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Coating Parameters Influences on Mechanical Properties of Coating

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Abstract: In this study investigated the influences of coating parameters on the mechanical properties of coatings. This study was an experimental. The AlMg3 alloy has been selected as a coated material. The Cr_2O_3 and Al_2O_3 material was selected as the coating material. Coating process was performed using the method of wire flame spray. In this process, the spray distance and thickness of the coating, the process parameters chosen (10, 12, 15 cm spray distance and 100, 200, 300 μm coating thickness). Microstructure characterization of coating structures was obtained. Images of the microstructure of the samples and micro-hardness analysis were examined. Micro-hardness results are displayed graphically. The highest hardness values for samples were obtained in 12 cm spray distance and 100 μm coating thickness.

Key words: Flame wire spray, coating parameters, mechanical properties, Cr_2O_3 and Al_2O_3 coating, microhardness

INTRODUCTION

The 200 material can be coated such as metals, alloys, ceramic, carbide, cermet and some plastic. With this method that has found a wide usage area at automotive, aviation, paper, textile and chemistry industry it is possible to improve and develop the materials erosion and corrosion endurance, electrical and thermal features (Celik, 2002).

During coating process, there are a lot of parameters that effect the coating quality. These parameters are spray distance, main material heat, main material surface roughness, coating thickness, the features of used gas and particle characteristics (dimension, dispersion and morphology) (Chang and Sun, 2004). Even a little change in these parameters that are related with each other, it effects coating's microstructure, mechanic and physical characteristics (Sarikaya, 2005).

There are studies in the literature on the subject: Holmberg *at al*. (2000) studied the tribological properties of thin coatings. Korkut *at al*. (2002) investigated coated process of low carbon still effect on the microstructure. Tom *at al*. (2001) studied wear and corrosion behavior of thermally sprayed cermet coatings.

In this study is investigated the coating parameters influences on mechanical properties of coating. The flame wire spray process is introduced generally. AlMg3 alloy is coated with Cr_2O_3 and Al_2O_3 ceramic wires by using different coating parameters (10, 12 and 15 cm spray distance and 100, 200 and 300 μm coating thickness). The microstructure characterization of obtained coated samples have been done and the effect of coating parameters on mechanical properties are investigated.

MATERIALS AND METHODS

Thermal spraying systems: Thermal spraying method is a term that is used to define a group method that is obtained from precipitation of materials that are very thin metallic or non metallic materials that are on the main metal's surface prepared before coating. Coating material can be as powder, strip or wire. Thermal spray gun is used to obtain necessary heat to melt the coating material, combustion gas obtains electric arc or plasma arc (Sarikaya, 2003).

The melted coating material is sprayed on the surface that is also called underlay. The granules that hit the surface with stroke effect are flattened and with the heat transmission to the main metal it becomes solid by getting cooler and created a layer by touching on each other. In Fig. 1 the process order between melted coating material and main material is shown (Sarikaya, 2003). During the thermal spraying, the process should not be interrupted until the required coating thickness is obtained. However, precautions should be taken in order to avoid from over heating that may have negative effect on the main material features or on coating's performance. If it is inevitable to stop the spraying process suddenly, in this case sudden

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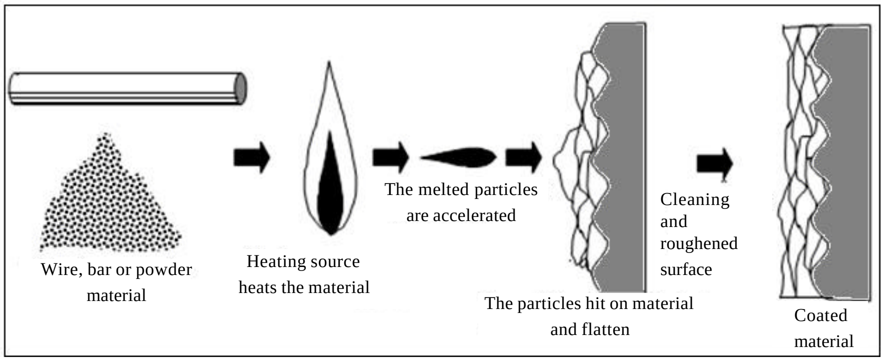

Fig. 1: The schematic display of thermal spraying coating method (Yetgin and Kucukrendeci, 2006)

Table 1: The chemical composition of underlay material (% weight) (Yetgin and Kucukrendeci, 2006)

Fe	Si	Mn	Ti	Cu	Mg	Zn	Others	-
Max 0.55	Max 0.55	Max 0.45	Max 0.2	Max 0.05	2.5-3.5	Max 0.1	Each 0.05, total 0.15	Al-remainder

fall of temperature should be prevented the total coating thickness at thermal spraying systems can be between 0.0025-10 mm (Yetgin and Kucukrendeci, 2006).

