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# EFFECT OF $CeO_2$ ADDITION ON WEAR, CORROSION AND RESISTANCE TO THERMAL FATIGUE OF INDUCTION HEATING Ni-WC COATINGS

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Ni-WC composite coatings with different rare earth $CeO_2$ additions were prepared on the substrate of 45 steel by induction heating. The wear resistance, corrosion resistance and resistance to thermal fatigue of the coating were checked with a self-made friction and wear tester, a medium-sized salt spray corrosion tank and a box-type resistance furnace. Meanwhile, the microstructure and WC morphology of each coating were analyzed by scanning electron microscopy to assist in the analysis of performance changes. The results show that the 0,5 / % $CeO_2$ content helps to refine the grain size and the WC morphology, and that the 0,5 / % $CeO_2$ content coating has the highest wear resistance, corrosion resistance and resistance to thermal fatigue.

*Keywords:* Ni-WC coatings, $CeO_2$ content, induction heating, wear resistance, corrosion resistance

## INTRODUCTION

As the level of industrialization continues to progress, the requirements for materials to resist high temperature, high pressure, corrosion, wear and fatigue resistance are increasing, driving the continuous progress of materials science research. New technologies are emerging, and some special requirements for materials are no longer met by a single material [1-3]. Induction heating [4,5] alloy coating process is a new technology of modern surface metallurgy, whose role is to change the composition and organization of the working surface of the base material, so that the material can meet the wear resistance, corrosion resistance, resistance to thermal fatigue and other various use requirements. It has been widely used in rolling steel guide system, internal combustion engine cylinder, mining wear parts and other important positions [6-8].

## TEST CONDITIONS AND NETHODS

### Specimen preparation

Raw materials: The specimen substrate was rolled state 45 steel with the size of 15 / mm × 25 / mm × 10 / mm; The powder was the mix of Ni45B and rare earth $CeO_2$ in different additions, the powder is the mix of Ni45B and rare earth $CeO_2$ according to the proportion of different additions. Chemical composition of Ni45B: C is 0,7 / %, Si is 3,5 / %, B is 3,0 / % Cr is 15 / %, Fe is less than 12 / %. Chemical composition of $CeO_2$: Cu is less than 0,002 / %, Fe is less than 0,002 / %, Rare earths (except Ce) is less than 0,5 / %. Chemical composition of WC: WC is 70 / %, Ni is 30 / %.

Preparation: The coating material was $CeO_2$ with additions of 0,0 / %, 0,25 / %, 0,5 / %, 0,75 / % and 1,0 / %, respectively, 30 / % WC, and the balance was Ni45B. The alloy powder was ground and mixed and the 1.5mm thickness of powder was pre-placed on the surface of the specimen, and the coating with different $CeO_2$ additions was fused onto the surface of the substrate using medium frequency induction heating technology.

### Test method

After polishing and corroding the specimen sections, scanning electron microscopy (SEM) were used to observe the coating, matrix and WC microstructure. The wear resistance, corrosion resistance and resistance to thermal fatigue of the coating were checked by means of self-made friction and wear tester, medium-sized salt spray corrosion tank and box-type resistance furnace.

## EXPERIMENTAL RESULTS

### Wear resistance of the coating

The surface slag of the coating with different $CeO_2$ additions was polished and the wear resistance of each coating surface was determined by using a self-made friction and wear tester. The experimental results are shown in Figure 1.

