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Effect of spray distance on the corrosion-fatigue behavior of a medium-carbon steel coated with a Colmonoy 88 alloy deposited by HVOF thermal spray

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ABSTRACT

The present work has been conducted in order to determine the influence of the spray distance, on the corrosion-fatigue behavior of a SAE 1045 steel substrate coated with a Ni base coating deposited by high velocity oxygen fuel (HVOF) thermal spray. The spray distances employed in the present investigation were of 380, 425 and 470 mm. The mechanical properties of the coated systems were evaluated by means of tensile and corrosion-fatigue tests conducted with cylindrical samples. Corrosion-fatigue tests were carried out under rotating bending conditions ($R=-1$), at a frequency of 50 Hz and maximum alternating stresses in the range of 250–420 MPa, employing a 3 wt.% NaCl solution. The results indicate that varying the spray distance in the range of 380–470 mm has apparently no significant influence on the corrosion-fatigue behavior of the coated systems. However, the presence of the Ni base coating gives rise to a significant increase in the corrosion-fatigue life of the coated substrate, in comparison with the uncoated steel. Such an increase varies between ~90 and 440% in the interval of maximum alternating stresses investigated in the present work. Also, the coated systems exhibited a better corrosion-fatigue performance in comparison with the same steel substrate coated with an electrolytic hard chromium (EHC) deposit.

1. Introduction

Coating deposition represents an important requirement of a wide spectrum of key industrial sectors, which include among others manufacture, automotive, oil and gas, petrochemical, aerospace, etc. In such areas, coatings have a broad range of applications and are commonly applied onto a variety of substrates in order to improve their tribological behavior and corrosion resistance, increasing thereby parts and components life.

Previous investigations have shown that thermal spray coatings offer the possibility of repairing in situ a number of components that require high wear and corrosion resistance. Thermal spray deposition is a more friendly process from the environmental viewpoint and a cleaner alternative than electrolytic hard chromium (EHC). Such coatings are widely accepted in a number of industrial applications and are currently in use in the aircraft industry for coating different surfaces subjected to wear, such as landing gears and other structural components which used to be previously coated with EHC. When thermal spray coatings are properly applied, these could give rise to an increase in component life and reduce the risks for catastrophic failures and maintenance costs in the long term [1].

In the past few years, a number of research studies have been carried out aimed at determining the effect of different deposition parameters on the fatigue behavior of components coated by HVOF [2–14]. In this sense, it has been found that fatigue properties could be very sensitive to changes in the spray parameters, even if the initial powders employed for the deposition process are the same.

Previous work indicates that components coated with Ni base coatings have a good fatigue resistance when testing is conducted in a corrosive medium [4–6,11]. However, a systematic investigation of the effect of spray distance on the fatigue performance has not been conducted and the available information regarding this aspect is quite limited. Therefore, the present investigation has been carried out in order to study in a systematic manner the influence of the spray distance, in the range of 380–470 mm, on the static mechanical properties and corrosion-fatigue behavior of the SAE 1045 steel substrate coated with the Ni base alloy deposited by means of HVOF thermal spray.

2. Experimental procedure

2.1. Materials and specimens preparation

The present investigation has been carried out employing samples of the SAE 1045 steel substrate with the following nominal chemical

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Table 1
Deposition gun characteristics and deposition parameters.

Deposition gun	Praxair-TAFA, HVOF JP-5000
Throat diameter	~8 mm
Exit diameter	~11 mm
Nozzle length	100 mm
Spray distance	~380, 425 and 470 mm
Powder feeding rate	~1.38 g s^{-1}
Particles size range	~22–62 μm
Kerosene flux	~6.22×10^{-3} ls^{-1}
Oxygen flux	~11.40 l s^{-1}
Kerosene pressure	~670 kPa
Oxygen pressure	~1400 kPa
Combustion pressure chamber	~620 kPa

composition: 0.43–0.50 C, 0.60–0.90 Mn, 0.15–0.35 Si, 0.04 S, 0.04 P and Fe Bal. The material was provided in the form of bars of 12.7 mm in diameter, from which a number of samples were machined for tensile and fatigue tests, according to the ASTM A370 and ASTM E606 standards, respectively.

2.2. Deposition powders and conditions

The Ni base powders employed in the present work are known commercially as Colmonoy 88. These have a quasi spherical geometry, with a mean nominal particle diameter in the range of approximately 22–62 μm, according to the information provided by the supplier. The nominal chemical composition (wt.%) of such a material is the following: 56.4 Ni, 17.3 W, 15 Cr, 4 Si, 3.5 Fe, 3 B, and 0.8 C. Prior to the deposition of the coatings the specimens surface was carefully cleaned employing a mixture of organic solvents. Subsequently, the samples were grit blasted with alumina particles of mean size in the range of 1–3 mm. Such step allowed the increase in the substrate roughness in order to improve the mechanical bonding of the coating. Grit blasting was conducted employing an erosion equipment located at ~150 mm from the specimens surface, at a pressure of ~400 kPa.

