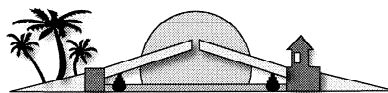


HEAVY MOVABLE STRUCTURES, INC.



**NINTH BIENNIAL SYMPOSIUM**  
"Preserving Traditional Values with New Technologies"

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**CEC – CERAMAX ENGINEERED COATINGS**  
A LOGICAL DEVELOPMENT IN PISTON ROD COATING TECHNOLOGY

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## **CEC; Ceramax Engineered Coatings**

### **A logical development in piston rod coating technology**

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## **Introduction**

With the introduction of Ceramax to the market in 1989 Rexroth Hydraudyne send a shock wave through the relative conservative civil engineering market. It proved very quickly that with Ceramax an inherent corrosion problem in the application of hydraulic cylinders in civil engineering was solved.



Fig. 1 : Hydraulic cylinder with CERAMAX coating

This is the reason that within several years after the introduction Ceramax had developed itself to a new global standard. The DIN comity was the first to adopt the Ceramax technology in its standard (see new DIN 19704, released in 1998). Currently followed by the JADEE, Japanese standardization comity.

It is not an overstatement to say that Ceramax has proven its excellence as a universal rod coating. New developments in coating processes enable us nowadays to fine tune the layer to its specific application demands. These varying from general industrial applications to severe applications requiring high wear and impact resistance in combination with exceptional corrosion and chemical resistance.

## **Chronological development**

The development in thermal spray technology goes way back to wire spraying. With this process low melting metals could be applied as Zn, Al, Mo etc for general corrosion protection purposes. A logical development was based on autogeneous techniques. The Autogeneous powder spraying made it possible to coat surfaces with Metallics like Fe, stainless steel and micro alloys. Together with the later developed In-melting process these technologies are unsuitable to use on piston rods for hydraulic cylinders. The break through in technology for piston rod coating came when the Plasma spray process developed via an open and middle spray technologies into a fine spray process. The first two allowed to spray  $ZrO_2$ ,  $Cr_2O_3$  and  $Al_2O_3$ , which are widely used in propulsion turbines for aircraft's and in the paper industry. The fine technology allows to spray  $Al_2O_3$  and  $TiO_2$  oxides resulting in the development of the Ceramax rod coating.

Recent developments have lead to a process, which makes use of lower temperatures and higher velocities. This process known as HVOF (High Velocity Oxygen Fuel) allows the spraying of stainless steels, Inconell and Hastalloy metal matrixes with imbedded hard particles as for instance carbides.

## Process Technology

### The Plasma process:

In this process a mixture of gases, usually argon and hydrogen, pass through a nozzle where a constricted arc can raise temperatures up to 30.000 °C. The gas exits the nozzle to produce a high velocity ionized plasma jet into which powdered material is injected. The powder is heated and accelerated to form a high

velocity spray of molten material, which subsequently impinges on a prepared substrate to form a dense integrally bonded coating (see photo 2).

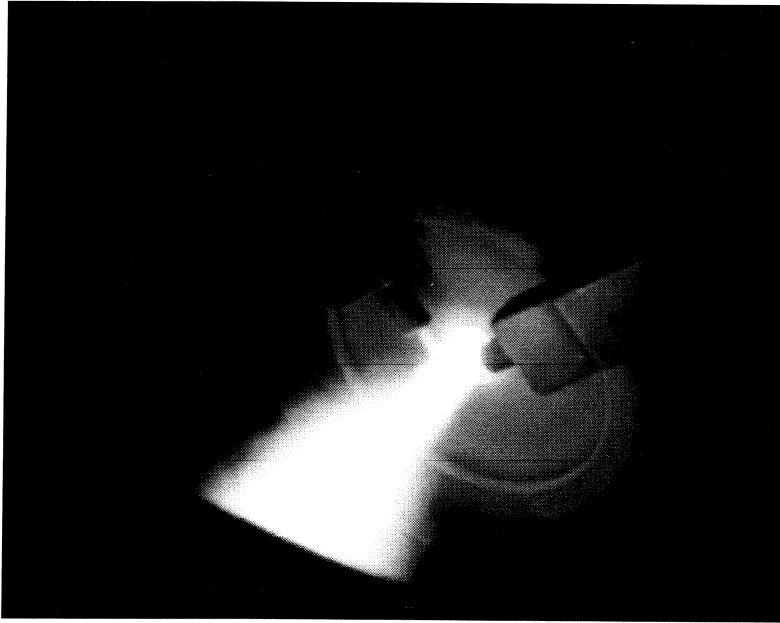


Fig. 2 : The plasma process

The benefits of the process are that hard, inert materials, which can not be applied by conventional processes, can be used to form a functional coating on piston rods. Despite the high temperatures of the plasma jet the substrate temperature is easily kept below 150 °C eliminating the possibility of distortion of metallurgical changes.

