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# RESEARCH ON ABRASIVE WEAR BEHAVIOR OF LASER CLADDING LAYERS OF HIGH - SPEED STEEL POWDER TYPE HS6-5-2 - M2

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## ABSTRACT

*The paper presents the wear behaviour on a rotating disk which carried abrasive paper of laser cladding layers with high-speed steel powder type HS6-5-2 - M2 compared to steel samples of the same quality but heat treated in volume. To see how temperature affects the wear behaviour by abrasion of the laser cladding alloy and the classically hardened steel, samples have been heated to 450°C, 550°C, 650°C and 700°C during a four hour exposure, after which they were subjected to testing. It was monitored the hardness and wear mass variation with temperature and the variation of micro-hardness in the laser cladding layer. In order to point out the microstructural aspects of the samples metallographic analyses were performed.*

KEYWORDS: laser cladding, high-speed steel, tool, powder, injection

## 1. Introduction

Laser cladding is one of the laser surface treatments. It was defined like a process used to melt, on a sub-layer, with a laser beam, a material with different metallurgical properties. With this technique particles of a second material are deposited and melted onto the substrate in order to form a dense layer on top of the substrate. The resulting laser treated surfaces have the advantage of being dense, homogeneous, and have a superior bonding across the surface. In order to keep the genuine properties of the cladded material, a very thin layer of the sub-layer has to be melting, in order to get a minimum dilution (0.5 – 3%) of metallurgical bond of addition material and sub-layer material [1, 2]. Several methods can be applied.

The clad material can be pre – placed and then melted together with the underlying substrate by the laser. Another method is to blow the clad material on the surface while blowing a shield gas protecting the laser optics from sputtering material.

Laser cladding can be used to good effect in processes which require a high productivity combined with flexibility without compromising on quality.

The paper presents the wear behaviour on rotating disk with abrasive paper of laser cladding layers with high-speed steel powder type HS6-5-2 - M2 compared with steel samples of the same quality but heat treated in volume.

## 2. Experimental conditions

For deposition use was made of powder of high-speed steel type HS6-5-2 - M2, SR EN ISO 4957/2002 (Rp 5, STAS 7382/1988) having the following chemical composition 0.82% C, 4.7% Mo, 6, 4% W, 0.3% Mn, 4.1% Cr, 0.32% Si and 2.02% V, and Fe [3, 4]. By sieving the grain fractions were separated in the range 80-90 μm to be used as added material. The powder had a spherical shape, which provided a smooth flow of the material additive through the injection system. Before placing the added material in the injection tank, the powder was dried at a temperature of 110°C for 15 minutes [3, 4].

The basic material used in the experimental research is steel 1C45, SR EN 10083-1:1994. Laboratory experiments were conducted on a $CO_2$ continuous wave system, type 1400W Laser GT (Romania), with working mass in x-y-z coordinates and computer programming of the working regime, provided with a powder injection system on the melted surface by means of laser, existing in SC UZINSIDER ENGINEERING Galaţi.

For the laser cladding it was used a laser beam of 1.8 mm diameter on the treated surface, at 1100 W power, scanning speed 5mm/s, by means of which partly overlapping parallel strips were deposited with a transverse step advance of 2 mm. The flow rate of the material added was 134mg/s. Final thickness of the deposited layer was 1.5 mm resulting in 5 overlapping layers.

The samples of steel Rp5 were quenching at 1220°C, with a subsequent triple annealing for one hour at 560°C.

To see how temperature affects the wear behaviour by abrasion of the laser deposited alloy and the classically hardened steel, samples have been heated to 450°C, 550°C, 650°C and 750°C during four hour exposure, after which were subjected to testing. The abrasive wear behavior of laser deposited layers with the nickel base alloy has been studied according to STAS 9639-81.

The method uses a connection of peg/disk friction of class IV-1. The method consists in pressing sequentially, under identical conditions, two samples of dimensions 6.2x6.2 mm, one of the material examined deposited by laser and the other from a material chosen for comparison purpose – improved high - speed steel Rp5 classical quenching on a rotating disk covered with grinding paper of 120 grains. A mechanism for radial displacement of the tube with 0.5mm/r provides a spiral movement on the surface of the rotating disk.

A device for implementing a load of 8.387 N ensured perpendicular pressing of the sample on the grinding paper at a pressure of 0.215N/mm$^2$. At disk speed of 25rpm, a number of 131 rotations have provided a length path of 82m.

