Wear behavior comparison between hard chrome and molybdenum based plasma spray coating on spheroid graphite cast iron

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Abstract: In this article, wear behavior, hardness and adhesion of hard chrome coating and molybdenum based plasma spray coating on the base metal of spheroid graphite cast iron has been compared. First of all, sample from base metal with the dimension of 30× 120 mm were prepared, then on the samples, hard chrome and molybdenum based plasma spray coating with identical thickness has been devised. Metallographic, micro hardness and wear testing were done for comparison. Wear test results shown that in the similar condition for both coating, molybdenum based plasma spray coating has better wear resistance

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1. Introduction

Properties of engineering pieces are not only dependent to their inner properties, but also dependent on their properties and characterizations of their surface [1]. This is especially true about cast iron pieces which are faced to wear, because they have to provide general properties required for pieces and also their surface have to be hard and resistible. Different coating is used on cast iron to increase mechanical and corrosion properties on pieces surface [2, 3, and 4].

Hard chrome coat can be obtained using electrolysis of chromic acid solution, and this acid is the main factor of process. There are many factors effecting on hard chrome coating process, if these factors go out of control there might be some default on coating. High hardness of electrochemical chrome coating leads to call it hard chrome in industry. One of important properties of hard chrome is low surface energy of it, and it is one of the metals with the lowest coefficient friction, so it is one of the most practical metals in industry. In addition most of liquids and solids cannot stick easily on chrome coat, so the chrome coat will remain clean and shine and has more durability.

Nowadays, plasma spray process is used for creation of coating with high wear resistibility and resistibility against corrosion. This method is used to increase wear resistibility of spices like bearing rein, sealers, valve seats, turbine motors, and refinery spices and so on. Plasma spray coating and generally all thermal spray coating are used widely in different industries. Molybdenum base coating on spices increase their surface corrosion resistibility notably, and resistibility of thermal spray coating of molybdenum against adherent wear can be controlled using coating parameters [5].

In this article chrome coating and molybdenum based plasma spray coating on the base metal of spheroid graphite cast iron has been compared. Metallographic, micro hardness and wear testing were done for comparison, and the result will be discussed.

2. Materials and Methods

Standard samples for wear and metallographic test were cast at Ring Khodro Pars Company, experimental samples of spheroid cast iron (with spherical graphite) based on structure and basement of figure 1 and based on chemical analysis of table 1, then 30×120mm dimension were obtained using machinery process. Since investigation of Wear and mechanical behavior of hard chrome and molybdenum based plasma spray coating on spheroid graphite cast iron was the purpose of this work, it was attempt to get the cast iron base of the samples, without casting fault such as Mac.

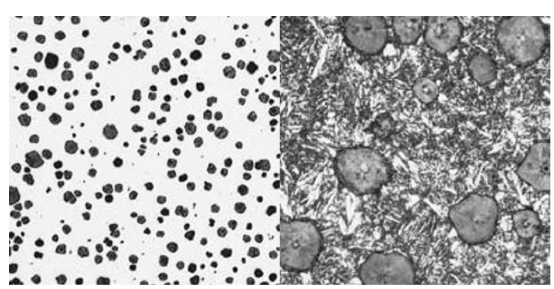


Figure1. Structure and basement of graphite cast iron [6]

Table1. Chemical analysis of graphite cast iron [6]

C	3.5 - 4.0
Si	2.4 - 3.2
Mn	max 0.5
P	max 0.3
S	max 0.05
Cr	max 0.2
Cu	max 1.0
Mg	max 0.1

2.1. Plating process of hard chrome on samples

Hard chrome coat was made on 15 samples using electrochemical plating process at Ring Khodro Pars Company. This was done by several steps; base surface polish, preparation and de fat of piece by three ethylene chlorate, rust removal, cleaning and sometimes heating, hard chrome plating, cleaning and drying, final polish and gas ans tension removal after polishing .Figure 2 shows process of hard chrome coat creation on samples. Specifications of electrochemical solution which was used are based on table 2.

Figure2. Hard chrome coat creating process

Table2. Specifications of electrochemical solutions

Material	Quantity
CrO3	300 g/l
SO_4^{2-}	2.3 g/l
F^-	0.55 g/l
$CH_3SO_3^-$	4.2 ml/l
Cr_2O_3	2 g/l

2.2. Plasma spray process on samples

In plasma spray process, thermal energy was obtained from electrical arc (usually between 40 to 80 K.W.) and a plasma gas which is usually Argon or Nitrogen for melting and throwing of coating materials with high speeds (600 m/s) on surfaces. The main use of this system is for generation of high temperature, around 16000°C. This high temperature is for spray materials with high melting point. Coating materials are often powders and for translating them into needle a carrier gas is needed. High speed and melting materials can make high strength bond in coat. Schematic of this process is presented in figure3.

