COATINGS

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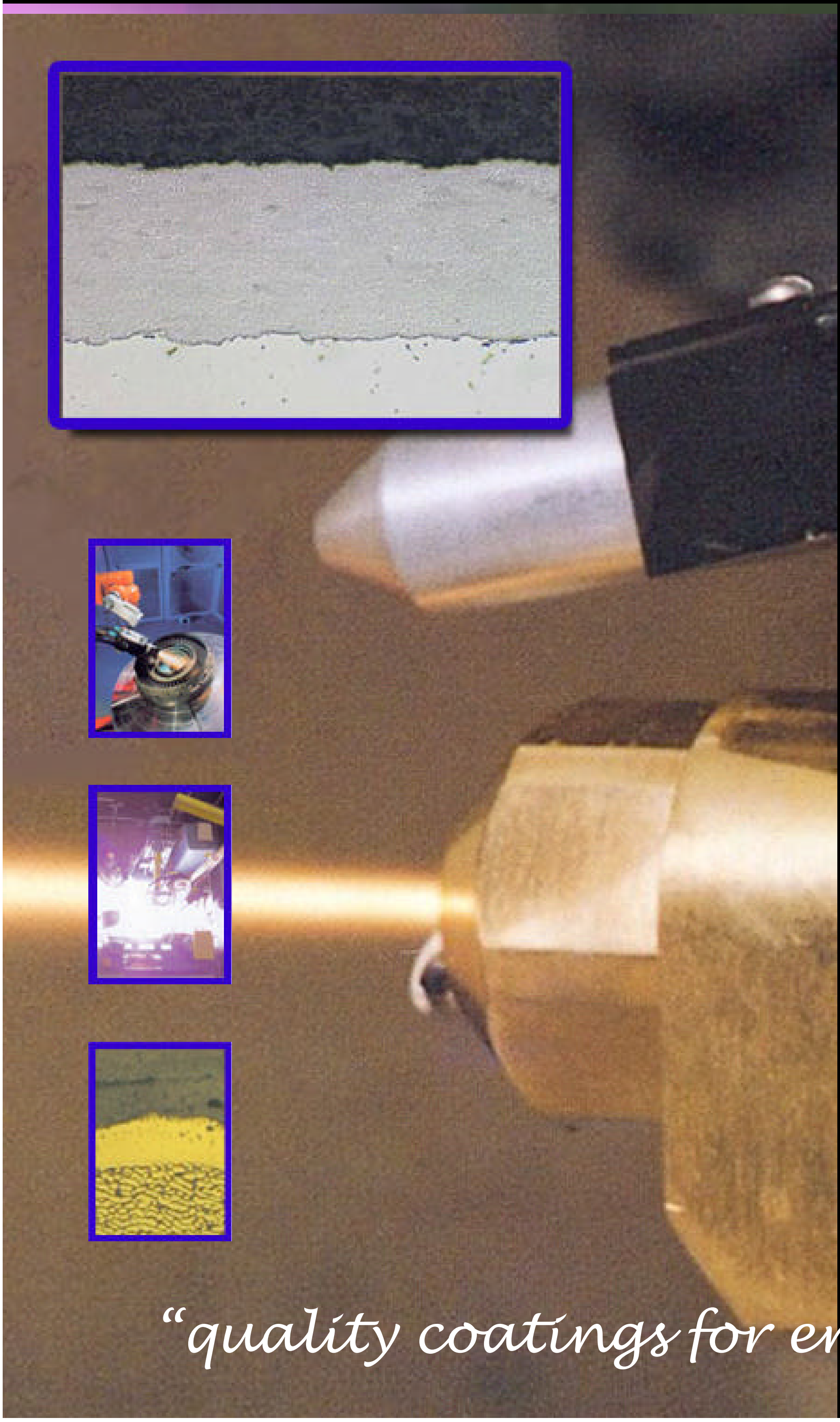

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“quality coatings for engineers”

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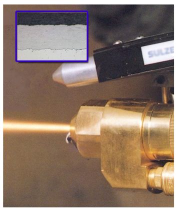

Micro of Diamalloy® 5824 (Wc Co 83 17) sprayed using Oxygen & Natural gas. The coating was achieved using the Sulzer Metco Diamond Jet ® System with standard DJ2600 hardware.

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Improved Deposition Efficiency and Bond Strength of Flame Sprayed Aluminium Coating Using the Liquid Withdrawal Propylene Delivery System

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The supply of fuel gases such as propane and propylene for flame spraying equipment has traditionally been by gas withdrawal from LPG containing cylinders. The cooling effect of the fuel gas during high levels of withdrawal due to its latent heat of evaporation will subsequently cause problems in maintaining pressure and flow rate. With modern thermal spray equipment looking to increase productivity by increasing coating deposition rate, the fuel gas flow rates and pressures of the flame spray process have increased beyond the safe capabilities of conventional manifold gas delivery systems.

This work looks at the use of the liquid withdrawal propylene system using nitrogen to back pressurize the cylinder forcing liquid propylene through a heated vaporizer. By controlling the inert gas back pressure and the vaporization of the liquid fuel gas, a constant pressure and flow rate can be achieved and maintained under any climatic condition and over any length of delivery hose using a single 47 kg cylinder. This liquid withdrawal method reduces both LPG cylinder holdings and cuts out some of the hazardous practices used to maintain pressure and flow rates.

The use of higher flame temperature propylene compared to the conventional propane fuel gas also improves the aluminium coating deposition efficiency and spray rate and also the relative bond strengths of the propylene sprayed aluminium over propane sprayed aluminium. Achieving offshore standards such as NORSOK 501 are not only made more economical through increased deposit rates but also increasing potential bond strength by 100%.

Introduction to Flame Spraying

The basic flame spray process is simply the spraying of molten metal onto a surface of a component to provide a protective coating. Materials such as aluminium and zinc in a wire or powder form are atomised in an oxygen fuelled combusted gas flame while the resultant atomisation and propulsion using compressed air forms a fine spray. When the spray contacts the prepared surface of a substrate material, the fine molten droplets rapidly solidify forming a coating. This well established flame spray process has been extensively used in the past for machine part rebuilding work and anti-corrosion coatings. There are many advantages in using the flame spraying process over other thermal spray procedures such as High Velocity Oxygen Fuel and plasma spraying. These advantages include limited capital investment, lower operating costs for wire and gas consumables, high deposition efficiency while being a portable system with the ability to work in remote areas. All these process benefits have led many thermal spray contractors to deposit flame spray coatings on jobs of considerable surface area. Corrosive protection of steel bridge and offshore structures, reclamation of worn surfaces, electrical and thermal protection of many components all benefit from the fast, reliable and relatively economical flame spray process.

