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# Investigation of the Wear and Hardness Behavior of ST 37 Steel Coated by the Powder Flame Spraying Method

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**Abstract**

In this study, ST 37 steel was coated with powders of Kobatek 5155, RotoTec®10185 and RotoTec®12486 by using powder flame spraying method. The hardness and wear behavior of coated specimens were investigated. The wear tests were performed on a pin-on-disc test apparatus. A SiC, 800 sandpaper was used as an abrasive material. The wear tests of coated materials were carried out at room temperature and at the speed of 300 rev/min with 10N loads. Optical microscope investigations were performed to characterize coated specimens. As a result, it was found that each coating powder has the unique effect of improving wear resistance.

***Keywords:*** Powder flame spraying; coating; wear.

## 1. Introduction

Although machines and equipment serviced different sectors by being produced with todays technology are designed very well, they might lose working ability because of negative factors resulted from both material and plant conditions. The wear, which is one of the most important factor preparing this result, is material loss progressing for a length of time or occurring suddenly. Even if material loss depends more than one parameter, the wear emerges as a surface problem in basic meaning. The wear occurring in surfaces that contacts each other, forms damage in surface, including material loss, as well. The wear amount causes increase of gap between pieces, freedom of undesirable movement, loses of sensibility, and a lot more fast wear [1]. The wear according to DIN 50320, was described as undesired material loss resulting in tribological stress in surface area of solid [2,3]. The layer resistance to wear is created by changing chemical composition of material surface. It can be earned advantage to material with this layer against different wear mechanism. Powder flame spraying method is one of the surface engineering heat process used for this purpose, too.

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Thermal spraying based on spraying of coating material by melting on main material (base plate) roughened earlier, differs in respect to energy source used (inflammable gas or electricity) [4, 5,6], coating material form (wire, powder or bar) and atmosphere (air, low pressure, or inert atmosphere) [7, 8, 9,10].

Among these technologies having extensive usage area in industry, flame spray coating and plasma spray coating are the most preferred [5,6,11]. Plasma spray coating is a method enabling more higher accumulating rate and thicker coating, and being able to applied metallic or ceramic coating for protecting from wear, corrosion, and high temperature [5,12]. In the flame spray process that is more economic and has more easier process control compared with plasma spray coating method, coating material is directly fed into flame via flowing of compressed air or inert gas (argon or neon). Ablative particles are acceleratingly sprayed on main material by helping of flame gases. Each ablative particles striking to main material become smooth on surface and solidify fast. Not only it can be obtained thin and multi-ply coatings by this method but also abraded surfaced can be repaired [6,8,10,13].

In this study, the hardness and the wear behavior of ST37 steel coated with powders of Cr-Ni-Boron-Si, Ni, and Cr-Ni-Si-Boron based by using powder flame spraying method were investigated.

## 2. Material and Method

### *2.1. Material*

ST37 steel with sizes of 100x100x10 was used as main material in experimental studies. Chemical composition of ST37 steel was given in Table 1 as percentage.

**Table 1:** Chemical Composition of ST37 Low-Carbon Steel (% weight) (% w.)

| **Element** | **C** | **Si** | **Mn** | **P** | **S** |
|---|---|---|---|---|---|
| % Ratio | 0.285 | 0.190 | 0.722 | 0.016 | 0.033 |
| **Element** | **Cr** | **Mo** | **Ni** | **Al** | **Cu** |
| % Ratio | 0.085 | 0.012 | 0.124 | 0.007 | 0.447 |
| **Element** | **Nb** | **Co** | **W** | **Sb** | **Fe** |
| % Ratio | 0.003 | 0.012 | 0.008 | 0.006 | <98.19 |

### *2.2. Coating Materials*

Three different powder varieties with Kobatek 5155, RotoTec®10185 and RotoTec®12486 code number was used in experiments as properties of them was given in Table 2.

### *2.3. Coating Process with Flame Spraying*

Coating process was performed with spray gun that can be connected to Castolin brand lathe bracket in workplace of RESOURCE CENTER Company. Coating parameters were given in Table 3. Spraying process was done after base material was tempered at maximum 300 C°, and powder feed in gun was disconnected when sufficient coating thickness was obtained. Coated specimens were let cool in open-air.