It was monitored the hardness and wear mass variation with temperature and the variation of micro-hardness profile plotting $HV_{0,1}$ (load 0,98N) in the cross-section of the laser cladding layer.

## 3. Experimental results and discussions

The samples where laser deposit was performed with high – speed steel powder type M2, the classically hardened samples and the support were subjected to wear testing on a rotating disc with abrasive paper. The results are presented in Table 1, which is the average of three determinations.

It may be noted that the laser cladding alloy is more resistant to abrasive wear than steel samples classically hardened, and especially to support. To see how temperature affects the wear behaviour by abrasion of the laser cladding alloy (code A, B, C, D) and the classically hardened steel (code 1, 2, 3, 4), samples were heated to 450°C, 550°C, 650°C, 700°C and exposed for four hours, after which they were tested.

***Table 1***. *Abrasive wear behaviour of the support, the deposit of high – speed powder, and the classically hardened high – speed steel unaffected by temperature*

| Material | Initial mass | Final mass | Mass wear | n |
|---|---|---|---|---|
| | [g] | | | [rotations] |
| 1C45 | 2.9150 | 2.7270 | 0.1870 | 131 |
| Laser cladding M2 | 3.1638 | 3.0818 | 0.082 | 131 |
| High – speed steel classically quenching | 2.6625 | 2.5608 | 0.1017 | 131 |

The results after heating are given in Table 2 and those obtained after wear tests are given in Table 3. Table 2 shows the samples code, the heat conditions and the hardness obtained on the surface of the samples. The variation of hardness vs. heating temperature is shown in Fig. 1.

***Table 2.*** *The heat conditions and hardness of the samples*

| Sample code | Heating temperature | Exposure time | Initial hardness $HV_5$ | Final hardness $HV_5$ |
|---|---|---|---|---|
| | [°C] | [h] | [MPa] | |
| A | 450 | 4 | 10490 | 9860 |
| B | 550 | 4 | | 9560 |
| C | 650 | 4 | | 7810 |
| D | 700 | 4 | | 5280 |
| 1 | 450 | 4 | 8910 | 8910 |
| 2 | 550 | 4 | | 8570 |
| 3 | 650 | 4 | | 7010 |
| 4 | 700 | 4 | | 4940 |

