe and Cr elements were also found, and low content of Si, Ni, Se; also, S, Cu and Mo.

Through the optical microscopy (OM) analysis shown in Figure 3, it was possible to identify grain boundaries and carbides for both analyzed specimen as was also observed by Nandakumar et al. (2018), thus proving the chemical attack efficiency for microstructure exposure.

Subsequently, the analysis was performed in the Scanning Electron Microscope (SEM). A study of the microstructure of the specimen using images and analysis by Energy Dispersive Spectroscopy (EDS) was carried out. In

the image study, grain boundaries were identified in a well-defined manner and due to it, it was possible to investigate in literature the types of steel that resemble the two samples analyzed. Besides, the EDS pointed out the presence of elements: Cr, Fe, Mn and Si. These analyzes for the cutting blade and for the shearbar were based on Figure 4 and Figure 5, respectively.

In order to obtain more accurate results, a SEM-FEG and EBSD analyses were performed, aiming to capture sharper images and extract more accurate information of the material microstructure. The EBSD analysis proportionate observing through the identification of the crystalline structure, that the EDS analysis was accurate in the identification of the presence of Cr, Fe and Si (Figure 6).

It was also possible to confirm the steel category and its series by comparing the aforementioned results, as well as using the results related to the specimen hardness (Rockwell C) presented in Table 1, with the standard ASTM A 681-08 (Annexes A and B; Tables A.2 and A.3 from the ASTM A 681-08) and literature (Shahram et al., 2010; Sujeet et al., 2018).

The literature match analysis indicates that the specimens are tool steels AISI D and it is probably of the series 3, i.e., AISI D3.

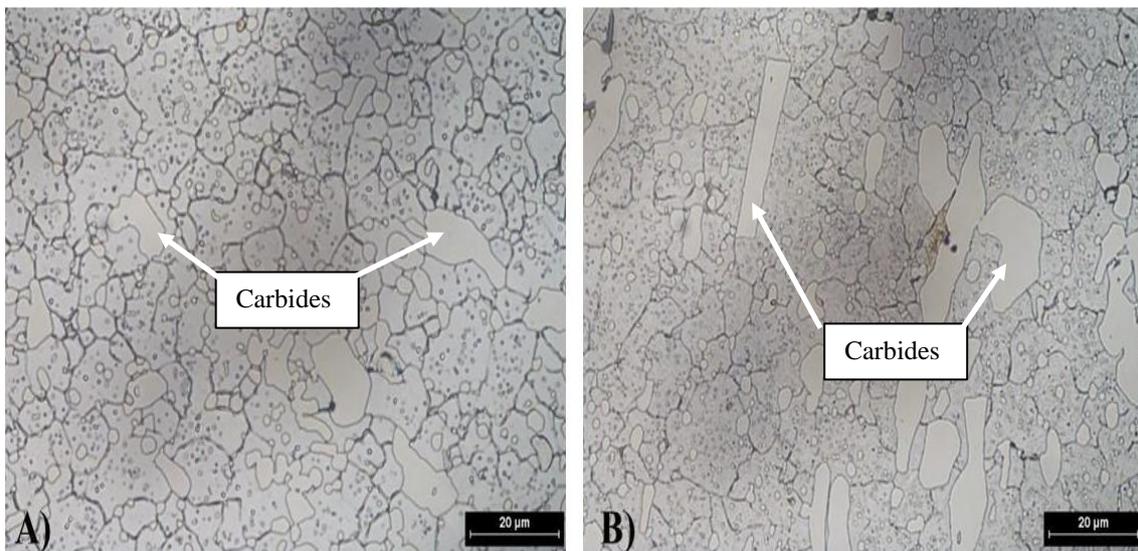


Figure 3. MO micrographs showing grain boundaries and carbides for A) Cutting blade and B) shearbar

