

# INVESTIGATION OF THE WEAR RESISTANCE OF ELEMENTS OF MACHINERY ROAD HARDFACING BY WELDING AND THERMAL SPRAYING

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**Abstract.** *The abrasive wear of elements of road machinery (tanks of excavation, transportation equipment, agricultural machinery, etc.) is a problem to be addressed, since this is a great item for depreciation of capital, equipment and source of expenditure for maintenance and replacement of mechanical components. This work aimed to study the abrasive wear resistance of these elements hardfacing by the arc welding with coated electrode and by thermal spraying, so the samples were subjected to tests of abrasive wear by the low stress ASTM G65-91 and testing the hardness, the method Rockwell C, with load of 150 kgf. After the completion of these tests it was found that the hardfacing used showed excellent wear resistance due to presence of the type  $M_7C_3$  carbide primary.*

**Keywords:** *Wear; Microstructure, Carbide; Welding, Thermal Spraying.*

## 1. INTRODUCTION

The high wear of the components of penetration in the ground of road equipment is caused primarily by the type of terrain, this mineral, lithological resistance and depending on the weather of the time, especially the humidity and temperature. Income and useful life by these elements are related to the composition of the alloy of the constituent material, the processes of heat treatment which were submitted as well as the operations realized properly or improperly by the operator of road equipment.

Cast elements, laminate and wrought, that make of the group of the components of penetration in the ground, have a direct influence of the abrasive wear. This wear participate, in certain situations up to 85% (eighty-five percent) of the cost of maintenance road equipment as routine, according AL RUBAIE et al 1999; CATAI et al.; FUSSE et al.; BAPTISTA et al. These elements, according to the intense or intermittent demand, are consumed over time. Producing, sometimes, sudden and unexpected stopped in front of work, causing, therefore, increase in production costs.

The wear on vital components of machinery and road equipment occurs in several different ways such as by sliding, by rolling, by abrasion, by erosion, by impact, corrosion and thermal shock. Already dealing with elements of penetration in the ground, the loss mass of these elements is caused almost exclusively by abrasive wear at low voltage, which is caused by the own material or load that the equipment will be required, by contact with this material and the relative movement between the parties involved in the system. One way of identification of the abrasive wear at low voltage is by observing the area to be examined, if it shows cut, scratched or penetration of material [BARRIERIA et al.].

