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Hardness Along with Electrochemical Corrosion Performance Examination of Hastelloy C276

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***Abstract:** Hastelloy C276 a versatile corrosion resistant alloy, is investigated at 298 K. The tribological properties such as frictional force, In the micro-hardness test at 40 N load, the hardness is increased by 25 % as compared to 10, 20, 30 N loading conditions. The experimental results indicated reduction in coefficient of friction values and thus an increase in the frictional force with the increase in normal load. The images of worn out surfaces confirm that the delamination and adhesion causes the material removal from the surface in dry sliding. Further, the analysis of the hardness characteristics of worn out surfaces shows surface hardening during sliding wear process under 40 N loads. The study on the corrosion wear behavior in the sulphuric acid showed a significantly lower value of corrosion rate (0.0016579 mm/y in H_2SO_4 solution) in comparison to other alloys frequently used in industries.*

***Index Terms**: Hastelloy C276, Hardness, Electrochemical, Corrosion, Load.*

I. INTRODUCTION

Super alloys remain created with nickel, nickel-iron, or cobalt which demonstrate a combination of mechanical strength and resistance to surface degradation and thus, favorably used in high-performance industrial applications where the ability to sustain high temperature, corrosive medium is of prime importance. The nickel super alloys are ideal materials for the components and elements of pumps, valves, piping arrangements, process equipment, turbines and assemblies in the marine, chemical processing, oil and accelerator pedal, aerospace, railway locomotive and military manufactures as they can withstand rough environments by exhibiting high heat resistance, erosion resistance and acid resistance [1]. Among all the nickel-based super alloys, Hastelloy (nickel-chromium-molybdenum alloys) is regarded as one of the best as the inclusion of molybdenum makes it harder, stronger at high temperatures, and also suitable for welding applications. They not only possess good ductility but also easily forged and cold worked.

Owing to their wide spread industrial applications several Ni-based super alloys are investigated for their wear behaviour by many researchers in the past.

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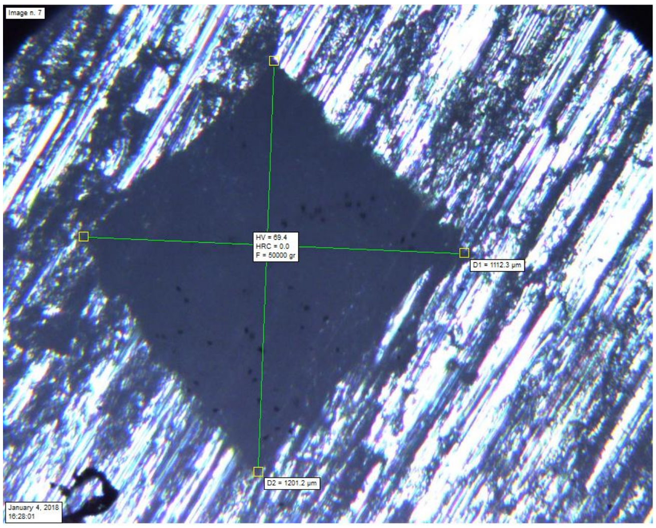
The corrosion and tribo-corrosion behaviour of Hastelloy C276 sliding against Al2O3 pin in artificial sea water is investigated with a potentiostat for electrochemical control [2]. Wagle et al. [3] evaluated the dry sliding wear properties of two-phase Ni3Al/Ni3V against a G5 disc at 298K and 573K. The tensile behaviour of C276 alloy at high temperature has also been studied [4]. Cheng et al. [5] reported the wear rate of TiAl alloy sliding against the SiC ball to be two orders of magnitude higher than with SCr15 and C276 alloy as the mating surfaces. The wear mechanism of cutting tool while machining Hastelloy C-22HS is also investigated by researchers [6]. Further, the investigation related to the dissolution mechanism of industrial used Ni-based Alloy 600 and Hastelloy C276 in a solution of 1M sulphate indicated identical mechanism of dissolution at 0pH [7]. Hastelloy C276 is also reported as the most non-corrosive material compared to titanium and stainless steel in plant operated desalination environment [8]. Therefore, the present work aims to study the micro-hardness and wear characteristics of Hastelloy C276.

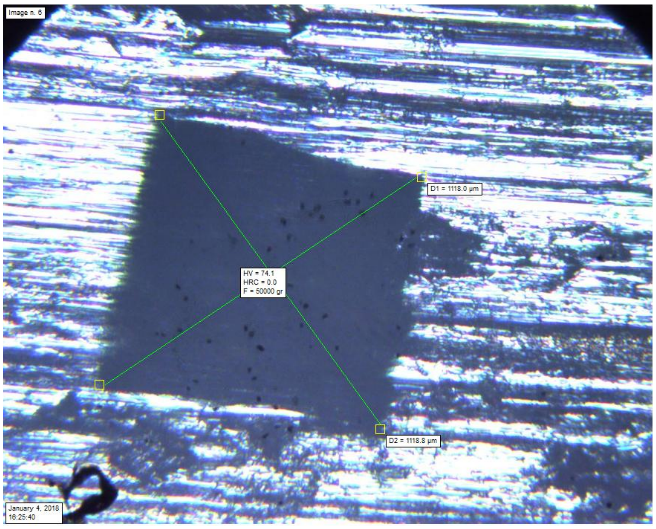
II. EXPERIMENTAL DETAILS

As a first step, the dry sliding wear test is performed on Hastelloy C276 alloy samples under four different load in conditions (10, 20, 30, and 40 N). Then, the wear propagation on the surface of the samples is observed through microstructure observation and subsequently the micro-hardness of all the samples is measured.

