CAVITATION RESISTANT LAYERS FROM CORODUR 65 ALLOY DEPOSITED BY TIG WELDING ON DUPLEX STAINLESS STEEL

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Abstract

The CORODUR 65 alloy delivered in the form of flux-cored wire electrode was deposited by TIG welding process on the surface of a duplex stainless steel in order to improve the cavitation erosion resistance of the technical components which are working in aggressive environments. Cavitation tests were performed using ultrasonic vibrating equipment that meets the requirements of the ASTM G32 - 2010 standard. The microstructure of the deposited layers consisted of complex carbides in a hardened alloy matrix with Cr solid solution which provides a high hardness and a significant increase of the cavitation erosion resistance compared to the base metal.

Keywords: Alloy Corodur 65, TIG welding, cavitation resistance, microstructure

1. INTRODUCTION

Today, industrial demand for complex, high-quality engineered structures frequently requires the selection and use of materials with improved properties to manufacture each individual component. In many applications, specific properties are only locally required and therefore are achievable through co-atings and surface heat treatments [1,3,4]. Duplex stainless steels exhibit excellent pitting corrosion resistance (PREN > 40), high yield strength, good machinability and lower cost price due smaller nickel content. These properties make them attractive for applications in the mining, chemical, food and marine platform industries. Their drawback is related to a lower cavitation erosion resistance compared to other stainless steels, a phenomenon due to the presence of ferrite in the microstructure and of the interfaces between ferrite and austenite [4, 10]. The welding hard-facing technique, frequently used for refurbishing parts in service, is an efficient way to increase resistance to various forms of wear and corrosion [5-8]. The present paper aims to investigate the role of TIG pulse welding deposited layers of Corodur 65 alloy on the surface of Duplex stainless steels to improve resistance to cavitation erosion.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The material selected for the substrate is Duplex X2CrNiMoN22-5-3 stainless steel subjected to solution treatment at 1060 °C with cooling in water. A self-protecting tubular wire, Corodur 65 - DIN EN 14700, with Ø = 1.6 mm, was used as filler material. The chemical composition of this electrode wire contains elements (Cr,W,Mo,V,Nb) that form hard and wear-resistant carbides [9]. For deposition of the 1 - 4 layers, whose thickness was 1.5 - 4 mm manual TIG welding in pulsed current was proposed, considering the small dimensions of the samples. Subsequently, samples were taken for cavitation tests and metallographic analysis. The shape and dimensions of the cavitation samples is shown in **Figure 1**. It should be noted that before cavitation the surfaces with the deposited layers were ground and polished to a roughness Ra = 0.2 μm.

The cavitation experimental research program was carried out on the vibrating apparatus with piezoceramic crystals (double vibration amplitude = 50 μm, vibration frequency = 20000 ± 2 % (in Hz), power of the electronic ultrasound generator = 500 W), within the Cavitation Erosion Research Laboratory from Politehnica University of Timisoara [1]. The procedure used during the experimental program is that prescribed by ASTM G32-2016 [2], and supplemented by laboratory custom [1], in terms of total test duration (165 minutes), intermediate mass loss determination durations (one each of 5 and 10 minutes and 10 at 15 minutes each), and of the approximation mode of experimental points by analytical averaging curves [1,3].

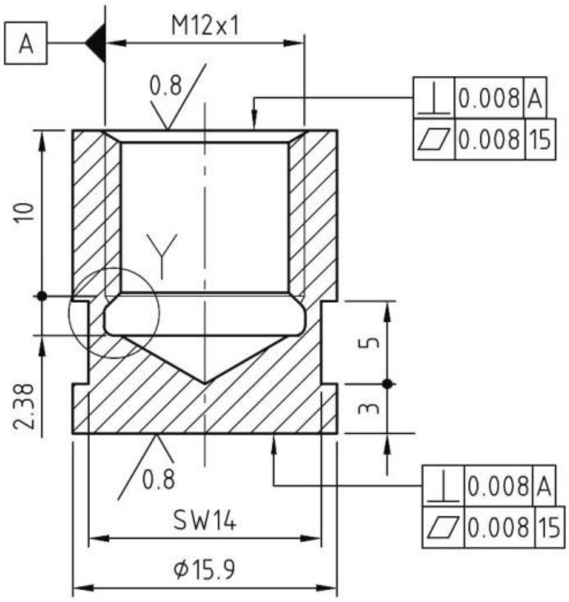


Figure 1 Cavitation Sample

According to laboratory rules, before and at the end of each intermediate period of exposure to cavitation, the samples were washed successively in a jet of tap water, distilled water and acetone, then dried in a stream of hot air and weighed on an analytical balance (precision 10^{-5} grams). After weighing, surfaces exposed to cavitation erosion have been visually examined and photographed with a high-resolution Panasonic camera.

At the end of the 165 minutes of exposure to cavitation, the samples were analysed under a Leica DM2700M optical and scanning electron microscope TESCAN VEGA 3LMU Bruker EDX Quantax, in order to identify the degradation of the structure of the layers deposited by welding under the stress of the cavitation microjets, generated in the hydrodynamic process by the implosion of the created cavitation bubbles.

