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Research Article

Experimental Investigation on Ceramic Surface Coatings on Aluminum using Detonation Gun

Sumith Kumar†*, Pusuluri Sriharsha†, Samatham Madhukar† and Birudala Raga Harshith Reddy†

†Department of Mechanical Engineering, Vidya Jyothi Institute of Technology, Hyderabad, T.S., India

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Abstract

The use of coatings on materials is now widespread in global manufacturing for reducing production cost and improving productivity, all of which are essential if industry is to remain economically competitive. As per industrial requirements materials may be get failed due to their mechanical properties like strength, hardness of these materials can be improved by coating. The durability of material depends on its quality. Good quality material is inherently durable. The durability can be increased by proper choice of materials propositioning, placing and curing. Another way of enhancing the durability of concrete is by applying a coating. The materials which are coated have high strength than that of the uncoated materials. Ceramic coatings can transform an ordinary metal into a high-performance surface. When applied by detonation gun, the coatings are dense, wear, corrosion & heat resistant, inert to acids, alkali and solvents. They improve the properties of any surface they're applied onto. Because of higher energy application method coatings have higher particle-to-particle cohesive bonding which translates into higher quality coatings. In this paper, we review the difference in hardness and microstructures between the two different surface ceramic coatings applied on the aluminum by detonation gun.

Keywords: *Ceramic coatings, aluminum, detonation gun*

1. Introduction

There are a wide range of ceramic coatings that can be applied to metal components in order to enhance their functional properties. Most ceramic coatings are electrically nonconductive (making them excellent insulators), have a significantly higher level of abrasion resistance than most metals, and are capable of maintaining their integrity under severely elevated temperatures, sometimes up to 4,500 degrees Fahrenheit. Wear-resistant ceramics, such as titanium nitride and chromium carbide, can be applied to work steels and air-hardening tool steels via chemical vapor deposition (CVD), which is one of the more common application methods currently in use.(S. S. Chatha, *et al*,2012)

2. Manufacturing Applications

Ceramic coatings are often used as barrier materials to enhance the interaction between moving metal parts, such as in the automotive industry. However, they are also increasingly being employed to augment certain manufacturing processes, and exhibit potential for improving the efficiency of some fabricating methods. Ceramic coatings are sturdy and have a high level of lubricity, but due to oxidation concerns, they are typically used in temperatures under 1,200 degrees (F). However, this allows them to be applied to hot forging dies, which operate at lower temperatures. Ceramic coating increases the operational lifespan for these dies, allowing them to produce a greater number of parts before wearing down. Ceramic materials, such as magnesium zirconate and zirconia, exhibiting a high level of hardness, thermal resistance, and elevated melting points are being used as heat barrier coatings for industrial parts (L. Singh, *et al*, 2012).

3. Ceramic Coating Processes

Applying a ceramic coating to a substrate is multi-stage process. The preparatory phases of cleaning, roughening, and undercoating (or priming) greatly influence the success of the project. The actual coating effectiveness depends largely on the mechanical, chemical, and physical bonds that determine the coating adherence and ultimate strength of the ceramic layer. Aside from chemical vapor deposition, the most common ceramic coating methods include:

*Corresponding author: **Sumith Kumar**

3.1. Plasma Spraying

In plasma spraying, ceramic powder is passed through an ionized gas at extremely high temperatures, sometimes approaching 30,000 degrees (F). The pressurized gas speeds molten ceramic particles toward the substrate where they bond onto its surface. The result is a strongly-adhering and high-density coating, but the process can be very expensive (V. A. D. Souza, *et al* , 2007).

3.2. Detonation Gun

The detonation gun process is most effective for particular ceramic materials, such a tungsten carbide, that are required for producing highly dense coatings on a metal surface. It creates an explosion of oxygen and acetylene gas at around 6,000 degrees (F), melting the ceramic and firing it at high speed toward the target substrate.(Venkataraman R, *et al* ,2006)

3.3. Oxygen Acetylene Powder

This method involves heating ceramic powder under a 5000 degree (F) flame, and using compressed gas to spray the coating onto the substrate. It creates porous coating layers with relatively low adhesion strength.