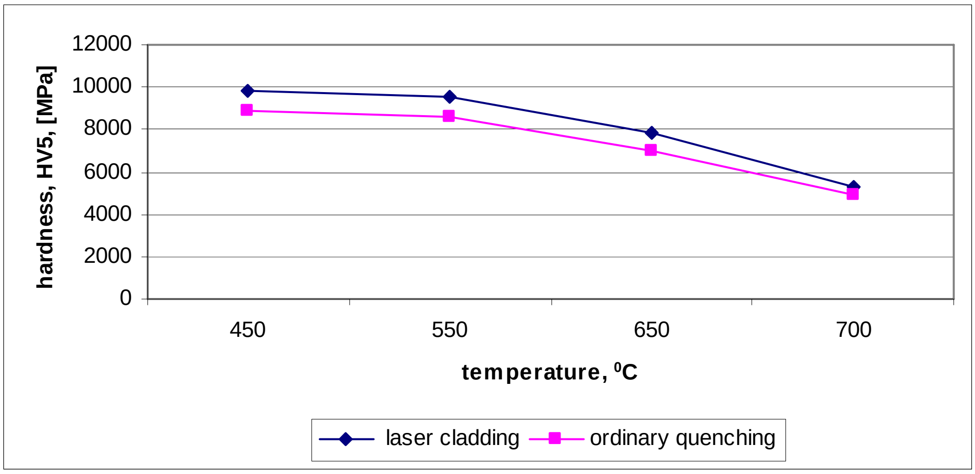



***Fig. 1.*** *Variation of hardness with heating temperature for laser cladding samples and quenching samples.*

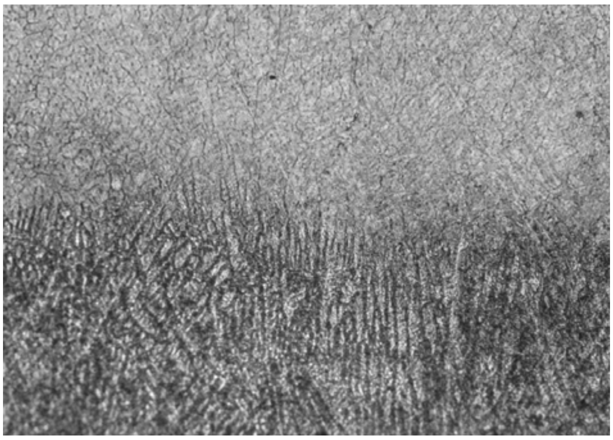
Analyzing Table 2 and Figure1, it can be noticed that, as the heating temperature increases there is a decrease in hardness for both in laser cladding layers and classically treatment samples. However the hardness of the laser layer is maintained at higher values as compared with the classical treatment of steel Rp5. Thus the minimum hardness of 58HRC is reached by the laser cladding at 690°C, while the classically quenching steel at 650°C. This may be correlated with the fact that with laser cladding, the ultra rapid cooling speed causes hardening since the liquid phase with the formation of more alloyed austenite by dissolution of the secondary and part of the primary carbides, chemically non homogenous, finer grains and increased amount of structural defects. High cooling speed guaranteed martensite transformation that inherits the austenitic characteristics, together with an increased amount of residual austenite. Recrystallization at overlaps favored dispersed precipitation of the carbides and diminished the amount of residual austenite.

Upon heating within the range of 450-700 °C, the high-alloyed martensite featured higher thermal stability than the martensite obtained by the classical volume treatment and implicitly higher hardness at the same heating temperature.

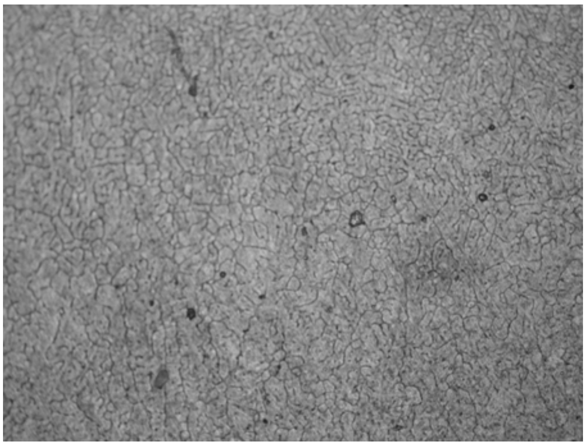
To highlight the microstructural aspects of the heated samples, metallographic analyses were performed at 500x magnifying, both for those with laser cladding and those obtained classically, the metallographic attack being made with nital 2%. They are given in Fig. 2 and 3.

From Fig.2 it can be seen a dendritic structure specific to the laser cladding with numerous carbides.

From Fig.3 it can be seen that as the heating temperature increases coalescence of carbides takes place along with lower degree of dispersion, which leads to lower hardness.



