Plasma Transferred Wire Arc Process Fortifies Aluminum Engine Blocks

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Thermal spray technology was invented in the late 1800s to restore worn metal parts and provide surface protection. Initially known as "metallizing," it became more popular during World War II for fast repair of tanks and other vehicles in high demand. Today, thermal spray encompasses a whole family of coating processes used to apply metals, polymers, ceramics, cermets, and other combinations of materials to a wide variety of metallic, polymeric, composite, and ceramic substrates.

The new all-aluminum engine block manufactured by Honsel uses Ford's patented plasma transferred wire arc (PTWA) cylinder liner technology to reduce weight and increase efficiency.

Generally, feedstock materials are projected toward the substrate in a liquid, semi-liquid, or solid state to apply coatings with thicknesses greater than 100 µm. Traditionally, feedstock materials (in powder, wire, or rod forms) are melted by combustion or electric arc/plasma, and then accelerated against the substrate by a high-velocity gas jet. In newer thermal spray processes, such as cold spray, special feedstock materials are accelerated by a supersonic gas jet to conform a deposit in the solid-state.

Combustion-based thermal spray processes include powder flame spray, wire flame spray, detonation spray, high velocity oxygen fuel (HVOF), and warm spray (lower temperature HVOF that uses nitrogen to cool combustion gases). Electric arc-based processes include plasma spray, arc wire spray, and their variations. The extremely high temperatures (>10,000°C) of plasma spray make it suitable for depositing elevated temperature materials, such as ceramics. On the other end, the new cold spray family includes processes such as downstream injection (low pressure) and up-stream injection (high pressure) which rely on the ability of the materials to deform at high impact velocities and at low process temperatures.

Traditionally, thermal spray has been widely used in the aerospace industry. Over the past few decades, and driven by the need to improve fuel efficiency, thermal spray is increasingly used in a wide range of automotive applications requiring corrosion and wear resistance, elevated temperature resistance, enhanced lubricity, and dimensional restoration. Examples include:

- Plasma spraying of Molybdenum for piston heads
- Plasma spraying of Mo-Ni-Cr for performance valve seats
- Twin-arc spray of various materials on top of resistance spot welds to improve aesthetics in luxury cars

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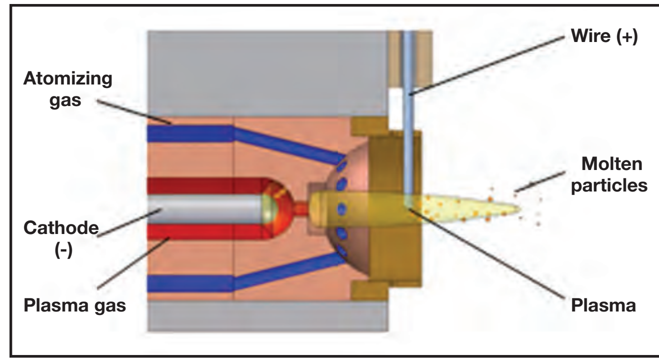

Fig. 1 — *Schematic of the plasma transferred wire arc (PTWA) torch commercial system. Courtesy of Comau[9].*

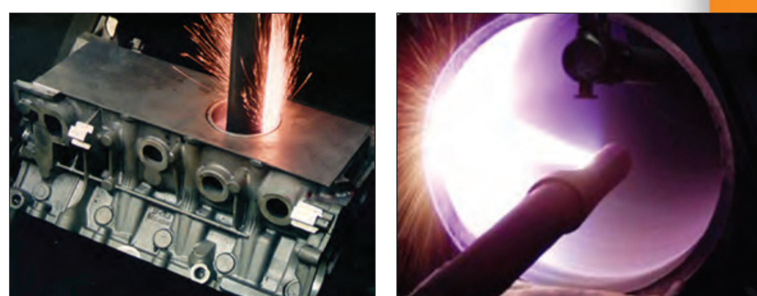

Fig. 2 — *Application of ferrous materials on internal surfaces of engine blocks by PTWA.*

