Technical paper

Highly Anticorrosive Cylinder Rods by using the HVOF Thermal Spraying Method

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Komatsu has been making efforts to reduce machine downtime by controlling oil leakage from hydraulic cylinders due to corrosion of cylinder rods, which occurs frequently in severely corrosive environments causing salt damage. In this report, we like to introduce our activities made for the cylinder rod, which is one of the critical components for the service life of the machine, to develop a highly anticorrosive cylinder rod made by the HVOF thermal spraying method.

***Key Words**: Cylinder rod, thermal spraying, durability improvement*

1. Introduction

Komatsu has been making efforts to reduce machine downtime by suppressing oil leakage from hydraulic cylinders due to corrosion of cylinder rods, which is often the case with installations operated in severely corrosive environments causing salt damage.

This report introduces our activities for improving the corrosion resistance of sliding parts of cylinder rod that is one of the critical components in regard to the oil leakage and having decisive influence on the service life of the machine, and for developing a highly anticorrosive cylinder rod made by the HVOF thermal spraying method.

2. Operation Site in a Salt Damage Area and the Aim of This Development Project

An example of worksite in a severely corrosive environment exists in Australia (**Fig. 1**). The soil and sand of this site contain a high content of chloride ion, which is mixed with lake water and are highly corrosive to metals.

Fig. 1 A machine operating in a salt damage area (Dump Truck HD 465)

An actual case of rusting on cylinder rod sliding parts operating in Australia is shown in **Fig. 2**. Usually, the sliding area will not corrode even if operated for more than 10,000 hours, but cases of rusting occurring in only 1,000 hours resulting in oil leakage are reported. If this happens, it is unavoidable to remove the machine from service, and the productivity is degraded. Accordingly, we developed highly anticorrosive cylinder rods by using the HVOF thermal spraying method with the objective of suppressing the oil leakage resulting from rusting of the cylinder rod sliding area.

Fig. 2 Rusting of a cylinder rod

Fig. 3 HVOF thermal-sprayed cylinder rod

HVOF thermal-sprayed cylinder rods were installed as steering cylinder rods on HD 465 and HD 785 machines respectively to evaluate the durability in a salt damage area. A cylinder rod in an operating state is shown in **Fig. 3**, and the operating hours until oil leakage occurs are shown in **Fig. 4**. As a result of the installing the rods on three machines (two rods per machine), their durability was 5,000 hours or more in average, indicating their intensely excellent corrosion resistance.

Currently, the HVOF thermal-sprayed cylinder rods are shipped for users in Australia.

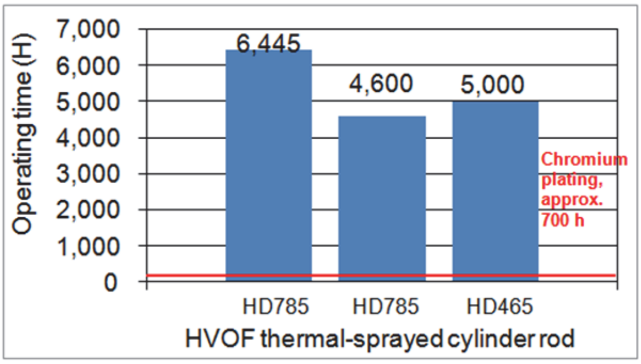


Fig. 4 Durability of HVOF thermal-sprayed cylinder rod

3. HVOF Thermal Spraying Method and Its Advantages

HVOF thermal spraying (**Fig. 5**) refers to the High Velocity Oxygen-Fuel (HVOF) thermal spraying process for generating a high-velocity flame derived from the theory of jet engine, where a powdery mixture containing metallic or ceramic particles is sprinkled into a flame and allowed to fly and collide with a target substrate to be laminated to form a coated film. Compared with other thermal spraying methods, the HVOF thermal spraying has the following general advantages:

(1) Its relatively low spray temperature prevents the process material from being degraded; and

(2) its supersonic velocity allows the work material to form a highly dense coated film (**Fig. 6**).

The powdery material for thermal-spraying was designed to consist of one or more carbides and metals (binder) having an adequate composition, formulating proportion, particle size and particle size distribution (**Fig. 7**). By controlling the optimum thermal spraying conditions (oxygen/fuel ratio, thermal spraying distance, powder feeding rate, etc), a highly dense coated film was successfully formed (**Fig. 8**).

