œrlikon
metco

Article 1: An Introduction to Thermal Spray Technology

by Steve Bomford
Training and Application Support Manager

I know that there are many of you out there that already have a deep understanding of the thermal spray process and equally, I am sure, some of you reading this article have come across this process for the first time. One thing I have learned over the years is that with thermal spray, every day is a school day!

With that in mind, I've decided to put virtual pen to paper and pass on some of my learnings from over the past 38 years. These may well be somewhat personalized, so don't take everything completely to heart…

In the coming weeks, the plan is to publish a series of articles concerning thermal spray opportunities and challenges. Hopefully you will enjoy reading them. Of course, if there are any subjects that you would like to follow up in more detail, please feel free to drop me a line and I will do my best to help.

So, What Is This Thermal Spray Process?

Well, it's nothing new. The Thermal Spray process is generally accepted to have been invented by Dr Max Ulrich Schoop from Zurich, Switzerland. The (possibly allegorical) story goes that he was playing with his son firing molten lead from a canon when he noticed it sticking to a wall. Whether this is true or not, in 1909, Dr Schoop successfully patented the use of a combustion process to melt wire and propel it directly onto a substrate. He secured his second patent in 1911, which incorporated an electric arc as a production heat source. Thermal spraying was born…

Figure 1: Dr Max Schoop and his electric arc wire invention.

Over time, the process developed. The ability to build-up worn components without concerns over part distortion and heat effects meant that the combustion wire process was uniquely suited to the need to quickly turnaround items needing repair as a result of military activities in the Second World War. Tank and ship parts could be rapidly made fit for service again.

It's difficult now to imagine the working conditions that existed back then, but as you can see, the gentleman in Figure 2, while multitasking, is a little short on what we would now classify as required PPE (Personal Protective Equipment)!

Figure 2: Combustion wire spraying with a Metco gun back in the mid 20th century.

Figure 3: Manual air plasma spraying (APS) with the Metco 3MB gun.

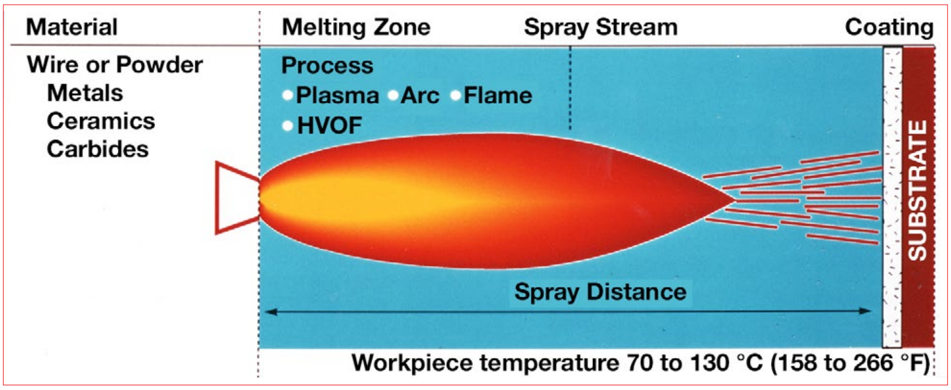

Figure 5: The basic principles of the thermal spray process

Jumping forward a couple of decades takes us into the world of plasma spray. In some ways the work-horse process of the thermal spray industry, this technology benefited from advances in the world of powder manufacturing techniques to produce coatings with a multitude of properties . The energy generated by an ionized gas was now available to transform a multitude of material compositions into functional deposits.

As you can see in Figure 3, our friend now has access to some improved PPE. While this may not be up to current standards, at least there is now some well earned eye protection available.

Thermal Spray Processes

Over the years, the thermal spray process has evolved to meet the need of a huge number of distinct applications with different challenges. Fortunately, this has provided the market with a complete range of complementary processes capable of meeting these demands and more! Figure 4 shows a view of the main (but by no means all) processes on offer and in particular how they are categorized into sections based on their respective energy sources.

The Basic Theory

Whatever the thermal spray process chosen, it will utilize the same basic operating principles as detailed in Figure 5. A material (normally either a powder or a wire depending on the process being used) is fed into a heat source. The material is softened (or melted) and accelerated via the heat source and process gases before it “splats” onto the surface to produce a coating. Key process variables are therefore the particle temperature and particle velocity. Both of these factors will have a profound influence on the ability to deposit the material to provide the desired coating properties.

Thermal spraying is characterized as a metallurgically cold process. This means that heat transfer to the substrate is low and therefore concerns over part distortion and negative effects on material properties are minimized. The coating bonds to the substrate via a mechanical adhesion process, so suitable substrate preparation via a roughening process is typically required.

