Effect of Surface Roughness on Adhesion of 67Ni18Cr5Si4B Alloy Powder Coating by High Speed Oxygen - Fuel Injection (HVOF) Method

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Abstract— **Currently, metal spraying technology in general and thermal spraying method in particular is still very new compared to other technologies, but has been widely applied in industries, especially in mechanical engineering, transportation, oil and gas.... Currently, metal spraying technology in general and thermal spraying method in particular is still very new compared to other technologies, but has been widely applied in industries, especially in mechanical engineering machinery, transportation, oil and gas.... Creating a coating capable of meeting working conditions such as anti-corrosion, wear-resisting, heat-resisting.... has been studied by scientists, the quality of the coating depends on many factors. In particular, the surface roughening factor is very important because it creates a mechanical connection between the steel substrate and the coating. In this paper, the author presents the process of creating surface roughness by changing the spray distance to 50mm, 100mm, 150mm, 200mm, respectively, and the abrasive grain size is G16, G20, G22 respectively for the inner surface roughness range from 58.43 to 69.38 µm. When analyzing the adhesion of the coating to the base metal, the results show that the adhesion depends on the surface roughness, the adhesion is proportional to the increasing direction of the surface roughness, when the surface roughness of the substrate The higher the steel, the higher the adhesion of the coating to the substrate and vice versa.**

Index Terms— **spray coating, thermal spray method, coating 67Ni18Cr5Si4B, adhesion, roughness**

I. INTRODUCTION

Among the surface treatment technologies used, thermal spray coating technology has been increasingly developed, expanded in scale, improved in quality, and demonstrated superior features compared to other treatment methods other surface both technically and economically [1, 2]. In order to meet the working conditions of the part in wear-resistant, anti-corrosion and heat- resistant environments…The study and influence of technological parameters on coating quality with evaluation criteria such as hardness, porosity, adhesion to meet the working requirements of the details is an urgent matter to be studied many scientists are interested in, in which the criterion of evaluating the adhesion strength of the coating is very important, it is decisive to the quality of the coating, meet the demanding needs of surface treatment of parts in industries. The adhesion of the coating to the base metal is based on mechanical bonding [3-5], in order to increase the adhesion of the coating before coating is sprayed, the substrate surface must be roughened. To evaluate the adhesion of thermal spray coatings and evaluate the influence of surface roughness on adhesion, various methods have been applied [6]. One of the most common methods is to use the compression method, which is a standard method JIS-H-8666-1980 (Japan).

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II. MATERIALS AND EQUIPMENT FOR TESTING

2.1 Material:

Base material: The base steel used for the test is C45. steel

Surface roughening grain: Brown corindon abrasive (Hai Duong Grinding Stone Manufacturing Joint Stock Company) with grain sizes (G16, G20, G22)

Spray material: Alloy powder 67Ni18Cr5Si4B provided by Surface enginnering alloy company (USA), with average grain size from 22 µm to 270 µm as shown in figure 1 for testing.

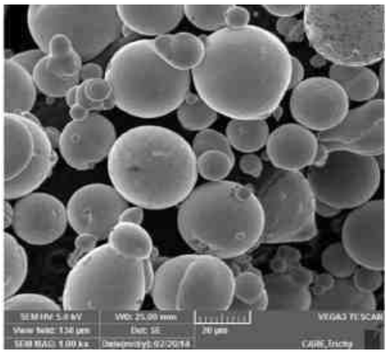

Figure 1. Pictures of spray powder 67Ni18Cr5Si4B

2.2 Equipment

The equipment used for the experiment is the HVOF injection system (Model: MP-2100 Manual HVOF Control Panel, of the Institute of Mechanical, Automation and Environmental Science and Technology, provided by the Equipment Co., Ltd.) Metallizing Pvt. Ltd. (MEC) – India.