- Plasma spraying of ceramic thermal barriers on exhaust manifolds, turbo-charge components, and diesel combustion chambers
- Twin-arc wire spray of aluminum to improve corrosion resistance
- Plasma transferred wire arc to improve tribological properties of cylinder bores in engine blocks made of low silicon aluminum castings

Plasma transferred wire arc process overview

One of the most recent success stories for thermal spray in the automotive industry involves the development of plasma transferred wire arc (PTWA) for aluminum engine blocks. Driven by the demand to increase fuel efficiency, automakers are placing emphasis on decreasing overall vehicle weight as well as improving engine efficiency by reducing internal friction losses. Consequently, over the past few decades there has been a strong push to produce engine blocks made of light cast alloys, such as aluminum-silicon cast alloys.

Hyper-eutectic aluminum-silicon cast alloys with silicon content higher than 12.6 wt% offer excellent tribological properties for engine block applications. However, their high silicon content makes them difficult to cast and machine, and therefore too expensive to produce. Unfortunately, the generally preferred A356 hypo-eutectic alloy (around 7-8% silicon) displays poor tribological characteristics for engine applications compared to high silicon alloys but it is cheaper to produce. Therefore, low-silicon aluminum blocks require reinforcement of the cylinder

Fig. 3 — *Ford Mustang Shelby GT500.*

bores, which is achieved by either using cast iron liners or electroplating with nickel and silicon carbide.

PTWA was codeveloped by Ford Motor Co., Dearborn, Mich., and Flame-Spray Industries Inc., Port Washington, N.Y.,[1-7] in an effort to eliminate the need for cast iron liners and further reduce weight. In this process, a high temperature (>10,000°C) plasma jet is created between a nonconsumable electrode and a consumable composite ferrous wire with a 1.6 mm diameter (Fig. 1). The plasma melts and atomizes the ferrous wire, which is continuously fed into a rotating spray gun that fits within the cylinders (Fig. 2). Pressurized air atomizes and accelerates metal droplets (20 to 30 µm diameter) onto the internal surface of engine block cylinders. The molten composite wire oxidizes and builds up a rapidly solidified ferrous structure consisting of nanocrystalline iron and ferrous-oxide to a final thickness of about 150 µm.

The resulting surface structure of the composite coating promotes favorable lubrication, low friction, wear resistance, improved heat transfer, and decreased bore distortion. Ford implemented the technology in their 2011 GT500 Shelby Mustang 5.4-L V8 (Fig. 3)[8]. The PTWA process eliminated approximately 3.8 kg of cylinder liners compared with previous models[8]. **iTSSe**

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References

1. D. Marantz, et al., U.S. Patent 5,808,270, High Deposition Rate Thermal Spray using Plasma Transferred Wire Arc, 1998.
2. J.Baughman, et al., U.S. Patent 5,938,944, Plasma Transferred Wire Arc Thermal Spray Apparatus and Method, 1999.
3. D. Marantz, et al., U.S. Patent 6,372,298, High Deposition Rate Thermal Spray using Plasma Transferred Wire Arc, 2002.
4. J. Chancey, et al., U.S. Patent 6,559,407, Cathode Assembly for an Electric Arc Spray Apparatus, 2003.
5. K. Bobzin, et al., Thermal Spraying of Cylinder Bores with the PTWA Internal Coating System, Conf. Proc., ASME Internal Combustion Engine, Charleston, SC, ICEF07-1745,Oct. 14-17, 2007.
6. K. Bobzin, et al., Coating Bores of Light Metal Engine Blocks with a Nano Composite Material using PTWA Process, *J. Therm. Spray Techn.,* 17 (3), p 344-351, 2008.
7. C. Verpoort and T. Schlaefer, Thermal Spraying of Nano-Crystalline Coatings for Al-Cylinder Bores, SAE Technical Paper, 2008.
8. Ford Motor press release, http://media.ford.com/images/10031/2011_GT500_Engine.pdf, Feb. 2010.
9. Comau, commercial system, www.comau.com/eng/offering_competence/powertrain/manufacturing/Pages/smart_spray.aspx, 2014.