### The H.V.O.F. Process:

This process is the most recent development in thermal spraying. It consists of burning under pressure oxygen and a fuel liquid or gas, the hot exhaust gases exit down a narrow bore nozzle where finely powdered material is axially introduced. The powder is heated and accelerated with the gas jet being propelled to the substrate at supersonic velocities of 1200 m/sec (see photo 3). On impact the thermal and high kinetic energy ensure excellent bonding. The coating produced is harder and denser than those produced by other thermal spray techniques.



Fig. 3 : The H.V.O.F. process

## Critical process parameters

- 1) Process of shot blasting, bond coat spraying and topcoat applying has to be executed in one uninterrupted sequence. (The cabin in which the process is executed may not be entered during the different stages of the process and the process in itself may not be interrupted).
- 2) No manual control is allowed for:
  - Gas flow
  - Electro plasma power
  - Powder feed
  - Rpm of the rod in relation to the longitudinal feed of the gun

Only by using a full-automated and controlled process with continuous recording of these parameters a continuous quality can be guaranteed.

- 3) The coating should be applied in a conditioned area (fully encapsulated and exhaust controlled) ensuring that inclusions of non-melted parts (globulin's) and/or dust do not exceed a factor of more than 1 % (see photo 4 and 5).

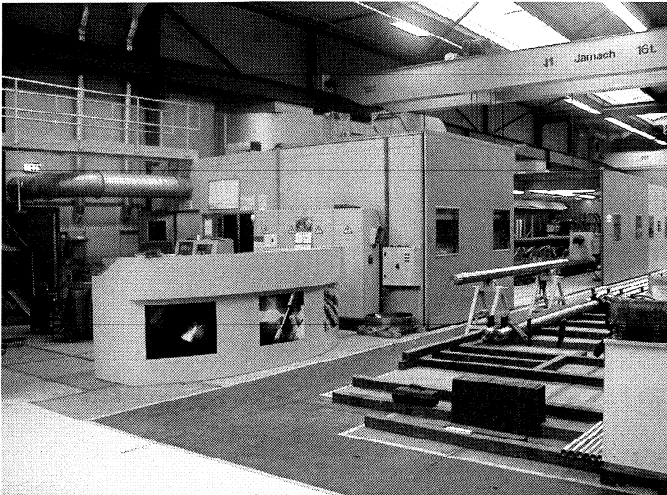


Fig. 4 : Plasma / H.V.O.F. installation (16 m)

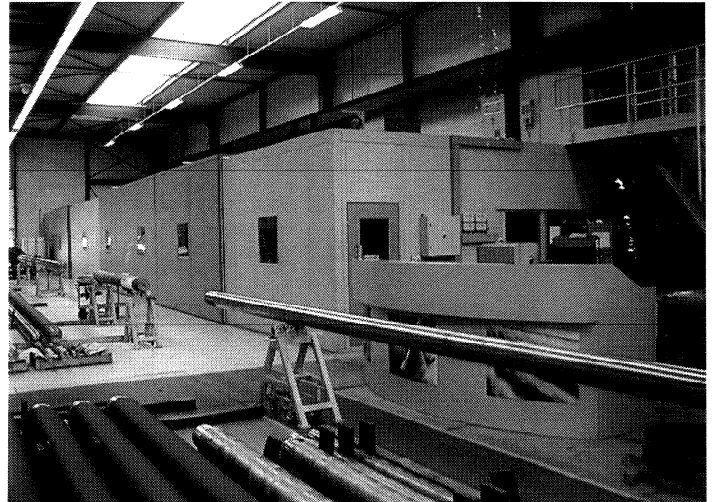


Fig. 5 : Plasma / H.V.O.F. installation (25 m)

## CEC; Ceramax Engineered coating

As a logical development to the original introduced general applicable Ceramax coating, Rexroth Hydraudyne has introduced, on the Hanover fair of April this year, a full range of coatings the so-called "Ceramax Engineered Coating" (CEC). This range of coatings varies by application of the plasma process and the new HVOF (High Velocity Oxygen Fuel) spraying technology.

