CVD hard coatings for mechanical face seals from Hardide Coatings

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Advanced surface coating company Hardide Coatings Ltd is producing Hardide CVD (chemical vapour deposition) tungsten carbide / tungsten coatings for use on mechanical seals for heavy-duty rotating equipment for the oil, gas and chemical processing industries.

Rotating equipment such as pumps, compressors and turbines use mechanical face seals to prevent leaks, exclude abrasive media and lubricate the mechanical assemblies. Seal reliability is critical for overall equipment reliability as seal failure can damage expensive equipment while inflicting high downtime costs.

Hard materials are often used for heavy-duty mechanical face seals, in particular to make the 'primary' sealing surface durable and capable of resisting three-body abrasion, erosion and corrosion. Solid hard materials such as silicon carbide, ceramic or sintered tungsten carbide are often used but these hard materials have significant limitations and disadvantages; they are brittle, expensive and difficult to produce, especially if the seal design includes finer features. Their thermal expansion properties differ significantly from steel which can lead to jamming when the temperature changes. A more effective approach, which also opens up opportunities for better seal design, can be to manufacture the mechanical seal components out of steel – which is tough, inexpensive and much easier to machine – and then coat with a hard coating.

There are various designs of mechanical seals but typically these include the primary sealing surfaces, often made as two rings or disks, with one part rotating and another stationary. When the seal rotates at speeds of 1000 rpm up to 60,000 rpm and more, the operation of the mechanical face seal depends on the fluid layer separating the primary seal components and lubricating their surfaces, reducing friction and preventing overheating. Coating one or both of these hard faces of a mechanical seal would protect the surface from being scratched by hard particles and prevent the formation of scratch asperities which could rupture the lubricating fluid film.

To enhance seal durability the coating must have several specific properties or characteristics. It must be sufficiently hard to resist abrasion by hard particles - if sand is present the coating hardness must be above 1000 Hv and preferably above 1200 Hv. It must have sufficient thickness to withstand the point load from hard abrasive grains; a rule of thumb recommends a coating thickness >10% of

the typical abrasive particle diameter. If sand is present the coating thickness should be >20 microns. A thinner coating can suffer from egg shell effect where a point load can cause substrate plastic deformation and break through the coating, ploughing the seal's surface.

The surface finish of the coating is also important as surface asperities on a rougher coating can rupture the lubricating fluid and damage the opposite sealing surface. As well as being able to be polished to a good Ra and Rz finish, the coating should be capable of maintaining a good finish when in use e.g. rotating at high speed and exposed to abrasive, erosive and corrosive environments. This requires the coating to have a uniform structure which will also wear evenly without forming hard asperities.

The ideal coating for mechanical seal faces should also resist corrosion and attacks by chemically aggressive media. This is especially important for petrochemical and chemical industry equipment that often handles aggressive media.

Several hard coatings are already used on mechanical seals including HVOF and plasma spray coatings (such as WC/Co), DLC and other PVD coatings. However, these traditional coating technologies do not meet all the key requirements for effective heavy-duty seal applications. For example, WC/Co HVOF and plasma spray coatings consist of hard WC grains in a soft cobalt binder and in abrasive or corrosive environments they can become very rough due to the selective leaching or abrasion of the binder. DLC and other PVD coatings are typically very thin, less than 10 microns, and have limited load-bearing capacity so can be "ploughed" by hard particles. Both spray and PVD coatings are line- of-sight processes that can only be applied to external surfaces and simple geometries.

Hardide Chemical Vapour Deposition (CVD) tungsten carbide / tungsten coatings meet all the key requirements for mechanical seal applications. Hardide coatings can be produced with a hardness ranging from 450 Hv to 3500 Hv, although we have found that 1100 Hv to 1800 Hv hardness is optimal for mechanical seal applications. Hardide coatings are typically applied with a thickness of 50 microns, although thinner or thicker coatings from 5 to 100 microns, are also feasible and might be used for some of the seal designs. Hardide coatings can be polished to a good finish, typically achieving an Ra that is better than 0.3 microns by just polishing and without the need for expensive grinding. Superfinishing can achieve a Hardide coating surface with an Ra finish of 0.02 microns. The uniform structure of Hardide coatings enables an even wear pattern which helps the coated parts maintain an optimum finish for longer, even in the most abrasive of conditions. Chemically, the coating consists of tungsten carbide and tungsten, both of which have excellent resistance to corrosive and chemically aggressive media, especially against acids. As disclosed in Hardide patents, the coating might be alloyed with small amounts of Fluorine or Fluorocarbons, which can further enhance its mechanical properties.

CVD Hardide coatings are crystallised from the gas phase atom-by-atom, producing a conformal coating which can coat internal and external surfaces and complex shapes. This means that as well

as hardening and protecting the primary sealing surfaces, the coating also protects the secondary sealing surfaces of the mechanical seals, such as O-ring grooves, or other surfaces exposed to the erosive flow of fluids which might carry abrasive particles.

Nano-structured Hardide coatings have been extensively tested in applications where coated metal parts are working against seals made of metals, graphite, elastomers, PTFE and other polymers. In most cases, the coating has proven to be seal-friendly and has protected the metal parts from abrasive wear while also reducing the wear of the seals. Hardide coating on the metal seal surface reduced wear of the elastomeric seals because of its high hardness, wear-resistance, uniform structure and good surface finish characteristics. It can be used not only on the metal surfaces in a rotating or reciprocating contact with an elastomeric, PTFE or other “soft” seal, but also for the mechanical seals. Mechanical seals often have elastomeric or PTFE seals incorporated. These may be stationary (not moving against the metal sealing surface) but changes of pressure, temperature, rotation speed variations and other deforming factors can eventually damage the elastomeric seals if the metal surface is abrasive. Hardide coating of the metal sealing surface will help prevent this and thus prolong the whole mechanical seal life before maintenance. Conformal Hardide coating with a good finish inside the O-ring groove is such an example.

Hardide coatings enable the design of high temperature metal-metal seals and bearings where all the bearing parts can be made of the same material and thus will expand and contract in concert when the temperature changes. Coating one or both components of such high temperature metal-metal seals or bearings would prevent galling and wear of the parts in abrasive conditions. Hardide coatings are enabling users in high wear applications including downhole tools, pumps and valves operating in oil and gas facilities, food manufacturing, refineries, cryogenic equipment and power generation to optimise part life, improve product performance and make significant cost savings. Typically, the coating triples the operational life of critical parts in abrasive conditions. Similar results can be expected on mechanical face seals.

Hardide Coatings Limited is the UK operating company of Hardide plc (AIM:HDD).

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