3.4. Oxygen Acetylene Rod

In this method, a fused ceramic rod is passed under an oxyacetylene torch burning at 500 degrees (F). Pressurized gas is then used to spray molten ceramic material onto a surface, producing a coating with a high level of cohesive bonding.(Du Hao, *et al* ,2005)

In addition to these standard processing methods, continuing research in ceramic coating technology has introduced newer techniques that may have a major influence on future ceramics work. For example, a procedure for coating metalworking dies with refractory materials, such as molybdenum and tungsten, employs a plasma spray gun and low-shearing compaction to achieve a highly effective and wear-resistant coating. (Rajasekaran B, *et al* , 2006)

4. Detonation Gun Spraying

D-gun spray process is a thermal spray coating process, which gives an extremely good adhesive strength, low porosity and coating surface with compressive residual stresses [4]. A precisely measured quantity of the combustion mixture consisting of oxygen and acetylene is fed through a tubular barrel closed at one end. In order to prevent the possible back firing a blanket of nitrogen gas is allowed to cover the gas inlets. Simultaneously, a predetermined quantity of the coating powder is fed into the combustion chamber. The gas mixture inside the chamber is ignited by a simple spark plug. The combustion of the gas mixture generates high pressure shock waves (detonation wave), which then propagate through the gas stream. Depending upon the ratio of the combustion gases, the temperature of the hot gas stream can go up to 4000 deg C and the velocity of the shock wave can reach 3500m/sec. The hot gases generated in the detonation chamber travel down the barrel at a high velocity and in the process heat the particles to a plasticizing stage (only skin melting of particle) and also accelerate the particles to a velocity of 1200m/sec. These particles then come out of the barrel and impact the component held by the manipulator to form a coating. The high kinetic energy of the hot powder particles on impact with the substrate result in a build-up of a very dense and strong coating. The coating thickness developed on the work piece per shot depends on the ratio of combustion gases, powder particle size, carrier gas flow rate, frequency and distance between the barrel end and the substrate. Depending on the required coating thickness and the type of coating material the detonation spraying cycle can be repeated at the rate of 1-10 shots per second. The chamber is finally flushed with nitrogen again to remove all the remaining hot powder particles from the chamber as these can otherwise detonate the explosive mixture in an irregular fashion and render the whole process uncontrollable. With this, one detonation cycle is completed above procedure is repeated at a particular frequency until the required thickness of coating is deposited.

Figure 1 Detonation Gun Spraying

5. Advantages of Ceramic Surface Coatings

1) Reduction in Friction
2) Confer corrosion protection to the surface
3) Increase the hardness of the substrate
4) Provide thermal insulation
5) Provide electrical insulation
6) Make the substrate more wear resistance

6. Experimental Procedure

In this experiment, first the aluminum material is coated using the detonation gun and then the coated material is tested using the Scanning electron microscope. The following order is followed to examine the coated materials.

- Material Selection
- Ceramic coating process
- Micro Vickers Hardness Testing
- SEM Analysis

6.1Material Selection

Aluminum is selected for the ceramic coating because of its best-known properties like light weight, low density and high strength. The figure 2 shows the aluminum plate that is used for the coating process

Figure 2 Aluminum material before ceramic coating

6.2 *Ceramic Coatings Processes*

In this process, the ceramic coating is applied to the selected aluminum material. The following are the two types of the coatings

1) Alumina oxide Coating
2) Alumina+40% Titania Coating

The detonation gun conditions for coating the both the coatings are given in Table 1

Alumina oxide Coating

In this alumina oxide powder is coated to the aluminum plate (Specimen 1). The material plate dimensions are given in Table 2 , chemical composition of aluminum oxide are given in Table are given in the Table 3 and physical properties of aluminum oxide are given in Table 4