Coating deposition was conducted along the axis of the specimens, employing an HVOF Praxair-TAFA JP-5000 gun with a mixture of kerosene and oxygen as fuel. The HVOF deposition parameters are presented in Table 1. All these parameters remained constant, with the exception of the spray distance, whose values were of 380, 425 and 470 mm. Coatings deposited under these conditions are identified in the forthcoming as DR1, DR2 and DR3, respectively. All the coated samples were polished to a mean coating thickness of ~150 μm. For comparative purposes, some steel substrate fatigue specimens were polished to a mirror-like finish and coated with an industrial EHC deposit of ~120 μm.

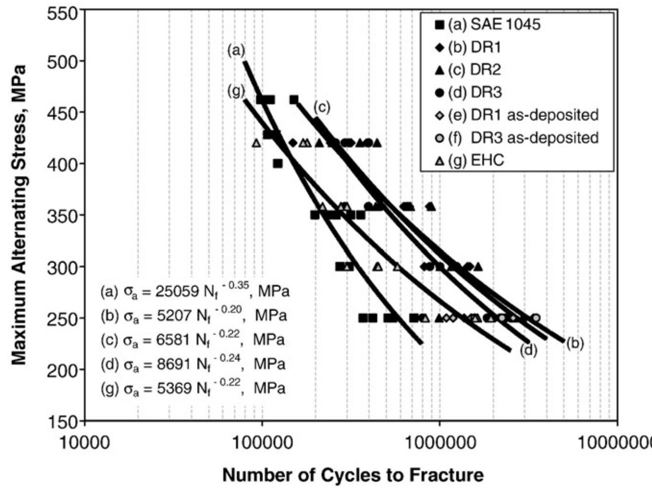

Fig. 2. Change in the number of cycles to fracture as a function of maximum alternating stress for the uncoated and coated SAE 1045 steel substrate.

2.3. Tensile and corrosion-fatigue tests

The static mechanical properties of the uncoated and coated samples were evaluated by means of tensile tests, employing two samples of the material in each condition. Such tests allowed the determination of the yield stress, ultimate tensile true stress and ductility (% elongation). The tests were conducted employing a Shimadzu universal mechanical testing equipment at a cross head speed of 2 mm min^{-1}. During the tests, the coated samples were closely examined in order to determine the moment at which cracks in the coating were visible to the naked eye.

Corrosion-fatigue tests of the uncoated and coated samples were carried out under rotating bending conditions at a frequency of 50 Hz, employing a RBF-200 Fatigue Dynamics equipment and a 3 wt.% NaCl solution as corrosive medium. 16 samples for each condition were tested at different maximum alternating stresses in the range of 250–420 MPa. Prior to testing both the uncoated and coated specimens

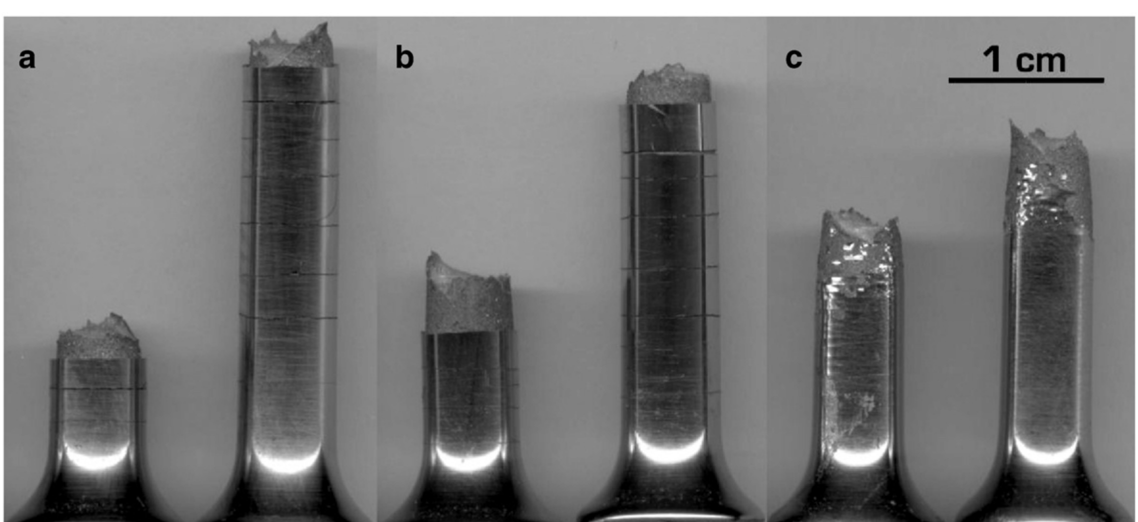

Fig. 1. Photomacrographs of different coated samples tested in tension. Circumferential cracking and delamination of the coating are clearly shown. (a) DR1, (b) DR2 and (c) DR3.