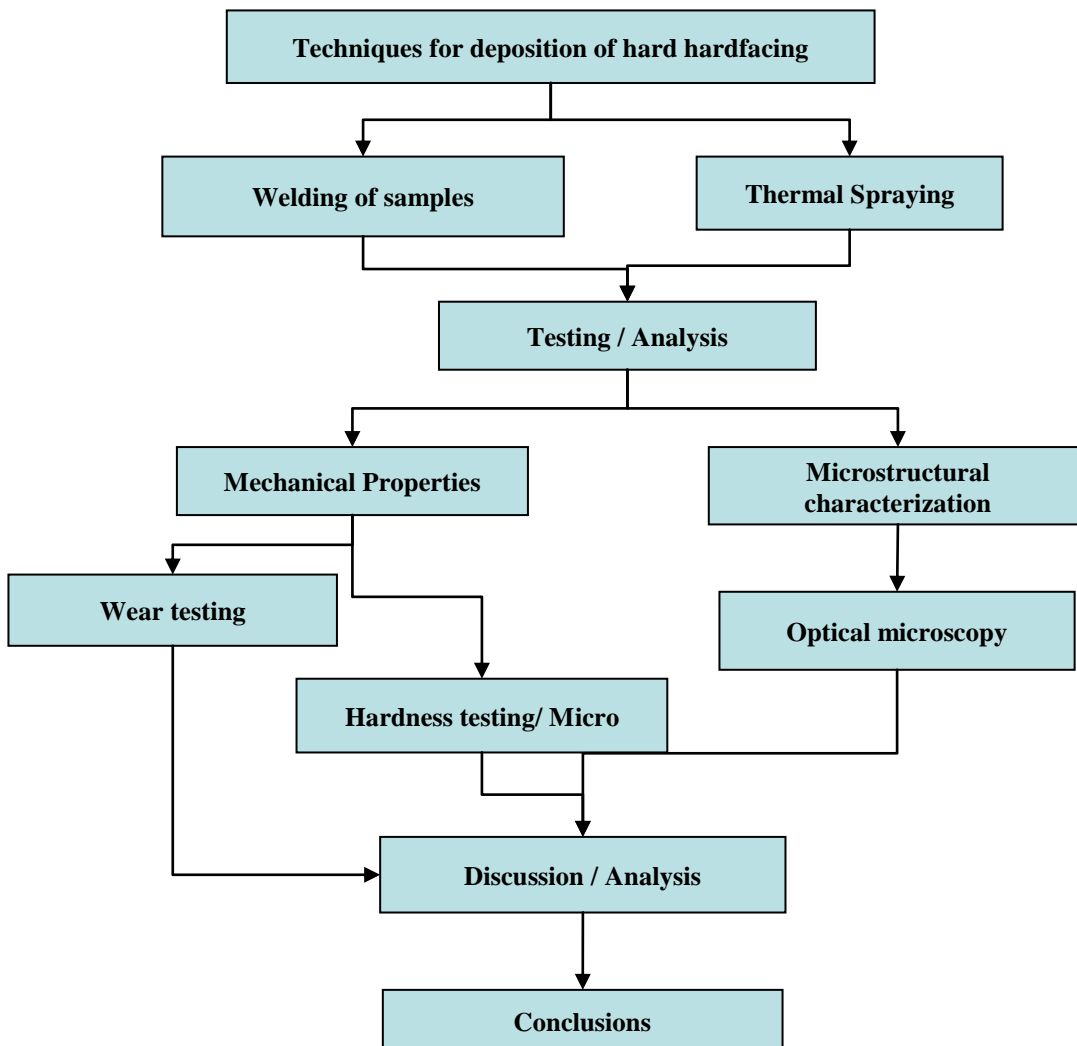
Considering that, through conventional manufacturing processes and the composition of alloys, has been virtually exhausted the possibility of developing materials more resistant to abrasive wear, the solution searched actually is the development of techniques of the hardening or superficial hardfacing, which makes these elements more resistant, such as welding, Cladding, electrodeposition, physical vapor deposition - DFV (PVD) [CATAI et al. and BRANDIM, 1998], chemical vapor deposition - DQV (CVD), and the thermal spraying technique the most promising due to their constant development [FUSSE et al.].

The search for information on this study aim at research and evaluate through of the analysis of various technologic tests to improve the materials as their resistance to abrasive wear, when they are in direct contact with the ground, in order to obtain material more resistant the abrasive elements, and contribute to the development of products of superior quality to the products currently offered by the market.

Examined the economic viability, with the introduction of new techniques of hardfacing such as LVOF and hardfacing by welding. Also has used as part of the study, teeth of tanks, supporter, links targeted to treadmills and nails of scarifiers of road machines. The elements of penetration in the ground that was used as reference in the inspection and study during the development of this project was used in intensive and / or intermittent in machinery road of the type motor graders, tractors of dunnage, backhoe loaders for tires tractors, backhoe and dunnage hydraulic excavators.

## 2. METHOD AND MATERIALS

### 2.1. FLOWCHART OF THE EXPERIMENTAL DEVELOPMENT



### 2.2. REFERENCE MATERIAL

The material which was used as a reference in comparative analysis of the processes of hardfacing, it was removed from samples of nails of wheel-loader scoops buckets in their original form, or supplied by the manufacturer of the road equipment and following the standards set by ASTM G65 -91. In the case of original materials, or provided by the machine manufacturer, was found by primary assessments as more resistant to abrasive wear and evidenced by the number of hours in which the elements were submitted in digging and loading operations.

