ENGINE VALVE ALLOYS & COATING

Technical Bulletin

Bi-metal Valves? Composite Valves? Specialty coatings? Choosing the best valve for your next diesel engine rebuild.

There is no doubt that the valves on a supercharged diesel engine are one of the hardest working components in a modern engine. Consider this: the valves must withstand super extreme temperatures [700 C° (1,300 F°)], while opening and closing 20 times per second [@2600 RPM], this happens every second, every minute, every hour, every day! That's 78,000 direction reversals every hour and more than a half million per day!

In order for the valves to not forge themselves into a clump of metal from these extreme temperatures and brutal impacts, engine valve manufacturers are constantly evolving their processes and choices of materials.

One perfect example of this evolution is the bi-metal valve. For a Valve to be strong and withstand constant pounding, the head of the valve needs to be extremely hard, at the same time it is critical for the valve stem to be able to handle the tensile forces that are trying to stretch it apart. In order to accomplish this, we need two types of materials for the "perfect Valve", this is where a bi-metal valve comes in. A bi-metal valve is constructed out of two different metals; Austentic Steel and Martensitic Steel. Austentic Steel is used for the head of the valve, due to its hardness, high heat and corrosion resistance properties. Martensitic Steel is used on the stem, which has high tensile strength and wear resistance properties.

So how are these valves manufactured? Bi-metal valves are rotary friction welded (**See Figure 1**), a welding process where either the stem or the head of the valve is spun at very high speeds and pressed against the other half of the valve which remains stationary. The frictional heat produced at the joint fuses the two parts together, creating an extremely strong joint of forged quality. Contrary to what many might think, friction welds create a 100% bond of the contact area. This results in a higher strength bond which greatly increases the design flexibility of the valve.

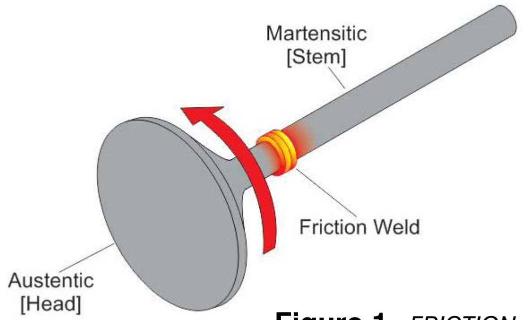

Figure 1 - *FRICTION WELDING*

INTAKE VS. EXHAUST

Intake valves and exhaust valves work differently are different and require different metal compositions. Exhaust valves operate at a much higher temperature than do intake valves. For that reason exhaust valves are designed for high temperature strength and corrosion resistance, while the intake valve's design primarily focus is endurance and wear resistance.

HIGH TEMPERATURE RESISTANT ALLOYS

Today's high performance diesel engines require higher temperature resistant alloy valves. These super alloy valves with their high nickel composition can handle temperatures exceeding 900 C° (1650 F°). As a result, a super alloy material is essential on the exhaust side, especially in today's modern computer controlled turbocharged diesel engines. One of these "Super Alloys" is Inconel®; a high-strength austenitic nickel-chromium-iron alloy. Inconel® which is sometimes referred to as "super-stainless steel" has a high nickel content, plus 15% chromium and 3% titanium, this offers superior high temperature strength and improved corrosion resistance.

Nickel alloy valves - Nickel and cobalt containing alloys improve the strength and corrosion resistance of the valves. These metals are the foundation of alloys used in the manufacturing of exhaust valves. Super Alloys containing chromium, tungsten, vanadium, silicon or molybdenum, are stronger and have a high corrosive resistance due to its low carbon content; high levels of carbon make alloy steels brittle, and undermine corrosion resistance. This is rapidly changing, as more specialty coatings enter the market.

Hardfacing - Several methods have been developed to increase the wear ability and corrosion resistance of just the valve face; the area where the valve makes contact with the valve seat. One such method is hardfacing; a process where harder or tougher material such as Inconel® or Stellite® is fuse-welded to the seat area. The fusing of the material is typically applied using thermal spraying like Powder Plasma Welding (**See Figure 2**).

Thermal spraying is a process in which melted powder alloys are sprayed and fused to the surface being treated. Stellite® is a cobalt base material with a high chromium content. It is generally applied to the valve face as a protection against wear and corrosion. Hardfacing is also applied to the valve stem tip for added wear resistance.