In thermal spraying systems generally Physical Vapor Declension (PVD), Chemical Vapor Declension (CVD), Sol-Gel (SG), Plasma Spraying (PS), Flame Spraying (FS), coating with Hot Isostatic Pressing (HIP) and Detonation Gun (DG) methods are used (Khedkar *et al*., 1997).

Flame spraying method: The coating materials that are used at spraying technique that is the easiest and cheapest method at thermal spraying can be wire, strip or powder form (Kahraman and Gulenc, 2002). Flame spraying technique can be called as wire with flame or powder with flame spraying technique according to the type of coating material that is used. In this system where the oxygen is used as burning gas, for materials that have low melting degree propane, for steel acetylene and for thin powder spraying hydrogen are used as flammable gas. At gas changing there is no need to change the flame spray gun (Sarikaya, 2003).

Flame wire spraying technique includes the process where a metallic (or ceramic) wire is melted and sprayed on to the surface of the coating that is under melting heat oksi-acetylene flame heat (3300°C) The coating wire is fed on spray gun nozzle with a driver. The wire is melted with the help of mixture of oxygen and flammable gas while it is passing through the nozzle and the melted metal is sprayed on the surface that will be coated by atomizing with high pressure air. In this method the flame function is obtained by melting the metal. Coating surface heat changes between 95-200°C (Kahraman and Gulenc, 2002). The coatings that are produced with this method have generally higher pores, lower quality and lower adherence resistance than the other methods. Also, it is the biggest disadvantage not to produce the coating material as wire. It has an advantage that is a situated method for oxide ceramic coating spraying and has high controllability with low cost.

Experimental studies: In this study, AlMg3 alloy underlay (main material) is used with 10×20×20 mm dimension chemical composition is given at Table 1 and has approximately 50-55 HV hardness.

Before coating process, the surfaces of AlMg3 alloy are cleaned with ethly alcohol. Underlay material surfaces are roughened by using quartz corrosive powder with 7 bar sandblasting pressure. In order to improve mechanical adherence between the underlay and coating materials NiCr alloy that is resistant to high heat is used as undercoat material and Cr_2O_3 and Al_2O_3 wires where their chemical compositions and physical features are given at Table 2 are used as coating materials. Coating processes are made manual at Koroglu Company (Kütahya/Turkey). The process parameters that are chosen according to the producing company's advice are given at Table 3.

In the research of coating microstructure I MM 901 optic microscope is used. Each sample is grinded with SiC sandpaper and their surfaces are polished with 1 μm diamond felt. The polished samples are washed with water and after that they are cleaned with alcohol their microstructure examinations are made with optic microscope and SEM.

In the determination of the coating thicknesses the average values are taken from the measurements that are made from 10 different areas of each sample and their values are determined approximately as 100, 200 and

Table 2: The chemical compositions and physical characteristics of coating materials as % weight (Yetgin and Kucukrendeci, 2006)

Chemical composition							
Material	Cr_2O_3	Al_2O_3	SiC_2	Fe_2O_3	MgO	SiO_2	TiO_2
Cr_2O_3	90.33	3.67	5.62	0.27	0.11	-	-
Al_2O_3	-	98.82	-	0.05	0.34	0.78	0.01

Physical features			
Material	Density (g cm^{-3})	Melting heat (C)	Hardness (HV)
Cr2O3	4.5	2300	1215
Al2O3	3.2	2050	812

Table 3: Flame wire spraying process parameters

Spray parameters	NiCr	Al_2O_3	Cr_2O_3
Spray distance (cm)	12	10-12-15	10-12-15
Coating thickness (μm)	-	100-200-300	100-200-300
Wire feeding speed (g sec^{-1})	2.5	2.5	2.5
Oxygen pressure (atm)	2.35	2.35	2.35
Acetylene pressure (atm)	2.35	2.35	2.35
Wire diameter (mm)	4.0	4.0	4.0

300 μm. Their Vickers microhardness measurements are made with HVS-1000 Digital Micro Hardness Tester device with 100 kg load and 20 sec. Loading time and their arithmetical average are taken.

