COATINGS OF EXCEPTIONAL PERFORMANCE

RECIPROCATING COMPRESSORS

INTRODUCTION

Reciprocating compressors are increasingly required to operate under extreme conditions, such as high pressure, unlubricated or lightly lubricated cylinders solid and abrasive particles or entrained condensate in the gas and, higher piston rod speed. Under these conditions the most severely stressed elements are obviously those with relative movement and thus subject to wear, such as piston rings, rider rings, packing rings, liners, rods and pistons.
Suitable plastic materials can improve the behavior of all of the seal elements, but the utilization of special hard-surface coatings applied, for example, to cylinder liners and rods, not only drastically reduces wear, but also allows the piston rods, rider rings and packing rings to in optimum geometric conditions, increasing their life still further. After years of research and experience with coatings, materials have been identified that exhibit the desidered properties:

- **Very hard surface (excellent resistance to wear).**
- **Maximum resistance to detachment.**
- **Maximum resistance to pressure.**
- **Maximum resistance to corrosion.**
- **Optimum surface roughness.**

TECHNICAL DESCRIPTION

Three types of coatings, designed for different applications, have been selected.

1. **tungsten carbide coatings**, for rods and liners of large diameter, are applied by high speed impact to the surface to be threated.
2. **plasma-aided titanium nitride coatings**, for liners of small diameter and in general for all holes or cavities of small size, are applied on a very hard base through electric discharge in a gaseous atmosphere.
3. **nickel coatings** for the grooves of rider rings and piston rings made of light alloy are applied by electrodeposition.

1. TUNGSTEN CARBIDE COATINGS

Coatings obtained by electrodeposition or by ceramic spraying have been found to be unsatisfactory for the severe functional requirements of large diameter components, due to limitations of, cohesion, porosity and fragility. These limitations, which limit their use in applications involving severe wear as well as high pulsating pressure, have been overcome through the use of tungsten carbide coatings. These coatings consist of tungsten carbide powders which contribute hardness and tribological characteristics, and a metal matrix of cobalt or cobalt/chromium which ensures cohesion and attachment to the substratum. Application is achieved by the impact of the powder particles heated and blasted at supersonic speed on to a base material of suitable characteristics (42CrMo4 for all applications except corrosive gases, in which case it is preferable to utilize stainless steels X12Cr13 or X20Cr13).

The coatings are characterized by:

- **Very hard surface** (a minimum value of 1100 HV)
- **Perfect adhesion**
- **Extremely limited porosity** (less than 1.5%; the density is so high that corrosion tests have demonstrated that the coating is self-sealing and has no through porosity)
- **Very low roughness** (0.1 μm)
- **Optimized thickness** (even when these coatings are utilized to restore worn surfaces, optimum performance is attained with precise thickness values)

Applications of Tungsten Carbide Coatings

The characteristics of these coatings enable their use in the following applications:

- **Rods**, in the sliding area of the packing seals (darker area in Figure 1), up to a maximum pressure of 1000 bar and with a gas temperature greater than - 30°C.
- **Liners**, in the sliding area of the seal elements and the rider rings (zone indicated by the arrow in Figure 1), with a gas temperature greater than - 30°C.

The coating is applicable to liners with ratio between inside diameter to length greater than 0.55.

2. PLASMA AIDED TITANIUM NITRIDE COATINGS

This technology (termed PA-CVD) consists of forming titanium nitride, on a previously hardened surface (ionic nitriding HV ≈ 700), through the deposition of metallic ions from a gas phase activated by an electric discharge. This process is unique in that the titanium nitride coating is

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deposited at a low temperature thus avoiding distortion of the part or deterioration of materials. To achieve this, the deposition process is conducted in a low pressure chamber where less thermal energy is required to initiate the necessary chemical reaction. Whereas this process occurs at 350 °C, all other types of CVD coating processes require high temperature on the order of 950 °C.

