HARD COATINGS USED IN VALVES

CONTENT Page

1. Introduction

Valves used in severe services, as example in oilfield or mining applications are subjected to hostile operating conditions. They must be corrossion resistante, be able to withstand high pressures, high temperatures, and resist erosive and abrasive wear. The critical parts of the valve that are most vulnerable to these conditions are the trim, seats and stem. Especially the trim and the seats are exposed to the condiciones at all times and must maintain a tight seal when opened or closed.

The coatings widely used for valves include chemical and thermical coatings, all of which provide a hard surface with much better resistance to abrasion compared to uncoated parts.

Metal seated ball valves achieve sealing by metal to metal contact between the trim and the seat. When “soft” metals (like stainless steel) of similar hardness slide against each other under even moderate pressure, the surfaces are scratched. Microscopic protrusions on the seating surfaces catch on each other, resulting in surface friction, heat buildup and plastic deformation. Typically the damage gets worse as the valve cycles until it becomes inoperable due to seizure. If no coatings are applied to the trim, galling will be visible almost as soon as the valve is cycled on the test bench.

Once installed in service, the various effects of difficult media would increase wear rate exponentially. Properly selected coatings reduce the friction between the trim and the seats allowing for smooth sliding operation over many numerous cycles, minimizing damage and wear due to galling, abrasion, erosion, particle impact, cavitation and thermal swings. Reducing friction in the trim lowers the valve’s operating torque which has several advantages.

2. Selection of trim coatings

Valve body, trim and seats materials are selected based on factors such as pressure, temperature and chemical compatibility. These criteria must also be considered when choosing trim coatings. Improper selection can cause almost instant failure of the valve upon startup. It is also important to note that properly selected trim coatings cannot make up for unsuitable base materials. Most coatings are porous to some degree and do not isolate the base material against the effects of corrosive media. Base material and coating must both be selected to meet the demands of the application and are compatible to the form of application.

2.1 Chemical coatings

Chemically applied coatings, e.g. electrolitically have generally a high corrossion resistance, but a lower mechanical resistance than thermical coatings. The most used are:

- Hard chromium
- ENP (Electroless Nickel Plating)

2.1.1 Hard Chromium

Hard Chromium is the standard coating and is suited to a wide range of applications in liquids and gases at moderate temperatures and pressures. Corrosion resistance of HCr is generally comparable with stainless steels. HCr do not resist strong acids like hydrochloric acid (HCl), hydrofluoric acid (HF) or sulfuric acid (H_2SO_4), and it should not be used with seawater, wet chlorine or other media with high chloride content.

Characteristics

Suitable base materials	Stainless steels, nickel base alloys
Composition	Chrome
Thickness	< 50 µm
Maximum temperature	350°C
Hardness	70 HRC
Chemical resistance	pH > 1

2.1.2 ENP (Electroless Nickel Plating)

Electroless Nickel Plating (ENP) is the deposit of a nickel-alloy coating by chemical reduction – without the electric current that's used in electroplating processes.
The majority of ENP for engineering purposes is a nickel phosphorus deposit containing up to 14% phosphorus.

The higher the phosphorus content the greater the corrosion resistance, however the compromise on increased phosphorus content is a decrease in hardness.

ENP is being widely applied in valve ball production with its advantages such as simple processing, low-cost, uniform thickness and large-area plating of the stem, trim and seats. Many clients will specify A105/ENP because they believe it to be a more cost-effective option than a full stainless-steel trim. The surface hardness of the ENP is quite high, the strength of the substrate is often the limiting factor, especially in the instance where line scale, sand or similar is caught between the trim and the seat. Once the ENP coating is compromised a failure will not be long in coming.

