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TECHNICAL ARTICLE—PEER-REVIEWED

Electrochemical Corrosion Behavior and Microstructural Characterization of HVOF Sprayed Inconel-718 Coating on Gray Cast Iron

Hitesh Vasudev · Gaurav Prashar · Lalit Thakur · Amit Bansal

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Abstract In the present work, Inconel-718 (IN718) coating was developed on a gray cast iron (C.I) substrate by utilizing a high-velocity oxy-fuel spray technique. The microstructural analysis was performed to know the topological characteristics of the deposited IN718 coating. Corrosion testing of bare and coated samples was carried out at an ambient temperature in a NaCl solution (3.5 wt.%) using potentiodynamic polarization technique. The kinetics of corrosion and surface characteristics of the as-sprayed and corroded coatings were studied by scanning electron microscopy/energy-dispersive spectroscopy techniques. The different phases in the feedstock powder and as-sprayed coating were determined through X-ray diffraction analysis. The reported average microhardness value of the developed IN718 coating was 563 $\pm$ 15 $HV_{0.2}$. The increased hardness of the IN718 coating is credited to the existence of Mo and Ti elements in the IN718 coatings. Corrosion testing showed that the IN718 coating exhibited the maximum corrosion resistance compared to a C.I. substrate due to a stable passive layer in the IN718 specimen.

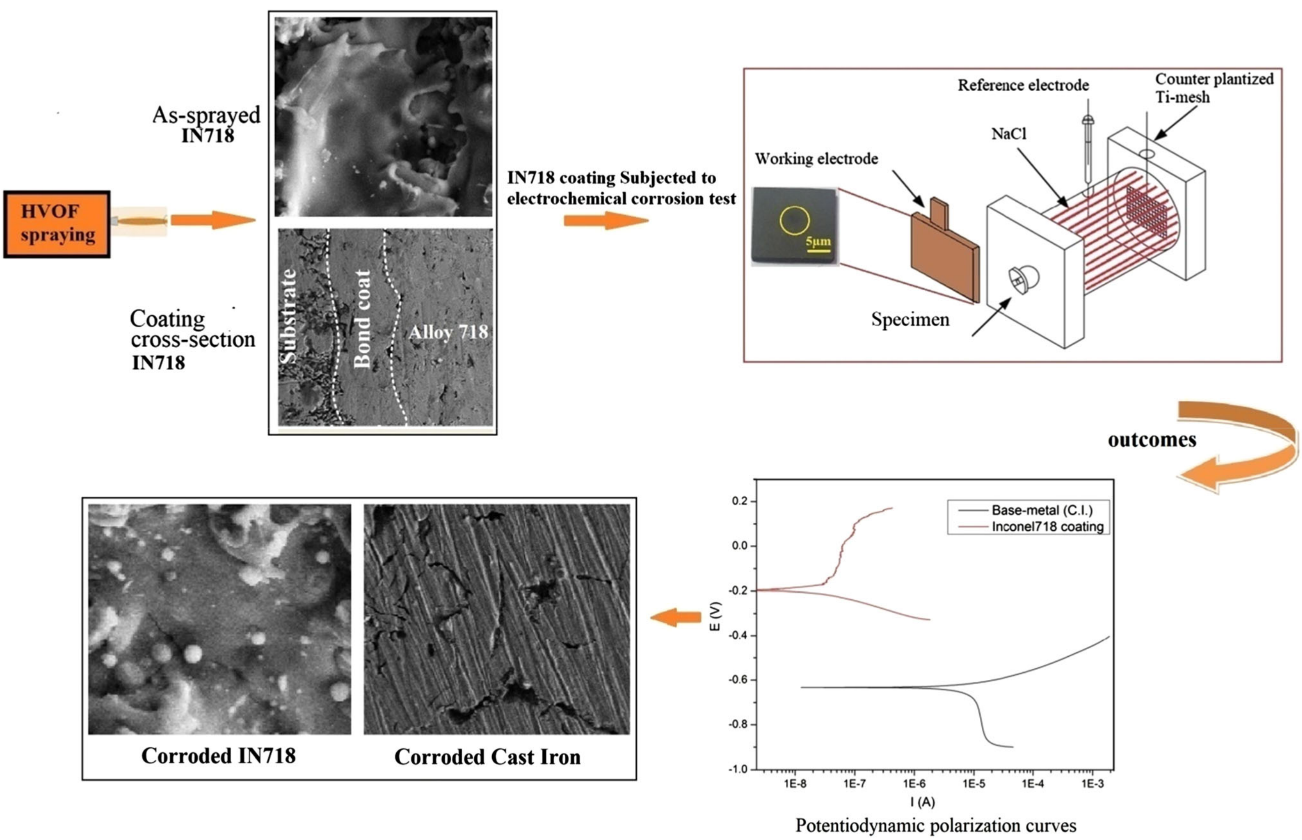
H. Vasudev (✉) · G. Prashar
School of Mechanical Engineering, Lovely Professional University, Phagwara 144411, India
e-mail: hiteshvasudev@yahoo.in; hitesh.24804@lpu.co.in