**Table 2:** Properties of Powders used in Coating

| **Powder Name** | **Composition** | **Properties** | **Hardness (Hv)** | **Code** |
|---|---|---|---|---|
| RotoTek10185 | Ni bazlı | Resistance to oxidation and corrosion in high temperatures, low friction coefficient | 360-420 | A |
| Kobatek 5155 | Ni- Cr- B-Si bazlı | Resistance to oxidation and corrosion in high temperatures, low friction coefficient | 720-860 | B |
| RotoTek12486 | Ni, Cr- Si- B bazlı | Used in surface filling of tools exposed to fatigue and corrosion | 610-760 | C |

**Table 3:** Coating Parameters

| Flame Spraying Parameters | |
|---|---|
| Spraying Range | 15 cm |
| Powder Feed Rate | 40m/sc |
| Oxygen Pressure | 0.4 bar |
| Acetylene Pressure | 0.6 bar |
| Powder Size | 250µ |

### *2.4. Micro-Harness and Optical Examination*

Specimens subjected to coating process were taken to bakelite by cutting sizes of 10x10x10mm for hardness measurement and microstructure examinations. Specimens in bakelite were ground by turning $90^0$ at every turn as equally in every way evenly with water SiC based emery paper numbered 400, 600, 800, 1000, and 2000, respectively. Ground specimens were polished on DP micro mat by using 1 µm diamond polisher, and polished specimens were seared with NITAL. Examination of microstructure of polished specimens was performed in PRIOR brand optical microscope, and it was paid attention to shoot areas involving interface and coating metal. Microstructure of main material and coating interface and harnesses of coating metal were taken from polished surfaces of specimens. INSTRON WOLPERT hardness equipment having $136^0$ and square-based Vickers bit was used for measurements and 30 kg of load was applied. Arithmetic mean of 8 numbers of main materials and coating material made were taken in measurements. It was elaborated that the distance between two measurements in hardness measurement was ≅ 0.25 mm.

### *2.5. Wear Experiments*

Coating surfaces of specimens prepared for wear experiment were protected from grease and dirt in order to not affect of wear adversely. Wear tests were performed in pim-on-disk wear experiment equipment showed in Figure 1 and in a dry environment. SiC emery paper with 800 grid was used as opposite abrader. Wear test of coatings were carried out at room temperature and at the speed of 300-rev/min of slip velocity with 10N loads. Wear amounts were determined according to weight lose. Shifting distances were specified as 180-360-540-720-900m, and arithmetic means were taken after 3 wear processes were performed for every test specimen.

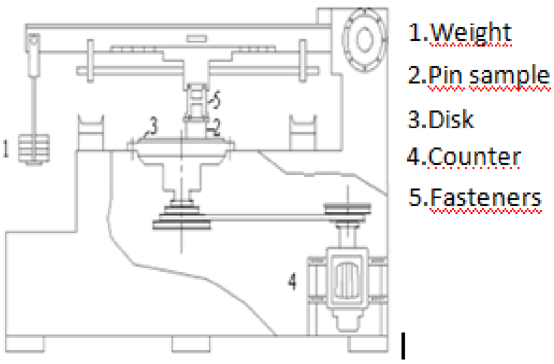


**Figure 1:** Wear experiment Equipment

## 3. Experiment Results

### *3.1. Micro Hardness Results*

Micro hardness values of coating layer, interface layer and main material were given in Figure 2. Micro hardness values that were taken from cross-section of specimens decrease regularly.

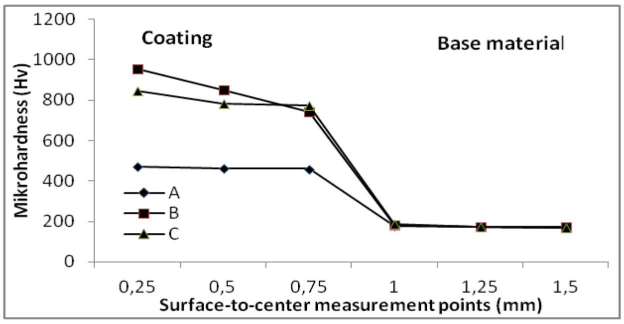


**Figure 2:** Micro hardness change

At the same time, micro hardness values of coating and interface layer are pretty higher than micro hardness values of main material. When Figure 2 is analyzed, hardness values for every coating material decrease towards main material (coated material), while hardness increase of coating materials is at the highest value.