Characteristics

Suitable base materials	carbon steel
Composition	Nickel (Ni) + 10,5 to 13 % phosphorous (P)
Thickness	< 75 µm
Maximum temperature	350°C
Hardness	70 HRC
Chemical resistance	pH > 4,5

2.2 Thermal coatings

"Thermal spraying" or "thermal coating" is the collective term for a variety of methods, all of which essentially involve metal, ceramic or composite materials being melted using a flame, electric arc, laser beam etc. and bonded to a surface using expansion or discharge pressure (air or gas pressure).

Some methods make use of high velocities (kinetic energy): The coating material thus "splatters" on impact with the roughened surface and mechanically digs into it. Other methods use extremely high thermal energy and need a separate fusion process after molten particles or droplets have been sprayed onto the surface. In such cases, fusion creates a metallurgical bond between the sprayed droplets and the base material. The coating material has a variety of forms such as wire, granulate or powder. All methods use some form thermal energy and a spraying system to expose the initial material to a high temperature and thus set it in motion (releasing kinetic energy). Laser-based methods use pure thermal energy to complete the welding process.

Different parameters such as temperature, velocity and particle/droplet size must be applied depending on the method used. This fact alone clearly shows that each method is subject to its own physical laws, and that each one can, as a result, produce widely differing characteristic or physical properties such as hardness, concentration, adhesion and other coating properties.

The symbiosis between method, base material and the design of the parts to be coated is extremely important to these methods. This symbiosis is responsible for the often excellent and, indeed, unique properties of the finished product.

Subsequent treatment is the real art to manufacturing prefinished metal sealing systems. Such treatment is imperative if – depending on the various factors of influence and operating conditions – sealing systems that are impervious to gases and are to be produced in compliance with the required leakage rate.

The most common technologies used for applications in valves are:

- Flame Spraying and Fusing
- HVOF (High Velocity Oxygen Fuel)
- APS (Atmospheric Plasma Spraying)

2.2.1 Flame Spraying and Fusing

Consists in the melting of the coating material by the combustion of fuel gas and oxygen and accelerating of the particles by expansion of the flue gas.
A subsequent fusing of the coating at temperatures of 1000-1100°C in a vacuum oven eliminates porosity and gives an excellent adherence due to metallurgical bond (diffusion)
Base materials are limited to self-fluxing alloys Stainless steel, Ni- or Co-based alloys

Advantages

- A wide variety of spraying materials
- The coating system is impervious to gases and liquids
- Non-porous coating layers
- Strong wear-resistance when subject to linear, concentrated and distributed stresses
- Powerful adhesive strength
- Metallurgical bond to the base material
- Coating lends itself to subsequent treatment (turning, milling, grinding and lapping)
- Strong resistance to corrosion by caustic solutions, weak acids and aqueous solutions

Disadvantages

- Partial coatings are not possible
- Chrome steel is not suitable for metallurgical bonding
- The base material is subject to significant temperature stresses
- The component geometry is subject to restrictions

Applications

- Severe service
- High operating cycles
- High pressure
- Low temperature (< -40°C)
- Low leakage rates
- Resistance to high thermal cycling and shock