The Thermal Spray Top 3…

The top three thermal spray processes are, of course, up for debate, but in the interests of available content space, I will go for…

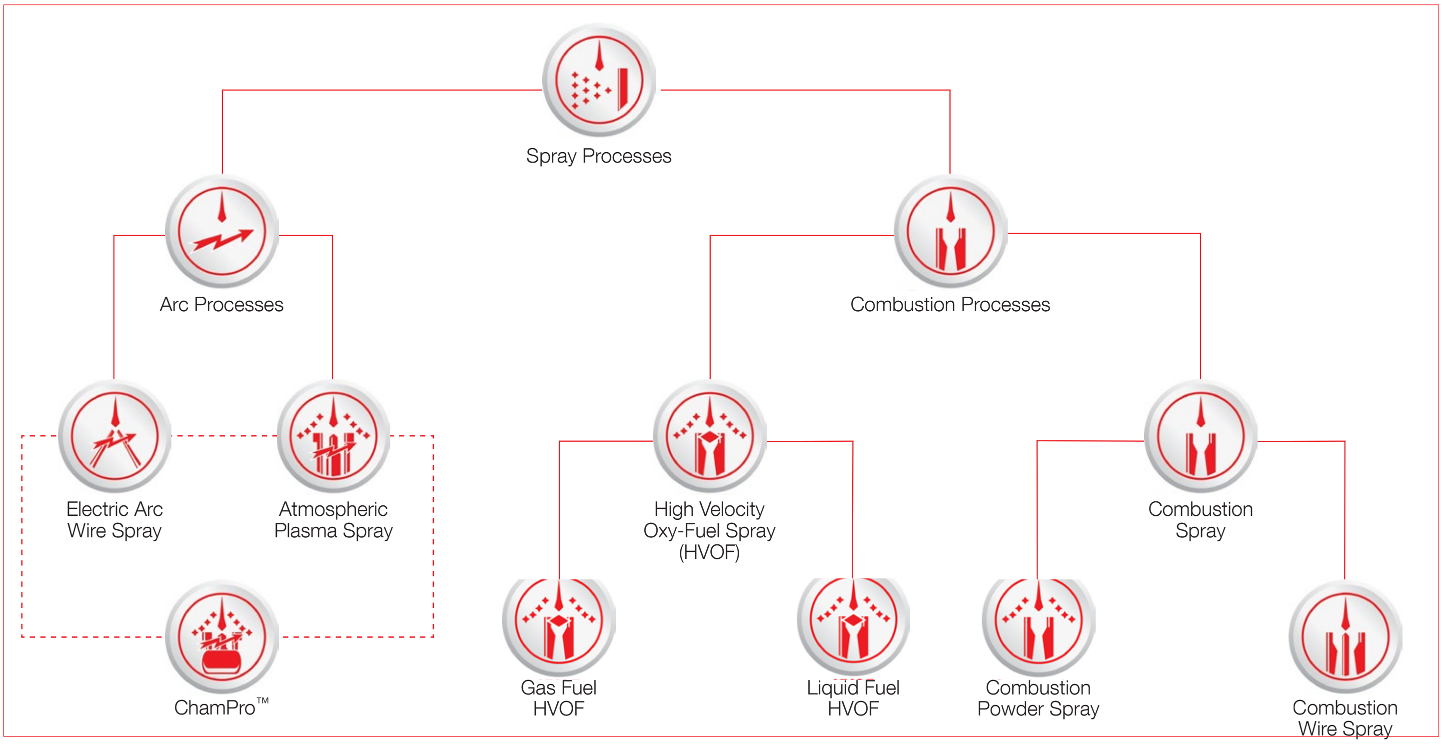

Figure 4: Overview of the main thermal spray processes.

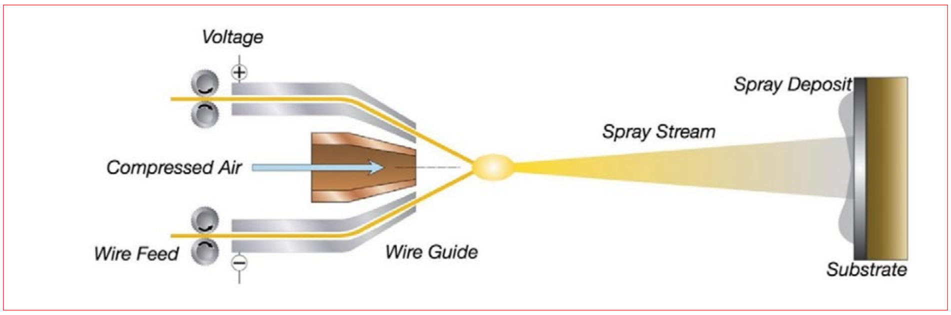

Figure 6: Electric arc wire spray

Number 3: Electric Arc Wire Spray
Electric arc wire spray uses two metallic wires as the coating material. They are electrically charged (one wire negatively charged, the other positively charged) and fed into the arc gun. When the wires are brought together at the nozzle, the opposing charges on the wires create an arc and heat to continuously melt the tips of the wires. Compressed air (or an inert gas) is used to atomize the now molten material and accelerate it onto the workpiece surface.