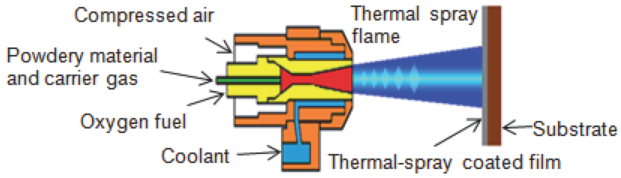


Fig. 5 Illustration of the principle of HVOF thermal spraying process

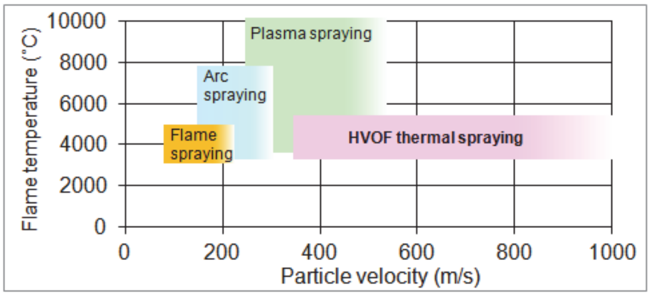


Fig. 6 Comparison of thermal spraying methods

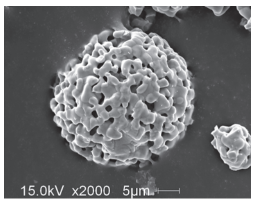


Fig. 7 Appearance of a particle to be thermal-sprayed

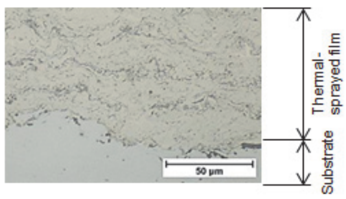


Fig. 8 Cross-sectional microstructure of HVOF thermal spray-coated film

4. Characteristics of Thermal Spray-coated Film

Table 1 summarizes the characteristics and evaluation methods required for the coated film of cylinder rod sliding parts.

The following describes the advantages of HVOF thermal spray coating in comparison with a common hard chromium plating:

Table 1 Demand characteristics and evaluation methods

Demand characteristics	Evaluation method
Abrasion resistance	Abrasion test with included foreign matters
Impact resistance	Falling weight test
Corrosion resistance	CASS test
Adverse effect on seals	Cylinder assembly leakage test

4.1 Abrasion resistance

We conducted a reciprocating sliding test simulating a case where soil and sand are included in the contact area between a cylinder rod and seals. While the test conditions are as given in **Table 2**, **Fig. 9** and **10**, the test as such that the test piece consisting of a curved butting end having a radius of R35 is allowed to depress the NBR plate.

Table 2 Test conditions

Load	10kgf
Speed	0.5m/s
Stroke	60mm
Oil temperature	Room temperature
Silica sand grain size	10μm
Testing time	12H

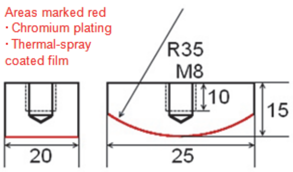


Fig. 9 Shape of test piece

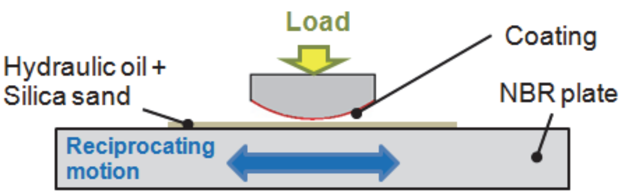


Fig. 10 Test method

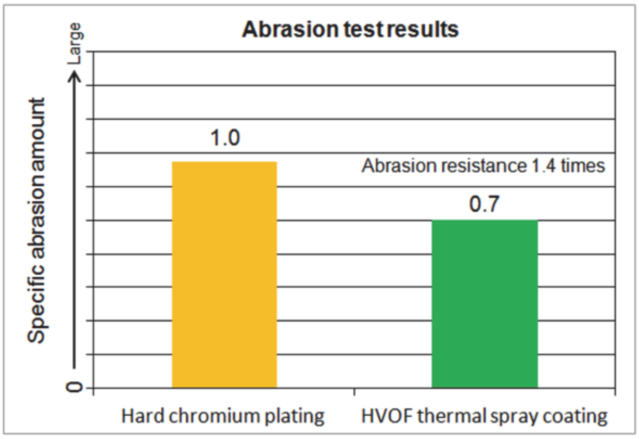


Fig. 11 Abrasion test with included foreign matters

Fig. 11 gives the test results. The HVOF thermal spray-coated product apparently has an excellent abrasion resistance as 1.4 times as high as a hard chromium plated piece.

4.2 Impact resistance

While a construction machine is in operation, the sliding area of its hydraulic cylinder is often hit by flying gravels or stones. The thermal spray-coated member is required to have adequate impact resistance. Accordingly, we verified the impact resistance of thermal spray-coated film by conducting a falling weight test. Its test method is schematically illustrated in **Fig. 12**. A ϕ20 steel ball was allowed to fall on a test piece that is placed with an inclination of 45 degrees, and the cracks or the dent formed on the coated film was examined. **Fig. 13** gives the test results. The limit height was defined at the point where the surface of coated film was cracked or dented. The limit height of HVOF thermal spray-coated piece was found to be 9 times as high as that of a hard chromium plated pieces, substantiating the favorable impact resistance.