A.a



A.b

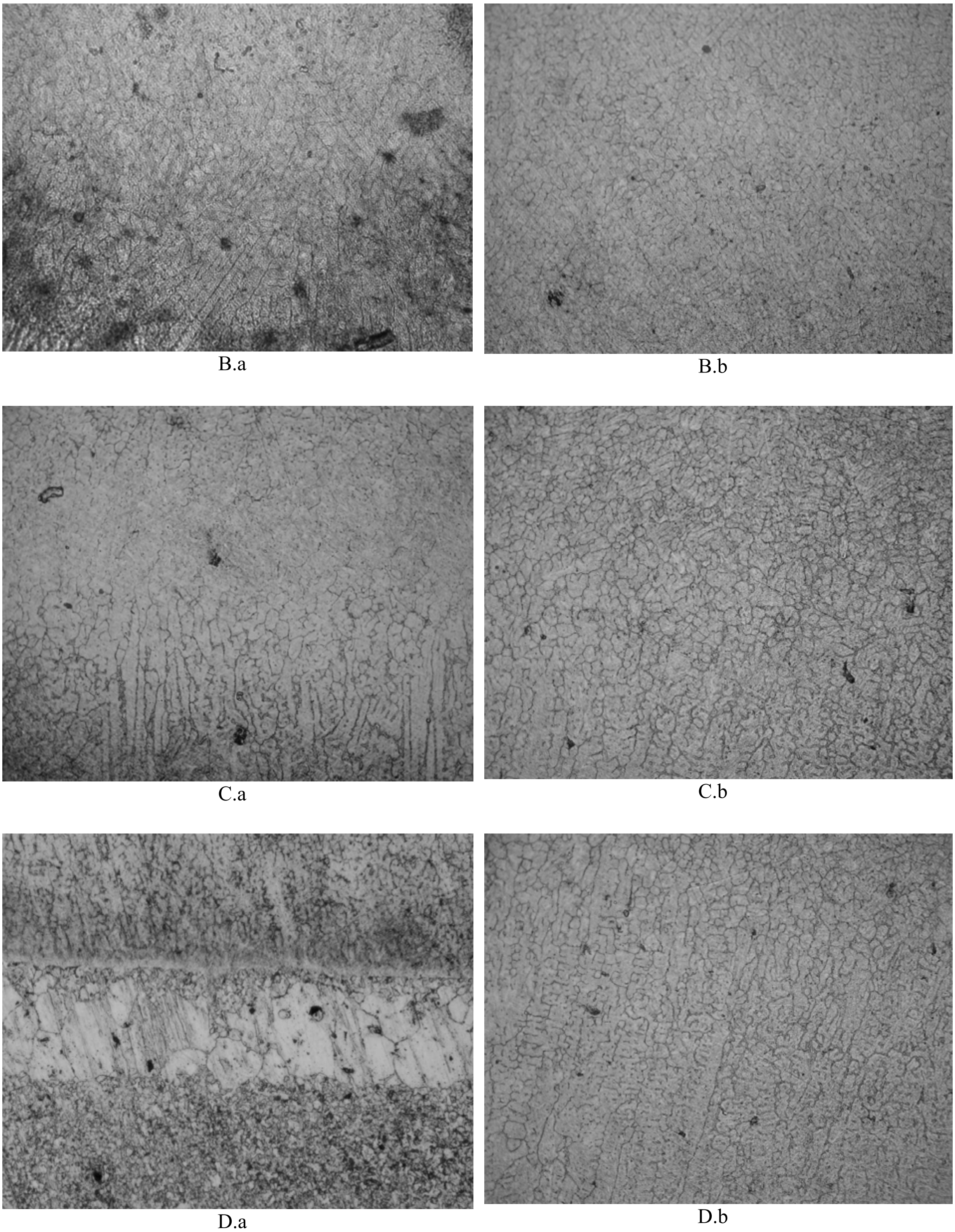



***Fig.2.*** *Microstructures of the laser cladding layers with powder of high-speed steel heated at different temperatures for samples code A - 450 °C, B - 550 °C, C - 650 °C, D - 700 °C: a)- layer base, b- layer surface (x500). Nital attack 2%.*