III. RESEARCH METHODS

3.1 Surface roughening method

There are many methods to roughen the sample surface before spraying such as: grooving, thread rolling, abrasive blasting...In order to meet the target and suit the actual conditions, in this study, brown corindon abrasive grains are used to create surface roughness, the advantage of this method is that the abrasive grains have high hardness, sharp edges and sharp edges can be reused many times. There are many factors affecting the results of roughening such as nozzle shape, spray air pressure, injection angle, injection time, distance from the nozzle to the roughening surface and abrasive grain size... However, in the study, only the influence of two important factors were considered: the distance from the nozzle of the spray gun to the roughing surface and the abrasive grain size. The remaining factors are kept fixed parameters such as nozzle diameter ∅ = 4 mm, spray gas pressure P = 8-10 atm, spray angle ∅ = 450, injection time t = 30 s.

To roughen the surface of C45 steel, use a TSA sprayer with selected parameters as follows:

+ Grinding grain: brown corindon (Hai Duong Grinding Stone Manufacturing Joint Stock Company)
+ Abrasive size: G16, G20 and G22.
+ Spray distance: 50mm, 100mm, 150mm, 200mm.

3.2 Method for determining coating adhesion

The determination of the adhesion strength of the coating has been studied by many scientists with different methods such as: Adhesive method, dowel pull method, sliding method... In this study, the coating adhesion strength was determined by the sliding method according to Japanese standard JIS H 8664 - 1977. This method gives accuracy and the ability to leave little or no deformation on the cutting surface and is highly efficient for data collection, and can measure the shear stress at the contact site of the cutting surface coating to the substrate, thereby determining the adhesion of the coating to the base metal. The process of determining the adhesion of the coating is used with a tractor, compressing machine MTS 809 of the Federal Republic of Germany at Hanoi University of Science and Technology (Figure 2) with the following characteristics:

+ Force range (-100¸100) kN, error 10 N
+ Working range: 300 mm
+ Maximum test temperature: 1200^0C

Figure 2. Tractor, compressor MTS 809

3.3 Selection parameters in the spraying process of alloy powder coating 67Ni18Cr5Si4B

Spraying process of alloy powder coating 67Ni18Cr5Si4B, with selected technology modes as follows:

- Blowing air pressure: P = 7.0 – 8.0 atm
- Oxygen gas pressure: P = 3.5 – 4.5 atm
- Combustible gas pressure: P = 6.0 – 6.5 atm
- Spray distance: L=100-300 mm
- Spray angle: = 90^0

IV. Results and Comments

4.1 Surface roughness before coating

The process of measuring surface roughness of C45 steel base on SurTest machine of Elektrophysik manufacturer - Germany is measured on a standard length L, using Rz value which is the average value of 5 distances from the peaks highest to 5 lowest bottoms of microscopic surface undulations. The surface roughness measurement results are given in Table 1.

Table 1. Results of measuring surface roughness of C45 steel substrate with different roughening modes.

Abrasive grain size	Particle spray distance L (mm)	Roughness of base steel C45 Rz (μm)
16	50	63.38
	100	65.37
	150	61.62
	200	58.85
20	50	66.36
	100	**69.38**
	150	64.62
	200	62.85
22	50	58.41
	100	63.38
	150	60.15
	200	58.43

From the results of the roughness measurement given in table 1, it is possible to build a 2D graph showing the influence of the abrasive grain size and the particle injection distance on the surface roughness of the C45 base steel shown in Figures 3 and 4.

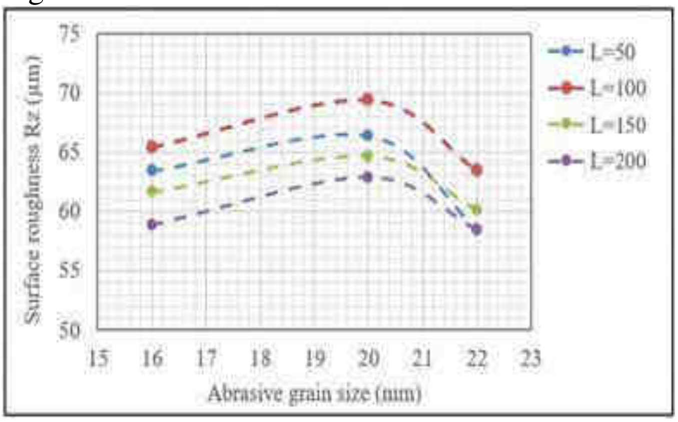

Figure 3. Effect of abrasive grain size on surface roughness of C45. base steel corresponding to the spray distance L=50 - 200mm