Fuel gas requirements for flame spray equipment

With high deposition efficiencies being a major feature of the flame spray process, the continued development and marketing of flame spray equipment has concentrated not unsurprisingly on increasing their deposit rates. Flame spray guns such as Sulzer Metco 14E and Metallisation Ltd Mark 73 promote spray rates of up to 12kg/hr for aluminium, 15kg/hr for copper and 50kg /hr for zinc. To maintain these deposit rates it is essential that sufficient heat energy be transferred into the wire to soften and melt the material in order to form a dense coating without significant levels of un-melted particles. In the arc spray technique, increased deposit rate is managed by increasing the amperage into the arc to generate the necessary thermal energy. In combustion spraying or flame spraying the energy levels are generated solely by its fuel gas combustion with oxygen. Historically acetylene (C_2H_2) and propane (C_3H_8) have been the fuel gases used for flame spraying, with acetylene recommended for the higher melting point materials such as molybdenum and tantalum, and propane being the most cost effective for zinc, copper and aluminium. Due to the low capital cost and portable nature of flame spraying, it is important that the gas supply systems be of a minimum size and quantity. Installation with other thermal spray systems such as HVOF and plasma tend to be fixed multiple cylinder manifolds necessary to generate and maintain the high flows and pressures.

Flame spraying, having been around for 60 years has changed little over that period especially the gas supply systems. Oxygen has predominantly been supplied from compressed gas cylinders either singly cylinders in packs or bundles as shown in Photograph 1. In its compressed form, oxygen pressures and flow rates are easily supplied for all ranges of equipment, differing coating materials and all deposit rates. From a single cylinder, holding around 10m^3 of usable gas the current maximum flow rates is around 4m^3 / hr resulting in cylinder lasting just over two hours. This spray time for the larger spray jobs is too short and would still require the cylinders to be changed, or multiple cylinders to be used. However the limiting factor in flame spraying over longer periods is with the fuel gas supply and not the oxygen.

Figure 2 *Shows a typical propane and oxygen supply system for flame spray process*

Propane

Propane (C_3H_8) or LPG is a single bonded hydrocarbon generally stored as a liquid in 60kg cylinders holding 45kg of usable product, which equates to 25m^3 of propane gas. Typical flow rates for flame spraying with propane is around 1.4m^3/hr so in theory there should be over 17 hours of spraying per cylinder. This appears initially to be considerably more practical then acetylene as a fuel gas option. An achievable flow rate from a 46kg cylinder is around 3.2kg/hr (1.7m3/hr) at 15^{0}C when the cylinder is full. However like acetylene, the gas withdrawal rates from LPG cylinders decreases as the contents of the cylinders reduces. At 50% empty, the gas withdrawal rate of a propane cylinder still at 15^0 C now decreases to only 2m^3/hr. This withdrawal rate reduces still further to 1m^3/hr when only 20% full. This results in a significant proportion of the LPG cylinder, estimated at around 30% is unusable for flame spraying at 15^{0}C and therefore wasted product. As temperatures drop below 15^{0}C and approach 0^{0}C, the withdrawal rate declines to 20-30%. This reaches a situation were a cylinder 50% full operating at 0^{0}C can only supply 0.9m^3/hr. Therefore to maintain the flows required for flame spraying using propane, multiple cylinders manifold together is essential as shown in Figure 1. but still with significant product loss.

Portable Liquid Withdrawal Propylene Delivery System

In order to overcome the problem with fuel gas withdrawal for flame spraying, it was necessary to look at a previous solution used to supply propylene to HVOF systems. High velocity oxygen fuel flow rates are significantly higher when compared to flame spraying with the added requirement of maintaining high-pressure not necessary for flame spray. The liquid withdrawal propylene system uses inert nitrogen as an artificial back-pressure to force liquid propylene out of the standard 46 kg cylinder. This is done via an adapted dual port cylinder valve which has a gas inlet valve and liquid outlet valve connected to a dip-tube. When withdrawing liquid from a cylinder there is no adiabatic drop in cylinder temperature as experienced with gas withdrawal cylinders. The liquid propylene is withdrawn from the cylinder is then passed through a 3 kW water-heated vaporiser, were all the liquid is vaporised into gas. The system used for HVOF is a fixed installation typically wall mounted as shown in Figure 2 with trace heated lines downstream of the vaporiser to avoid any re-condensation back into a liquid.

A solution for the flame spray fuel gas withdrawal rate problem was to adapt the larger wall mounted liquid withdrawal system for use in remote locations supplied from a smaller size single cylinder but providing the necessary flow rate and with no significant product loss (<3%). The dual port cylinder valves used on the 46kg size cylinders were used on the smaller 23kg cylinders. The larger 3 kW

Figure 2 *Shows a wall mounted liquid withdrawal propylene delivery system with inert gas back pressure using nitrogen and 3kW-waterbath vaporiser*

water heater was replaced with a smaller 1kW copper block vaporiser supplied by 110v at a fraction of the weight. The vaporiser can either be hooked onto the collar of the cylinder shown in Figure 3 or floor mounted next to the cylinder. The unit has indictor lights showing when the heater is up to the required temperature allowing liquid via a solenoid valve to enter the vaporiser coil. A pressure relief valve and flash back arresor are incorporated into the system to avoid over-pressurisation of the unit and protect the cylinder from flashbacks.

Figure 3 *Shows a typical propane and oxygen supply system for flame spray process*

Due to the lower pressure requirement of flame spraying, generally around 344 kPa (50psi), it was not necessary to use nitrogen as an inert gas back pressure to force the liquid out of the cylinder as the natural vapour pressure of the cylinder is sufficient even at low temperatures. With an estimated spray time of over 8 hours per cylinder at a typical flame spray flow rate, these cylinders are an ideal size and weight for remote access sites.

Benefits of Propylene over Propane

The portable vaporiser unit can be used with LPG, propane and propylene. For HVOF, propylene is generally specified for its purity compared to propane with the added benefits of increased flame temperature. In most cases propane has been the recommended fuel gas for flame spraying due to its relatively cheaper cost and worldwide availability. When higher melting point materials such as molybdenum are sprayed, acetylene is then recommended.

By using propylene with its improved flame temperature over propane table 1. it is possible to achieve a greater degree of softening of the atomised materials within the flame. This is primarily down to its higher level of liberated heat of combustion (kJ/kg) with oxygen and a 75^{0}K increase in maximum flame temperature compared to propane. A further benefit of using the liquid withdrawal propylene method over gas withdrawal is its ability to increase both the flows of oxygen and fuel gas which potentially can increase the deposition rate of coating material. The deposit rate of flame spraying is generally limited by the fuel gas flowrate taken off a standard gas withdrawal cylinder determined by its vapour pressure. Increasing spray rates, using larger diameter wire, higher wire feed rates and increased compressed air flows are always desirable but restricted by the lack of energy within the combustion flame to fully soften the atomised wire. With this design of delivery system, the fuel gas flow rate is restricted only by the size of the vaporizer and design limitation of the flame guns.

