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WEAR BEHAVIOUR AND ITS CORRELATION TO RESIDUAL STRESSES FOR NICKEL HARD IRONS

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ABSTRACT

The material, Nickel- Chromium, is extensively used for wear resistant applications in thermal power stations, mining, earth moving applications and other engineering industries. While the erosion and abrasion behavior are known in respect of Nickel-hard under various test conditions, the residual stress levels arising due to varied processing conditions, like heat treatment, cooling rate etc, needs to be investigated as the literature on this is scanty. These aspects have been addressed in the present work by linking wear and residual stresses of materials. The experimental results show that the residual stress levels as well as wear properties get affected due to varied cooling rates employed during casting process. The heat treatment of the castings has brought about significant change in the stress levels as well as erosion and abrasion behavior. The structural aspects linking wear and residual stresses in Ni-hard have also been brought out. Thus, a good correlation between wear (erosion and abrasion) and residual stresses has been established.

Key Words: *Ni-Cr irons, abrasion, wear, retained austenite, residual stresses*

1. Introduction

Attempts to alloy white iron had gained tremendous momentum, eventually leading to the development of martensitic iron [1]. Ni-hard is a white cast iron alloyed with 8 % Ni and 3% Chromium. The addition of Nickel and chromium to white iron melts and influences both the primary and eutectic phases. The presence of Nickel wholly in the primary austenite phase will suppress the tendency to transform to pearlite on cooling and result in a mixed structure of martensite and retained austenite.

In addition, chromium is found wholly in the carbide phase where it replaces iron in the iron carbide lattice structure, thereby altering the properties of the carbide and thereby resulting in improved toughness [2,3].

The optimum composition of Nickel Chromium iron alloy depends on the properties required for service conditions[4,5]. This Ni-Cr iron is extensively used in wear resistant applications. In the present work, the wear resistance of Ni-Cr is intended to enhance further by suitable heat treatment. The unique feature of the study is to correlate residual stresses with erosive and abrasive wear of Ni-Cr irons.

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2. EXPERIMENTAL PROCEDURE

2.1 Composite Fabrication

The castings were prepared by the melting route using a coreless type induction furnace of 15 kw. Sand moulds were prepared using sodium silicate binder. The pattern used was made of wood having a dimension of 110x90x25 mm. The sand moulds were dried in an oven to a temperature of 50 0 C(preheating). The castings were then cut into pieces of the required dimensions and subjected to tests in both the as cast and the heat-treated conditions as per ASTM standards.

2.2 Hardness (Brinellhardness)

Rectangular pieces were ground on a belt and emery to obtain a flat surface. A load of 150 kg was applied. The load was applied for 20 seconds and then released.

2.2Rubber Wheel Abrasion Test

This test was conducted to obtain a measure of the wear resistance of material to abrasion.It consists of a wheel with a rubber beading around the circumferential periphery of the wheel. The abrasive silica sand was made to fall in between the rotating rubber wheel and the pressed specimen at a constant discharge through the nozzle attached to the reservoir. The test was conducted for 30 minutes or 6000 revolutions. The rubbing of the abrasive sand particles against the specimen, leads to physical wear

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of the sample. The difference between the initial and final weights of the sample gives the weight loss.

2.3 Jet Erosion Tests

An air jet erosion test rig basically uses the principle of solid particle erosion mechanism. The test is carried out according to ASTM G 99 as per the specifications with 35 m/s as the velocity of the particle with an angle of impact of 10-90^0 and a mass flow rate of 0.5 to 1kg/min.

2.4 Microstructural Analysis

Test specimens were cut from the castings obtained to a size of 10x10 mm and polished using different emery grit sizes of 220, 400 and 600. After polishing the specimens were etched with 2% Nital. Microstructures were taken using metallurgical microscope.

2.5 X-Ray Residual Stress Measurement

The X-ray residual stress measurement test rig works on the basic principle of X-ray diffraction technique as per ASTM standards.

2.6 Carbide Volume Fraction

Carbide volume is an indication of the percentage of carbides present in the microstructures of samples, which can be calculated approximately from the carbon and chromium contents of the alloys.

$$\text{Carbides}(\%) = 0.1233\,C + 0.0055Cr - 15.2 \qquad 1$$

2.7 Heat Treatement Cycle

The sand molded Ni-hard samples were given an austenitizing heat treatment of temperature between 750 and 790^{0}C with a soaking time of 8 hours for complete transformation. The castings are then air or furnace cooled not beyond 300^{0}C, followed by tempering/stress relief heat treatment of 200^{0}C for 2 hours.