These coatings, easily recognizable by their characteristic golden color, are applied to a suitable base material (42CrMo4 for all applications except corrosive gas, in which case it is preferable to utilize stainless steel X12Cr13 or X20Cr13) and are characterized by:

- **Very hard surface**; microhardness analysis indicates a minimum surface hardness of 2100 HV and a mean hardness of 2500 HV.
- **Perfect Adhesion**; due to the reduced flex imparted by an initial hard coating from ionic nitriding.
- **"Cold plasma"** procedure; it is possible to coat finished parts of considerable size without inducing deformation and guaranteeing very precise tolerance, an achievement which is impossible with all other chemical vapor depositation precise.
- **No limitation in shape or geometry.**
- **Very low roughness,** (0.2 µm)

Applications of Titanium Nitride Coatings

These coatings are well suited to the following applications:

- **Liners** in the area indicated in Figure 2, **with ratio of inside diameter to length less than 0.55** (where tungsten carbide coatings are not applicable).
- **Piston ring and rider ring grooves**; with pistons used for high pressure and especially with gas containing solid residue piston ring groove wear has been observed, as show in Figure 3a.

This problem has been completely resolved by applying a titanium nitride coating to the piston grooves (Figure 3b).

3. NICKEL COATINGS

In high speed compressors, piston rods made of light alloy are frequently utilized to minimize dynamic thrust on the machine. In this case abnormal conditions such as solids or liquids entrained in the gas cause rapid wear on the piston ring grooves. This problem has been resolved by the application, through chemical bath coating, of a thin layer of nickel to the surfaces in question, as shown in Figures 3a and 3b. These coatings exhibit:

- **Optimum surface hardness.**
- **Perfect adhesion.**

BENEFITS OF COATINGS

The elevated hardness and compactness of the coatings along with the very low degrees of machining have made it possible to achieve the following objectives:

- Maximum resistance to wear.
- Dramatic increase in life not only of the coated parts, but also of all of the elements subject to wear (piston rings, rider rings and packing rings) because they operate under optimum conditions.
- Dramatic increase in maintenance intervals, and MTBF, and lower operating costs.
- Tungsten carbide and titanium nitride coatings have made it possible to resolve problems of early wear to the point of arriving at practically insignificant levels of wear and dramatically increasing the life of piston rings, rider rings and sliding elements. For pistons made of light alloy, from wear rates of almost a millimeter every six months it has been possible to achieve 32,000 hours of operation with negligible wear. Although tungsten carbide and titanium nitride coatings are standard for pressures of over 200 bar and have resolved problems linked to severe operating conditions (solid and abrasive particles entrained by the gas, fluids, high pressure), they can also be used to extend maintenance intervals and to drastically reduce operating costs in applications with less severe operating conditions.

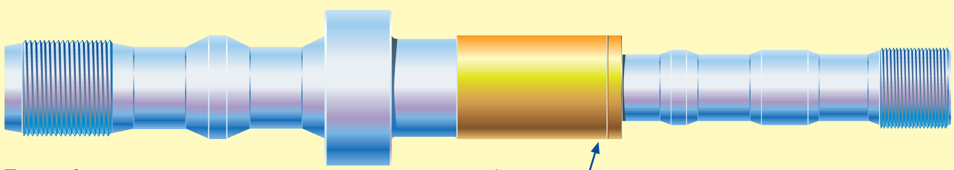

Figure 1

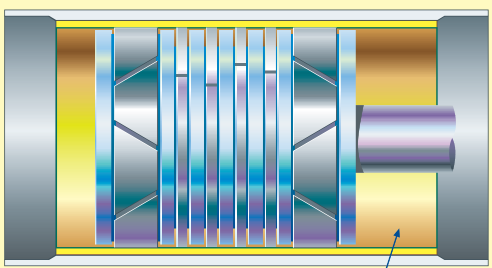

Figure 2

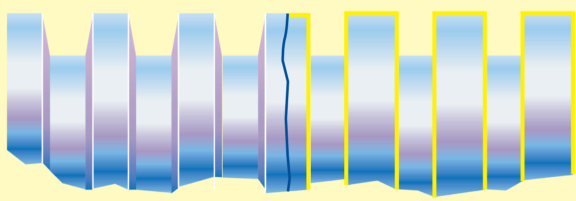

Figure 3a *Figure 3b*

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