Capable of producing excellently bonded metallic coatings with a wide variety of functional properties, this process is used extensively in a broad spectrum of industries. From anti-corrosion coatings for Offshore applications to high specification dimensional restoration deposits in the aerospace sector, electric arc wire spray has proven itself to be a flexible tool for hand-held and automated processes.

In fact, when used for the demanding requirements specified in aerospace, it has replaced more traditionally used deposition techniques for metallic coatings. Operators see shorter spray times because of the high wire feed rates employed as well as fewer issues with dis-bonding of coatings during machining. A win-win situation!

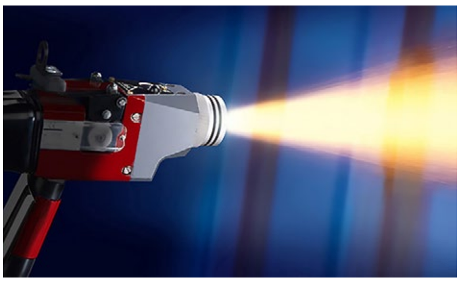

Figure 7: LD/U2 electric arc wire spray gun

Number 2: High Velocity Oxygen Fuel (HVOF)
In fact, I'm cheating a little here as I've thrown in two processes for the price of one! HVOF gas-fuel and HVOF liquid-fuel.

Typically, with HVOF-GF, an oxygen-fuel gas mixture is ejected from a nozzle and ignited externally of the gun. The ignited gases form a flame. Powder is injected axially into the combustion zone. The powder exits the gun through the flame and is propelled to the workpiece. In the case of the Oerlikon Metco Diamond Jet™ HVOF gun (cross-sectioned in Figure 8), the process also uses compressed air or an inert gas to cool the internal workings of the gun as well as reducing negative reactions of powder particles with the outside atmosphere.

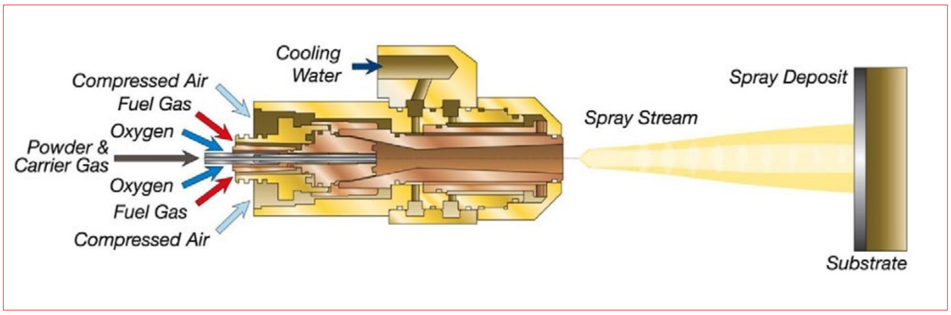

Figure 8: The HVOF gas fuel (HVOF-GF) process

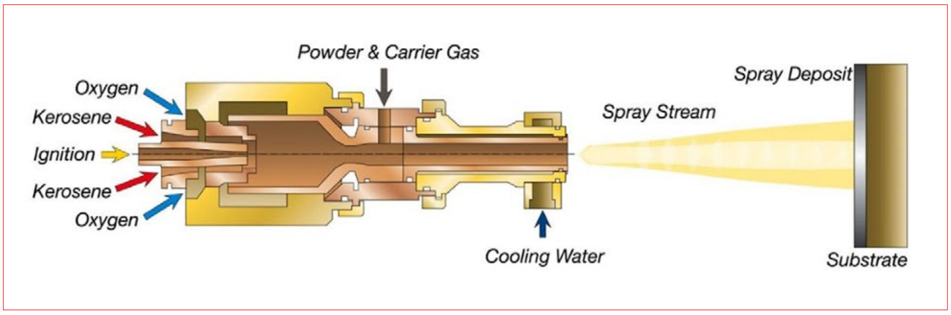

Figure 9: The HVOF liquid fuel (HVOF-LF) process

Figure 10: WokaStar™ 610 HVOF-LF spray gun

In the case of HVOF-LF, an oxygen-kerosene mixture is injected into a combustion chamber within the gun. Either a pilot hydrogen flame or a spark plug will ignite the flame. Powder is injected radially into the combustion zone. The powder exits the gun through its barrel and is propelled to the workpiece.

A late-comer to the list of thermal spray processes, HVOF was invented in the 1980s by Jim Browning. Interesting fact that Jim's invention was originally designed to be a rock-splitting tool! It quickly changed application direction and became the forerunner of the HVOF guns we are familiar with today.