Table 1 Working Conditions of Detonation Gun

Heat Source	Acetylene and oxygen
Material	Carbide, Ceramic and Metallic Powders
Flame temperature	Nearly 3,000^0 C
Particle velocity	Up to 1000 m/s
Substrate temperature	20-140^0 C
Coating Thickness	100 microns

Table 2 Specimen 1 dimensions

Specimen Material	Aluminum
Length of specimen	50 mm
Width of Specimen	50 mm
Thickness Specimen	10 mm

Table 3 Chemical Composition of alumina oxide

Typical Composition	Weight (%)
Al_2O_3	98.5
SiO_2	1
Other	Balance

Table 4 Physical Properties of Alumina Oxide

Melting Point	2000^{0}C
Thickness of coating	100µm
Density	3.3
Porosity	Low
Bonding	Good
Emissivity	0.2-0.3
Thermal shock resistance	Very Good

The alumina coated material is shown in Figure 2

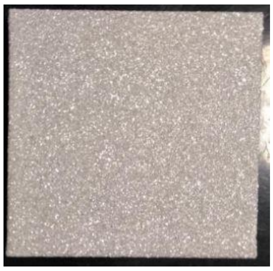

Figure 3 Alumina coated material

Alumina+40% Titania Coating

In this alumina Titania powder is coated to the aluminum plate (Specimen 2). The material plate dimensions are given in Table 5 , chemical composition of aluminum oxide are given in Table are given in the Table 6 and physical properties of aluminum oxide are given in Table 7.

Table 5 Specimen 2 dimensions

Specimen Material	Aluminum
Length of specimen	50 mm
Width of Specimen	50 mm
Thickness Specimen	10 mm

Table 6 Chemical Composition of alumina oxide

Typical Composition	Weight (%)
TiO_2	40
Al_2O_3	Balance

Table 7 Physical Properties of Alumina Oxide

Melting Point	1840^{0}C
Thickness of coating	100µm
Density	3.5
Porosity	Negligible
Dielectric Strength (volts/Mil)	Good
Emissivity	0.2-0.3
Thermal shock resistance	Very Good

The alumina + Ti 40 % coated material is shown in Figure 3

Figure 4 Alumina + 40 % Ti coated material

6.3 Vickers Micro Hardness Testing

The two coated aluminum materials and the uncoated aluminum are tested for the micro hardness on the vickers hardness testing machine. The results are tabulated in the Table 8

Table 8 Vickers Micro Hardness

Material	Aluminum	Alumina Coated	Alumina + 40% Titana Coated
Hardness Values (HV)	85.7	420.80	550.57

6.4 Scanning Electron Microscope (SEM) Analysis

The two coated materials are examined using the SEM for the microstructure. The Figure 5 shows the SEM machine, Figure 6 shows the two coated specimens mounted on the SEM specimens