2.2.1.1 Flame spray and fusing coating Nickel based

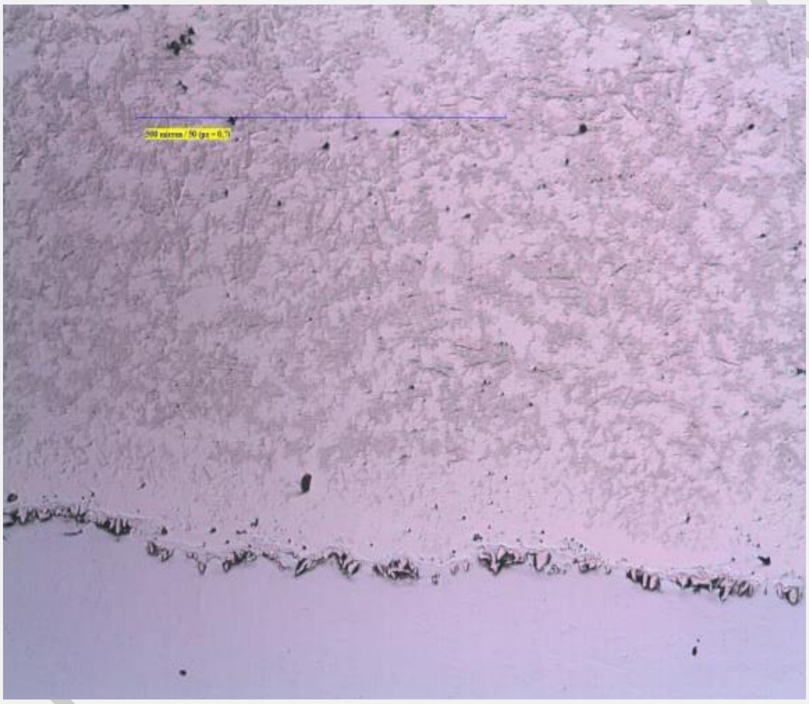
Suitable base materials	self-fluxing alloys
Composition	70%Ni / 17%Cr / 4%Fe / 4%Si
Thickness	< 600 µm
Maximum temperature	750°C
Hardness	58 / 62 HRC
Bond strength	> 150 MPa

2.2.1.2 Flame spray and fusing coating Tungsten carbide based

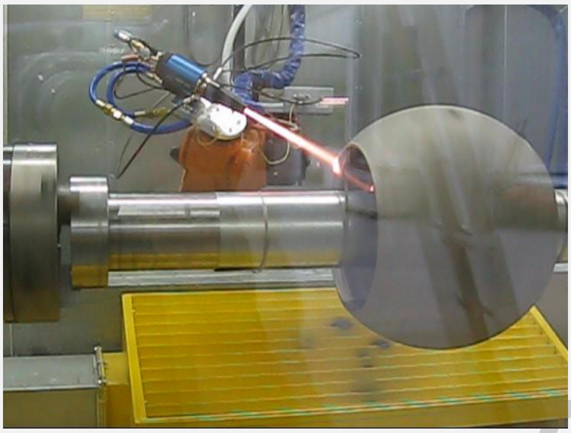
Suitable base materials	self-fluxing alloys
Composition	50%WC / 26%Ni / 7%Cr / 3,5%Si
Thickness	< 600 µm
Maximum temperature	750°C
Hardness	62 / 65 HRC
Bond strength	> 150 MPa

2.2.1.3 Flame spray and fusing coating Cobalt based

Suitable base materials	self-fluxing alloys
Composition	42%Co / 13%Ni / 19%Cr / 15%W / 3Si
Thickness	< 600 µm
Maximum temperature	800°C
Hardness	59 / 62 HRC
Bond strength	> 150 MPa



2.2.2 High Velocity Oxygen Fuel (HVOF)



Consists in the melting and acceleration of the spray particles by high pressure combustion of fuel and oxygen and spray through special designed expansion nozzles that lead to supersonic gas and particle velocities (up to 900m/s).

The short dwell time in the flame minimizes decomposition and oxidation of the coating material obtaining a low porosity (<1-2%) and good bond strength (>75Mpa).
Most versatile process regarding coating selection and base materials.
Low thermal load of the coated parts eliminates shape distortion

Advantages

- Applicable on any metallic base material
- Highest hardness and wear resistance