A further benefit of propylene over propane for flame spraying is its

Tanle 1 Compares the different fuel gas properties of propane with propylene

	Propane	**Propylene**
Heat of combustion (kJ/kg)	2632	2833
Maximum flame temperature (K)	3100	3175
Oxygen: Fuel gas requirement (maximum temperature)	4.3:1	4.7:1
Chemical formula	C_3H_8	C_3H_6

Fuel Gas	O$_2$ Flow Rate l/min	**Fuel Gas Flow Rate l/min**	**Wire feed speed kg/hour**	**Deposition Efficiency (%)**
Propane	66	19	5.16	70
Propylene 1	66	19	5.52	77
Propylene 2	66	22	7.18	81

Tanle 2 Flame spray aluminium parameters

oxygen requirement for its maximum flame temperature. The table shows that for propane to achieve its maximum flame temperature a ratio of 4.3:1 oxygen to propane is required. For propylene only 3.7:1 oxygen to fuel ratio is necessary. This means that for a greater temperature, 14% less O$_2$ volume is required when using propylene, which could be a significant saving on larger operations.

Experimental Trials using Propylene

Metalilisation Ltd's flame spray equipment has been associated with surface coatings and in particular corrosion protection since the early 1920s. The Metallisation Mark 73 flame spray system using propane is one of the highest deposit anti-corrosion guns available. Work carried out at Metallisation using propylene in place of propane showed an improvement in deposit efficiency and significant % increases in deposit spray rates.

Using a 4.76 mm Aluminium (99.9 wt%) wire using conditions shown in table 2. an experienced operator optimised the wire feed speed to give the highest achievable coating deposit rate. Using propane the gas conditions set permitted a wire feed speed of 5.16 kg hr^{-1} resulting in a deposition efficiency of 70%. By measuring the weight increase of coating on a large plate sprayed under these conditions for a constant period of time shown in photograph 3, a resulting deposit rate of 3.6 kghr^{-1} was measured.

Using the same pressure and flow rate settings for the optimised propane and replacing it with propylene, the operator was able to set a much higher wire feed speed based on the properties of the flame and wire characteristics. The results showed that using identical gas flow rates and pressures a wire feed rate of 5.52 kg hr^{-1} or 7% increase could be achieved. However results showed that the deposition efficiency also increased by 7% up to 77% delivering a deposit rate of 4.2 kg hr^{-1}

Table 1 shows that the oxygen to fuel ratio requirement of propylene is around 14% lower than propane. In order to achieve the maximum flame temperature properties of propylene its was either necessary to reduce the oxygen flow rate or increase the propylene flow rate to reach the correct ratio. In using the liquid withdrawal propylene delivery system it was possible to increase the propylene flow rate over that possible from a gas withdrawal cylinder system. In order to achieve higher flow rates it would require an increase in external heat or increase in the number of cylinders.

Propylene condition 2 shows a 10% increase in propylene flow rate over propylene 1 and propane conditions. This increase in flow gives the operator the ability to increase the wire feed rate up to 7.38 kg hr^{-1} which equated to a 37% increase in wire feed.

Conclusion

By modifying the existing liquid withdrawal propylene delivery system used for HVOF applications, constant pressure and flow rate can be guaranteed with smaller and lighter 23 kg cylinder ideal for remote flame spraying applications. The portable system supplies the necessary propylene pressure and flow rate under the most extreme climatic condition. This compares favourably to the conventional gas withdrawal propane systems that uses much larger and heavier 46 kg (product weight) cylinders often manifolded together while still requiring a recovery period between uses to maintain the flow rates. The portable system also reduced the significant fuel gas wastage when using the gas withdrawal system and can decrease the operating costs of flame spray aluminium especially on large surface area operations.

I would like to take the opportunity to thank Metallisation Ltd for the use of their facilities and equipment.

Ceramic coatings by HVOF spraying

Dr. Melissa Riley
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The topic covered in this article is part of TWI core research projects mainly concerning HVOF spraying of alumina.

The objectives of the work are to:

- **Determine the role of HVOF spraying parameters on coating properties**
- **To characterise the properties of ceramic coatings prepared by HVOF spraying**
- **To establish the range of ceramic coatings that can be prepared by HVOF spraying**

The main differences between the different thermal spraying processes are the particle temperature and particle velocity (Figure 1). Higher temperature processes such as plasma spraying may be unsuitable for spraying some materials due to oxidation, loss of elements from alloy powders and thermal transformations. The lower temperatures involved in HVOF spraying make it a better option for spraying metal and cermet coatings. Increasing particle velocities result in increased coating adhesion and cohesion and reduced porosity. However the reduced temperatures may mean the process is unsuitable for producing quality ceramic coatings.

The advantages of HVOF are:

- It produces high quality, low porosity and high adhesion coatings
- HVOF can be used to spray a variety of materials with coatings that may be from 2—50 mm thick
- Low heat input to the substrate
- Used for new parts and repairs
- Line of sight process
- Commercial process - there are over 80 systems in the UK alone and at least 1000 globally

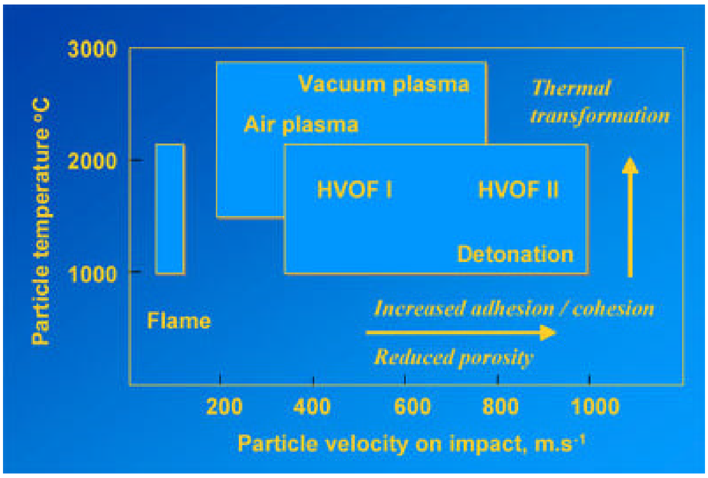


Figure 1 Comparisons between the different thermal spraying processes..

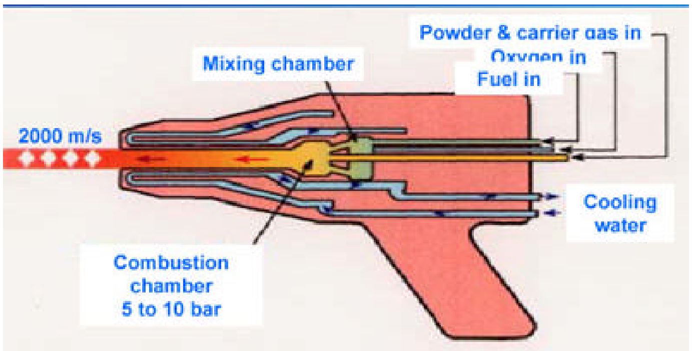


Figure 2 A typical HVOF spray gun

Typical fuel gases are hydrogen, acetylene and propylene. The oxygen and fuel gas are fed in and are then mixed in the mixing chamber. (Figure 2) The oxyfuel mix then combusts at high pressure and is accelerated out of the gun forming the high velocity gas jet. The velocity of the jet is approximately 2000m/s. The powder is fed in along the gun axis in this case, by a carrier gas such as argon or nitrogen. The particles are then completely or semi-molten in the combustion chamber before exiting the gun and impinging on the substrate to form a coating.