This range of coating allows us to engineer the coating to the specific application demands (see selection matrix). These varying from general industrial applications to severe applications requiring high wear and impact resistance in combination with exceptional corrosion and chemical resistance.

## Qualification tests

Before introducing a new product to the market it is of imminent importance to warrant the reliability and durability. The qualification tests can be divided in two main divisions:

- Laboratory tests
- Practical field tests

Based on our experience with the development of Ceramax a selection of laboratory tests have been made which gives us the ability to estimate the performance of the coating in practical applications.

## Static bending tests

A rod with a diameter of 60 millimeter and a length of 1 meter is statically bend under a load coursing a stress equal to the yield point of the material (see photo 6). This load is applied to the rods for 10.000 times to simulate fatigue in the layer. After this test the rod is cut in the middle and specimens are taken from the compression and tension zone. The specimens are inspected under an electronic microscope and are checked on cracks and/or any imperfections and are subjected to a corrosion test.

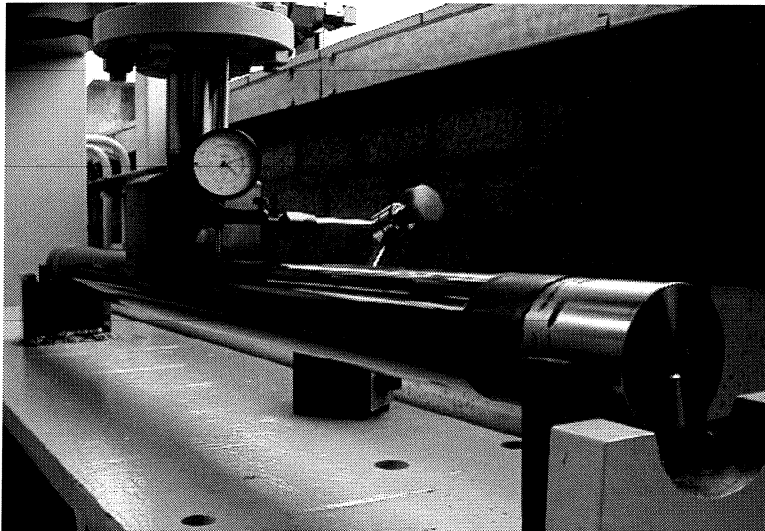


Fig. 6 : Static bending test

## Dynamic bending tests

The static bending tests give you good insights in the durability i.e. fatigue resistance of the layer. As it is also important to know how a layer behaves when next to bending a shear force is applied to the layer a dynamic test bench was constructed (see photo 7 and 8). The test bench allows us to judge the shear resistance of the layer combined with a bending load. This represents working situations of long stroke cylinders working under an inclination or cylinders which face big side loads. Next to the effectiveness of the layer this test gives a good view on piston rod bearing behavior under these working conditions.



Fig. 7: Dynamic bending test

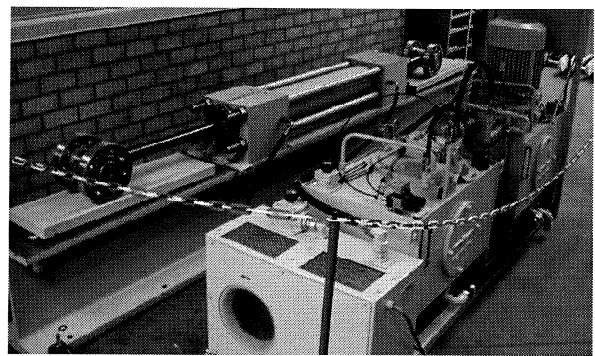


Fig. 8 : Dynamic bending test

## Corrosion resistance tests

The salt spray test according ASME G 85 / DIN 50021 / ISO 9227 is globally accepted as a representative test method to determine the corrosion resistance of the piston rod coating (see photo 9). The Salt spray test is based on spraying a test sample with a solution of:

- Sodium chloride 50 g/l
- Acetic acid
- pH of 3.1 – 3.3
- at 35 °C

With the introduction of Ceramax Rexroth Hydraudyne set the standard for a minimum of 1000 hours resistance.