It can be seen from the figure that the initial wear amount is relatively large, which is due to defects such

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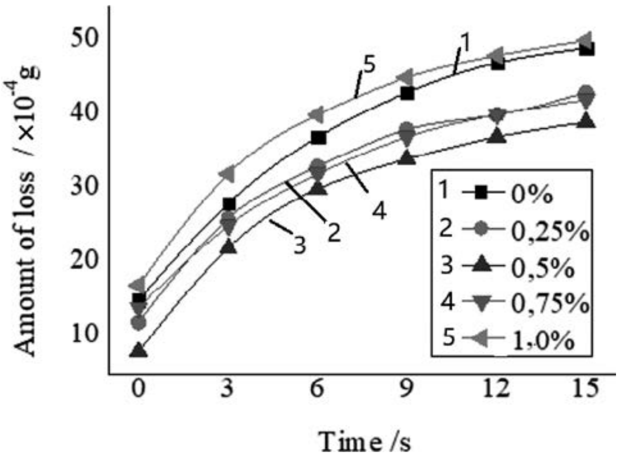



**Figure 1** The curve of Friction and wear of coatings with different $CeO_2$ content

as looseness and pores on the surface of the coating. At the same time the hard phase WC is relatively sparse, after that the wear increment gradually decreases. When $CeO_2$ addition is 0,5 / %, the coating has the least wear weight loss and the best wear resistance. This is because the appropriate amount of $CeO_2$ addition makes the grain refinement of the coating alloy finer, so that the nickel base can absorb a lot of strain energy and the toughness becomes better, which provides a favourable support and bonding effect to the WC particles. At the same time the appropriate amount of $CeO_2$ addition makes the hard phase refine and disperse the distribution, as shown in Figure 2. The increasingly good wear resistance of the alloy eases the cutting and ploughing process and improves the wear resistance of the coating.

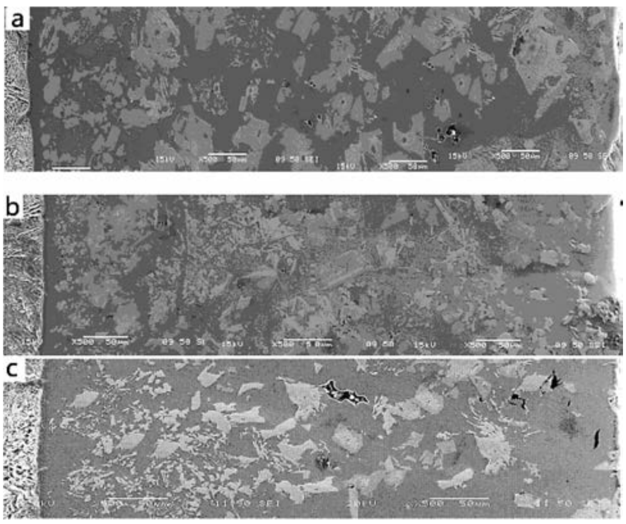
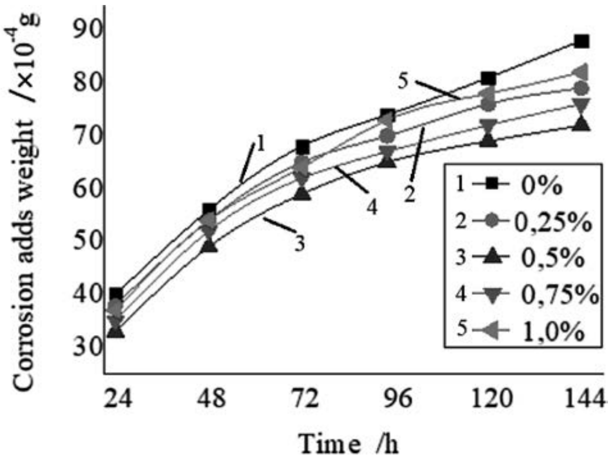


**Figure 2** SEM of the coatings with different $CeO_2$ content
a - 0 / % $CeO_2$ b - 0,5 / % $CeO_2$ c - 1,0 / % $CeO_2$

## Corrosion resistance test of coating

Make the specimen into 20 / mm×10 / mm surface, wrap the other surfaces with phenolic resin and put it into a medium-sized salt spray corrosion tank to corrode for 144 / h. The corrosion rate was calculated by using accurate to $10^{-4}$ / g weight changes for every 24 / h. The corrosion curve is shown in Figure 3.