From the graph of Figure 3, it can be seen that, with the same spray parameters such as: injection distance, spray pressure and spray angle, when using different sizes of abrasive particles, different surface roughness values will be given. When keeping the distance from the nozzle to the sample surface fixed and gradually increasing the particle size corresponding to the decrease in the particle size (in the survey region), the results show that the roughness reaches the maximum when using the G20 grain size. This can be explained as follows. When using the G16 particle size, it means that the particle size is large from 1400 to 1180 µm, combined with the spray gas pressure from 8 to 10 atm, resulting in particles impacting on the sample surface with great kinetic energy forming traces concave on a wide surface, and at the same time, due to the density of particles acting on the dense sample surface, the roughness is not high. When using the G20 particle size, the particle size decreases from 1180 - 1000 µm, while the constant gas pressure will increase the kinetic energy of the particle, then the particles impacting on the sample surface will make indents on the surface surface reaches depth (roughness increases). When using the G22 particle size, the particle size continues to decrease from 1000 to 850 m while the spray pressure remains unchanged, leading to the increased kinetic energy of the spray particles when in contact with the sample surface and being shot back, hinders the movement of particles to the substrate surface leading to difficult indentation formation on the sample surface (reduced roughness).

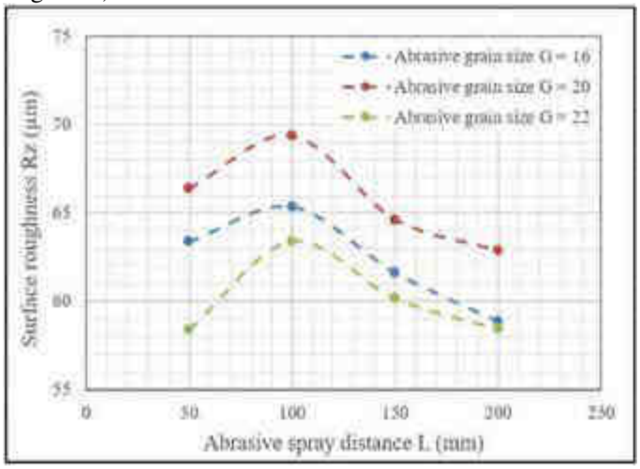

Figure 4. Effect of spraying distance on surface roughness of C45 steel with grain sizes G16, G20, G22

Figure 4 shows the effect of spraying distance on surface roughness of C45 steel base. From the graph, it can be seen that, when gradually increasing the spraying distance L = 50 ÷ 100 mm, the surface roughness increases. However, when increasing the injection distance L = 100 ÷ 200 mm, the roughness tends to decrease. It can be explained as follows: If the nozzle is placed too close to the sample surface L = 50 mm, the abrasive particles flying at high speed will collide with the sample surface and be broken up by jet. In time to fall, the particles at the back flew to collide with it, thus hindering the kinetic energy of the abrasive particles impacting the surface of the sample, so the efficiency of roughening was not high. If the nozzle is located too far from the sample surface L = 200mm, it will reduce the blower pressure, leading to a decrease in the kinetic energy of the spray particles, and the roughening efficiency is not high. Thus, for each abrasive particle size, there will be an optimal injection distance L.

The highest roughness value on the sample is Rz = 69.38 µm, corresponding to the abrasive blasting mode with grain size G20 and injection distance L = 100 mm.

The surface roughness Rz in the range 50 ÷ 100 m measured on this sample satisfies the requirements for the quality of the substrate metal surface treatment for thermal spray coatings, which are stated in 3 international standards related to spraying heat coating [7 ÷ 9]. Therefore, in this case, selecting the roughening mode corresponding to the G20 particle size and the injection distance L = 100 mm is optimal. With such a high roughness parameter, it will ensure the best adhesion of the coating to the substrate in the investigated treatment modes. On the basis of the obtained results, the optimal surface treatment regime for C45 steel base is given in table 2.

