Cold Spray

Synonyms

Kinetics Spray, Supersonic Spray, Cold Gas Dynamic, Cold Gas Spray, Cold Gas Dynamic Manufacturing.

Definition

Cold Spray (CS) is a solid-state additive process, whereby material layers are added onto substrates or more general engineering components through the acceleration of the feedstock material (in the form of powder) up to supersonic speed in a converging-diverging nozzle. Melting temperatures in the process are never reached.

Theory and Application

Introduction and Working Mechanism

In the 1980s, a group of scientists from the Institute of Theoretical and Applied Mechanics of the Siberian Branch of the Russian Academy of Sciences (ITAM of RAS) in Novosibirsk, Russia, conducted experimental and theoretical work on the interaction of a two-phase flow with the surface of immersed bodies. They used new gas dynamics diagnostic tools to study two-phase flow around bodies, which resulted in the discovery of some sort of "deposition phenomena". The scientists had in fact observed thin Copper layers deposited on the back walls of the wind tunnel they were using; soon after they realized the mechanism and formation of such was from a small amount of copper "dust" propelled at high velocity on the walls. As many of the most successful inventions in engineering, also this one happened totally by chance.

A number of USSR patents followed to the initial discovery of the technology; however, in its modern form Cold Spray (CS) was patented in 1994 in the US by A.P. Alkhimov and A.N. Papyrin (A.P. Alkhimov et all. 1994).

Despite the simplistic working principles, CS is an efficient additive technology whereby material is added to a general substrate in a solid-state manner, hence melting temperatures are never crossed. As shown in Figure 1, a supersonic converging-diverging nozzle is fed with a high pressure gas (nitrogen or helium at pressures between 10 and 50bar), which expands as it flows through the nozzle internal profile. Supersonic speed is therefore reached at the exit of the device (M>2). At the same time, solid particles (~40μm in size) are injected at the inlet of the nozzle. The generated fast jet stream can accelerate the particles up to velocities to cross 1000m/s; upon impact against a substrate material the particles will plastically deform and bond to it. Hence the formation of a deposit. In most cases the carrier gas is also pre-heated before entering the nozzle through a Gas-Heater; this is to increase the sonic speed, hence exit velocity.

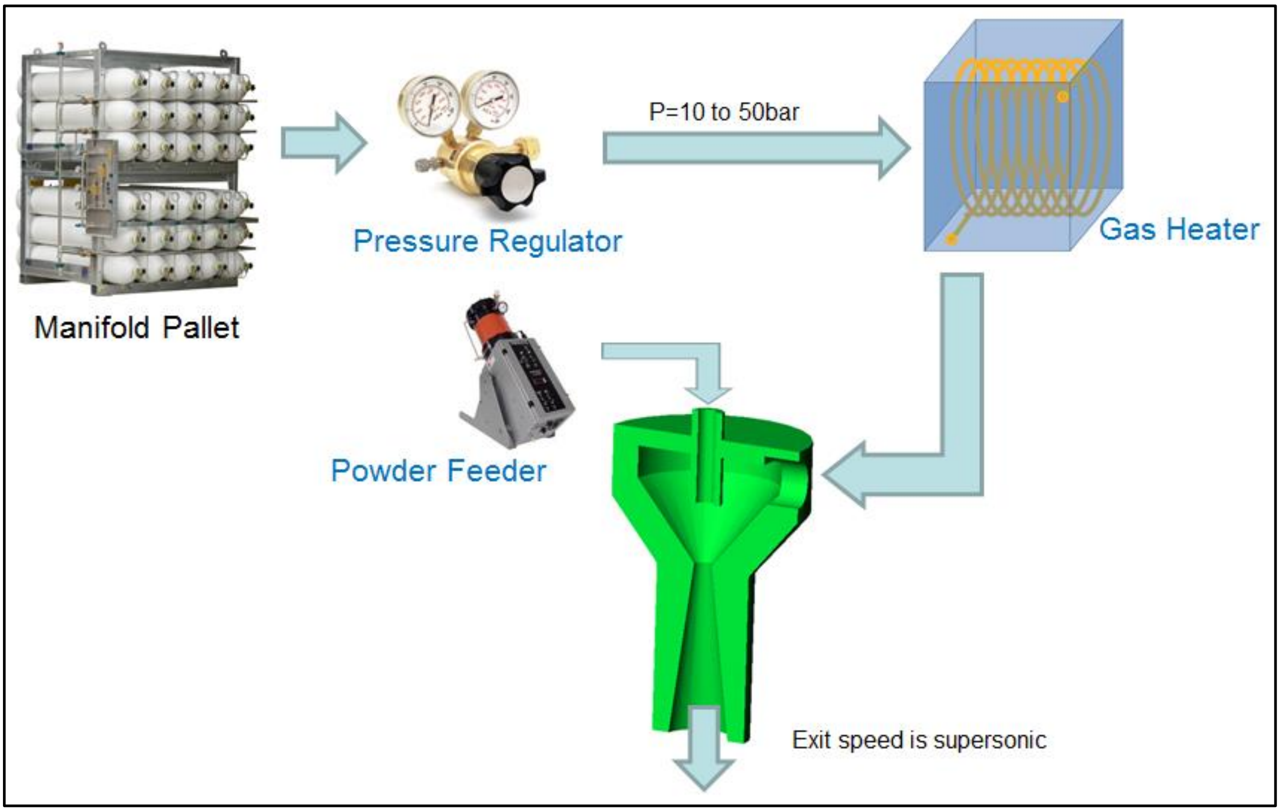

Figure 1: Cold Spray working principles.

