The Comparison of the AST 908, AST 915 and AST 928 of Micro-Hardness of Tungsten Based Alloy Films on AISI 1050 Steel by HVOF Coating Method

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Abstract. In this study, the commercial powder tungsten based alloys was sprayed by using high velocity oxygen fuel (HVOF) method on AISI 1050 steel substrate. These films of powder tungsten based alloys of AST 908, AST 915 and AST 928 were included. The powder was mainly composed of tungsten (W), Chromium (Cr), Nickel (Ni) and Cobalt (Co) with an average particle size in the range of 10-45 µm. The microstructure and compositional analysis was used by the scanning electrode microscopy (SEM) and energy dispersive spectroscopy (EDS) respectively. The micro-hardness of coating films was investigated by Vickers micro-hardness tester. The SEM results exhibited good deposition between the coating films with the specimens (AISI 1050 steel). Accordingly, the coating films showed a very homogeneous microstructure. In addition, the micro-hardness of substrate was 81.30% lower than the AST 908 particles. Finally, the AST 908, AST 915 and AST 928 coating improved the micro-hardness of 1559.3 HV, 1468.4 HV and 1306.2 HV respectively

1. Introduction

Industry was the activities of processing or manufacturing procedure of raw materials to make new materials to be useful according to the purpose of using machines or labour for mass production which could be sold as a product. A main factor of the production of each factory was the machinery for production. When these machines had been used for the mass production for a long time, [1] there were some parts of the machines that would be damaged or worn out after using them. Industrial examples in most countries such as steel smelting industry, automotive industry and others had large machines. When these parts of the machines were damaged that they couldn't avoid for machinery and engineering structures, selecting suitable materials for using and processing improvement a quality of the material was utilized to increase efficiency. As well as an understanding of the nature of wornness and eligible maintenance, it was a necessity for those accomplices of usage and maintenance for the wornness of some parts of industrial machines which could be repaired by various methods and brought to come back to life. The damaged parts were welded to the maintenance. It was an interesting way to use the heat-treated coating process which could be applied to many types of work. Spray coating with thermal flame was a useful technique in various industries. [2-3]. There are electronics, automotive, turbine and aircraft industries. This technique was often used in preventing wornness, heat and corrosion in chemicals and then used for repairing worn-out pieces. We could choose an infinite coated materials to get the desired properties. The used materials for the coating were metals, alloys,
ceramics, composites and polymers. Spray coating with heat flame had a simple principle by heating with materials for coating on the surface that could be a powder or wires [4]. The thermal spraying technology was a coating method which was used extensively for the application on manufacturing and maintenance in Thailand. This research was studied the thermal spraying technology of worn-out resistance for tool life expansion. The aim of the study is to characterize the microstructure of tungsten based alloy films on AISI 1050 steel with different three-type powders namely; AST 908, AST 915 and AST 928 respectively.

2. Experimental procedure
In this study, high velocity oxygen fuel (HVOF) spraying method was coated on the specimen (AISI 1050 steel). The dimension of the specimen was 25.4 x 50.0 x 6.0 mm and chemical composition of specimen as shown in Table 1. The commercial powder tungsten based alloy namely AST 908, AST 915 and AST 928 was selected as coating materials. The powder tungsten based alloy was mainly composed of tungsten (W), chromium (Cr), nickel (Ni) and cobalt (Co) with an average particle size in the range of 10-45 µm. These commercial powder tungsten based alloy of experiment were AST 908, AST 915 and AST 928 which was shown in Table 2.

| Specimen  | Chemical composition (%wt) | Hardness (HV) |
|-----------|---------------------------|---------------|
| AISI 1050 | C 0.47-0.55, Mn 0.60-0.90, P 0.020-0.035, S 0.020-0.035, Si 0.15-0.35 | 247 |

Table 2. The chemical composition of commercial powder tungsten based alloy.

| Type of powder | Chemical composition (%wt) |
|----------------|-----------------------------|
|                | W 73, Co -20, Cr 7         |
| AST 908        |                            |
| AST 915        | W 88, Co 12, Cr -4         |
| AST 928        | W 80, Co 6, Cr 10          |

The parameters of HVOF coating optimized process were illustrated according to Table 3. Before HVOF coating process, the prepared specimens of surface properties were polished with silica-paper and cleaned with acetone. This objective of study was to compare the micro-hardness of tungsten based alloy films on AISI 1050 steel by HVOF coating method. Three films of powder tungsten based alloys were AST 908, AST 915 and AST 928 respectively.