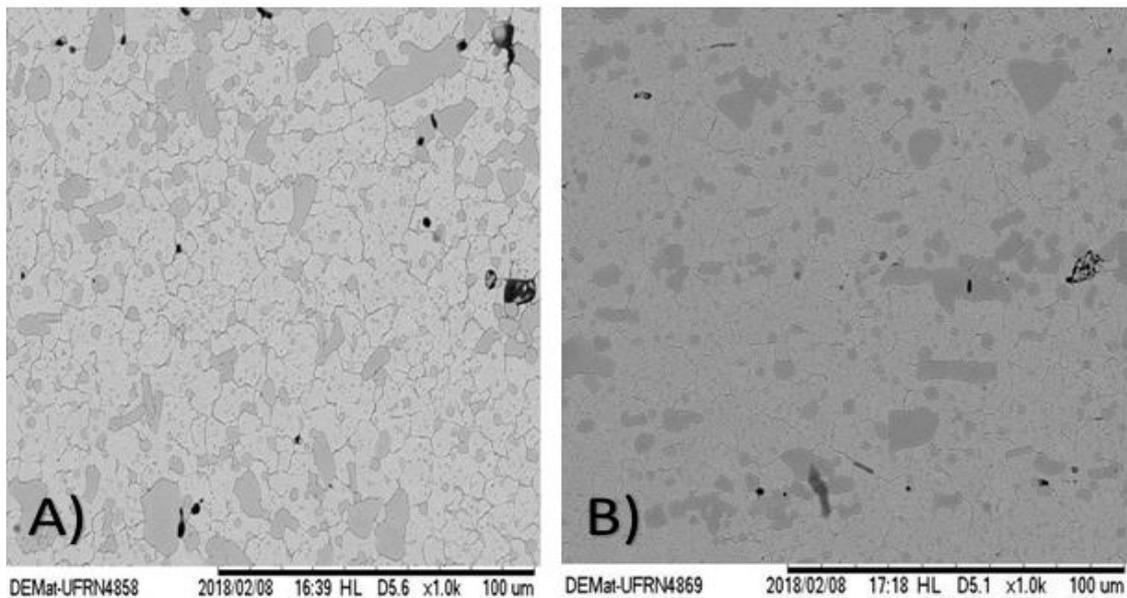


Figure 4. Microstructure magnified at 1000x using SEM for A) Cutting blade and B) shearbar