G. Prashar
e-mail: grvprashar@yahoo.co.in

L. Thakur
Mechanical Engineering Department, NIT Kurukshetra, Kurukshetra 136119, India
e-mail: lalitthakur@nitkkr.ac.in

A. Bansal
Mechanical Engineering Department, IKGPTU, Jalandhar 144603, India
e-mail: amit.bansal978@gmail.com

Graphic Abstract



Keywords Gray cast iron · Inconel-718 · HVOF · Electrochemical · Corrosion

Introduction

Corrosion may deteriorate the surface and subsurface of the typical engineering components in aggressive mediums. The enhancement in the engineering components' surface properties by utilizing surface engineering techniques can significantly improve the life of a component used in the aggressive environment condition. Cast iron is commercially used in industrial applications like agriculture, oil, gas-based industries, marine ships, machine tools, roller mills, and petroleum industries [1, 2]. The significant research and development (R&D) activities have been conducted to find out the ways to enhance the mechanical and wear-resistant properties of the C.I. components during the actual practical conditions. A material that has a combination of improved mechanical, physical, and chemical properties is considered as the most efficient for material selection in strenuous conditions. Most industrial applications commonly deal with surface modification of the structural parts; therefore, applying a layer of material with good surface properties by using the surface coating techniques is recommended. This modification in the component surface properties helps to achieve the desired properties of the C.I. component to the level required in a particular application. This is particularly true for wear-resistant and corrosion-resistant components because these components' surface has to play a vital role during the operating conditions [3]. In addition to electro-deposition, laser cladding, and weld overlays assisted coating methods, the thermal spraying technique is mostly preferred for depositing the coatings on the C.I. substrate [4–9]. The surface of C.I. rollers employed in industries such as mining and paper is coated with WC/Co-Cr by using a thermal spraying process [10, 11]. The materials for deposition of coating primarily include some contents of the tungsten carbide (WC) mixed with better abrasion resistance materials like WC-WB-Co [12], WC [13], and WC/Co-Cr [14]. In the extremely corrosive environment and harsh abrasive conditions, poor corrosion resistance was the main obstacle in using such coatings. In the automotive sector thermal spraying technique has been explored in the research and development activities to improve the surface properties of C.I. parts [15].

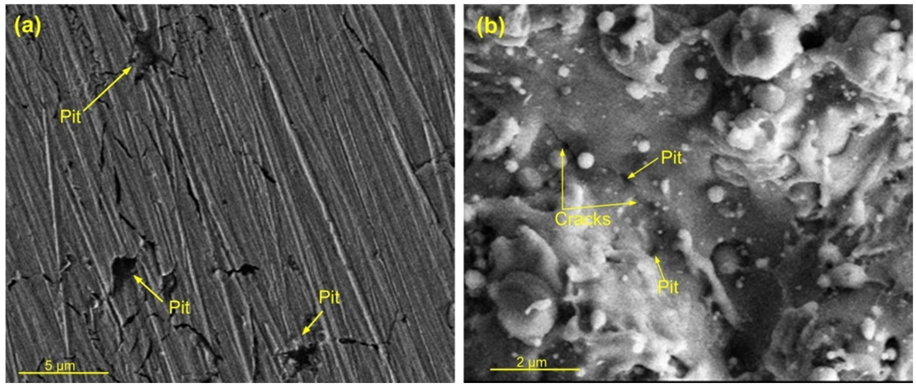


Fig. 9 SEM micrographs illustrating (**a**) the corroded surface of C.I, and (**b**) the corroded surface of IN718 coatings