3. EXPERIMENTAL RESULTS

3.1. Cavitation curves

In **Figures 2 and 3** are shown the diagrams of the experimental values and analytical approximation curves for the cumulative mass losses (Figure 2) and for the velocity related to these losses (**Figure 3**), characteristic for the TIG-welded Corodur 65 layers and Duplex stainless steel substrate.

<u>**Note**</u>: the experimental values (marked by points of different shapes to differentiate the number of layers deposited by TIG welding) are averages of those obtained on the three samples in each set.

In order to highlight the behaviour and cavitation resistance of Corodur 65 layers, in the two diagrams are shown the experimental values and the averaging curve for the substrate material (Duplex stainless steel X2CrNiMoN22-5-3 subjected to solution treatment at 1060 °C, cooled in water).

The findings resulting from the diagrams shown in **Figures 2** and **3** are:

- the evolution of the mass loss curves (**Figure 2**), with linear variation starting at minute 75, and of the erosion rates, with a tendency to stabilize at the maximum value after the same exposure time, suggest, as stated in [4,5,10], that the strength of the layer is high, specific to surfaces with high hardness, relatively fine structure and homogeneous dispersion of the mechanical properties in the volume of the deposited layer;
- the dispersion of the experimental values of the erosion rates towards the mediation curve (**Figure 3**) is the expression of a fine-grained structure [1], which leads to an increased resistance to cavitation erosion;
- comparison with the substrate material, the curves marked with 1, show that:
    - the increase in strength expressed by the total mass value (M_{max}, after 165 minutes) varies from 4.01 to 8.1 times, depending on the number of layers;
    - the increase in strength, as a function of the number of layers deposited by TIG welding, expressed by the value towards which the erosion rate tends to stabilise (v_s) after 165 minutes of cavitation attack, varies from 3.9 to 7.7 times;
    - growing number of layers deposited by TIG welding leads to increased resistance to cavitation. The surfaces with 3 and 4 layers have approximately identical behaviour and strengths, higher with (80...100) % than the surface with one layer and with (39...50) % better than the surface with two layers.
    - fact that the differences in behaviour and resistance to cavitation erosion between 3 and 4 layer surfaces is insignificant shows that any increase in the number of layers beyond 3 is uneconomical.