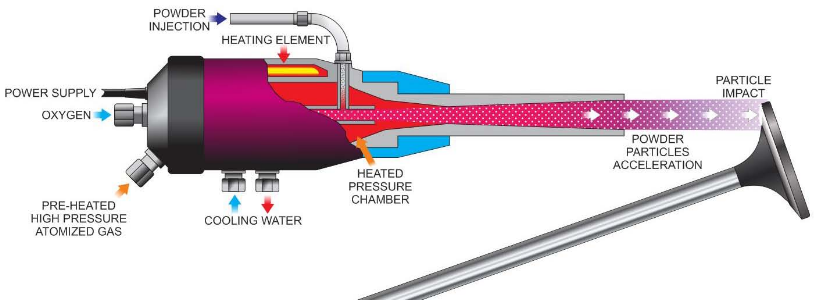

Figure 2 - *POWDER PLASMA WELDING*

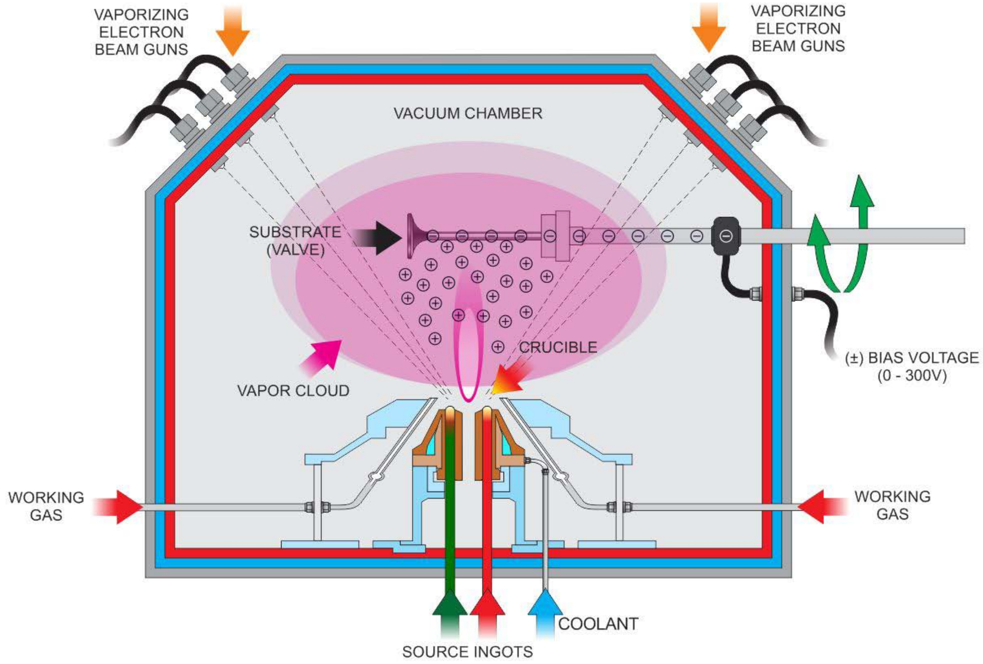

Figure 3 - *VAPOR DEPOSITION*

SPECIAL COATINGS AND TREATMENTS

To improve the valve's temperature, wear and corrosion resistance properties, valve manufacturers offer various coatings and treatments. For many years hard Chromium plating was the king of valve coatings, however most modern coatings use rare elements and specialty processes like salt baths, Chemical Vapor Deposition (CVD), and Physical Vapor Deposition (PVD) that surpass the benefits of hard chromium. Vapor deposition (**See Figure 3**) processes are the future in valve coatings. The Physical Vapor Deposition (PVD) process in valve making is pretty straightforward; a negatively (electrically) charged valve is placed inside a vacuum chamber. The material to be deposited, called the source, is heated to a sufficiently high temperature that it evaporates, the material condenses and becomes attached to the valve's surface forming a deposited thin film.

Although only a few microns thick, PVD coatings are extremely effective in enhancing the valve's wear and corrosion resistant properties (for size comparison, a human hair is about 75 microns across). Chemical Vapor Deposition can be used to apply non-metallic anti-friction coating to the valve stems, creating a super slick surface that requires less [oil] lubrication. Ceramic thermal barrier coatings can also be applied to the head of the valve, this reflects heat away from the valve, running cooler and lasting longer.

Hard Chromium - plating extends the life of the valve stem and guide by reducing friction due to its hardness and reduced contact area. For decades Chromium has been the standard in valve coatings. The hard chromium plated surface provides excellent wear resistance in several ways. The chrome plating provides a hard surface that is resistant to wear. The plating process produces microscopic pores that help in retaining oil for lubrication. These micro-pores also provide less surface area on the stem less surface area means less friction.

Black Nitride coating on valves compared to chrome plating creates a thinner but harder surface layer. The nitride, a black finish coating, which is applied in a salt bath treatment, provides a super hard coating. Black Nitride coating with its microscopic bumps and ridges that resemble fish scales, provides less surface area, less surface area means less friction, therefore less heat build up on the stem and less wear. Black Nitrite does an excellent job in protecting the valve stems against scuffing and wear. Manganese phosphate is another similar "black" coating which is also applied in a salt bath treatment, Manganese phosphate has the highest; hardness, superior corrosion and wear resistances of all phosphate coatings. Trufftride is yet another salt bath treatment that provides a super hard layer over the entire valve, providing excellent wear properties with the added benefit of stress relieving the valve, the finished look of Trufftride is black.

Chromium Nitride (PVD) provides superior wear and corrosion resistance. One of the biggest benefit of chromium nitride coating is that it significantly increases the valve's heat resistance property. Chromium Nitride coating is a great solution for valves that operate in extremely high temperatures and must perform flawlessly under such conditions for a very long time. Chromium Nitride results in a variation of colors; from shiny silver to black,includinga deep dark purple. Titanium Nitride (PVD)with its golden yellow finish and superior hardness level (1600HV), Titanium Nitride coating significantly increases the valve's wear resistance properties, while also improving the valve's high corrosion resistance and durability properties.

Zirconium Nitride (PVD) is a hard ceramic material similar to titanium nitride. The Zirconium Nitride coating substantially increases the valve's corrosion resistance property. Zirconium Nitride coating is recommended for valves operating in extremely corrosive environments. Zirconium Nitride coating also provides improvement to the valve's wear resistance property, significantly increasing the valve's lifespan.Zirconium Nitride's color is a shiny golden white.

When you look and see how many variations of valve coatings and treatments are available in the marketplace, it becomes evident that manufacturers are no longer making a "one valve fits all" product. Engine valve coatings have evolved to endure the high temperatures and corrosive environments of today's performance diesel engines. Hard Chromium, Trufftride, Manganese Phosphate, Chromium Nitride, Titanium Nitride, Zirconium Nitride, are but a few of the coatings available in valve manufacturing today. Sure, these coatings increase the cost of the valves substantially, but the benefits and the performance gains most definitely outweigh the costs.