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The Cold Spray Coating Process: A Future Technique in Material Deposition

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Abstract **- Cold Spray coatings is a material deposition technique from the broad family of thermal spray coatings with the difference of depositing spray particles at the temperature below melting point as it is a solid state process. The spray particles are impinged on the substrate with supersonic velocities. This paper imparts some light on application of this emerging technique with pros and cons. As this technique come up from last 20 years yet practical area is limited and confined to some research only. As this is a quite beneficial technique and help require from public/private sector to commercialize this technique and hope in coming years it comes up with a good growth in this area.**
Keywords: **Cold spray, coatings**

I. INTRODUCTION

An emerging solid state process quickly being adopted by many researchers and industries. It is capable of enhancing the various properties of substrate without effecting the original properties and there are no undesirable effects of process temperatures [1]. Cold spray is very much capable for coatings on various surfaces of different materials e: g Metals, Polymers and Composites etc. It also have the ability to prevent oxidation, residual thermal stresses, vaporization, etc. [3] Cold Spray finds attractive in industries working on advanced materials, such as nanotechnology.

It is a new tool introduced in the field of thermal spray coatings. Cold spray is also known by various names as Cold Gas Dynamic Spray, Gas Dynamic Spray, Kinetic Energy Metallization, and Kinetic Spraying. As a part of thermal spray coatings, Cold Spray produces coatings for large number of applications [1-4]. However cold spray produces coatings on vide range of materials at much lower temperatures and without any thermal effects [6]. This article reviews evolution, technology, applications and benefits of the most advanced / latest technique Cold Spray.

II. HISTORY

Thermal spray consists of a family of coating processes which are used for coating of metallic and non-metallic materials to different metal substrates [8]. In traditional processes, molten particulates formed from feedstock material (typically in powder, wire, or rod form) by combustion or electric arcing, which are then gathered and accelerated toward the substrate by a jet of hot gas [7]. The particles become splat when they strike on the substrate material and adhere to the substrate and upon solidification making a solid joint [9]. Thermal spray invented in late 1800s and was commonly known as flame spraying and was primarily used for applying protective coatings and to restore worn metal parts. It gain importance during and after World War II when thermal spray is widely used to repair tank and aircraft components [13-16]. Today, the number of applications for thermal spray is countless as they are widely used to improve nearly all properties of materials e: g resistance to corrosion, elevated temperatures, oxidation, and wear, etc. [18-19] Thermal spray found applications in power generation, aerospace, automotive, medical, heavy equipment, nuclear.

III. HOW DIFFERENT IS THE COLD SPRAY

Traditional thermal spray technology can produce coatings of high-quality on variety of materials, but due to their high process temperatures the deposits and substrates are exposed to oxidation, metallurgical transformations, and residual thermal stresses caused by the uncontrolled solidification rates of individual particles as they hit the substrate. It was the group of Russian researchers in 1980s at the invention of cold spray is credited to a group of Russian researchers working in the Institute of Theoretical and Applied Mechanics at the Russian Academy of Sciences in Novosibirsk. [20]. they demonstrated that the bonding of small particles (1-50 microns) on substrate could occur when they are imparted at supersonic velocities and forms a bond. This is how the cold spray differs from traditional thermal spray processes where particle velocities are generally lower, but particle temperatures can be quite high, as illustrated in Fig. 1

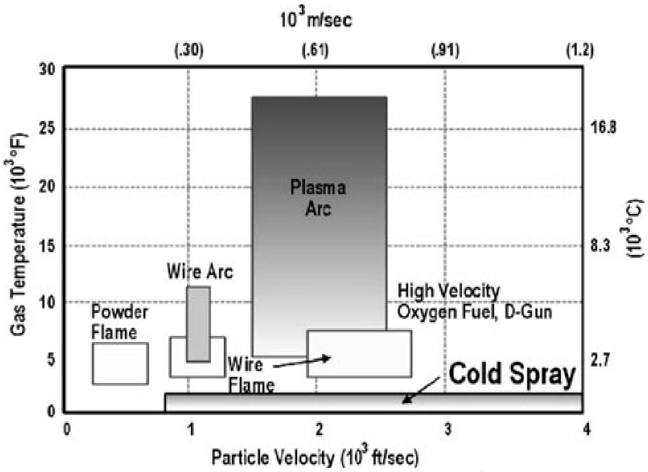

Fig. 1 Process temperatures and particle velocities of various coating processes [6]

IV. HOW DOES COLD SPRAY WORK

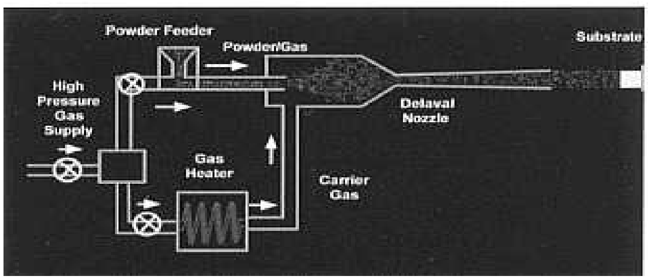

Fig.2 Setup of cold spray coating

In one setup (Fig. 2), the gases(helium or nitrogen) at high pressure is injected into a chamber under pressure and heated to 300°-700°C – which doesn't heat the particles, but used to increase the velocity of gas jet. Particles are feed through Powder feedstock into the gas stream, which is not hot enough to melt the particles. The powder/gas mixture is then passed through nozzle where the particles are accelerated to supersonic velocities [21]. The particles at supersonic speeds impact the substrate with enough kinetic energy to produce mechanical/metallurgical bonding without melting and/or solidification. Upon deposition, there are very small microstructural changes, in Fig. 3.