There is a wide range of commercial systems available which are all different in their design, fuels, and materials they can spray. The most common commercially available systems are shown in Figure 3. They are the Jet-Kote, TopGun, Diamond Jet and JP5000. The JetKote and TopGun have large combustion chambers. The JP5000 use liquid kerosene fuels whereas the Diamond Jet, JetKote and TopGun use gas fuels.

If looking to spray ceramic materials, however, then we must select a suitable spray system to enable us to melt the ceramic particles. The melting points of common ceramics are:

Titania	1850°C
Alumina	2050°C
Chromium oxide	2250°C
PYSZ	2700°C

Figure 4 shows the temperatures attainable with each of the HVOF systems we have installed at TWI using different fuels.

Figure 3 The most common commercially available HVOF spraysystems

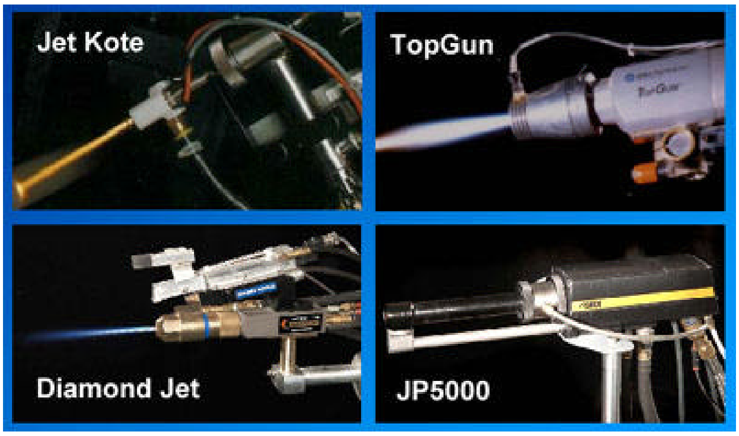
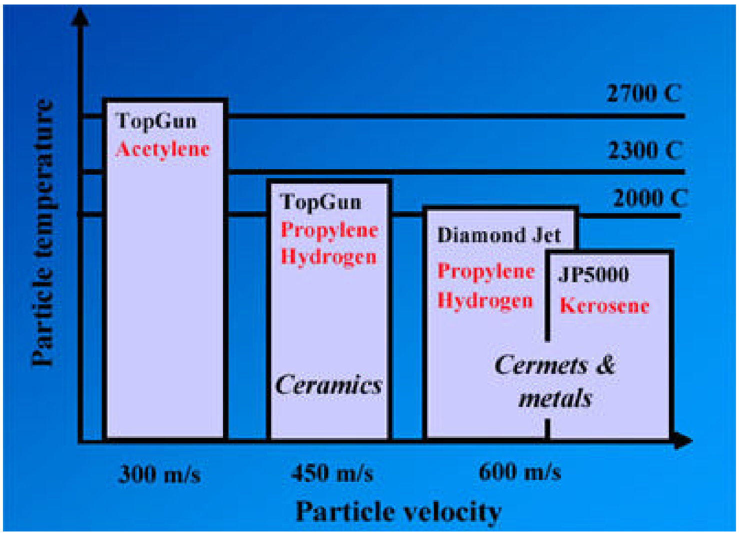


Figure 4 Typical particle temperatures and velocities attained in the most common HVOF systems.



Coatings produced by HVOF by the TopGun and DJ show similar properties although the TopGun coating exhibits slightly higher hardness (Table 1). The coatings exhibit similar properties to the DGun coatings. The roughness may be higher due to the coarser powders used with the DGun.

Most ceramic coatings however are deposited by plasma spraying processes. The air plasma coatings are produced at much higher temperatures but exhibit similar porosity. The higher roughness is again likely to be due to the coarser starting powders. The hardness of the coatings is higher than the HVOF coatings but not significantly.

From this data it appears there are no advantages in using HVOF as it is a high cost process. However, as you will see later HVOF coatings offer a significant improvement in wear resistance compared with other processes.

Figure 6 shows the XRD phase analysis for the alumina starting powder and deposited coating. The starting powder is a Al_2O_3. When sprayed the powder is melted and then rapidly quenched and solidifies when it hits the substrate. The coating produced contains a mixture of α and γ alumina.

Looking at this and the literature and previous work it can be seen that the TopGun and Diamond Jet systems are the most suitable for spraying ceramic materials due to the high temperature requirements. The highest temperature can be achieved using TopGun and acetylene fuel.

Also TopGun has a large combustion chamber which means that the particles are within it for longer periods giving more opportunity for melting before they exit the gun.

The JP500 has a large chamber but because it uses kerosene fuel combustion occurs at a lower temperature than TopGun using either hydrogen, propylene and acetylene gas.

Figure 5 shows a typical alumina coating deposited using the TopGun system with hydrogen as the fuel gas. The coating is dense with little porosity. Some pores exist put this may be due to polishing. The coating shows good adhesion to the substrate.

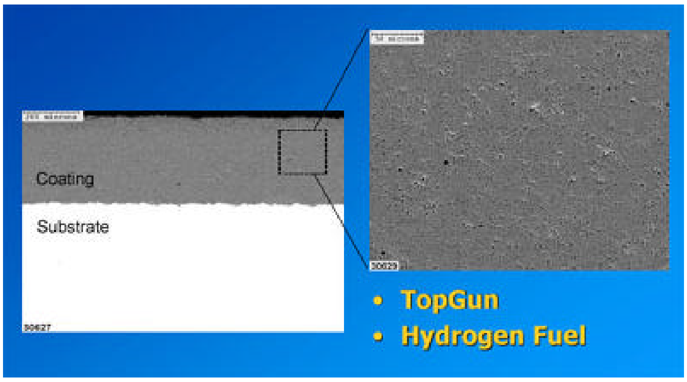


Figure 5 A typical alumina coating deposited using the TopGun system with hydrogen as the fuel gas.