coatings. The IN718 coatings exhibit better passive behaviour than the C.I. specimen, which was attributed to the greater anodic slope β_a (V/decade) of IN718 coating, as illustrated in Table 3. The greater anodic slope of the IN718 coating was due to the presence of chromium oxides in the surface layer of IN718 coatings, as delineated in XRD spectrum of Fig. 5c [43]. The presence of IN718 coatings remarkably improved the resistance of the C.I. substrate material against electrochemical corrosion attack. The improved corrosion resistance of the IN718 coatings was credited to the existence of various alloying elements like Ni, Cr, and Mo in it. These elements are well known for their protective nature against corrosion [44]. The electrochemical performance of the HVOF coatings was significantly affected by the lower porosity content [45]. Once the electrolyte entered the C.I sample via micro and macro-cracks, galvanic pair was developed among the coating and the C.I sample, resulting in the accelerated corrosion and finally leading to the degradation of the coating. There is no interconnected porosity observed in the deposited coatings in the present case, which indicates that the aqueous solution is not reached to the base material surface. The presence of IN718 coatings was effective in turning down the electrochemical corrosion rate of C.I in the present study.

SEM micrographs exhibiting the surface morphology of C.I. sample after corrosion testing in NaCl solution (3.5 wt.%) are shown in Fig. 9a. A large number of pits having size ranges from 2 to 4 µm were observed on the corroded C.I. specimen. These pits were mainly observed near the graphite needle/iron matrix interface, as the open space along the graphite and iron matrix act as an easy site for the initiation of pits. The C.I. exhibited a limited loss of the graphite through scores developed by a selective corrosion process of the ferrite phase of the pearlite structure. Surface pitting was seen with different sizes ranging from 1 to 2 µm distributed randomly onto the surface. The higher conductivity of the NaCl solution enhances the chloride ions absorption on the C.I. surface and, therefore, increases the metal dissolution rate. Graphitic corrosion takes place exclusively in C.I., which has a continuous network of graphite in its microstructure. Graphite acts as a cathode, which accelerates the surrounding nearby iron's anodic dissolutions, leaving behind a graphite network, which maintains the structural shape but loses the mechanical strength.

The SEM micrograph of the as-sprayed corroded IN718 specimen is delineated in Fig. 9b. It is understandable from Fig. 9b that a small number of cracks and pits were also observed in the corroded IN718 coatings, but the size of pits formed is considerably less than that of the pits observed in the tested C.I. specimen. Furthermore, the density of pits formed in the corroded IN718 coatings is also less observed in the corroded C.I. specimen. It confirms the protective nature of IN718 coatings against the aqueous solution of NaCl (3.5 wt.%).

Conclusions

In the present work, the HVOF sprayed IN718 coating was characterized for their microstructural, mechanical properties and corrosion resistance capability. The following conclusion has been drawn from this experimental work:

1. The surface topology of the HVOF sprayed deposited IN718 coating showed melted, partially melted, and un-melted particles.
2. The IN718 coating showed good intactness with the base material using NiCrAlY as abond coat.
3. Microhardness of the deposited IN718 coating (563 ± 15 $HV_{0.2}$) was found to be increased as compared to the substrate (245 ± 15 $HV_{0.2}$). The increased hardness of the IN718 coating was owing to the existence of Mo and Ti elements.
4. The deposited coating's porosity was less than 1%, which can be attributed to the coherency of intersplats of deposited IN718 coating.

5. A significant decrease in the corrosion rate of IN718 coating was observed as compared to the C.I. substrate material.

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