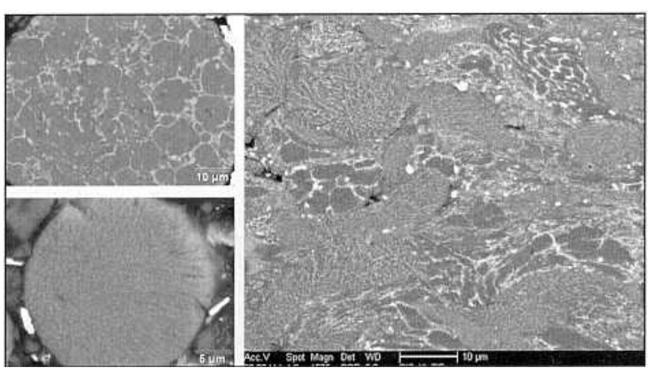

Fig. 3 Left: Particles of AA2618 aluminium alloy with equiaxed (top left) and columnar (bottom left) grain structures. Right: Cold spray deposit produced with a blend of these two powders showing the preservation of the original grain structure for each of the powder constituents (Ref. 5) (Photo courtesy of the University of Ottawa, Canada.)

For different material, there are different range of supersonic velocities for the bonding , if the velocities are above the range , the deposition efficiency is considerably high and if it is below this critical velocity range, then the particles are likely to cause some irregularities i:e surface erosion due deflection of particles.

The critical velocity ranges for pure metals such as Cu, Fe, Ni, and Al have been estimated at greater than 550 m/s [21]. In an advancement of this technology [22], the position of the powder feedstock is made downstream into the nozzle (Fig. 4).

This eliminates the requirement for injecting powder into a pressurized compartment and avoids potential nozzle erosion and clogging. Only clean dry air at 80-90 Ib/in is required for its operation. The air is preheated to 200°-400°C inside DYMETTM gun [22] to increase the velocity to supersonic velocities at the diverging section of the nozzle.

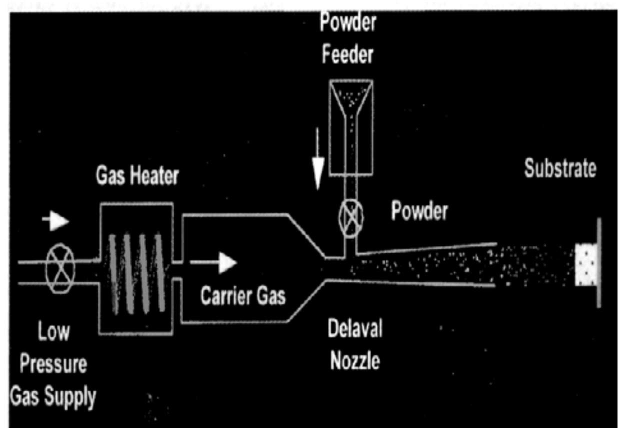

Fig.4 Schematic diagram of a variant of the cold spray process, where the powder is injected downstream in the DeLaval nozzle [22].

By using this method, a wide selection of materials can be deposited, including metal mixtures, metal alloys, cermets, epoxy resins, polyurethane, and thermoplastic polymers, over wide range of substrates [29-30].

V. APPLICATIONS

Cold spray technology is an advancement of well-established thermal spray coatings enhancing the scope and methods of coatings. The various applications of cold spray technology are in Table 1[15-25].

TABLE I THE VARIOUS APPLICATIONS OF COLD SPRAY TECHNOLOGY

Applications	Examples
Metal restoration and sealing	Engine blocks, castings, molds, dies, weld joints, auto body, HV AC, refrigeration, cryogenic equipment, heat exchangers [22]
Thermal barriers	Aluminium piston heads, manifolds, disc brakes, aircraft engine components
Heat dissipation	Cu or AI coatings on heat sinks for microelectronics
Soldering priming	Microelectronics components and printed circuit boards
Electrically conductivecoatings	Cu or AI patches on metal, ceramic, or polymeric components [12]
Dielectric coatings	Ceramic coatings for aerospace, automotive, and electronic packaging
Antistick properties	Deposits Impregnated with release agents such as PTFE or silicone
Friction coatings	Rolls for papermaking
Localized corrosion protection	Zn or AI deposits on affected helms, weldments, or other joints in which the original protective layer has been affected by the manufacturing process
Rapid prototyping and near-net manufacturing	Well-defined footprints. Fabrication of parts with custom composite or gradient structures
Biomedical	Biocompatible/bioactive materials on orthopedic implants, protheses, dental implants. Porous coatings of these materials on load-bearing implant devices facilitate implant fixation and bone in. growth, replacing cements and screws
Wear-resistant and decorative coatings	Numerous applications

VI. SUMMARY

Cold spray coating is future and an advancement of coating processes. This is not the replacement of the existing processes but an additional process to enhance the processes. Cold spray coatings has a huge benefits in coating of boilers and incinerators to increase there life by preventing them from various defects . It is expected that the coming years see the progressive growth of this process.

VII. ACKNOWLEDGMENT

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