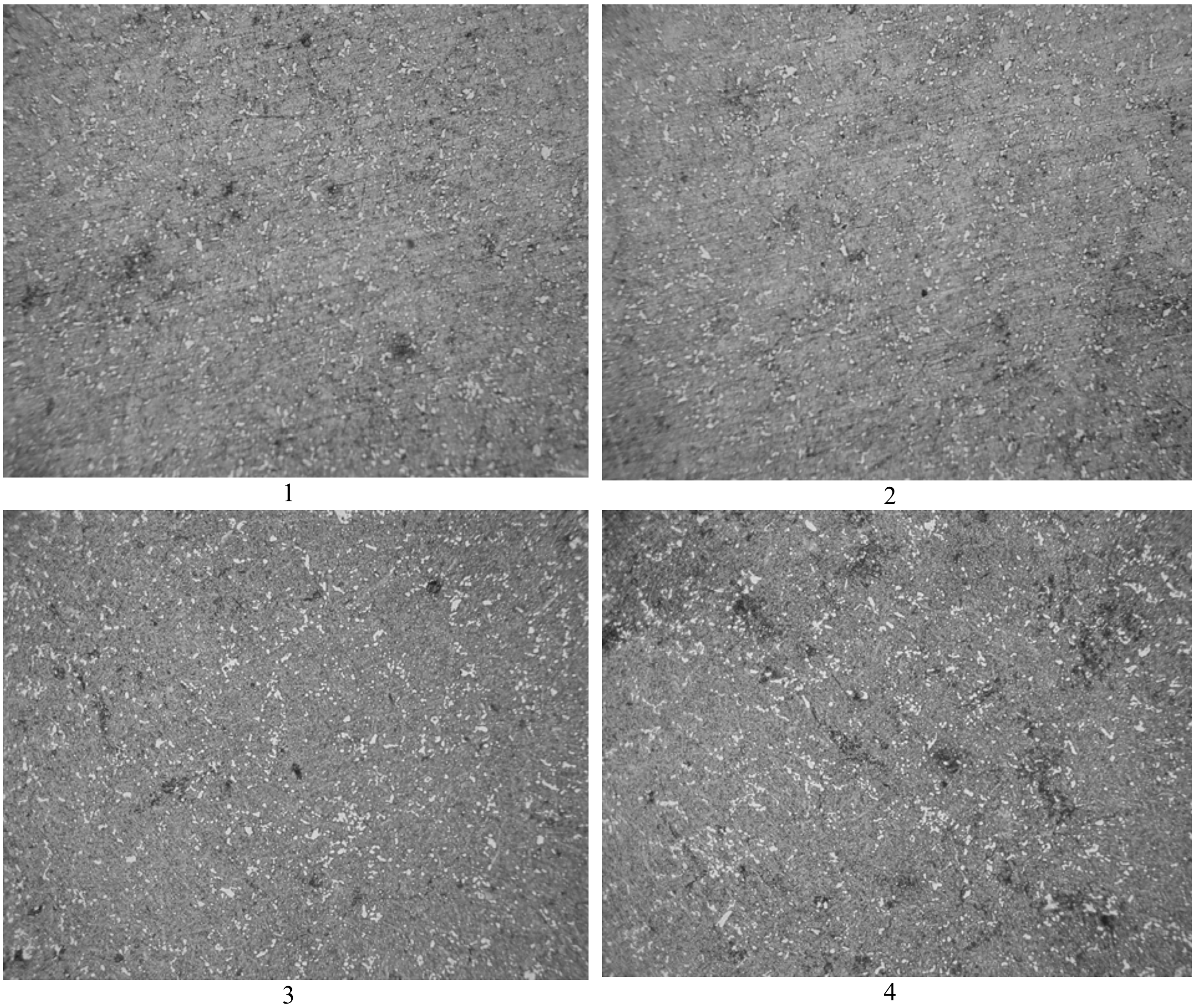



***Fig.3.*** *Microstructures of high-speed steel Rp5 classically heated at different temperatures for samples code 1 - 450°C, 2 - 550°C, 3 - 650°C, 4 - 700°C (x500). Nital attack 2%.*

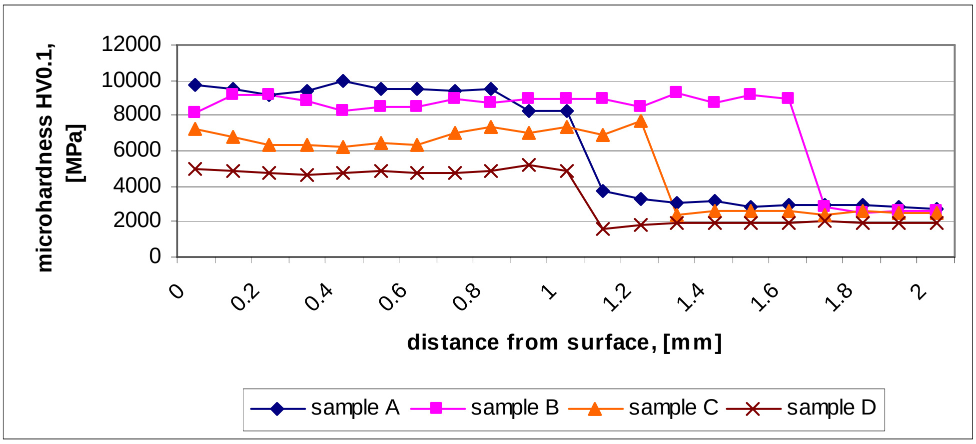



***Fig.4.*** *Variation of microhardness of the cladding layer after heating for samples code A – 450°C, code B – 550°C, code C – 650°C, code D – 700°C.*

According to qualitative phase analysis [3], the microstructure of the deposited layers heated at different temperatures contain martensite, residual austenite and eutectic colonies of carbides interdendritically spaced and at the grain limit, the basic hardening phase being $Cr_7C_3$. Variation of microhardness of the laser layer with high - speed steel type M2 obtained after heating the samples code A, B, C, D at 450°C, 550°C, 650°C, 700°C with a four hour exposure time.

Results are given in Fig.4. Table 3 presents results from wear tests (mass wear, mass wear/length of path covered) in rotating disk with abrasive paper both laser cladding samples and those classically hardened in volume.