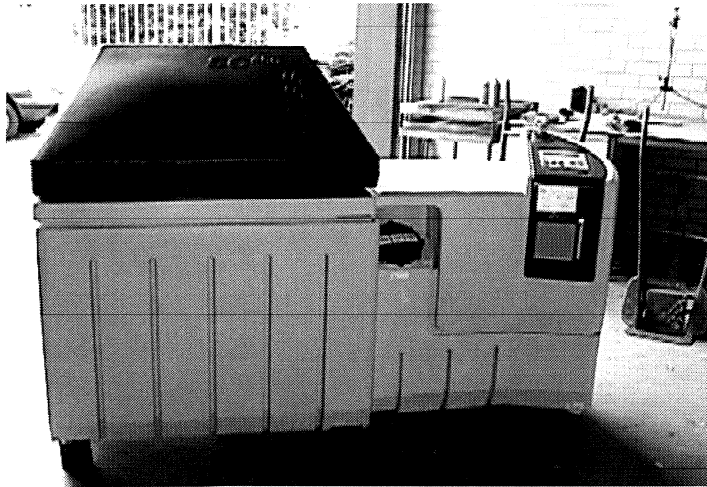


Fig. 9 : Salt spray test

When introducing the new layers based on metal matrixes processed by the HVOF (High Velocity Fuel technology) method the salt spray test became obsolete. This as the new layers showed a resistance to corrosion far exceeding the limits of the Salt spray test. It is therefore that Rexroth Hydraudyne researched for a more severe universal acceptable corrosion test method.

In close cooperation with TNO research laboratories in Holland and DNV (Det Norske Veritas) from Norway a whole new scheme of corrosion resistance testing is being developed. This test bases on three main pillars:

### Corrosion potential

The measuring of the corrosion potential indicates the electron balance at the corroding surface. By relating to a known potential to for instance the standard hydrogen electrode (SHE) or the saturated silver/silver- chloride electrode (sat. Ag/AgCl), an indication is retrieved for the behavior of the surface, influenced by galvanic corrosion.

Measuring this potential is therefore a very sensitive method to determine the amount of micro cracks for coatings applied on piston rod base materials.

### Polarization curve

The polarization curve gains information on surface orientated processes as supply of oxygen forming oxides. In fact it measures the current resulting from the corrosion process. During monitoring the polarization curve the potential will change in relation to the normal potential i.e. corrosion potential.

### Acceleration of the corrosion process

By influencing the electron balance on the surface of the corroding material, to the benefit of the metal-soluble reaction, the surface protection can be dissolved in an relatively short period of time. This gives a good indication of the life time i.e. durability of the layer in exposed conditions.



Based on the material compound monitoring which is applied to all three methods the quality of the different layers can be determined. When applied in comparison to traditional corrosion protection coatings and field experiences, this method gives a good indication on the expected behavior in exposed condition. Further investigations are in process to establish a benchmark for corrosion resistance.

## Scratch and wear tests

In a special developed test bench the surface coating is exposed to three types of abrasive material:

- Silver sand
- SiC grit
- Al<sub>2</sub>O<sub>3</sub> Shot blast grid

All materials are dissolved in a 3,5% salt-water solution and pre-stressed around the sample rod. The abrasion resistance is reported and compared to traditional coatings. The effect of different layer make-ups can be compared and form the basis for an application selection (see photo 10).

## Seal behavior test

We know from the past development of Ceramax that the morphology and surface structure of the layer are determining for the behavior of seals, bearings and wipers. To be able to know the sealing properties