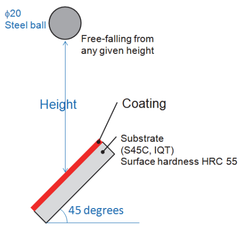


Fig. 12 Falling weight test method

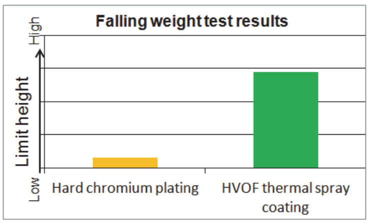


Fig. 13 Falling weight test results

4.3 Corrosion resistance

Assuming that the site was in a salt damage area, we employed the CASS test that was known to include a particularly strict pH value among a number of applicable JIS standards. For the evaluation after testing, a relative evaluation based on the time elapsed from rating number denoting the corrosion area factor to rusting was employed conforming to the JIS standards.

As shown in **Fig. 14**, while red rust was observed on a hard chromium plated piece after 48 hours of exposure, the HVOF thermal spray-coated piece showed similar red rusting after 96 hours. These results indicate that the corrosion resistance of HVOF thermal spray-coated product is twice as high as that of the other, and thus the new product can be destined to salt damage areas.

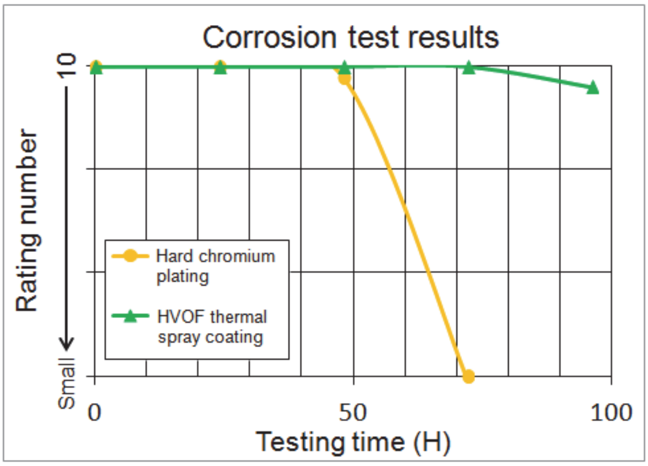


Fig. 14 Corrosion test results

4.4 Adverse effect on seals

It is required that the hydraulic cylinder should not excessively attack sealing members. The test method is schematically illustrated in **Fig. 15**. The reciprocation shaft of hydraulic cylinder was horizontally held above the floor, and the sample was allowed to perform a reciprocating motion in full stroke for a specified period of time.

Fig. 16 indicates the test results. The tightening allowance for the seal could be maintained at 0 or more and favorable results were obtained without any fault or abnormal dimensional change and discoloration during the sliding.

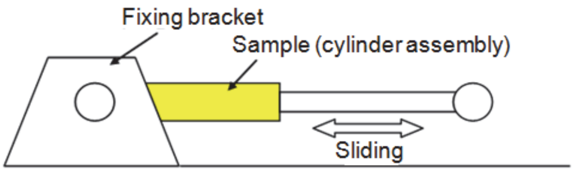


Fig. 15 Test method

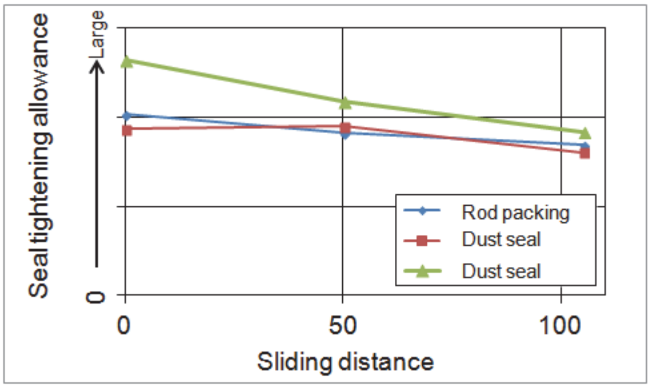


Fig. 16 Variation in seal tightening allowance

5. Conclusion

To achieve the objective of improving the corrosion resistance of hydraulic cylinder rods operating on site in a salt damage area, we have developed the cylinder rods by applying the HVOF thermal spraying method and introduced them for the actual services in the field.

Results of characteristics evaluation of the HVOF thermal spray-coated film are as follows:

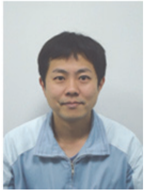
(1) Against a common hard chromium-plated product, the subject film gives 1.4 times of abrasion resistance, 9 times of impact resistance and two fold of corrosion resistance.

(2) The subject has no adverse effect on sealing members.

(3) The evaluation of an on-site machine gave 6.5 times as high durability as that of conventional products.

In response to the above-described results, we have introduced the rod having the HVOF thermal spray-coated film to the cylinder of dump trucks operated in Australia, specifically in salt damage areas where the corrosion of cylinder rods are causing troubles.

Introduction of the writers



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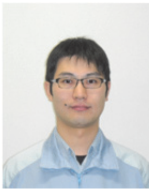

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[A comment from the author]

In this report, we have introduced the durability of hydraulic cylinder operating in the severe environment particularly in salt damage areas. Further, we would like to continue the development of new technologies for minimizing the customers' LCC by paying attention to not only this case, but also machines that are deployed and operated in the global marketplace.