At thermal spray process, samples were at a fixed place like figure 4 fixer for getting the coat. In this article for a solution based on chemical composition of table 3 was used for coating Molybdenum base. After creating chrome and base molybdenum coat on samples by electrochemical and plasma spray method, coat thickness on all samples got the same value of µm100 by grinding. Figure 5 shows samples after coating and grinding.

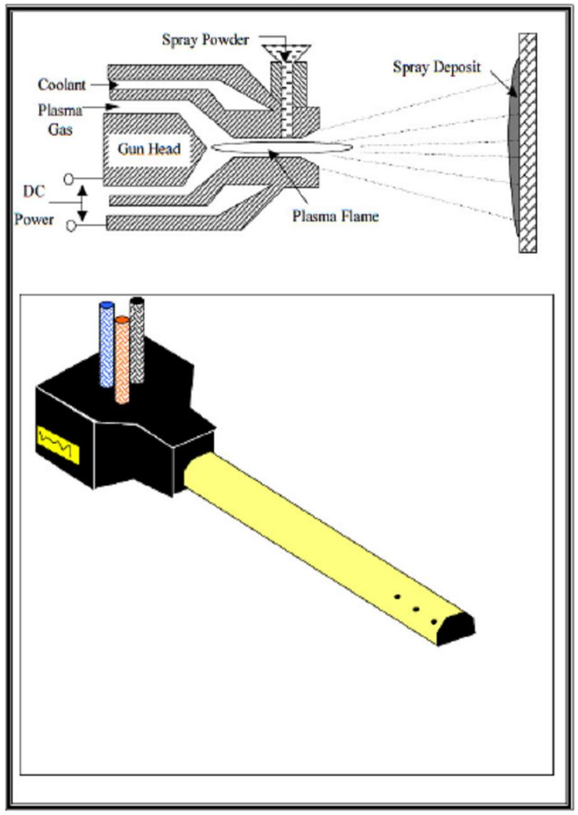


Figure3. Plasma spray process schematic

Figure 4. Plasma spray gun on samples for molybdenum coat creation

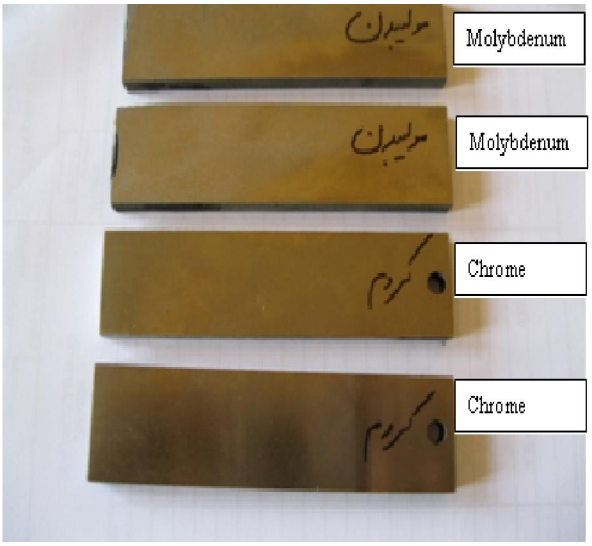


Figure 5. Coated samples after grinding

Table 3. Chemical composition of molybdenum coat powder

Element	Ni	Cr	B	Si	Fe	Mo
Weight percent	18	4/5	%8	2	1	-

3. Results and discussions

3.1. Results of wear test for comparison between hard chrome and molybdenum based plasma spray coating

For wear test the Pin test was done on cubic samples. This test was based on ASTMG99 standard. In this test the value of weariness was obtained by weight or volume reduction. Coefficient of friction was also calculated using this test. In this test a pin of 52100 steel with 63HRC hardness were put vertical on hard chrome and molybdenum coated Blocks, after passing a specified distance with a specified force, weight (volume) reduction per distance was measured.

Based on standards, samples were washed, dried and weighted with 0.0001g accuracy before test. It is important to note that the samples should not wash with Chlorinated solutions or solutions which can make films. Samples were fixed on device, proper force and necessary speed was specified by controller sections of device. Output of this test is the wear rate based on coefficient of friction and slip distance. In this work the weight reduction was used for wear studies. Wear test and wearing pin conditions are listed in table 4.