Disadvantages

- Some porosity and mechanical bond
- Cracking and spalling happen very seldom

Applications

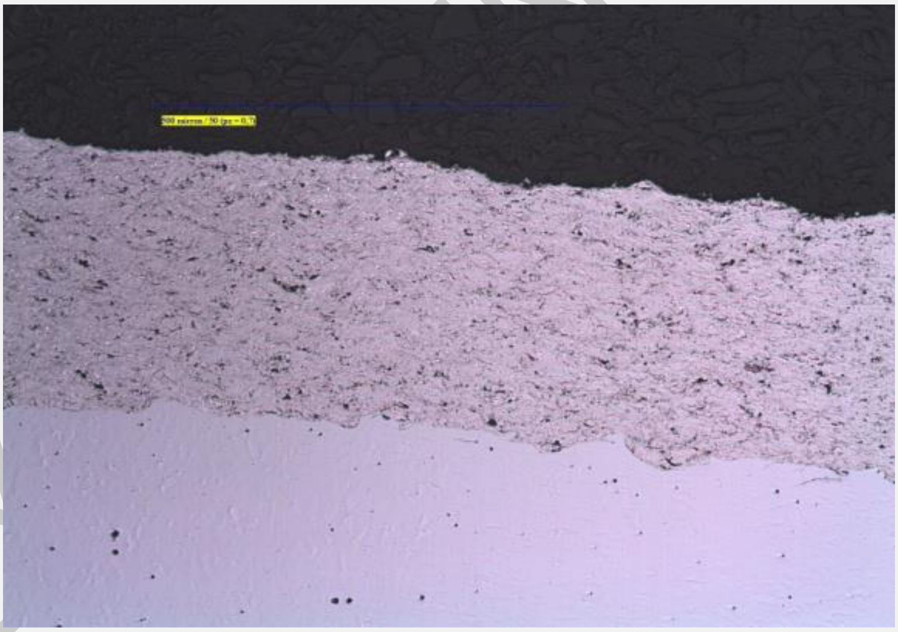
- General service
- For gas pressure <150bar
- Moderate operating cycles
- Higher leakage rates for gas at pressure >150 bar

2.2.2.1 HVOF coating chromium carbide based

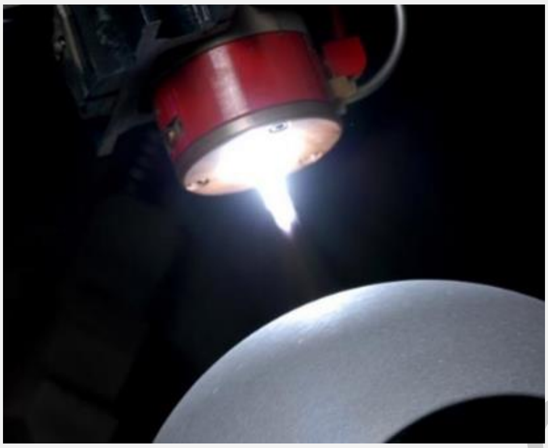
Suitable base materials	Any metal
Composition	Chromium Carbide with Nickel Chromium Matrix Cr_3C_2-NiCr 75:25
Thickness	< 200 µm
Maximum temperature	650°C
Hardness	> 68 HRC
Bond strength	> 75 Mpa

2.2.2.2 HVOF coating tungsten carbide based

Suitable base materials	Any metal
Composition	WC 10Ni 5Cr
Thickness	< 200 µm
Maximum temperature	450°C
Hardness	> 70 HRC
Bond strength	> 75 Mpa



2.2.3 Atmospheric Plasma Spraying (APS)



This type of application is used mainly for ceramic coatings.
The melting and acceleration of the spray particles is produced by high and hot plasma gas flow (up to 20000K).
Special designed expansion nozzles lead to supersonic gas and particle velocities (up to 450m/s).
Short dwell time in the flame minimizes decomposition and oxidation of the coating material Porosity (1-10%).

Good bond strength (>45Mpa).
Low thermal load of the coated parts eliminates shape distortion.

Advantages

- Applicable on any metallic base material
- High hardness and wear resistance
- Highest corrosion resistance

Disadvantages

- Porosity and lower mechanical bond and danger of brittle
- Cracking and spalling happen very seldom

Suitable base materials	Any metal
Composition	Bond coating: Ni Cr
	Top coating: TiO_2 (99,9%)
Thickness	Bond coating: 0,1 mm
	Top coating: 0,2 mm
Maximum temperature	450°C
Hardness	58 / 63 HRC
Bond strength	> 45 Mpa