Process	Type	Micro Hardness (± 100)	Surface Finish (mm Ra)	Porosity (%)
TopGun	Hydrogen	1215	1.3	1.6
Diamond Jet—Hybid	Hydrogen	1198	2.0	2.0
D-gun	LA2	1128	6.1	2.0
Air plasma	PT F4 MB	1290	3.8	2.0
	MT SG100	1400	4.4	2.0

Table 1 Showing the properties of alumina coatings produced by different thermal spray processes

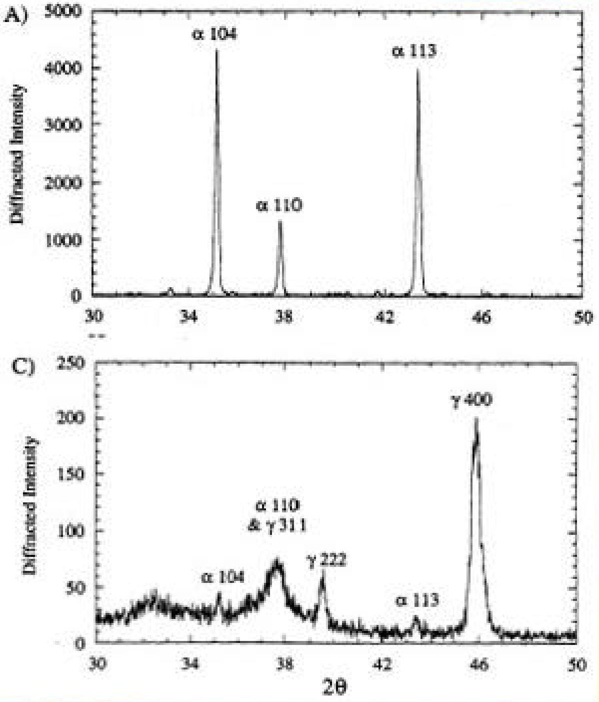
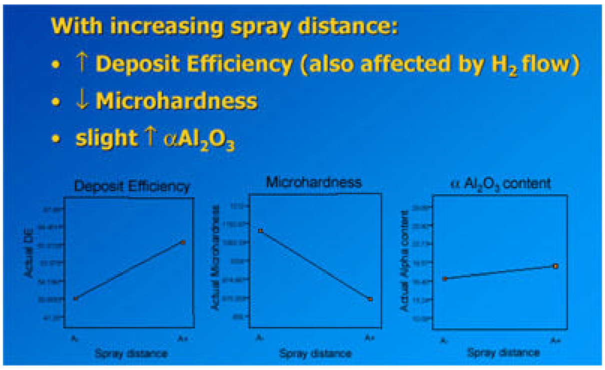


Figure 6 Phases present in the powder and applied Al_2O_3 coating.



With increasing spray distance:

- **↑ Deposit Efficiency (also affected by H_2 flow)**
- **↓ Microhardness**
- **slight ↑ αAl_2O_3**

Figure 7 The effects of spray parameters on coating characteristics

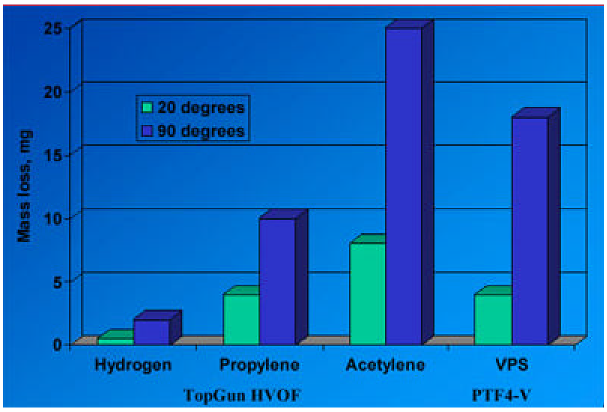


Figure 8 The effects of spray parameters on coating characteristics

Table 2 shows typical αAl_2O_3 contents for HVOF and plasma sprayed alumina coatings A higher degree of particle melting in the flame gives better deformation of the particles on impact with the substrate. The liquid droplets flatten out on impact before crystallisation starts to occur. If the impacting particle is completely molten then the particle will recrystallise as γAl_2O_3. If particles are not completely molten then they will contain residual α. However, γ alumina is less desirable than αAl_2O_3 as it is softer and hydroscopic (absorbs water) but the coatings produced are more dense and cohesive if the impacting particles are completely molten. Therefore there is a conflict between the two.

Table 2 αAl_2O_3 contents for HVOF and plasma sprayed alumina coatings

System		aAl_2O_3 %
TopGun	Hydrogen	10
	Propylene	35
	Acetylene	36
APS	PT F4 MB	7
	MT SG100	8

The effects of spray parameters on coating characteristics are shown in Figure 7 This shows that spray distance is an important factor which needs to be controlled. From design of experiment work on the HVOF spraying of alumina using hydrogen fuel it is apparent that the spray distance has an effect on the deposit efficiency, microhardness and % αAl_2O_3.

With increasing spray distance the deposit efficiency increases. This is also affected by hydrogen flow. The microhardness decreases whilst there is a slight increase in αAl_2O_3.

Based on this data a series of optimised coatings were produced which were then subject d to wear testing.

Table 3 Erosion test conditions

Parameter	Value
Impact angles	90° and 20°
Impact velocities	50 m/s (0.15 bar)
Erodent	Silica sand (~200µm)
Feed rate	1 g/min
Specimen position	15 mm from nozzle end
Nozzle internal dia.	6.3 mm

The wear performance of alumina coatings has been investigated using erosion and abrasion testing. In the erosion test silica sand is impacted onto alumina coatings at 90° and 20° angles at 50m/s. The specimen is located 15 mm from the end of the nozzle and the powder is fed through at 1g/min.

The results of tests on thermal sprayed alumina (Figure 8) show that the best wear performance is obtained for HVOF coatings produced using the Top Gun system and hydrogen fuel. A low mass loss indicates low wear and there will always be more damage produced at an angle of 90° compared with 20°C where the abrasive particles will only skim the coating. The wear performance of the HVOF coating is superior to those produced by vacuum plasma spraying. However the wear performance of the coatings produced by HVOF also depends on the fuel gases used. Hydrogen has been shown to produce the most wear resistant coatings followed by propylene and acetylene.

Wear has also been evaluated using a rubber wheel sand abrasion test in ac-

Parameter	Value
Lubrication	Dry
Abrasive	Quartz grain size ~200µm
Abrasive flow rate	250-300 g/min
Surface speed	8.6 km/h
Load	100N
Test duration	60 min
Wear length	8.6 km

Table 4 Rubber wheel and sand abrasion test details as defined in ASTM G65-91

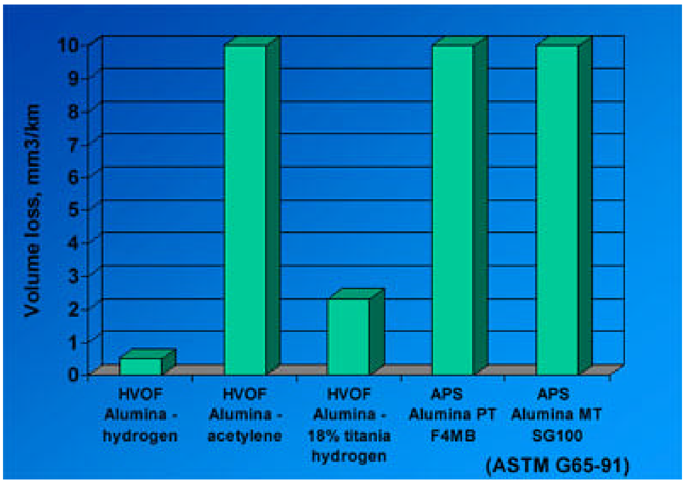


Figure 8 Wear abrasion test results for the alumin coatings tested as defined in ASTM G65-91.

cordance with G65-91. (Table 4)
The sample is pressed against a rubber-rimmed wheel with abrasive silica introduced between the sample and the reel. The grain size is 200mm and flows at 250-350 g/min. The wheel rotates at 8.6 km/hr with a load of 100N. The test duration is 1 hour, which equates to 8.6 km wear length.