2. RESULTS AND DISCUSSIONS

3.1 Hardness

The following table (Table No1.) gives the Brinell hardness number of the samples of the present work. It is seen from table that the sample Ni-hard in heat treated condition shows the highest value of hardness. This is further supported by the change in the micro structural features as compared to the other as cast and heat-treated samples.

Table 1. Hardness and Micro structural observations of samples

Sl. No	Sample Designa ti-on	Hardness (BHN)	Carbide Volume Fraction %	Matrix	Retained Austenite (%)
1.	Mild Steel	150	----	Ferrite + Pearlite	-----
2.	Ni-Cr (ascast)	510	27.4	Predomin--antly austenite	38
3.	Ni-Cr (heat - treated)	570	26.8	Predomin--antlymarten site	12

The microstructural analysis of the sample MS (figure 1) in the normalized condition reveals the presence of ferrite and a pearlitic matrix. Since the matrix of ferrite and pearlite is a much softer matrix, the sample has shown lower hardness value.

The microstructural analysis of the samples NHAC (figure 2) in the as cast condition, reveals the presence of primary discontinuous M_7C_3 eutectic carbides. Due to the presence of high chromium percentage in the sample, M_7C_3 chromium carbides are formed which forms a relatively discontinuous eutectic carbide distribution in a predominantly austenitic matrix. Since austenite is a relatively softer matrix, it has shown lower hardness value.

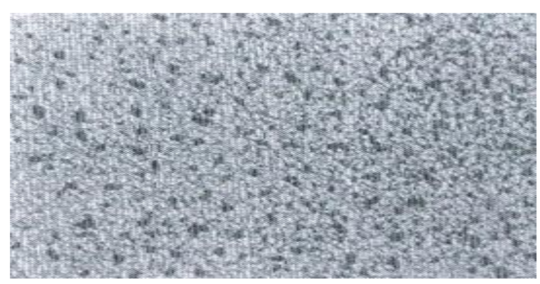

Fig. 1 Microstructure of Mild Steel (MS) 200X

Fig. 2 Microstructure of Ni-Cr as cast (NHAC) 200X

Fig. 3 Microstructure of Ni -Cr heat treated (NHHT) 200X

Upon heat treatment of the sample NHHT as shown in the figure 3, the structure reveals the presence of a predominantly martensitic matrix. Primary discontinuous M7C3 carbides are present along with some secondary carbides. Since retained austenite is very less in this sample, due to the change in the carbide size, distribution etc. and secondary carbide precipitation, the hardness of the heat treated samples are very much higher compared to the as cast samples.

3.2 Jet Erosion ,abrasion tests and residual stress

The jet erosion tests were conducted at 15, 30, 45 and 90^0 jet impingement angles. A graph of impact angle (in degrees) v/s erosion weight loss (g) is plotted as shown in the Figure 4 and Table II.

Table 2. Erosion Weight Loss of Samples

Sl. No.	Sample Designation	Jet Erosion			
		15^0	30^0	45^0	90^0
1.	MS	0.022	0036	0.042	0.019
2.	NHAC	0.015	0.020	0.027	0.023
3.	NHHT	0.013	0.019	0.024	0.021

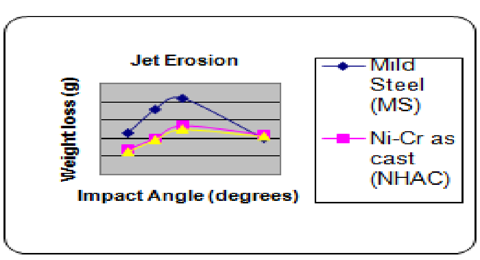

Fig. 4 Graph of Erosion weight loss v/s Impact angle

It can be seen that the maximum erosion loss has occurred at an angle of 45˚. Among the samples NHHT has shown higher erosion resistance at all impact angles. Table III shows the rubber wheel abrasion values of the samples. It can be seen that the sample NHHT also shows better abrasion resistance than the other samples.

Table 3. Abrasion Weight Loss of Samples.