### 2.3. MATERIAL BASIS OF PROCEDURES OF HARDFACING FOR WELDING AND BY THERMAL SPRAYING

The source material used in the manufacture of the sample for analysis of abrasive wear resistance by processes welding and thermal spraying was the steel ABNT 1015 with the following dimensions: 75 mm in length, 24 mm wide and 4 mm thick, the samples for welding and 48 mm in length, 24 mm wide and 4mm thick in the sprayed samples. These dimensions were necessary to meet the standard, but also to allow a perfect fit to the support of the abrasômetro of the loss of mass testing.

Consumables used to coat the sample in the process of superficial hardfacing by welding were the electrodes for severe abrasion, erosion and cavitation of manufacture Böhler Thyssen Welding, UTP 713 type special development, with the following concentrations: C-4%, Cr-23, 5% Mo-6, 5% Nb-6, 0%, W-0, 8%, V-0, 9%, with hardness of 65 HRC.

Already the coated samples by thermal spraying process by LVOF, and consumables used in P type samples a mixture of 17.0% of Cr, 4.0% for Fe, 4.0% of Si, 3, 5% B, 1.0% of C and balance Ni. The type M samples were coated

using the same consumables used in the type P samples with the addition of 10% of the tungsten carbide on base cobalt (81% + 12% of tungsten, cobalt + 5% + 2% carbon iron).

Two types of consumables were used in the samples coated by thermal spraying, in order to also evaluate the performance of hardfacing, as abrasive wear resistance using the testing for wear resistance and hardness in both types of consumables. Taking into consideration, mainly, the cost of the hardfacing.

#### **2.4. EXPERIMENTAL SEQUENCES**

The first step to develop the comparative evaluation project and to analyze the efficiency of both superficial coating processes and the commercially found and used material was the confection of samples following the specifications of the norm which regulates tribological studies (ASTM G65-91). After the conventional procedures of preparing the samples regarding the three conditions of evaluation (welded, superficially coated by thermal spraying and ordinary or commercial condition), they went by the experimental period.

The experiments intended initially to assess the samples abrasive resistance performance when submitted to the superficial coating processes by both welding and thermal spraying procedures. Such experiments based mainly on microscopic analyzes through optic microscopy and abrasive resistance by rubber-wheel test and on the analyze of acquired hardness level through durometer.

##### **2.4.1. ABRASION WEAR TESTING FOR THE LOW VOLTAGE ASTM G65-91**

The samples were prepared and tested according the procedures of ASTM G65-91 in similar abrasômetro to that presented in Figure 1. The force exerted by the body of evidence on the wheel was 130 N. The rotation of the wheel of rubber was maintained at 200 rpm +10 rpm, when in motion and pressure testing. We applied for the number of rounds of rubber wheel one inductive sensor. The total number of turns of the wheel for automatic interruption of the trial was pre-set at 6000 revolutions. To rectify the surface of the ring of rubber, when you need, using a sand grain size 320, while the lever arm of the equipment free of charge, to avoid pressure on the wheel and provide a sufficient gap for the introduction of sand between the wheel and support the sample port. The flow of sand was kept within the limits of the ASTM G65-91, ranging between 350 and 360 grams / minute.

The tests were carried out with the rubber wheel rotating in the same direction towards the welding employee. After testing of each batch, there was the grinding of the surface of the rubber ring. The loss of mass and volume, according to ASTM G65-91, when determined in a wheel of rubber with different external diameter of 228.6 mm, should be corrected by the linear relationship of volume loss (PV) x 228.6 mm / diameter of the wheel at the end of the test, was used when necessary, this correction [HAWK et al, 1999].



Figure 1 – Abrasômetro.

##### **2.4.2. HARDNESS TESTING**

To determine the hardness was used Rockwell C method, with load of 150 kgf. Before making the measurements, was checked for calibration of equipment by means of standards of hardness. Each body-of-evidence was submitted to at least three measures of hardness in different points of the surface.