In CS each material is therefore characterized by a “Critical Speed”. Such is the minimum to be achieved at impact for the deposit to start forming. Strong materials (such as Ti and its alloys or WC-Co) have a high critical value, they will therefore require the use of helium to be processed (helium is a low density gas with high sonic speed).

CS has a number of technical advantages, over other methods that are based upon the partial or full melting of materials, such as Laser Cladding, HVOF and Plasma/Flame spray (V.K. Champagne 2007):

- The preservation of feedstock properties, no microstructural changes.
- There is no Heat Affected Zone (HAZ) at the deposition interface.
- Deposition rates (or build rates) can be very high.
- Environmentally friendly relative to others due to the ambient temperature working conditions.
- No theoretical limit in achievable deposition thickness.
- No thermal distortion and good bond strength.

- Metallurgical compatibility feedstock/substrate is in theory not a requirement.

Since its invention and first implementations CS has rapidly evolved at both European and Global levels with a rather diverse field in terms of generated Intellectual Property (E. Irissou et al. 2008). A number of major companies have formed in across the globe, primarily coming from University spin-outs and currently selling CS equipment. Research is very active in the field, with the main groups located in Ireland (Trinity College Dublin), the UK (University of Cambridge, University of Nottingham, The Welding Institute - TWI), in France (School of Mines – Paris) and Germany (Federal Armed Forces University - Hamburg, European Aerospace Research Institute- EADS). There are other key research facilities in Spain, US, Japan, Canada, Russia, South Africa and Australia.

Examples of Applications

A vast variety of feedstock/substrate material combinations has so far been attempted with the process, with reasonably good results. The major advantage is its flexibility and absence of the thermal component; however CS can be an expensive process to run. When helium is required, processing costs become industrially not viable. This is the reason of why the vast majority of CS systems is currently installed in R&D facilities (such as Universities or Research Institutes) and not in production lines. Research is active in this topic, therefore in the proposition and testing of new solutions so as to address the cost problem.

The list below provides some examples of recent applications, in relation to the deposition of:

- Hard-facing materials, such as WC-Co, onto steel (S. Dosta et al. 2013).
- Super-Alloys (D. Levasseur et al. 2012).
- Reactive materials, such Al/CuO mixtures (A. Bacciochini et al. 2013).
- MAX-phases (H. Gutzmann et al. 2012).
- Tantalum (M. D. Trexler et al. 2012).

Recent work has also highlighted the potential for CS to be used for alternative purposes, such as joining. As an example Figure 2 shows two axial-symmetric components (approximately 30mm in outer diameter), made out of Ti64. They were joined through the application of a Ti64 track around the geometry using CS. This work is interesting due to the not suitability of Ti and its alloys to be welded using conventional thermal processes due to its high affinity to oxygen.

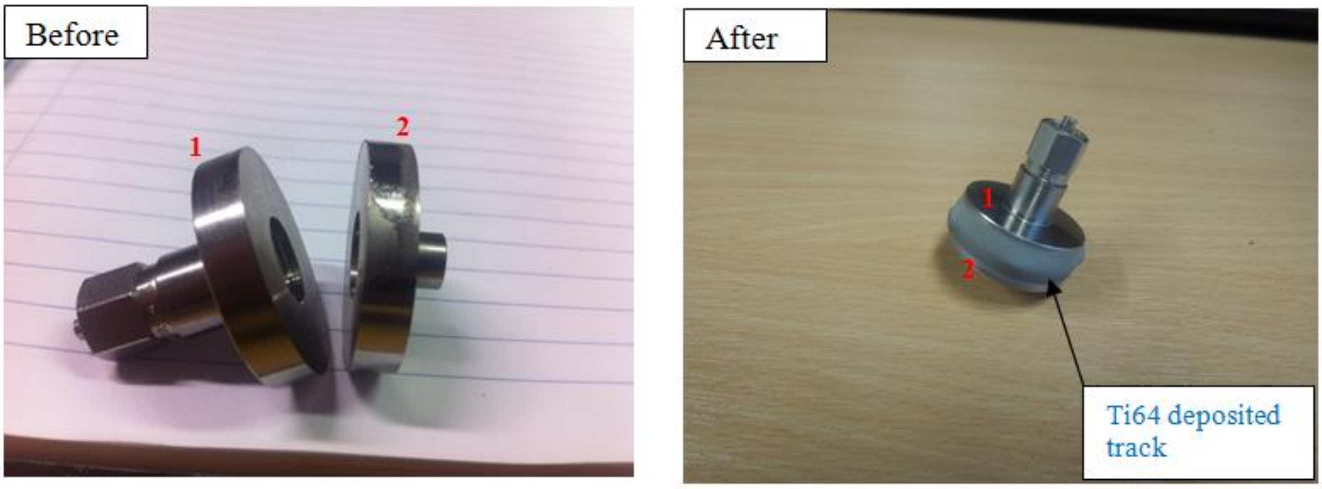

Figure 2: Joining Ti64 components with CS (courtesy of Trinity College Dublin and University of Twente).

Cross References

Coating

Additive Manufacturing Technologies

Additive Manufacturing

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