RESULTS AND DISCUSSION

The microstructure of coatings: The microstructure characteristics of coating's are important to determine the mechanical behaviours of the materials and there is a need to adjust according to the chosen parameters during coating process to obtain the required features in coating.

In Fig. 2, 200 μm coating thickness for Cr_2O_3 coating material optic images are given. It is seen that there is an regular structure between undercoat materials and coating materials and an appropriate transition is obtained at interface. At sample is seen that a complete adherence is not obtained between undercoat material and main material and a porous transition is formed. As coatings characterization the pores, unmelted particles and oxide layers do not appear inside structures.

In Fig. 3, Al_2O_3 that has 200 μm coating thickness belonging to coated samples SEM images are given. It is seen that the NiCr undercoat is both connected to main material and to coating as zigzag and obtained a good interface transition and a full adherence is obtained.

The coating surface roughness provides the most appropriate adhesion ground and reduces minimum gaps between underlay-undercoat and undercoat-coating materials.

As it is seen that flame wire spraying method melts the coating materials, provides the necessary particle speed on undercoat (NiCr) coating and this method is appropriate for coating this type of materials.

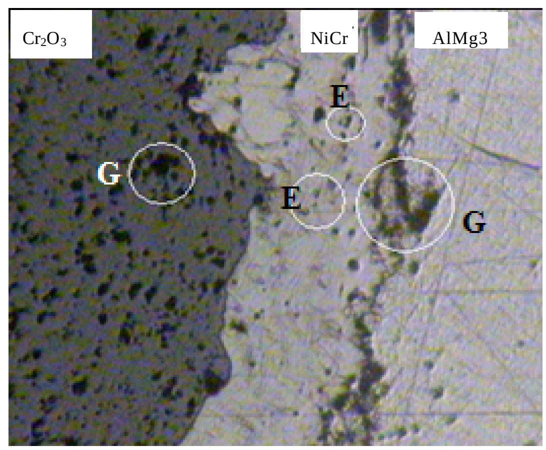

Fig. 2: The optic microstructure images of Cr_2O_3 coated sample (200 μm x100) E: unmelted particles, G: pore

The hardness rates of coatings: For both materials when coatings are evaluated generally, it is determined that the microhardness rate is not the same at every part of coating cross section. Coating hardness rates change contingently beside coating material's own features, the pore, oxide, unmelted or half melted particles rate inside coating. With a good adhesion of melted particles more intensive coatings and higher hardness rates can be obtained.

Spray distance affects coating's microstructure features and when spray distance increases, the pore inside coating increases and hardness decreases.

In Fig. 4, the hardness changes are given according to spray distance at 10, 12 and 15 cm. It is determined that hardness values decreased with increased coating thickness at both coating material and three spray distances. While the highest hardness values for both

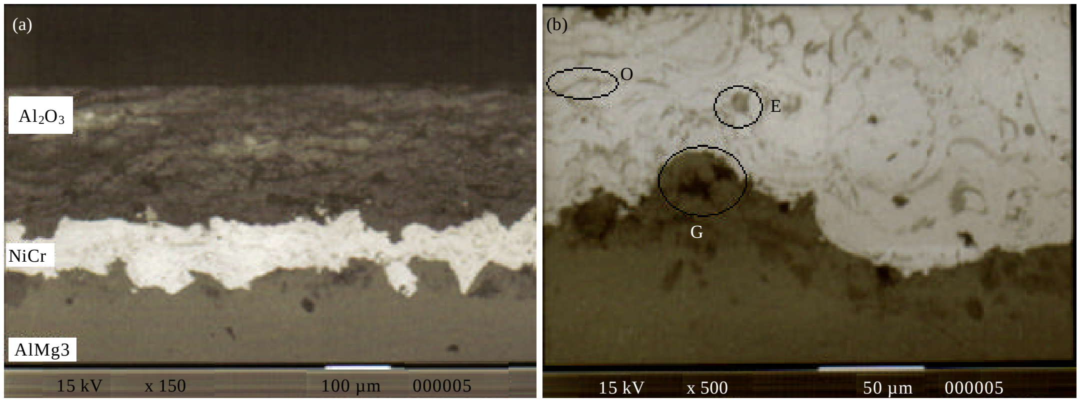

Fig. 3(a-b): Microstructure image of the coating cross-section belonging to AlMg3 alloy coated with Al_2O_3 (200 µm thick) (a) Main material (AlMg3), undercoat (NiCr), coating material (Al_2O_3) and (b) Microstructure image of undercoat and coating (E: Unmelted particle, G: Pore, O: oxide)