The key characteristic of HVOF is the exceptionally high particle velocities (supersonic in most cases). This enables deposits produced to exhibit very high bond strengths together with low porosity levels. The resultant coatings are used widely where properties such as exceptional wear and corrosion resistance are mandated.

Number 1: Air Plasma Spray (APS)
Last, but by no means least, is air plasma spray.

By generating an ignition between an electrically positive pole (anode/nozzle) and an electrically negative pole (cathode/electrode), an arc is generated. Through the pressure of the gas, the temperature of the arc increases, the gas ionizes and a plasma develops. Once parameters have stabilized,

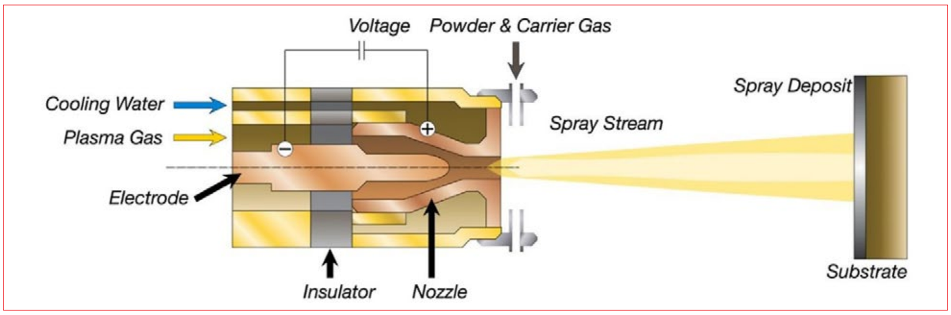

Figure 11: The (traditional) air plasma spray process

powder is injected into the plasma jet; the powder particles soften and reach the surface of the workpiece at high velocity creating a coating.

The APS process is an enormously flexible one. The high level of enthalpy available together with the wide range of sprayable powder compositions means that it is applicable to a wide range of applications. Coatings can be applied that resist wear (carbide containing materials), offer high temperature insulation (Thermal Barrier Coatings — TBCs), improve corrosion performance in extreme environments (MCrAlYs, e.g., materials containing cobalt and/or nickel with chromium, aluminum and yttrium). The list goes on.

The future is also very bright for plasma spraying. The development of cascaded arc technology has created a more stable and higher enthalpy plasma system. The extended arc produced (see Figure 12) allows for higher feed rates, more efficient deposition and less process variability. All things the market desires.

This is just really a taste of where we are with thermal spray. The world is in constant change and we at Oerlikon Metco strive to keep pace with new developments. I hope, therefore, in the coming months to keep you abreast of these, as well as filling in with some historical anecdotes along the way.

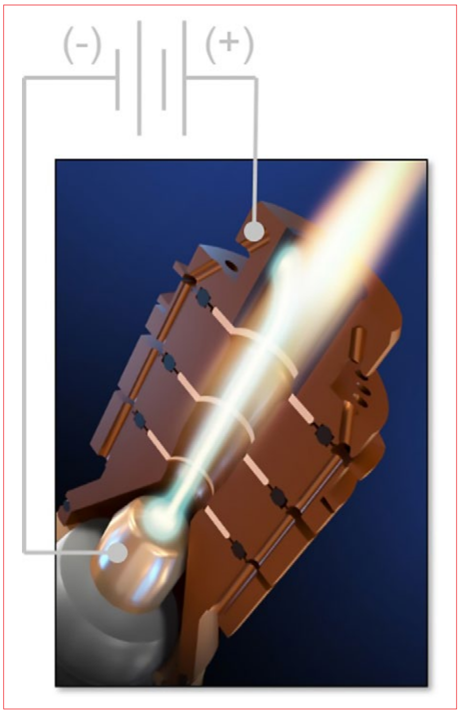

Figure 12: Cascaded arc plasma spray hardware cross-section

A Note From the Author

Dear Friends and Colleagues,
I know that many of you reading this are senior technical experts in thermal spray, while some are just starting on the thermal spray learning curve. I the hope of providing interest, education and entertainment to all, I have decided to write my version of the thermal spray process review. The plan is to publish a blog of short articles, related to the thermal spray. The idea behind this is to give you a subjective overview of the process and the latest developments in the world of thermal spray. This overview may well be wide and varied. It will not focus on too many technicalities, but it should hopefully provide an entertaining summary enabling a better understanding of the technology and its advantages. If you are a more experienced reader, I would like to invite you to join me in the discussions, ask questions, and leave your personal opinion. If there is a related topic you want me to write an overview of, I will be happy to consider that. I hope it will be interesting to read and will be happy to get your feedback.

www.oerlikon.com/metco
info.metco@oerlikon.com