A. Micro-hardness Test



(a) Load of 20 N



(b) Load of 40 N

Figure 1. Photograph of specimen after micro-hardness test with different loads

To interpret the effect of heat induced during the friction on the sliding surfaces the samples (after the study of surface morphology) were taken to the micro-hardness tester for the observation of micro-hardness on the surfaces which were previously tested. The variation of the micro-hardness were analysed for samples under loading condition of 10, 20, 30, 40 N. Vickers hardness number is measured by the use of a cone indenter with a cone diameter of 136^0.

B. Corrosion Test

For the study of corrosion behaviour of the material an electrochemical corrosion test is conducted by the use of a potentiostat (Fig. 2). For the experimentation purpose a cylindrical sample of 8mm diameter and 80mm long (Fig. 3) is prepared by using the CNC lathe.

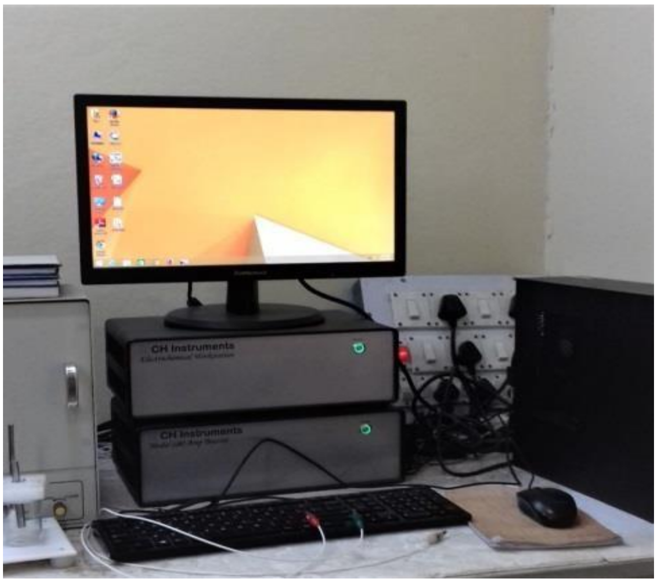


Figure 2. Electrochemical potentiostat with three electrode system

The cylindrical sample is polished with very fine grit emery paper and then it was coated with epoxy resin all-over the surface except the two faces for electrical conduction during experimentation. The specimen tested in a solution of 1M sulphuric acid (H_2SO_4). For the experimentation purpose, a container half filled with 1M sulphuric acid solution and three electrodes comprising a specimen (working electrode), Pt counter electrode and calomel reference electrode were used. These electrodes are connected with the potentiostat connected with a monitor for plotting the graphs from the data those are collected during the experimentation.

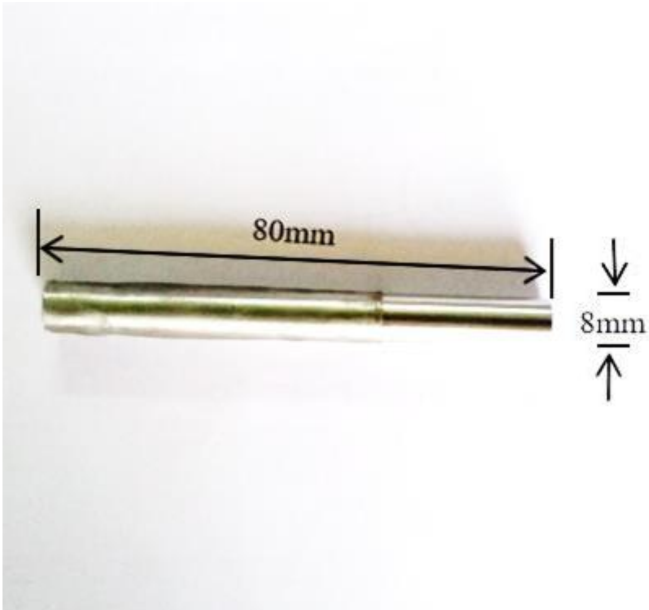


Figure 3. Cylindrical sample for electrochemical corrosion test with coating of epoxy resin

III. RESULTS AND DISCUSSION

In this section, the results acquired by following the experimental procedure discussed in the previous section are analyzed and discussed in detail.

