Recent advancements in Thermal Spray Coatings

Baljit Singh
Dept. of Mechanical Engineering, DBFGOII, Moga, Punjab, India

Abstract

Within most industry segments, significant financial losses may be incurred due to accelerated wear of various components. In order to minimize the effects of mechanical wear and extend product life, thermal spray coating solutions introduced into production and is further developing them to meet even more demanding wear applications. Applying coatings using thermal spray is an established industrial method for resurfacing metal parts. The process is characterized by simultaneously melting and transporting sprayed materials, usually metal or ceramics, onto parts. In this paper some studies on Thermal sprayed wear resistant coatings have been reviewed.

Keywords
Thermal Spray, Detonation Gun, Wear, Wear Resistant Coatings

I. Introduction

Thermal spraying is a family of processes that use combustion or plasma energy to heat and accelerate the millions of particles, which impact onto the surface of a target/forming remarkable continuous uniform solid layer [1]. Thermal spraying is an effective and low cost method to apply thick coatings to change surface properties of the component [12]. Coatings are used in a wide range of applications including automotive systems, boiler components, and power generation equipment, chemical process equipment, aircraft engines, pulp and paper processing equipment, components, and power generation equipment, chemical process equipment, etc. [12]. For depositing wear resistant thermal spray coatings, the commonly used powders are WC–Co (with Co lying in the range 8–15 wt.%). Previous experimental studies have revealed that the hardness and elastic modulus of coatings obtained using the above powders are substantially lower than the hardness and modulus of bulk material of identical composition [5-6]. Indeed, these mechanical properties are dependent not only on the nature and distribution of phases present in the coating (largely determined by powder composition) but also on a host of other properties like coating microstructure (layered structure resulting from splat formation during the coating process), porosity, the nature of residual stress and its magnitude within the coating and finally the coating-substrate adhesion. The purpose of this paper is to present the development status of the Thermal spray wear resistant coating with Detonation gun.

II. Thermal Spray Processes

Thermal spraying can be used to apply coatings to machine or structural parts to satisfy a number of requirements: Repair worn areas on parts damaged in service Restore dimension to mismachined parts Increase a part’s service life by optimizing the physical surface properties The primary advantages of thermal spraying include the range of chemically different materials that can be sprayed, a high coating deposition rate, which allows thick coatings to be applied economically, and spray equipment portability. Heath et al [8] have summarized the thermal spray processes that have been considered to deposit the coatings, are enlisted below:

- Flame spraying with a powder or wire,
- Electric arc wire spraying,
- Plasma Spraying,
- High Velocity Oxy-fuel (HVOF) spraying,
- Spray and fuse,
- Detonation Gun.

III. Detonation Spray Process

Fig. 1, given below represents the detonation spray process in which 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 3500 m/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 1200 m/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 buildup 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.

VI. Studies Related to Thermal Spray Coatings

Wang et al [2] have tried to protect the conticaster rolls which were frequently out of operation due to severe working conditions. Rolls...
were coated with Cr$_3$C$_2$–NiCr detonation spray coating. Using the orthogonal test, suitable technological parameters were obtained. They concluded that the coatings were very dense with good bonding to substrate as well as high resistance to high temperature oxidation and wear. It was concluded from the results (obtained in service tests at one Steel plant) that the Cr$_3$C$_2$–NiCr detonation spray coating produced by authors has at least doubled the roll life.

Murthy et al [3] investigating the effect of grinding on the erosion behaviour of a WC–Co–Cr coating. As a part of this work a comparison has also been brought out between two high velocity coating processes namely High Velocity Oxy-Fuel (HVOF) and detonation gun spray process (DS). A WC–10Co–4Cr powder has been sprayed on a medium carbon steel using the above mentioned high velocity sprays processes. The coating in both ‘as-coated’ and ‘as-ground’ conditions has been tested for solid particle erosion behaviour. It has been found that surface grinding improved the erosion resistance. This work presents detailed characterization of the WC–Co–Cr coating in both ‘as-coated’ and ‘as-ground’ form. A detailed analysis indicates that the increase in residual stress in the ground specimen is a possible cause for the improvement in erosion resistance.

Yang et al [4] studied the effects of the powder particle size and the acetylene/oxygen gas flow ratio during the detonation spray process on the amount of molybdenum phase, porosity, and hardness of the coatings using MoB powder were investigated by X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), etc. The results show that the presence of metallic molybdenum in the coating results from decomposition of MoB powder during thermal spray. The compositions of the coatings are metallic Mo, MoB, and Mo$_2$B, which are different from the phases of the original powder. The amount of molybdenum phase increases monotonously with the oxygen/acetylene ratio, but the increasing rate for the fine powder is faster than that for the coarse powder. The porosity and hardness of the coating are related to the amount of molybdenum phase. The phase constitution of the coating is discussed.

Kharlamov et al [9] evaluated that detonation gun spraying, is a technique of thermal spraying, and achieves well-bonded dense protective coatings through ultra high velocity, medium temperature deposition of powders. In this paper the science and technology of detonation spraying reviewed related to other associated methods of thermal spraying (e.g. plasma spraying). Special attention centred on optimization methods for a range of engineering applications. The mechanism of formation of detonation-sprayed coatings will be discussed.