While the highest value of hardness was measured for B specimen from coating specimens, C and A specimens follow it respectively. The reason for that hardness shows a tendency to thus is that Cr, Si, and B located in coating powders used in coating of B and C specimens play an important role on coating layer. Another reason for the increase of hardness is that it was thought that porosity oxide and non-melted particles have an effect on the hardness of coating layer[4,6].

### *3.2. Wear results*

As results of wear experiment results, total weight loss values against every time were found in total weight loss-shifting distance curves. Every specimen was determined by taking arithmetic means of 3 specimens worn in same conditions. As results of wear experiments, the wear behavior or coating powder under 10N load were showed in Figure 3. The common characteristic of test specimens is the increase of weight losses depending on shifting distance, when Figure 3 analyzed. It is constant that this increase is more at the starting of wear for all specimens. As it is understood from wear curves, the specimen coated with A powder has the least wear resistance. The reason is that A powder is Ni based, and the amount of Cr, B, and Si found in other coating powders are very low. B and C specimen are more resistant against wear compared to A specimen. This is because it’s thought that the effect of Cr, B, and Si located in B and C powder. When weight loss changes of coating materials depending on shifting distance are looked at, B specimen was experienced 0.0186 mg weight loss in 540 m of shifting distance, while A specimen was 0.1222 mg and C specimen was 0.0364 mg. Similar results were obtained for other shifting distances, as well. The best wear resistance was obtained for B specimen. When wear values and hardness values are compared in experimental studies done, B specimen, which has the highest hardness value, is the most resistant to wear. It was observed that wear resistance decreases by decreasing hardness in other specimens. It was accepted that wear resistance substantially depends on hardness in performed studies[9,14,15].

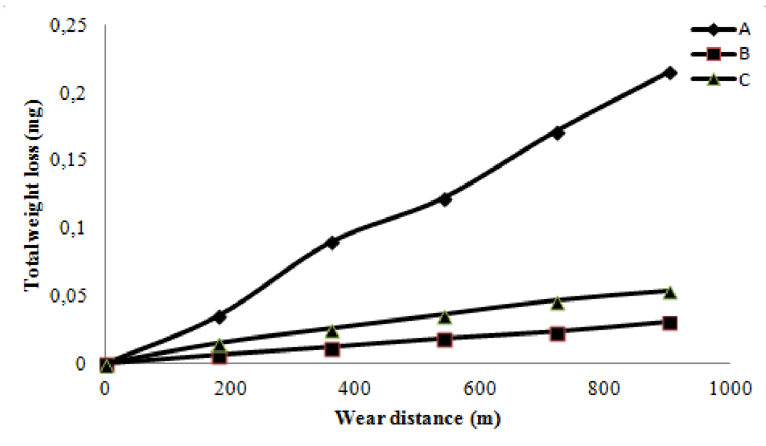


**Figure 3:** Shifting distance- weight loss changes of coating powders

### *3.3. Micro Structure Results*

Optical microscope images of coating specimens obtained by thermal spray coating method were shown in Figure 4. Even if it is not exactly reveled what extent material microstructure affects wear, it’s a common knowledge that microstructure significantly affects wear. However, phase and particle size in microstructure are important factors affecting mechanical properties[1,16]. Characterization of thermal spray coating includes quantitative measurement of geometrical properties such as porosity (spaces, cracks, and other faults), analyzes of coating materials such as splat structure, interfaces, and phases [17,18]. Microstructure properties of coating layer are explained depending on these properties. Although coating material and main material in A and B specimen are connected as intended as a result of surface roughness and adhesion is provided completely, C specimen is less intended and adhesion is provided less compared other specimens.