### **3. RESULTS AND DISCUSSION**

#### **3.1. WEAR RESISTANCE**

The analysis of wear resistance is compared with a reference material. In this study, we used the actual material constituent of nail bucket of a shovel loader articulated tractors. For the general view of the materials involved in this work is presented in Figure 2, a comparison of the loss of volume in which the values are the averages of all tests.

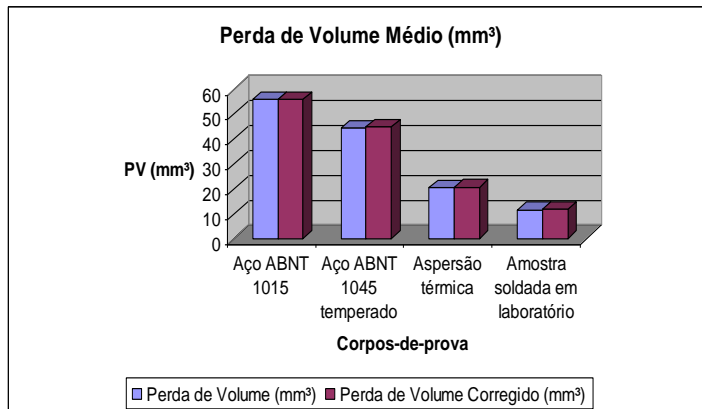


Figure 2– Loss of volume of samples.

### 3.2. HARDNESS

The results of the hardness values shown in Figure 3, does not note large dispersion of results for body-of-proof when considering between the same materials, or when comparing the coatings obtained by different techniques in the case of welding and thermal spraying. The body-of-evidence of the material that was used as a reference showed a good result due to the hardness of martensite in its microstructure.

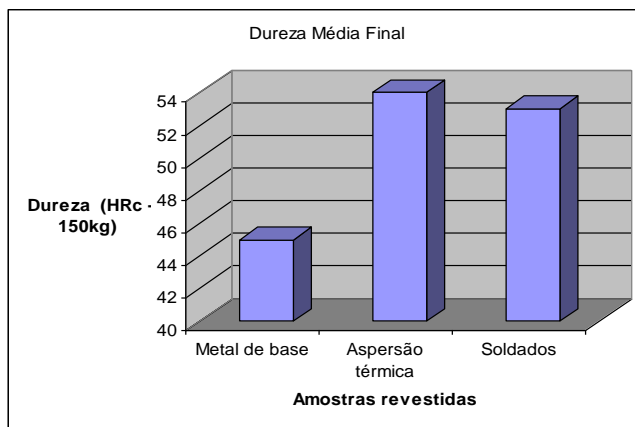


Figure 3 – Hardness HRC of samples.

### 3.3. MICROSTRUCTURAL ANALYSIS

The microstructural analysis was performed for all proof-of-bodies studied in this work, or for samples that were coated by thermal spraying LVOF the types P and M and to those welded using the technique of optical microscopy.

#### 3.3.1. MICROSTRUCTURE OF THERMAL SPRAYING SAMPLES

The thermally sprayed samples showed the microstructures as shown in Figures below. In these you can see a significant amount of pores of varying sizes, mainly at the interface between the sprayed layer and the substrate. The formation of these pores is due to reaction with gases during the process of spraying and the atmosphere in contact with the material as liquid.