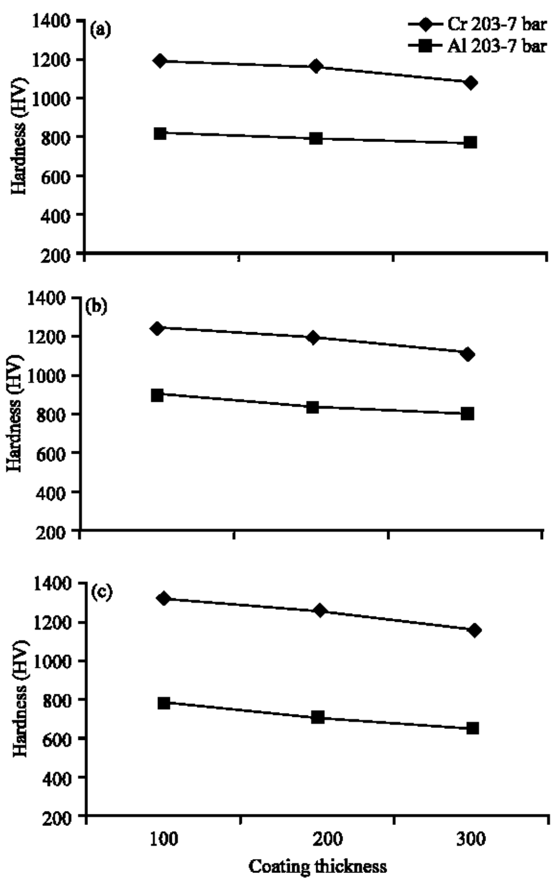

Fig. 4(a-c): The relation between spray distance and hardness (a) 10 cm, (b) 12 cm and (c) 15 cm

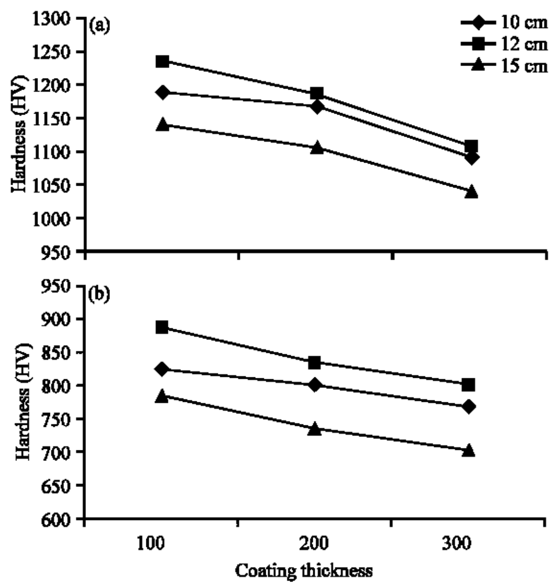

Fig. 5(a-b): The relation between coating thickness and hardness (a) Cr_2O_3-7 Bar and (b) Al_2O_3-7 Bar

coating materials are obtained as 12 cm spray distance and 100 µm coating thickness, at 15 cm spray distance the lowest hardness values is obtained.

The results of this study are consistent with results of the study of Sarikaya (2005). The study of Sarikaya (2005) used a steel material, AlMg3 alloy was used in this study. The method of plasma spray coating is applied in the study of Sarikaya (2005). The method of flame wire spray coating was used in this study.

At Fig. 5, the changes between coating thickness and hardness relation are given according to coating materials. Both material's hardness rates decreased with increasing coating thickness. The highest hardness rate for Cr_2O_3 coated sample is obtained at 100 µm coating thickness. With increasing coating thickness, unmelted pieces during coating process and pores amount decreased hardness values, because their decreased adhesion resistance of coating particles.

CONCLUSION

From this study results, the following conclusions are made: It is determined that coating interfaces have regular structure and provide appropriate transition. It is determined that spray distance is the most effective parameter on coating's microstructure and hardness rates. At 12 cm spray distance the highest hardness rates are obtained for both coating samples. It is observed that with increasing of coating thickness, there is reduction on hardness. The highest hardness rates for both materials are obtained at low coating thickness (100 μm). Cr_2O_3 coated sample's hardness rates are higher than Al_2O_3 coated samples.

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