Again alumina HVOF coatings produced using hydrogen fuel show superior wear performance compared with air plasma sprayed coatings. However, for HVOF coatings produced using acetylene the wear performance is comparable with APS coatings. Alumina-titania coatings produced by HVOF with hydrogen fuel also show low wear rates compared with APS.

The reason for the improved wear resistance may be greater amounts of cohesive bonding and less microcracking in the coatings due to the reduced amounts of particle cooling in the HVOF process. Although HVOF is more expensive than APS it offers superior wear resistant coatings.

Figure 9 shows a typical alumina coating produced using the TopGun system. Al-1110-HP powder manufactured by Praxair consisting of αAl_2O_3 with a particle size of –22/+5µm. The coatings produced consist of α and γ Al_2O_3 and have a microhardness of 1190_{HV}, a roughness of 1.53µm and adhesion of 38 MPa. The deposit efficiency is 68%.

Figure 10 shows an alumina 3% titania coating sprayed using the TopGun system. The starting powder was ALO-278 consisting of a Al_2O_3 and titanium oxide in two forms. The particle size was again –22/+5 as this had been shown to feed through the gun well. A dense coating was produced with a microhardness of 1120_{HV}.

Figure 11 shows an alumina 13% titania coating sprayed using the TopGun system and hydrogen fuel. The powder used was ALO-188 manufactured by Praxair with a slightly larger particle size than the previous ones of –31/+5µm. The starting powder consisted of a Al_2O_3, rutile and aluminium titanium oxide. The coating produced had a microhardness of 1110_{HV} and porosity of 1.9%.

Figure 12 This is a chromium oxide coating produced using the TopGun system and acetylene fuel. The starting powder is Al 1025 TG manufactured by Praxair with a particle size of –22/+5µm consisting mainly of αCr_2O_3. The microhardness is approximately 1600_{HV} and roughness of 2.5µm with the coating consisting of aCr_2O_3.

Figure 13 shows a yttria partially stabilised zirconia coating produced using the TopGun system and acetylene fuel. Acetylene is the only fuel gas that can be used to spray zirconia using the TopGun system due to the high melting point of the material (2700°C).

The starting powder is Metec 1081 SF with a particle size of 3-44µm consisting of a mixture of tetragonal/monoclinic PSZ with 8% yttria.

The coating produced has a microhardness of $600\text{-}1000_{HV}$ and a surface

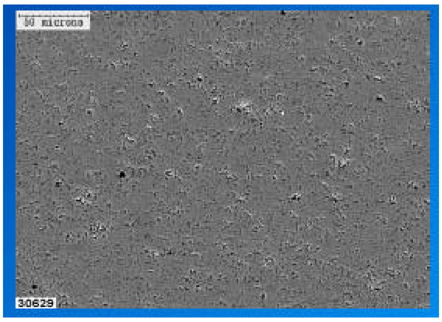


Figure 9 Typical alumina coating produced with the TopGun system.

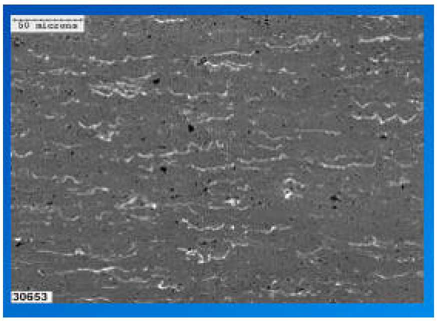


Figure 10 Typical alumina 13% titania coating produced with the TopGun system.

Figure 11 Typical alumina 13% titania coating produced with the TopGun system.(H_2)

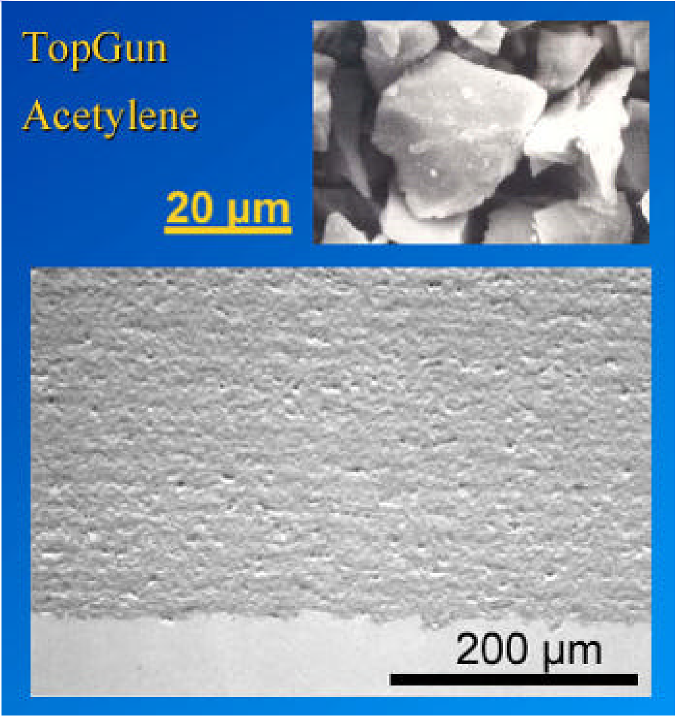


Figure 12 Chromium oxide coating produced using the TopGun system and acetylene fuel.

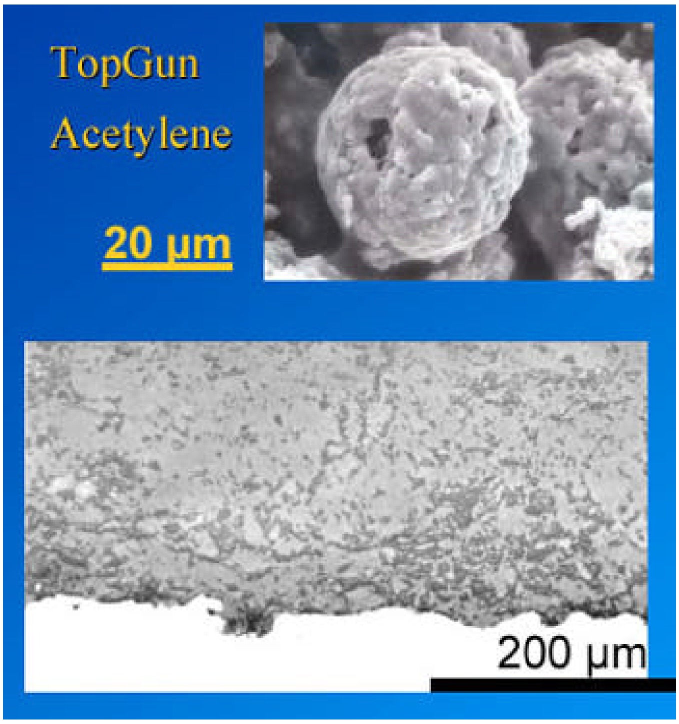


Figure 13 Yttria partially stabilised zirconia coating produced using the TopGun system and acetylene fuel.

roughness of 2.6µm and is mainly a tetragonal structure.