Sundararajan et al [10] have been deposited wide range of wear resistant coatings utilizing the detonation spray process and found that tribological performance of thermal spray coatings depends on a host of properties like coating composition, nature of phases and their distribution, microstructure, porosity and residual stress. The resulting coatings have been characterized in terms of phase content and distribution, porosity, micro hardness, and evaluated for erosion, abrasion and sliding wear resistance.

Murthy & Venkataraman [7] in their study deposited the tungsten carbide-based and chromium carbide-based coatings by high velocity processes like High Velocity Oxy-Fuel (HVOF) and Detonation Gun Spray (DS) techniques which are known to provide best wear performance for a variety of wear resistance applications. They compared the low stress abrasion wear resistance of these coatings. The abrasion tests were done using a three-body solid particle rubber wheel test rig using silica grits as the abrasive medium. Finally it was concluded that performance of DS coating is slightly better than the HVOF coating possibly due to the higher residual compressive stresses induced by the former process and WC-based coating has higher wear resistance in comparison to Cr$_3$C$_2$-based coating.

Rajasekaran et al [11] has investigated that influence of detonation gun sprayed alumina coating on Al–Mg–Si alloy (AA 6063) test samples subjected to cyclic loading with and without fretting. Coated samples were grounded to have coatings of two different thickness values, 40 and 100 μm. Under plain fatigue loading, 100 μm coated specimens exhibited inferior lives due to the presence of lower surface compressive residual stress compared with uncoated and 40-μm-thick coated samples. Under fretting fatigue loading, uncoated specimens exhibited inferior lives compared with coated samples owing to the very low hardness of the uncoated specimens). The reason for the superior fretting fatigue lives of 40-μm-thick coated samples compared with 100-μm-thick coated samples was the presence of relatively higher surface compressive residual stress in 40-μm-thick coated specimens.

J.P. Singla et al [12] evaluated that wear occurs on both surfaces when two surfaces are in contact. Surface coating is a best way to improve surface characteristics like increase the wear and corrosion resistance of steels. Detonation gun coatings are often considered to the premier coatings which are having very dense microstructure (0.1–1% porosity). It is used for coating of ceramics, cermets, composites, metals & alloys.

Manoj Kumar Singla et al [13] studied the results of CNT(Carbon nano tubes) reinforced nano composite coatings produced by thermal spray process. It is anticipated that, if properly deposited, nano composite ceramic coatings could also provide improved properties like wear resistance. Thermal sprayed nano composite coatings shows improvement of resistance to wear, erosion, corrosion and mechanical properties.

Singh et al [14] Materials are precious resources. Different methods are employed to protect the material from degradation. Thermal spraying is one of the most effective method to protect the material from wear, high temperature corrosion, stresses and erosion, thus increasing the life of material in use. Detonation gun spraying is one of the thermal spraying techniques known for providing hard, wear resistant and dense microstructured coatings. This paper summarizes the results of previous research done by various authors on different coatings done by detonation gun spraying technique.

Gill et al [15] Various techniques are employed to protect the material from degradation. As the wear is a surface phenomenon and occurs mostly at outer surfaces. Therefore it is more appropriate and economical to use surface engineering for making surface modifications. Detonation gun spraying is one of the thermal spraying techniques known for providing hard, wear resistant and dense microstructured coatings. This paper reviews the previous research done by various authors on different coatings done by detonation gun spraying technique.

Magdi et al [16] Cermets-based coatings are being increasingly used to combat erosion-corrosion in oil and gas industries such that occurring in offshore piping, production systems and machinery involving fluid and/or slurry flowing corrosive media which often contain solid particles such as sand. This leads to material/substrate damage caused by the combined surface degradation mechanisms of erosion and corrosion. This review assesses the erosion-corrosion resistance and performance of cement coatings.
applied by different thermal spraying methods. Electrochemical measurements, which monitor the erosion-corrosion mechanisms and coating integrity by themselves and when both erosion and corrosion act simultaneously are considered. In addition, surface characterization, and the extent of weight loss that covered through different combinations of cermet were reviewed.

V. Conclusion
It is possible to use the Detonation-Gun Spray system for developing protective Thermal spray coatings of almost any material like oxides, carbides, metals, hard alloys and composite material powders onto mild steel, and other EN series. There is no doubt that considerable progress has been made in the Detonation –Gun Spray process by optimizing the process parameters like Fuel Ratio, Carrier gas flow rate, frequency of detonations, and spray distance over the last few years. Applications of detonated sprayed coated components include gas turbine blades, camshafts, wire drawing pulleys, ball and gate valves, valve spindles, brake drums etc. Although Nano-structured coatings have been deposited by various other thermal spray processes like HVOF and plasma spray, however further studies are necessary to study the detonation sprayed nano-structured coatings on carbon nano tubes, Use of Thermally sprayed coatings on boiler steel to increase service life of boiler. Thermal spray coatings apply on grey cast iron to reduce wear and to test microbiological behavior of different Thermal spray coatings.

References

Baljit Singh is working as a Assistant Professor at Desh Bhagat Foundation Group Of Institution, Moga, Punjab, India. He is working on his Ph.D. in the field of mechanical Engineering.