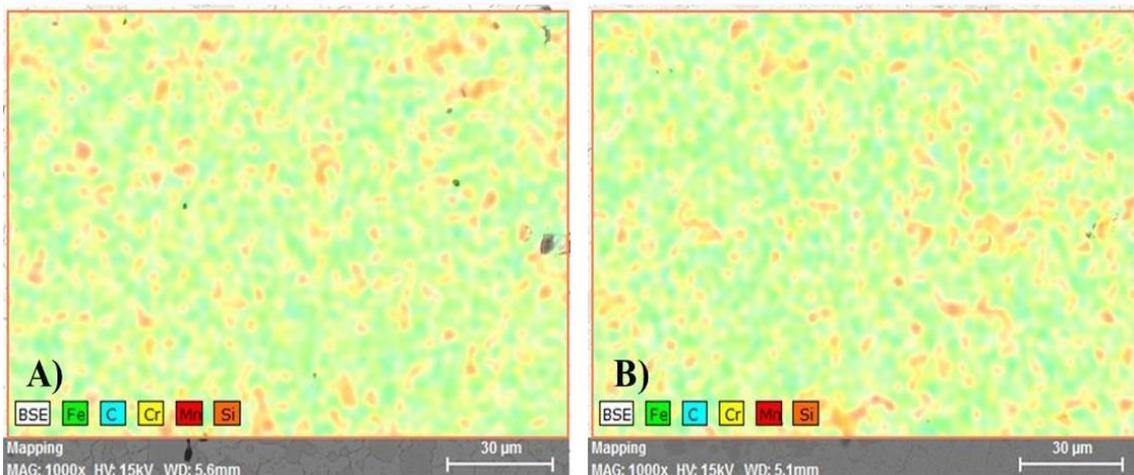


Figure 5. Composition analysis using EDS for A) Cutting blade and B) shearbar

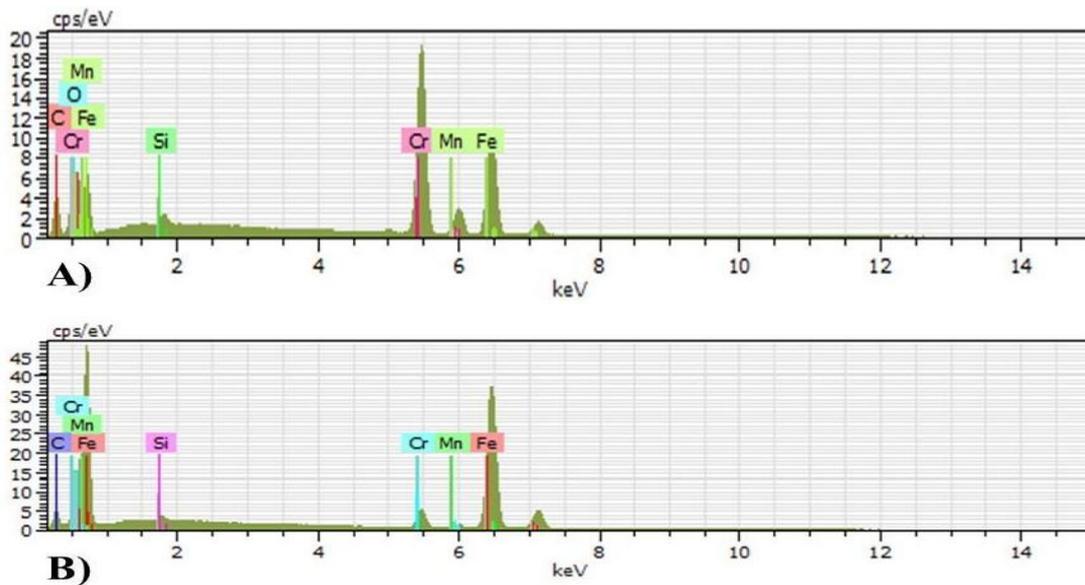


Figure 6. Analysis of composition using punctual EBSD for A) Cutting blade and B) shearbar

Table 1. Specimen hardness

Specimen	Hardness (HRC)				
	Indentation 1	Indentation 2	Indentation 3	Average	Standard deviation
Cutting blade	60	60	59	59.67	0.58
Shearbar	62	62	62	62.00	0

4. CONCLUSIONS

After the tests which were performed according to the methodology described in this work, relative to the objective of determining the composition as well as the thermal treatments used in the specimen, the pair “cutting blade and shearbar”, which were subjected to chemical analyze, microstructural analyze and mechanical analyze, it was inferred that:

- I. Both materials studied are tools steel AISI D;
- II. The literature match analysis indicates that the tool steel AISI D is probably of the series 3, i.e., AISI D3.

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6. ANEXXES

ANEXXE A. Chemical Requirements (%) from Standard ASTM A681 – 08

Type	Carbon		Maganese ^C		Phosphorus, max	Sulfur, ^D max	Silicon		Chromium		Vanadium		Tungsten		Molybdenum	
	min	max	min	max			min	max	min	max	max	min	min	max	min	max
D2	1.40	1.60	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.00	0.50	1.10	...	...	0.70	1.20
D3	2.00	2.35	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.50	...	1.00	...	1.00	...	...
D4	2.05	2.40	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.00	0.15	1.00	...	...	0.70	1.20
D5	1.40	1.60	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.00	...	1.00	...	...	0.70	1.20
D7	2.15	2.50	0.10	0.60	0.030	0.030	0.10	0.60	11.50	13.50	3.80	4.40	...	...	0.70	1.20

ANEXXE B. Heat-treating requirements and minimum hardness for tool steels class D from Standard ASTM A681 – 08.

Type	Preheat Temperature, °F (°C)	Salt Bath	Austenitizing Temperature, °F (°C)		Quench Medium	Tempering Temperature, °F (°C)	Minimum Hardness, RC
			Controlled Atmosphere Furnaces	Austenitizing Time, (minutes)			
D2	1500 (8016)	1825 (996)	1850 (1010)	10-20	Air	400 (204)	59
D3	1500 (816)	1750 (954)	1775 (968)	10-20	Oil	400 (204)	61
D4	1500 (816)	1800 (982)	1825 (996)	10-20	Air	400 (204)	62
D5	1500 (816)	1825 (996)	1850 (1010)	10-20	Air	400 (204)	61
D7	1500 (816)	1925 (1052)	1950 (1066)	10-20	Air	400 (204)	63

7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.