Figure 5 Scanning electron microscope

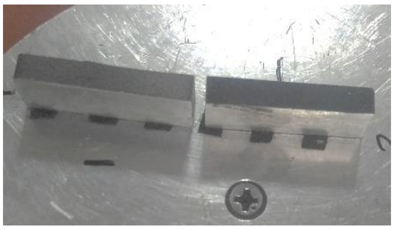

Figure 6 SEM Specimens

- Microstructures of Alumina Coated material

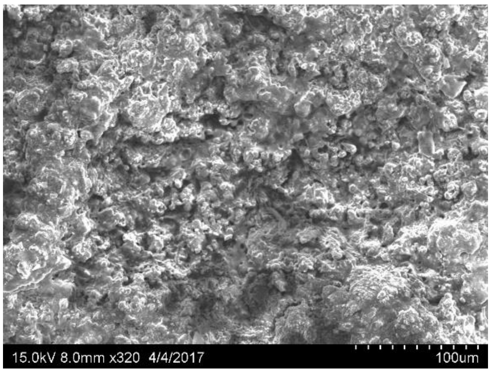

Figure 7 Microstructures of Alumina Coated material

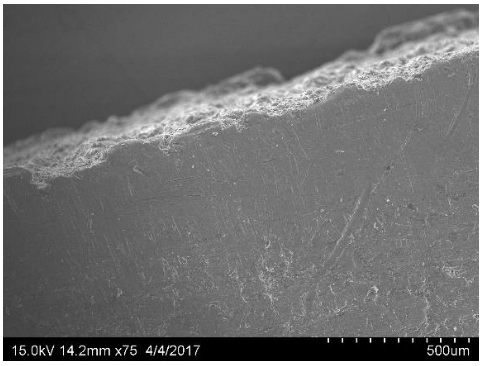

Figure 8 Microstructures of Alumina Coated material

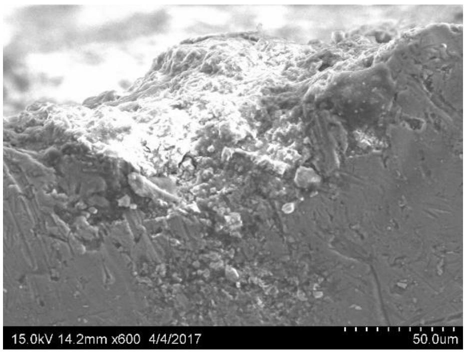

Figure 9 Microstructures of Alumina Coated material

- Microstructures of Alumina Titana Coated material

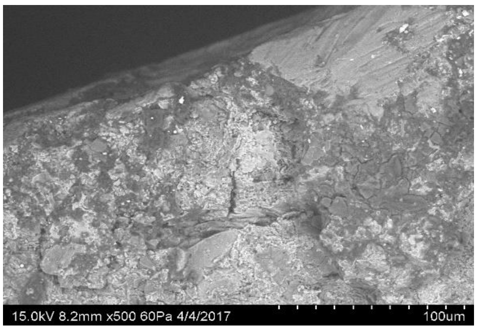

Figure 10 Microstructures of Alumina Titana Coated material

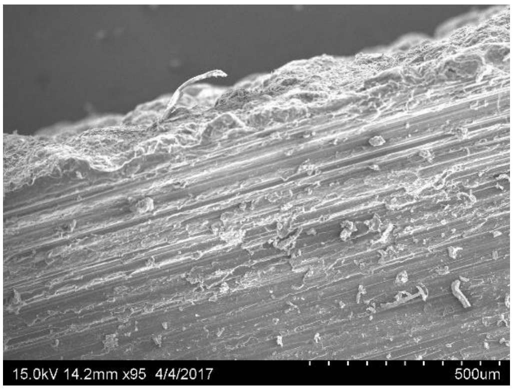

Figure 11 Microstructures of Alumina Titana Coated material

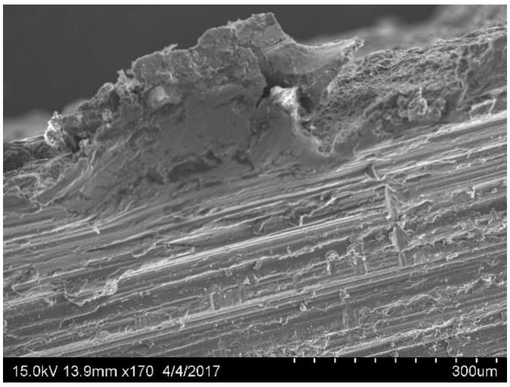

Figure 12 Microstructures of Alumina Titana Coated material

Conclusion

The present paper has investigated the difference seen in the two types of coatings by detonation gun in micro vickers hardness and SEM analysis. The major results can be summarized as follows:

- The micro hardness of the material had increased more in the case of Alumina Titania when compared with the uncoated aluminum and alumina coated material
- From the SEM photographs it is observed that the abrasion resistance is increased for the alumina Titania when compared with the alumina coated material
- The microstructures shows that the coating quality is good in the case of Alumina Titania
- The microstructures show that the corrosion is easily taking place in the alumina coated material than the alumina Titania Coated materials

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