***Tabel 3.*** *The samples abrasive wear behaviour after heating at several temperatures*

| Sample cod | Heating temperature | Keeping time | Initial mass | Final mass | Mass wear | U/L |
|---|---|---|---|---|---|---|
| | [°C] | [h] | [g] | | | [g/m] |
| A | 450 | 4 | 2.9865 | 2.9030 | 0.0835 | 0.00104 |
| B | 550 | | 2.9781 | 2.8929 | 0.0852 | 0.00107 |
| C | 650 | | 3.1055 | 2.9881 | 0.1174 | 0.00136 |
| D | 700 | | 3.1118 | 2.9478 | 0.164 | 0.00202 |
| 1 | 450 | | 2.6625 | 2.5599 | 0.1026 | 0.00123 |
| 2 | 550 | | 2.5827 | 2.4792 | 0.1035 | 0.00126 |
| 3 | 650 | | 2.7234 | 2.5982 | 0.1252 | 0.001502 |
| 4 | 700 | | 2.6004 | 2.4306 | 0.1698 | 0.002093 |

It is noted that heating at different temperatures affects the wear behaviour of the deposit.

Thus as the temperature increases the wear resistance decreases at temperatures higher than 650°C, which is due to coalescence carbides and decrease in their dispersion. Fig. 5 and Fig. 6 show the variation of mass wear and the ratio of wear mass/length of path covered with the heating temperature for samples: code A, B, C, D and code 1, 2, 3, 4.

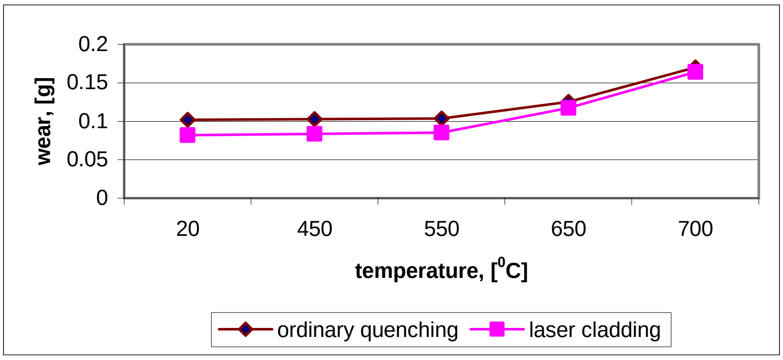



***Fig.5.*** *The variation of mass wear with the heating temperature for samples: code A, B, C, D and code 1, 2, 3, 4.*

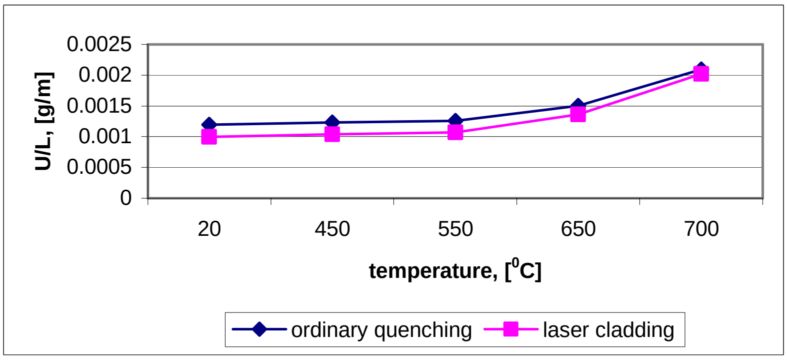



***Fig.6.*** *The variation of the ratio of wear mass / length of path covered with the heating temperature for samples: code A, B, C, D and code 1, 2, 3, 4.*

Analyzing the above figures it may be noted that the wear mass and wear ratio mass/length of the path covered increase with increasing temperature, more pronounced at values higher than 650°C, which is due to coalescence carbides and decrease in their dispersion.

## 4. Conclusions

As regards thermo-stability of the laser cladding with high - speed steel powder M2 and heat treated samples in volume it was found that as heating temperature increases there is a decrease in their hardness because of coalescence carbides and their decreased dispersion.

Abrasive wear behaviour of laser cladding layers of high - speed powder M2 showed a higher resistance compared to steel 1C45, and Rp5 classically hardened steel.

The ultra rapid cooling speed in laser cladding causes hardening since the liquid phase with the formation of more alloyed austenite by dissolution of the secondary and part of the primary carbides, chemically non homogenous, finer grains and increased amount of structural defects.

High cooling speed guaranteed martensite transformation that inherits the austenitic characteristics, together with an increased amount of residual austenite.

Recrystallization at overlaps favored dispersed precipitation of the carbides and diminished the amount of residual austenite.

With respect to abrasive wear resistance of the laser cladding layers, heated at different temperatures it can be observed that the mass wear and the ratio of mass wear/length of the road covered increase with higher temperature, even more at values higher than 650°C, which is due to coalescence carbides and their decreased dispersion.

Also the dilution zone is changed which is visible due to the decrease in the difference in hardness between the cladding layer and the substrate.

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