Conlcusions

In summary this work has demonstrated that HVOF spraying can be used to prepare oxide ceramic coatings.

These coatings have similar characteristics to plasma sprayed coatings i.e. low porosity and high hardness.

Although the process is a higher cost than plasma spraying, coatings with superior wear resistance can be produced.

This paper was originally presented at the TSSEA Annual Conference 16th July 2003

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Australia Manufacturing Offered Leadership in Cold Spray Technology

Dr. Mahnaz Jahedi &
Dr. Cameron Begley
CSIRO Manufacturing & Infrastructure Technology
Australia

Cold spray technology, or cold gas-dynamic spray technology, is a revolutionary and rapidly emerging industrial coatings technology, which offers wide opportunity for Australian manufacturing.

Cold spray, or more appropriately 'room-temperature spray' technology, unlike traditional thermal spraying, applies metal and alloy particles at temperatures much lower than the melting temperature of either the coating or substrate.

The distinguishing feature of cold spray is the ability to produce coatings with a gas jet temperature, which is lower than other processes such as powder flame, wire arc, plasma arc and high-velocity oxygen fuel. This eliminates the detrimental effects of high temperature on coatings and substrates It is a revolutionary system that avoids the raft of high-temperature effects such as oxidation, vaporisation, melting, crystallisation, residual stresses and gas release.

Not surprisingly, Dr Mahnaz Jahedi of CSIRO Elaborately Transformed Metals, offers enthusiastic descriptions of cold spray technology.

'It is the next milestone for the thermal spray industry', say Jahedi.

CSIRO, and Dr Jahedi in particular, have made it possible for easy access to the development of cold sprayed, exotic coatings for Australian industry, by importing the first cold spray system to Australia.

CSIRO says that there are useful applications for cold spray technology in just about any industry utilising thermal spraying: from the biomedical industry where it can be used for prostheses with improved wear characteristics (Figure 1), to the aerospace industry where it offers coatings of greater fatigue resistance, to the chemical and mineral processing and die casting industries, to applications in the electronics, paper, oil, gas and glass industries.

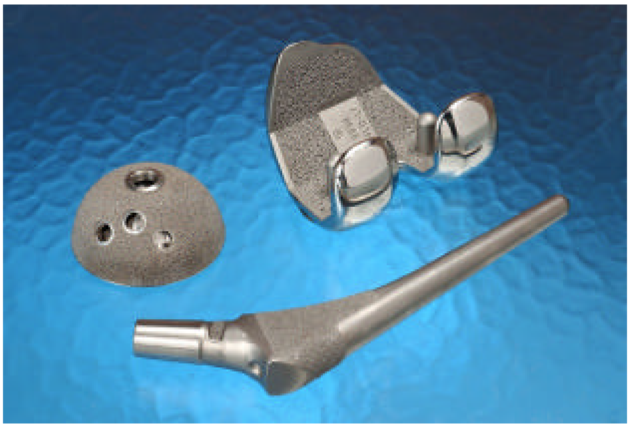

Figure 1 Prostheses with cold spray technology applied to improve wear resistance.

Dr Jahedi says, 'By virtue of its "low temperature" nature, cold spray technology is also expected to be useful for the 70% of materials which could be sprayed but are ruled out by the high temperatures required by current thermal technology'.

What is cold spray technology?

Conventional 'thermal spray' processes require the sprayed materials to be preheated so the particles are in a semi-molten state when they reach the substrate, allowing them to splash across the surface. But as the 'splats' cool, they contract slightly, creating residual (stored) stresses or flaws at the interface that can cause subsequent defects within the coating later.

Cold sprayed materials typically remain at or near room temperature until impact, slamming into the substrate so fast (500-1500 m per second) that a tight bond is formed without the undesirable chemistry changes and stresses associated with conventional thermal processes.

Dr Jahedi says, 'Researchers believe this high-velocity impact disrupts thin metal-oxide films on the particle and substrate surfaces, pressing their atomic structures into intimate contact with one another under momentarily high interfacial pressures'.

Cold sprayed materials experience little to no defect-causing oxidation during flight, and exhibit remarkably high densities and conductivities once fabricated.

Other possible uses of the technique include fabricating layer by layer, low-defect small piece parts, joining chemically dissimilar materials with bonds that graduate from one material composition to another, and as a low-temperature alternative to welding.

Cold spray as a fabrication process also has some significant advantages in developing industrial prototypes and advancing new design quickly, and comparatively inexpensively, compared to the usual prototyping processes.

'Direct fabrication for more cost-effective product development is a major plus', says Dr Jahedi.

However, utilising the process for specific applications require tailoring by CSIRO. Dr Jahedi says research is required to identify the best materials, particle sizes and impact velocities as well as an examination into gas dynamics, plastic deformation, and spray nozzle configurations for each job.
Advantages of cold spray technology

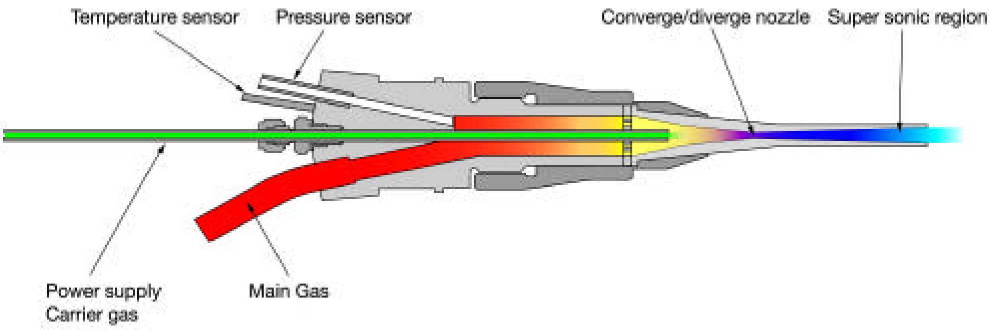

Figure 2 Schematic of a cold spray gun.