It can be seen that as the corrosion time increases, the weight of all the coating corrosion specimens increases, but the increment gradually decreases. This is because the nickel base alloy in the salt spray produced passivation film hinder the rapid corrosion. Eexcept for the coating containing 1,0 / % $CeO_2$, add $CeO_2$ coating weight increase all less than the nickel base alloy coating without adding $CeO_2$. The coating with 0,5 / % $CeO_2$ has the highest corrosion resistance. This is because the appropriate amount of rare earth $CeO_2$ is preferentially present at the defect enrichment sites such as grain boundaries. In the corrosion process, grain boundaries are fast diffusion channels for the material particles, and metal cations will preferentially diffuse outward from the grain boundaries to form the passivation film. The enrichment of $CeO_2$ here will block the channels for the outward diffusion of cations, making the anion $O^{2-}$ inward diffusion dominant, changing the porous, loose structure due to the outward diffusion of cations, making the adhesion of the passivation film containing $CeO_2$ coating and the body greatly improve, thus reducing the formation of cavities due to the outward migration of $Cr^{3+}$ at the interface between the passivation film and the alloy substrate, preventing the outward diffusion of metal ions and making the rate of corrosion lower.




**Figrue 3** Corrosion loss curve of coatings with different $CeO_2$ content

## Thermal fatigue resistance of coating

Put the coating specimens with different $CeO_2$ content in the box-type resistance furnace, then heat up to the set temperature (650 / °C, 750 / °C) respectively, keep warm for 5min and then take the water cooling immediately, carry out thermal cycling treatment in this way. Observe the situation of appearing cracks on the coating, and record the number of thermal cycles when cracks first appearance on the coating. The experimental results are shown in Figure 4.

It can be seen from the figure, when the thermal cycling temperature is 650 / °C and 750 / °C, times of the adding rare earth $CeO_2$ coatings' crack first appearance are higher than those without adding the coatings, and the addition of 0,5 / % $CeO_2$ coatings have the most

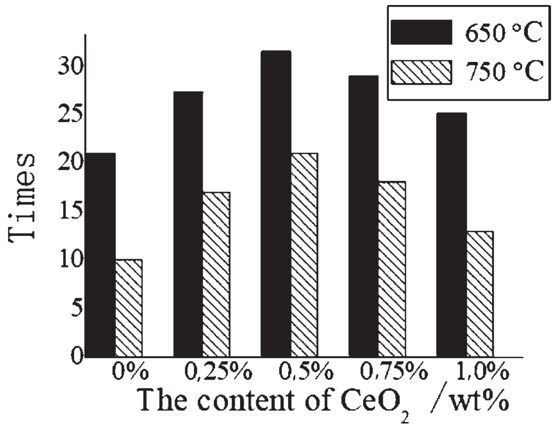



**Figure 4** Times of the coatings' crack first appearance with different thermal-cycle temperature

cycles and the best resistance to thermal fatigue. This is because the appropriate amount of $CeO_2$ can effectively refine the WC morphology, refine the coating organization, reduce the defects such as pores and cracks in the coating, and reduce the source of cracks due to thermal fatigue.

## CONCLUSIONS

The appropriate amount of $CeO_2$ addition can effectively refine the WC morphology and coating organization and reduce the defects such as pores and cracks.

The wear resistance of the coatings is all improved by the addition of $CeO_2$ (except 1,0 / %), and the best wear resistance of the coatings is achieved at 0,5 / % $CeO_2$ addition.

When the addition of $CeO_2$ is 0,5 / %, the coating has the best salt spray corrosion resistance.

The resistance to thermal fatigue of the coatings with the addition of $CeO_2$ is all improved, and when $CeO_2$ is added at 0,5 / %, the resistance to thermal fatigue of the coatings is the best.

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**Note:** The responsible translator for English is Yan Wu,
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