Weight of samples was measured using Sartarius LA-230S balance with 0.0001g accuracy. After starting the test weight reduction of sample was measured in 100, 200, 300, 500, 700, 1000 m distance. Figure 6 shows the used device for wear test.

Diagram of friction coefficient based on slip distance was draw simultaneously by wear device employing following formula:

$$\mu = \frac{F}{N}$$

Where F is friction force which is recorded based on mentioned process, and N is vertical force of pin on the sample.

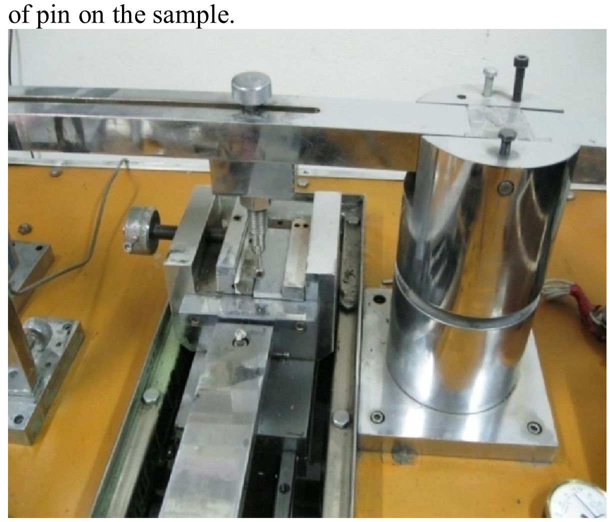


Figure 6. Wear test device

Table 4. Wear test and wear pin conditions

High temperature wear test	Parameter
10 (N)	Vertical force
8(m/ min)	Pin speed
85(mm)	Wear path distance
Steel pin 52100	Wear
1000 (m)	Slip distance

3.1.1. Studies of weight change of samples due to wear

Diagrams of weight reduction of hard chrome and molybdenum coating on graphite cast iron samples are present at figure 7 and 8, and figure 9 shows the comparison of them. As it can be seen due to 1000m wear on both samples with same conditions, molybdenum coat samples had the less wear in weight scale. Based on column diagram of weight reduction of figure 9 with comparison weight changes of coats it can be predicted that wear age of molybdenum based plasma spray coat is twice than hard chrome coat.

1.1.1. Studies of frictional condition of samples due to wear and analysis of wear mechanism

Friction coefficient diagram of coated samples with hard chrome and molybdenum are presented at figure 10 and 11. As it can be seen in figures molybdenum coat had the lower friction coefficient in comparison 52100 steel than hard chrome. This is in agreement with weight reduction result. This is because of more wear particles from hard chrome coat wear, 3 bodies grazing wear condition and increase of friction coefficient due to fouling of wear particles between pin and coat.

Wear test shows 52100 wear pin on hard chrome coat had more weight reduction than molybdenum coat, and this indicate that hard chrome coat has more wear than molybdenum (generally due to existence of grooves and activation of grooves mechanism) and also it makes more wear on other spices. Fluctuations in hard chrome coat friction coefficient diagram per distance is due to cutting of bigger particles from coat surface and tackling of them between pin and coat, this indicates superficial wear and rejoining of grooves and remove of coat due to tensions.