Table 2. Surface roughening mode for C45 steel base.

TT	Regime	Parameter
1	Type of abrasive grain	Corindon Al_2O_3
2	Abrasive grain size	20
3	Compressed air pressure (atm)	8-10
4	Spray distance (mm)	100
5	Spray angle (θ^0)	90^0

4.2. Determination of adhesion of 67Ni18Cr5Si4B alloy powder coating on C45 steel base

The results of measuring adhesion of alloy powder coating 67Ni18Cr5Si4B on C45 steel base are performed on measuring device MTS 809 are presented in Table 3

Table 3. Result of measuring adhesion of alloy powder coating 67Ni18Cr5Si4B on C45 steel base

Abrasive grain size	Particle spray distance L (mm)	Surface steel roughness C45 Rz	Adhesion (Mpa)
16	50	63.38	62.42
	100	65.37	64.18
	150	61.62	60.76
	200	58.85	58.77
20	50	66.36	73.09
	100	69.38	76.53
	150	64.62	71.48
	200	62.85	68.43
22	50	58.41	60.41
	100	63.38	62.38
	150	60.15	59.35
	200	58.43	57.69

From the results of measuring the adhesion of the 67Ni18Cr5Si4B alloy powder coating in table 3, it is shown that the roughness is an important factor affecting the adhesion ability of the coating to the substrate surface, with each surface roughness value. Different surfaces give the corresponding adhesion of the coating. The effect of surface roughness on the adhesion of the coating to the C45 steel base is depicted on the graph of figure 5

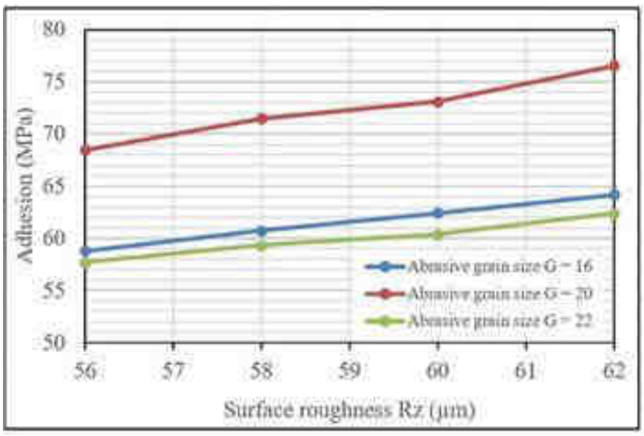

Figure 5. Effect of surface roughness on adhesion of 67Ni18Cr5Si4B alloy powder coating to C45 steel substrate

From Figure 5 it can be seen that: The adhesion of 67Ni18Cr5Si4B alloy powder coating depends on the surface roughness. The graph has an increasing characteristic curve with an almost linear increase, which shows that the adhesion is proportional to the increasing direction of the surface roughness, as the surface roughness increases, the adhesion ability of the layer increases coating with increasing background and vice versa is as follows:

- When surface roughness Rz = 65.37 µm, the corresponding adhesion is σ = 64.18 Mpa,
- When surface roughness Rz = 69,38 µm, the corresponding adhesion is σ = 76.53 Mpa,
- When surface roughness Rz = 63.38 µm, the corresponding adhesion is σ = 62.38 Mpa.

CONCLUSION

Experimental research has determined the values of roughness and adhesion of 67Ni18Cr5Si4B alloy powder coating on C45 steel by HVOF spray method.

A 2D graph has been built that reflects the relationship between spray particle size (abrasive grain) and surface roughness and between surface roughness and coating adhesion, thereby selecting areas of technological parameters. Reasonable spray for the highest adhesion coating. At the same time, two test methods such as surface roughness and coating adhesion have been selected, the measurement results are reliable. Roughness reached the highest value Rz = 69.38 µm when using abrasive grain size equal to G20 with injection distance L = 100mm. The analysis results show that the adhesion of the coating depends on the surface roughness, as the surface roughness increases, the adhesion ability of the coating to the substrate increases and vice versa.

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