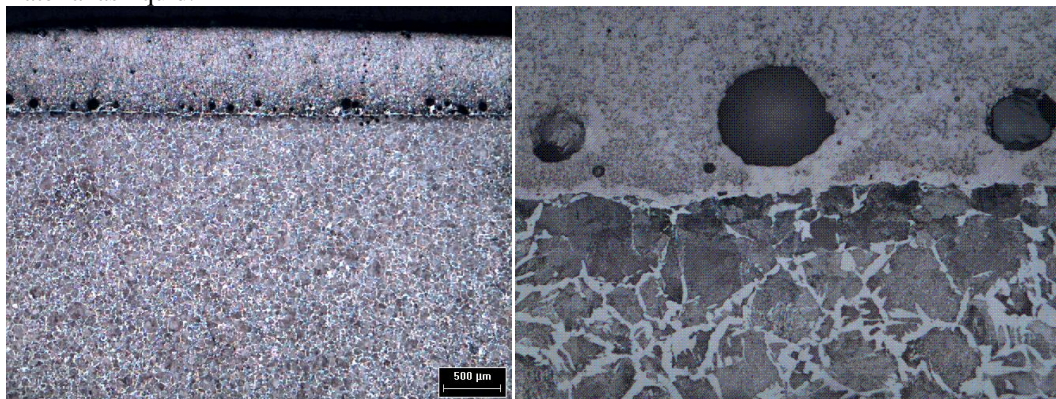


Figure 4 – Sprayed type P samples expanded to 100 and 500X.

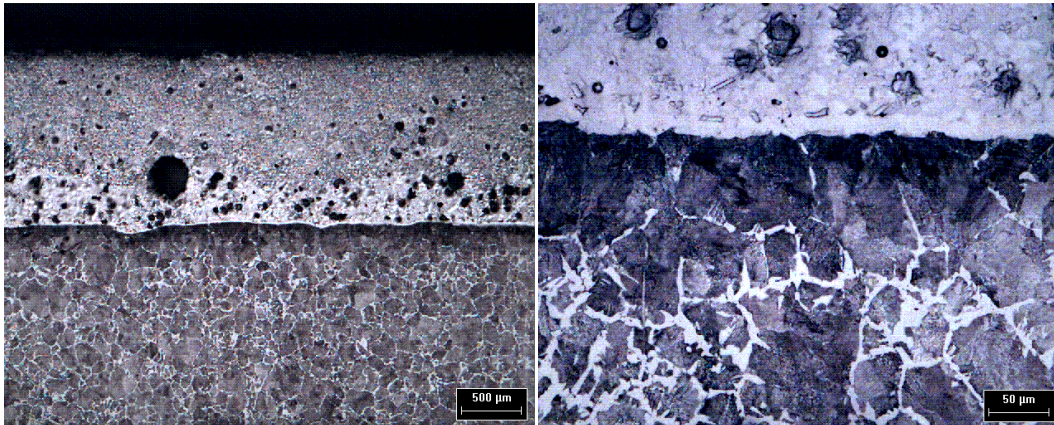


Figure 5 – Sprayed type M samples expanded to 100 and 500X.

### 3.3.2. MICROSTRUCTURE OF COATED SAMPLES BY WELDING

The weld samples had eutectic microstructure with intense amount of carbide  $M_7C_3$  chromium complexes of the type as shown in Figures below. This is due, mainly by the chemical composition of the electrode used, which had C-4%, Cr-23, 5% Mo-6, 5% Nb-6, 0%, W-0, 8%, V-0, 9%, with hardness of 65HRC. When these elements participate in the formation of alloy, add and improve some mechanical properties of materials.