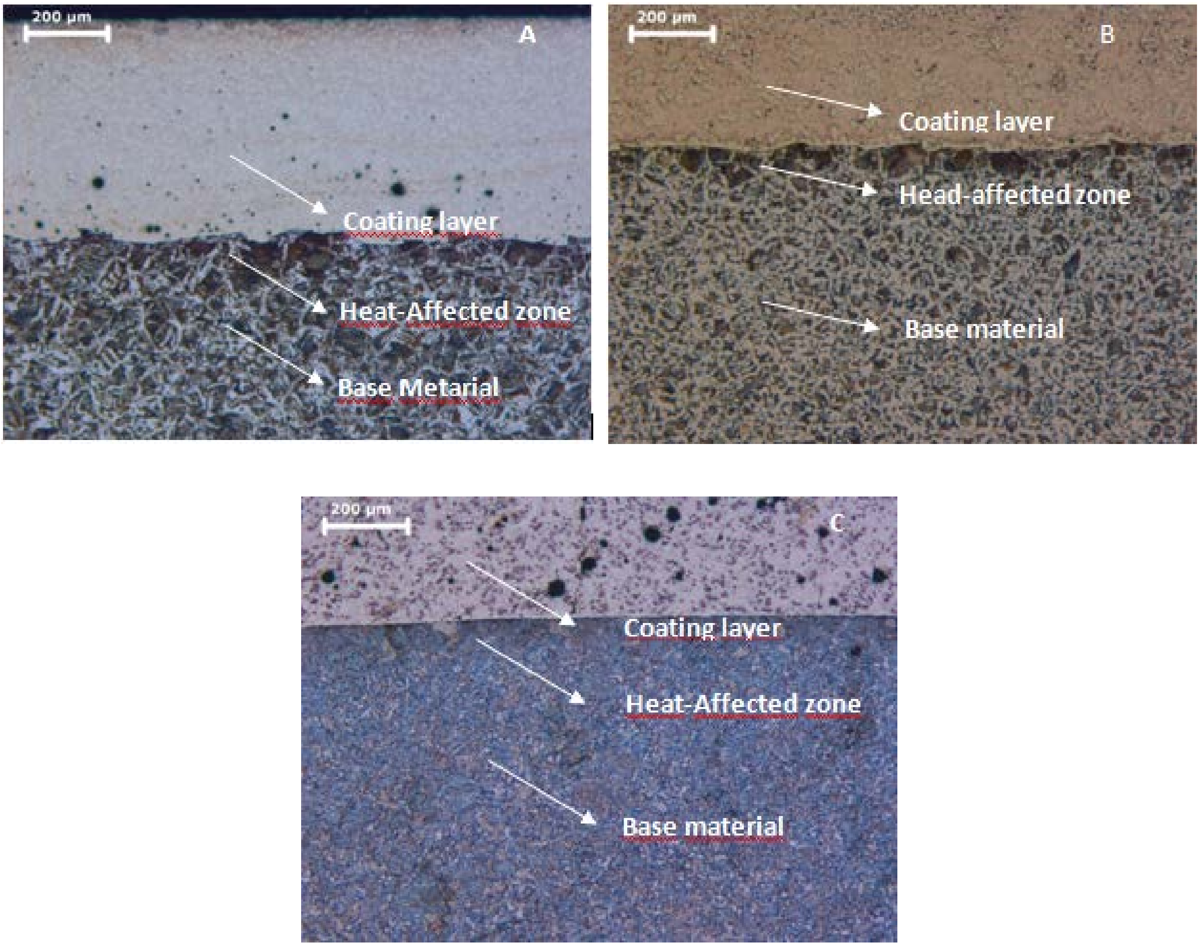


**Figure 4:** Optical microscope images of A, B, C specimens

## 4. Conclusion

As a result of performed study, obtained findings are introduced as following:

1. Hardness values decreased from coating layer towards main material, and the highest hardness value was obtained in B specimen (Cr-Si-Ni-B). At the same time, micro hardness values of coating and interface layer are pretty higher than micro hardness values of main material. Hardness values for every coating material decrease towards main material (coated material), while hardness increase of coating materials is at the highest value.

2. It was established that weight loss of all coating specimens increased by increasing shifting distance.

3. It was determined that B specimen is more resistant against wear.

4. While the highest weight loss was seen in A specimen, the lowest weight loss was seen in B specimen. When wear values and hardness values are compared in experimental studies done, B specimen, which has the highest hardness value, is the most resistant to wear. It was observed that wear resistance decreases by decreasing hardness in other specimens.

## 5. Suggestions

There was a connection between hardness and wear, the specimen having the highest hardness value is more resistant to wear, and the specimen having the lowest hardness value is less resistant against wear.

As a result of experiments, it was defined that each coating material improved wear behavior in different degrees.

## 6. Special Thanks

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