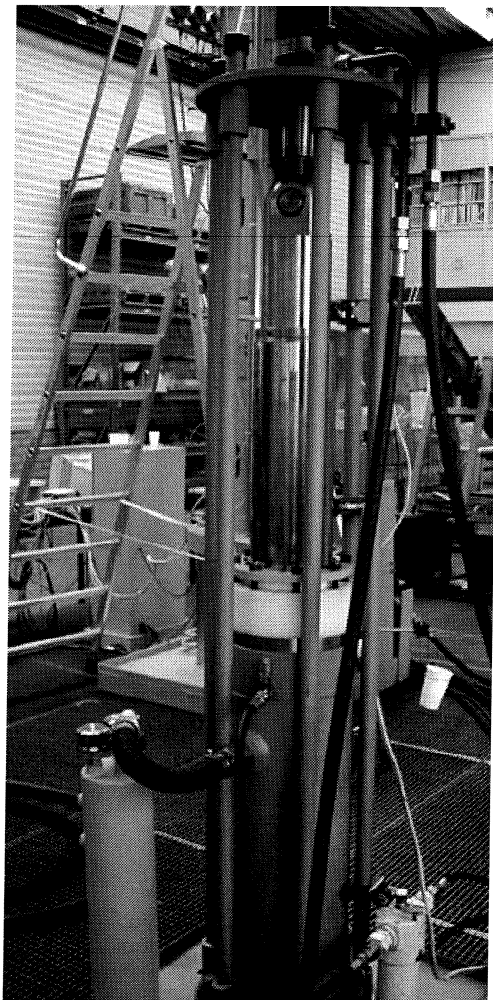


Fig. 10 : Scratch wear

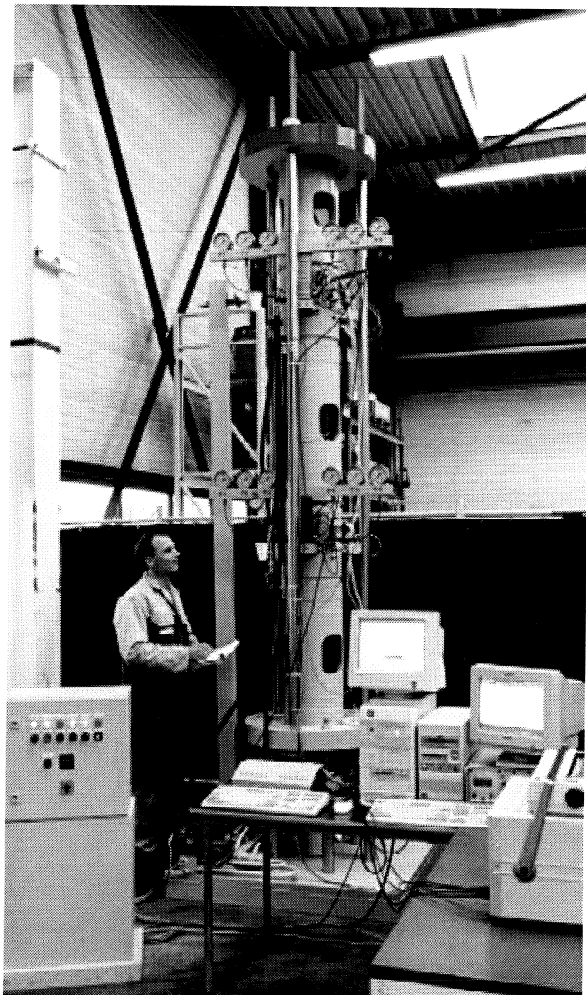


Fig. 11 : Seal tester

of seals on different layers the seals are dymical tested (see photo 11). These tests are achieved in a Test unit, monitoring sealing properties, static and dynamic friction and lifetime. In contradiction to the traditional Ceramax normal seal compounds can be used for the layers comprised from a metal matrix. The Ceramax Engineered coatings therefore cover the whole spectrum of layer make up, related seals, bearings and wipers.

## Impact test

As the properties of the base material highly influence the resistance of the coating to impact it is necessary to determine a proper representative test for impact resistance. It proved that the “ball” test gives the best indication of the impact resistance of the layer.

With this test a calibrated ball is dropped on the coating surface. The dropping height at which the layer starts fracturing represents the impact resistance.

## Field-tests

For the new layers based on a metal matrix pilot tests have been started in different test environments. These varying from high abrasive heavy industry applications to extreme corrosive and chemical environments in Offshore. In Civil engineering pilot projects are in Brunshüttel (North German seacoast) and Tübingen in the south of Germany. In combination with further field test programs, started for the CIAMS absolute measuring system, new pilot projects will be selected during the second half of the year 2001.

## Supply record

Number of cylinders supplied with C.E.C. 1.0 coating	: > 12.000
Number of pilot cylinders supplied with C.E.C. 2.0 coating	: > 170
Total cylinder stroke coated with C.E.C. coatings	: > 50.000 meter
Total surface covered with C.E.C. coatings	: > 30.000 square meter
Total volume of applied powders	: > 15 m <sup>3</sup>
Total weight of applied powders	: > 60 tons
Production share of C.E.C. coated cylinders	: > 85%

It is not an overstatement to say that the C.E.C. (Ceramax Engineered Coatings) opens new possibilities in improving the lifetime of the equipment used in civil engineering applications. This by adjusting the layer properties to the specific application demands.