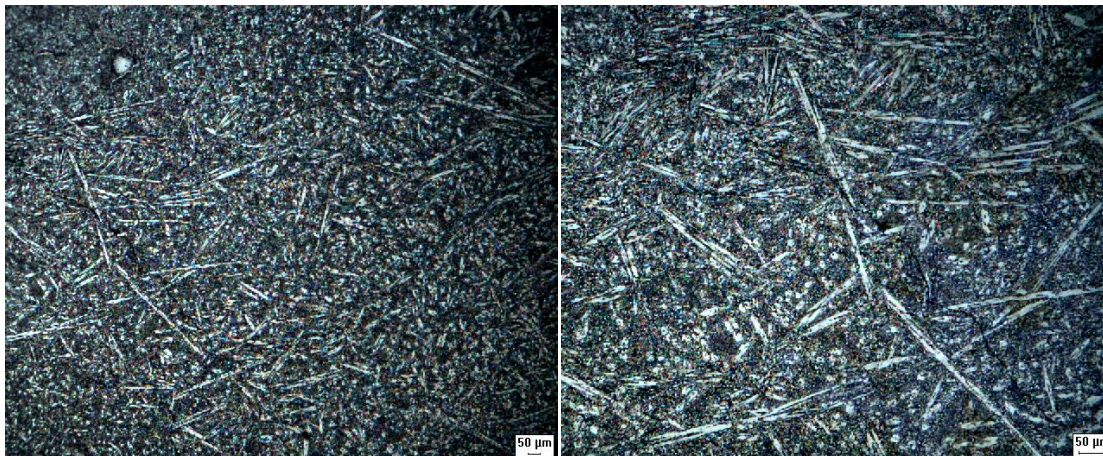


Figure 6 – Coated samples by welding of 100 and 200X zoom, respectively.

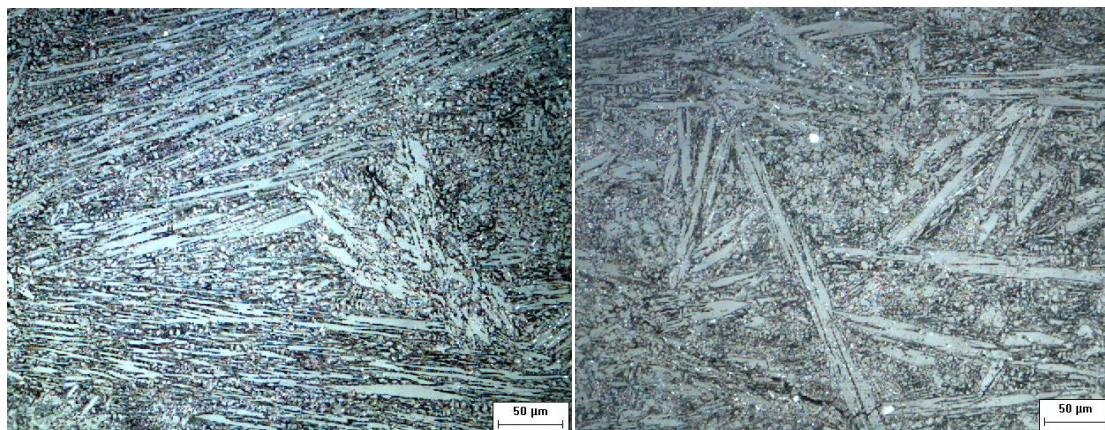


Figure 7 – Coated samples by welding extended to 500X.

The samples show a eutectic microstructure and elongated profiles of clear hue representing complexes of chromium carbide of the type  $M_7C_3$  points clear and representative of the components of the alloy composition of the electrode, and the chromium carbide which is not developed. The profiles of representative complexes of chromium carbide  $M_7C_3$ , elongated to give a coating which promotes the high hardness greater resistance to abrasive wear, but in the same way that increase this wear resistance also favors the appearance of cracks that can accelerate the process abrasive according to permit the penetration of abrasive grains between the cracks of broken.

#### 4. CONCLUSIONS

The materials coated by thermal spraying process presented a more uniform surface appearance and better when compared to coatings soldiers, but not the requirement for surface finish, for this type of tool, it will contact the soil, the elements covered by welding have some advantage in performance. The loss of volume observed in the coatings examined it was found that the coatings deposited by thermal spray were more efficient, but the variety of materials present in the soil, such as stone, clay, sand etc.. There is a need to improve adhesion between the sprayed material and metal base, which is not necessary when analyzing the material coated by welding. Thus, although is not recommended be tools of penetration in the soil of road equipment that are subject to impact the process of thermal spraying. In this view the materials covered by welding are still most appropriate.

#### 5. ACKNOWLEDGMENTS

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