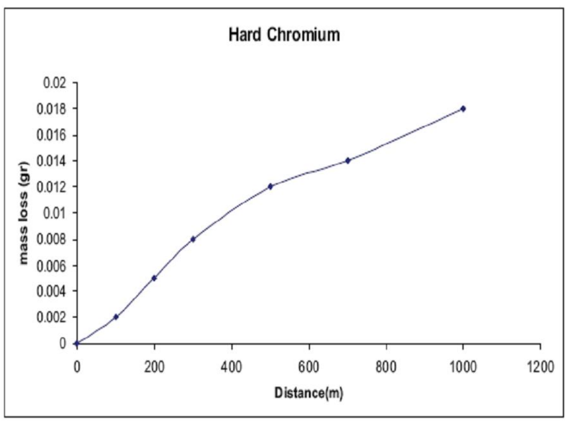


Figure 7. Diagram of weight reduction of hard chrome coat samples

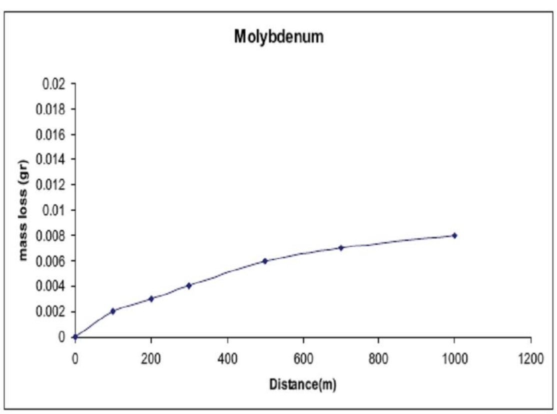
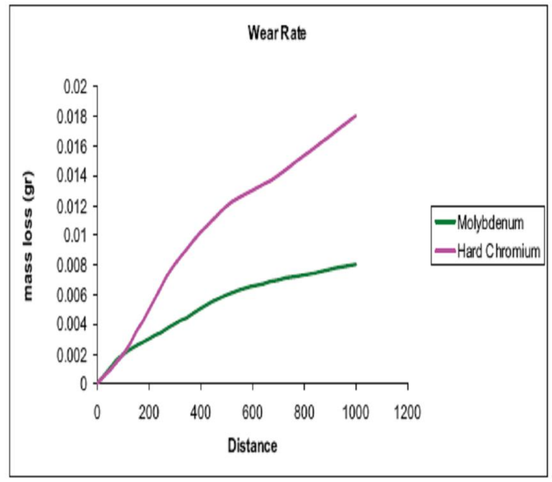


Figure 8. Diagram of weight reduction of molybdenum coated samples.