| Parameters             | Type of tungsten based alloy |
|-----------------------|-------------------------------|
| Oxygen pressure (ft³/min) | AST 908 | AST 915 | AST 928 |
| Fuel (gal/min)         | 1900     | 2000     | 1950     |
| Nitrogen pressure (ft³/min) | 6      | 6        | 5.75      |
| Powder feed rate (rpm) | 23 ±2   | 21 ±2    | 26 ±2    |
| Spraying distance (mm.) | 300-400 | 300-400  | 300-400  |
| Temperature (ºC)      | 3000-3600 ºC | 3000-3600 ºC | 3000-3600 ºC |

2.1 Microstructure and surface hardness of coatings
The micro-hardness of coating films were investigated by Vickers micro-hardness tester (Matsuzawa MM5321X model MMT-X7-LCD). This tester micro-hardness of coating films was found. Twenty
positions of measuring were the 10-testing points on flat surface and 10-testing points on cross section as shown in Figure 1. The measuring method used the applied loads of 100 g and time range of 10 sec. with each testing point. In addition, the microstructure analysis of specimens was used for the scanning electrode microscopy (SEM) and energy dispersive spectroscopy (EDS).

![Figure 1](image_url)

(a) Testing point on flat surface. (b) Testing point on a cross section.

**Figure 1.** Positioning of micro-hardness testing.

### 3. Result and Discussion

#### 3.1 Microstructure

The SEM micrographs (as shown in Figure 2) were exhibited with the three coating films on cross section and deposition characteristic of coating films. These micrographs demonstrated that the coating films in good deposition with the specimens. Moreover, the coating films indicated a very homogeneous microstructure [5]. However, the porosity value in the coating films on cross section was low according to the evident. The EDS analysis of coating film on the flat surface was shown in Figure 3 and Table 4. According to the SEM micrographs results, the powder particles consist of W, Cr, Ni, Co and C. The as sprayed tungsten based alloy composite results hard W particle results in the formation of WC during the remelting [6].

![Figure 2](image_url)

(a) AST 908 (b) AST 915 (c) AST 928

**Figure 2.** SEM micrographs of three coating films on cross section.
Figure 3. EDS analysis of coating films on flat surface.

Table 4. The EDS analysis of each coating films on flat surface.

| Type of powder | Chemical composition (%) |
|---------------|--------------------------|
|               | C  | Na | P  | Zn | Co | Mg | K  | Cr | Fe | Ni | W  |
| AST 908       | 18.65 | 0.5 | -  | -  | -  | -  | 18.52 | 1.27 | 9.33 | 51.73 |
| AST 915       | 22.81 | -  | -  | 4.36 | 16.72 | 0.67 | -  | 2.6 | -  | 52.84 |
| AST 928       | 20.86 | 1.45 | 0.52 | -  | -  | -  | 0.43 | 14.9 | 2.15 | 25.48 | 34.39 |

3.2 Vickers Micro-hardness

The variation of micro-hardness on coating films was shown in Figure 4. It revealed that AST 908 coating film higher hardness of 1583.9 HV was achieved whereas the hardness of specimen (AISI 1050 steel) was 300.5 HV. In addition, the AST 915 coating film and AST 928 coating film were improved the hardness of 1476.9 HV and 1316.4 HV respectively. It indicated that the hardness of specimen (81.30%) was lower than AST 908 coating film.

Figure 4. The variation of micro-hardness on coating films and substrate.

Figure 5. showed the micro-hardness along the cross section of substrate and coating films. It could be seen that the increase of the micro-hardness by adding the spray distance from the substrate to coating layer of AST 908 coating film, the surface coating of 1559.3 higher hardness HV by gradually pressed of the position shifts from surface coating towards bond layer. At the bond layer it is reduced to 699.6 HV and further reduced in substrate material to 313.4 HV. The AST 915 powder coating and AST 928 coating improved the micro-hardness on the AISI 1050 material by 1468.4 HV and 1306.2 HV respectively.
Figure 5. The spray distance of micro-hardness on coating films and substrate.

4. Conclusion
In this work, the surface characteristics during HVOF spayed coating on AISI 1050 substrate material using three different powder coatings have been investigated. The micro-hardness and microstructure were studied. The following conclusions can be drawn as follow:

- The cross section micrographs demonstrated that the coatings reasonably had good interface with the substrate material and the coating showed a very homogeneous microstructure.
- The micro-hardness of substrate was 81.30% lower than the micro-hardness of surface coating when using AST 908 powder particles.
- In the micro-hardness along the cross section, the AST 908, AST 915 and AST 928 powder coatings improved the micro-hardness on the AISI 1050 material by 1559.3 HV, 1468.4 HV and 1306.2 HV respectively.

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