- Retains properties of initial particles
- Deposition of oxygen-sensitive materials without vacuum
- High deposition efficiencies
- Low oxide content
- High density
- High thermal and electrical conductivity
- High hardness, cold work microstructure
- Low residual stresses
- Fatigue-resistant coatings
- Corrosion-resistant coatings
- Minimal grain growth - possible to retain nanocrystalline structure
- Plastic coatings without volatile solvents
- Intermetallic coatings/repair (phase and compositional stability)
- Improved wear resistance
- Metal on ceramic
- Metal on glass

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News/Notices

TSSEA AGM 16th July 2003

Mr K Lawson, having completed his term of office, handed over the chair to Dr T Lester. In his absence Dr Lester asked for the following message to be read out to the meeting. This message is so very aptly put that it is worth recording, for the benefit of those not present.

Message from the incoming Chairman.

Firstly let me apologise for not being present at this meeting but I have been called overseas. As many of you will know I have been involved with the TSSEA for many years, firstly on the Technical Committee of the TSA then as a previous chairman. When you take the long perspective, the fortunes of the TSSEA wax and wane and challenges present themselves to be overcome and opportunities arise to be taken. As always your association is the epitome of a non profit making organisation. However the finances are on a significantly stronger footing now that we publish Coatings electronicallyand we can look forward to focussing on what new initiatives we might persue rather than looking over our shoulders at our liabilities. We should thank the Committee of Management, the past chairs and of course, Ivor, for seeing us through to this position.

The production of a document such as the Code of Practice on Safety demonstrates the capacity of the Association to speak authoritatively on thermal spraying. Furthermore if the UK spraying industry and its customers choose to take it up, YOUR TSSEA could be THE body to accredit thermal spray operators under the CEN standard. We just need some contractors to take the plunge and qualify their personnel then the process is likely to snowball as customers are presented with the choice of contractors with qualified personnel and those without. You may think that overseas companies are no threat but already Dutch contractors have sprayed some London infrastructure. Whilst it is always possible to compete on price alone it is an unrewarding and risky practice. How much better it would be to provide a more reliable product through quality assurance and demonstrable training and retain business in the UK through meeting agreed standards ahead of competition. In conjunction with improving our quality levels we need to convince Specifiers of the value of choosing accredited contractors and that can be a task for YOUR TSSEA.

I really believe that our association is a force for good for the industry and deserves our support. I hope that in the coming year we can work together to push the issues that will benefit our industry We are the voice of the industry but that voice will only be heard if we all sing from the same sheet. Hence I would call upon the whole of the membership to be active in guiding the Association in furthering its aims.

Once again I thank the committee for electing me as Chairman and look forward to helping the association pusue the aspirations of its members.

Terry Lester.

As is normal practice changes to membership of The Committee of Management are approved at the AGM and the following are now included in this committee.

- Mr A Coomber, Sulzer Metco Limited
- Mr A Williams, Air Products Limited
- Dr M Gee, National Physical Laboratory.

The meeting gave a warm welcome to these new members.

At the same time the resignation of Mr K Harrison of Sulzer Metco Limited was regretfully accepted..

Members of the Committee are honorary and they give their time to attend meetings and undertake tasks in order to determine the most appropriate activities in which the association should be engaged. Inevitably there comes a time when pressure of work is such that members can longer continue to serve.

Mr K Harrison has served the committee for several years and has had two successful terms of office as Chairman. In recognition of his services a presentation was made and the outgoing chairman (Mr K Lawson) expressed the gratitude of the committee for his valuable services.

TSSEA 2003 Programme

Autumn Conference 2003

Surface engineering coatings for the National Utilities

To be held on 6h November 2003
Himley Hall,
Himley,
Dudley DY3 4DF,

These industries have needs for surface coatings of many varieties applied by such methods as Thermal spraying, Vapour Deposition, Welding and Plating, to name a few. Each of these technologies have variations on their common theme providing a multitude of coating characteristics which find applications in all engineering industries. These variations have been introduced by research and development in the search for ever more flexibility and quality and hardly a year goes by without the introduction of more advanced methods. Changes in existing coatings occur much more frequently.

For example, in recent years the Thermal spraying industry has seen conventional flame spraying overtaken first by electric arc, then Plasma in turn improved by High Velocity systems and lately the introduction of Cold spray. These changes do not replace the old systems, but introduce more scope for applications, previously untried, and, perhaps more importantly, a better understanding of expected performance in service.

The expert speakers listed here will not only cover the typical coatings presently being applied by the contracting industry and users, but also a view of future trends being established by leading research and development organisations in the U.K.

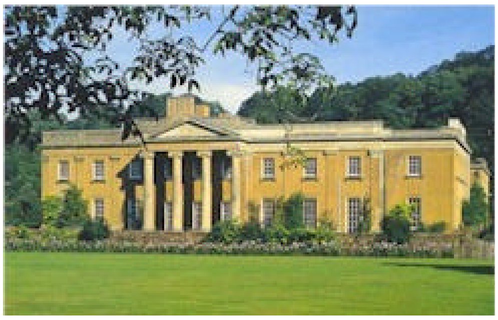
The association is convinced that such events as this conference, held on a regular basis, are essential to provide engineers up to date information on the ever changing technologies in surface engineering.

Himley Hall, Himley Dudley. Started by John William the 4th Viscount of Dudley Built in 1823 and designed by William Atkinson of London the hall sits in a beautiful park landscaped by capability Brown.

Over the years the hall has seen service as the home of the Ward family, who have entertained Royal visitors at the hall, a hospital during the war, the headquarters of the regional Coal board and now as a conference centre run by Dudley Council.

You can find out more about Himely Hall on their web site at:

http://www.dudley.gov.uk/tourism/himley/content.htm



Programme

Morning Session	Registration 09.30
10.00-10.30	Dr.T.Lester Metallization Ltd *Thermal spraying in power generation*
10.30-11.00	Dr.S.Winnik Exxon Chemicals *Using thermally sprayed aluminium (TSA) to combat corrosion under insulation (CUI)*
11.30-12.00	Tea/Coffee Break
12.00-12.30	Mr.D.Harvey TWI Ltd *The use of advanced thermal spray process for corrosion protection in marine environments*
12.30-13.00	Dr.B.Allcock Monitor Coatings and Engineers Ltd. *Coatings for National Utilities*
13.00-14.15	Lunch
14.00-14.30	Dr.H.Dong University of Birmingham *Thermo chemical surface engineering technologies for National Utilities*
14.30-15.00	Mr.R.Hatch Praxair Surface technologies Ltd. *Surface engineering coatings*
15.00-15.30	Mr.B.Johnson QCoat Ltd. *Thermal spray solutions for abrasive wear problems in centrifugal pumps*
15.30-16.00	Cranfield University *TBA*

Any changes of details or timings and presentation titles will be issued on the day.

TSSEA 2003 Programme

Further Dates for 2003

ERRATA

Please note the One Day Workshop — *Cold gas dynamic spraying for coatings and manufacture* advertised in the first edition of *Coatings—October 2003* was included in error.

The workshop in fact took place last year and will not be taking place in December this year.

Please accept our apologies for this oversight.