A. Examination of Micro-hardness

Initially, a sample of Hastelloy C276 is taken for micro-hardness testing prior to the wear test (regarded as the base sample). The Vickers hardness number of the base sample is found to be 69.7. Subsequently, once the dry sliding wear test under different normal load is done, the corresponding samples are taken for micro-hardness test to analyse the variation in hardness number of the worn surfaces due to friction. The Vickers hardness number (HV) of the worn out samples under different loading conditions are provided in Table 1.

Table 1. Vickers hardness number of the worn out samples.

Normal load (N)	Vickers hardness (HV)
10	67.46
20	71.23
30	73.68
40	76.03

It is observed that the sample under 10 N load has the hardness number lesser than the non-experimented (base) sample and the hardness increases with the increasing normal load. This may be attributed to the fact that under 10 N normal load the upper layer of the machined surface wears out and a fresh layer of material emerges which is softer than the machined surface. However, at higher loading condition the sublayers come into the contact of the disc material. Due to the friction between surfaces heat is produced and accumulated on the surfaces which could be the cause of the hardness of the material. It can be concluded that the surface of Hastelloy C276 is hardened due to the rubbing action against EN 31 stainless steel and the hardening is greatly dependent on the normal load applied axially on the surface of the material. The corresponding load versus hardness plot is also demonstrated in Fig. 4.

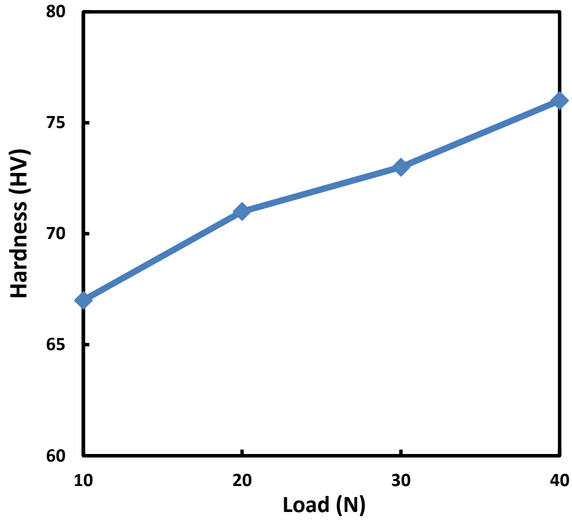


Figure 4. Load vs. hardness

B. Examination of Electrochemical Corrosion

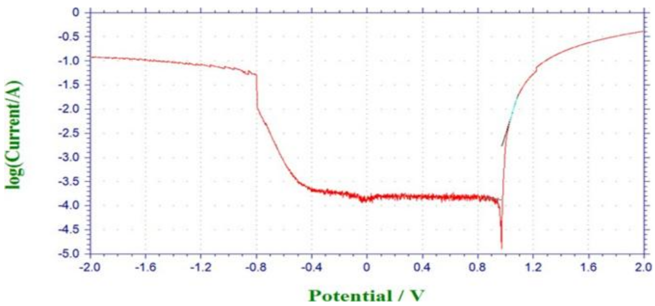


Figure 5. Tafel plot of Hastelloy C276 in H_2SO_4 solution

To measure the corrosion wear of Hastelloy C276 in the sulphuric acid (H_2SO_4) solution an electrochemical corrosion test is conducted by the use of a potentiostat. The corresponding Tafel plot is depicted in Fig. 5.

According to the Open circuit potential (OCP) curve and the Tafel plot the corrosion potential (E_{corr}) and corrosion current (I_{corr}) are found out by using the extrapolation method of both anodic and cathodic reaction. The electrochemical corrosion parameters and the values obtained are tabulated in Table 2.

Table 2. Electrochemical corrosion parameters and result.

Ecorr (V)	Icorr (μA)	Equivalent weight (g)	Density (g/cm^3)	C.R.(mmpy)
0.972	0.0005362	21.145	8.89	0.0016579

The corrosion rate of Hastelloy C276 in 1M H_2SO_4 solution in the unit of mm per year it is found to be 0.0016579, which is very less than the corrosion rate of other materials used in industrial purpose.

IV. CONCLUSION

The hardness and electrochemical corrosion performance on the surface of Hastelloy C276 are studied under different loading conditions. By conducting the test, the images and hardness of the worn out surfaces and measurement of the corrosion rate in sulphuric acid, few useful inferences are drawn. The wear mass loss and wear volume loss rate are significantly dependent on the loading conditions. The effect of debris plays an important role in corrosion mechanism. It is worthy to note that at greater load the adhesion of surfaces is more resulting delamination of the softer material. The microstructure analysis of the worn out surface revealed the occurrence of ploughing and shearing of the surfaces at lower and intermediate normal loads, respectively. However, at higher loading conditions the plastically deformed layers were delaminated and subsequent sublayers were came into contact with the disc material. It is seen that the surface hardness increases with the increase of normal load. The corrosion rate of Hastelloy C276 is found to be very less in comparison to the other super alloys used for high performance applications.

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