Sl. No.	Sample Designation	Abrasion Weight Loss (g)
1.	MS	1.09
2.	NHAC	0.21
3.	NHHT	0.09

This is further supported by the change in the microstructural features as compared to the other as cast and heat-treated samples[6,7]. The microstructural analysis of the sample MS in the normalized condition reveals the presence of fine grains in a ferritic and a pearlitic matrix. Due to the presence of a much softer phase than austenite and martensite, the mild steel sample shows least value of abrasion and erosion resistance. The microstructural analysis of the sample NHAC reveals the presence of primary discontinuous M_7C_3 chromium carbides in a predominantly austenitic matrix. Due to the low percentage of chromium in the sample, the carbide volume is less as compared to the other samples. Since austenite is a relatively softer matrix, the NHAC sample has shown lower hardness value. It can be seen from the structure that the carbides are coarse and larger in size, hence showing lower values of abrasion and erosion wear resistance.

It can be seen that the abrasion resistance of the sample increases with an increase in hardness.Upon heat treatment, the sample NHHT reveals the presence of a much harder martensitic phase and the carbides are much smaller. It can be seen from the table (Table No. I) the retained austenite content is much lower than the NHAC sample, hence owing to an increase in the hardness. Since, there is an increase in hardness and the carbide size distribution is smaller, the abrasion resistance of NHHT is much higher than the sample NHAC.The effect of microstructure on residual stresses measured in MS, Ni-hard are explained below. The results pertaining to the residual stresses of these materials are as shown in the Table IV. It is seen from the above data that MS sample, which has been given normalized heat treatment, has shown compressive stresses of higher magnitude. This is due to the fact that MS sample is cold drawn and given normalizing heat treatment. The normalizing treatment generally helps in refining the grain size i.e. the grain size becomes more finer. As the grain size becomes finer, the compressive stresses also tend to increase in magnitude. This could be one of the reasons for showing higher compressive stresses in MS sample. The effect of residual stresses on the Ni-Cr irons and any hard samples are given in the following section. The presence of higher amount of austenite in a matrix, the stress levels approaches the +ve side (tensile side).

Table 4. Residual Stresses before and after abrasion and erosion

Sl. No.	Sample Designation	Initial Stress (Mpa)	Stress after Erosion (Mpa)	Stress after Abrasion (Mpa)
1.	MS	-210	-305	-244
2.	NHAC	-214	-319	-239
3.	NHHT	-241	-330	-240

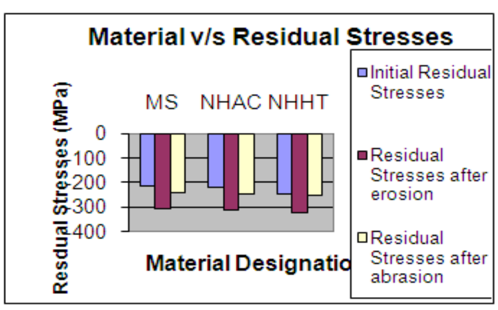

Fig. 5Graph of Material V/S Residual stresses.

Hence it can be seen from the Table IV and Figures 5, that as NHHT sample has lower amount of retained austenite than the other samples, it has shown lower values of residual stresses.

3. CONCLUSIONS

1. Among the samples studied, the nickel chromium irons in the heat-treated condition shows a good promise as an erosion/abrasion resistant material.
2. It is seen that carbide morphology, retained austenite and hardness also influences the erosion and abrasion behaviour of materials to a great extent.
3. The present work attributes to the phase transformations, taking place in materials as mainly responsible for the changes in the stress levels.
4. It is observed that, a correlation can be obtained between erosion, abrasion behaviour with the stress levels of the materials considered in the present study.

REFERENCES

1. *Hebbar B M and Seshan (1999), "Wear resistant castings for Thermal Power Plants", IISC Workshop on Wear and Erosion of materials in Thermal Power Plants, Vol. 3 (A1-A9).*
2. *Durman R W (1976), "The applications of alloy white iron in crushing, grinding and material handling applications", British Foundry man, 141-150.*
3. *Richard B and Gundlach (2009), "High alloy white iron in crushing, grinding and material handling applications", Climax Research Services ASM Handbook, Vol.15, 678-685.*
4. *Bereza J M (1988), "Wear and impact resistant white cast iron", British Foundry man, 205-211.*
5. *ASM Handbook, Vol. 15, Casting, 702-735.*
6. *ZumGahr K H (1979), "How Microstructure affects abrasive wear resistance", Metal Progress, 46.*
7. *Metals Handbook (1978), ASM 19th edition, Vol.11, 75.*