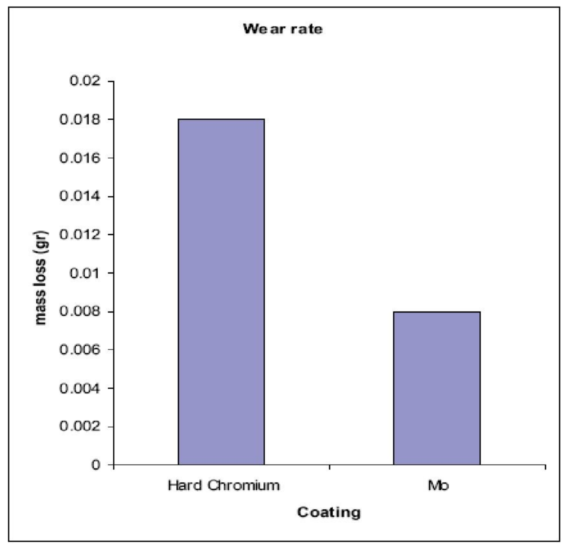


Figure 9. Comparison weight reduction changing of coats

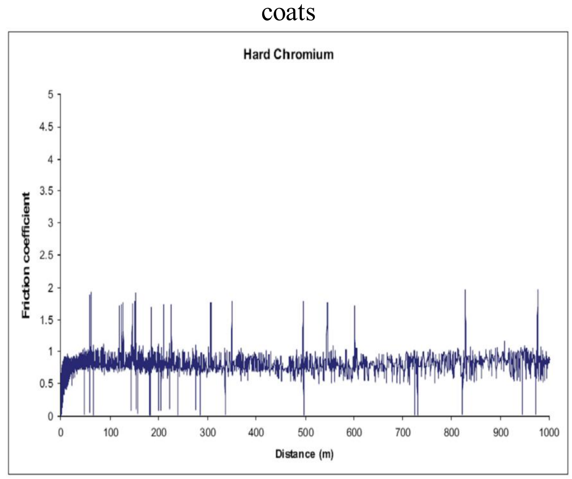


Figure 10. Friction coefficient of hard chrome coated samples

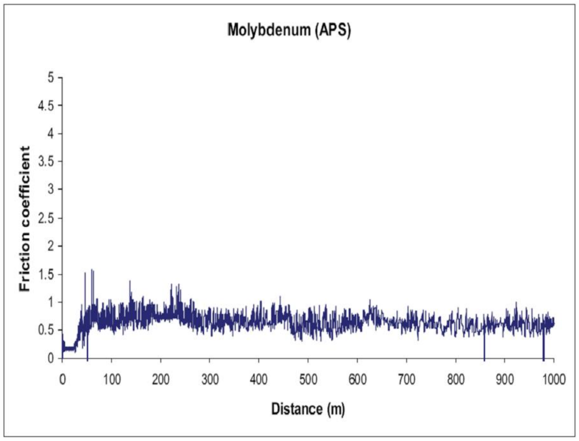


Figure 11. Friction coefficient of molybdenum coated samples

1.2. Studies of hardness of hard chrome coat and plasma spray molybdenum coat

Studies of hardness and wear behavior relation of coats was done by Vickers hardness test on four samples of molybdenum coat and four samples of hard chrome coat. Hardness of chrome coat is 900-1150 HV 0.1 as it can be seen in figure12. The main point about molybdenum coat is existence of two different phase of molybdenum (bright phase) and other elements phase NiCrBSi (dark phase). Clarifying of dark and bright phase of molybdenum coats (figure 13 and 14) can be done using H Murakami solution [7]. Because of existence of two different phase of molybdenum (bright phase) and NiCrBSi phase (dark phase) Vickers hardness test was used in coating section, as it can be seen in optical microscope of Vickers hardness test device dark and bright phase were test individually, and the mean hardness for 10 effected point of any phase was reported as final hardness of any samples.

Mean hardness of dark phase is 468.7HV 0. 05 and mean hardness of bright phase is 896.7HV 0.05 . Therefore, based on wear and hardness test molybdenum coating with less hardness has better operation as far as wear is concerned.

1.3. Coat adherence test

Adherence test was done on samples of figure 15 to study the coating adherence to substrate based on standard (ASTM C633-1). Samples of base metal in cylindrical shape of 25mm diameter and 38mm high were prepared. One side of them was sandblast and coated. Coated surface of samples was stacked to same samples without coating, using epoxy of 50 Mega Pascal epoxy and was put into tension test device using special fixer, and was separated using tension force. Studies on all samples of hard chrome and molybdenum coat show that separation was not from interface of coat and sample, and it was in epoxy itself, therefore it can be accept that for both coating adherence is more than 50 Mega Pascal ,which is a notable amount. But due to limitations in epoxy power, we couldn't answer which coating has higher adherence.

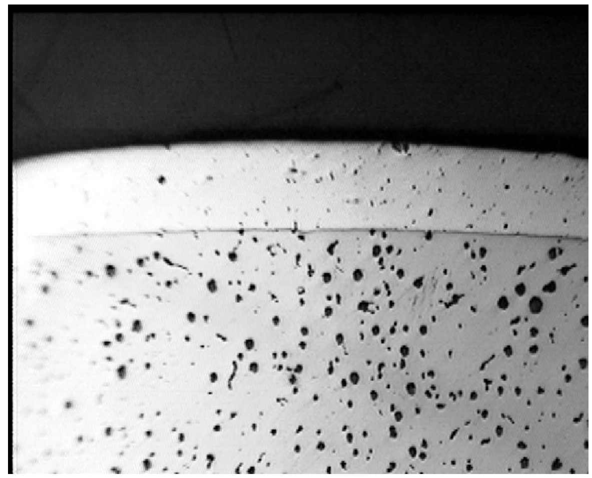


Figure 12. Hard chrome coat on cast iron with spherical graphite

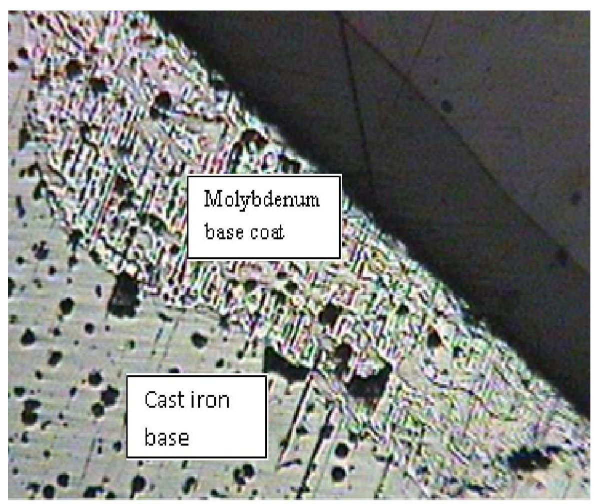


Figure 13. Molybdenum coat on cast iron with spherical graphite before H Murakami solution

Figure 14. Molybdenum coat after H Murakami and creation of dark and bright phase

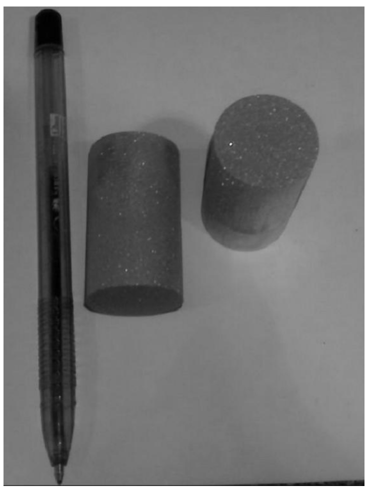


Figure 15. Adherence test sample

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