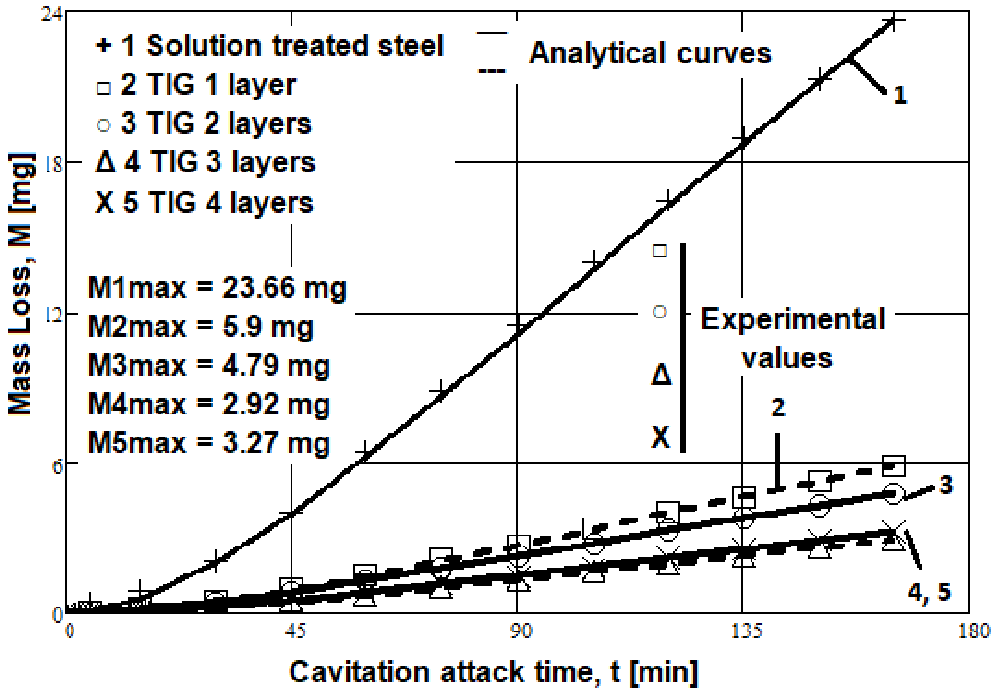


Figure 2 Evolution of mass loss with cavitation attack duration

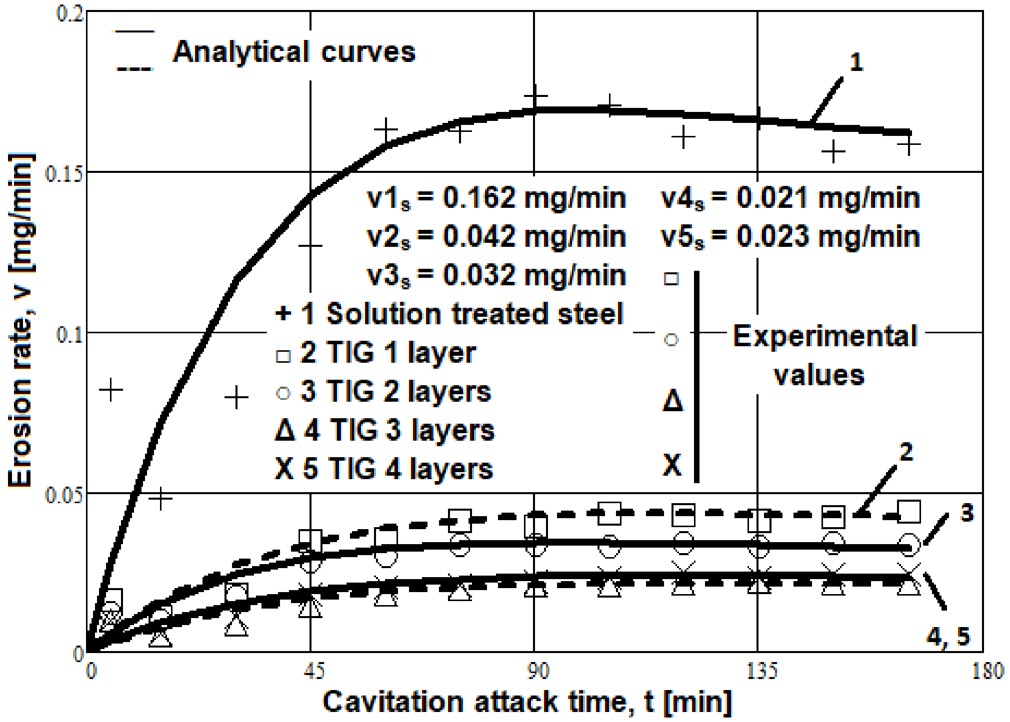


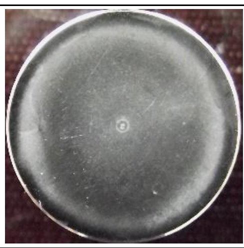
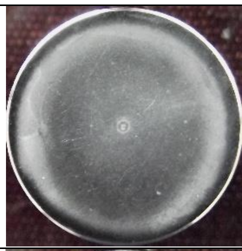
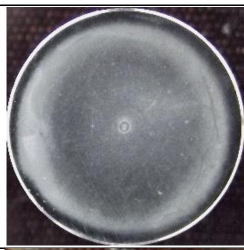
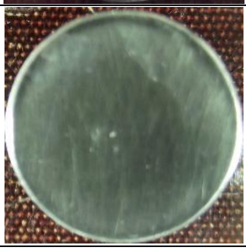
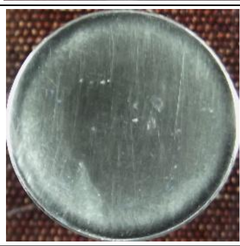
Figure 3 Variation of erosion rate with duration of cavitational attack

4. MACRO – AND MICROGRAPHIC EXAMINATIONS

4.1. Macrographic examinations

Figure 4 shows the macrographic images, obtained with the Panasonic A 450 camera, of the surface of the samples after significant durations of exposure to cavitation erosion, revealing the surface degradation, in accordance with evolution of the curves from **Figures 2** and **3**.

It is observed that after 75 minutes of cavitation, the eroded area is complete in size, the evolution being only in depth, and dependent on structural granulation.

Number of layers	30 min	75 min	120 min	165 min
1				
2				

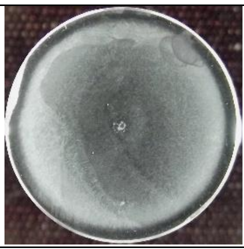
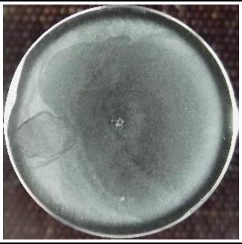
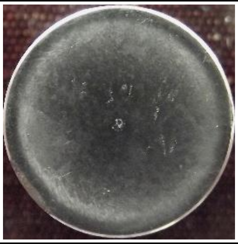
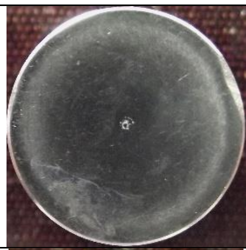
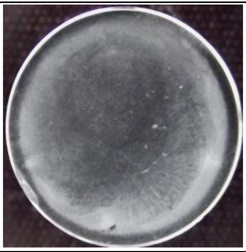
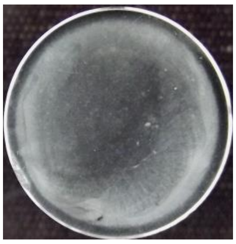
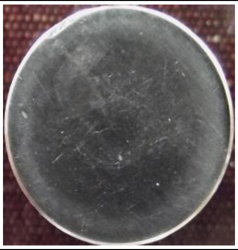
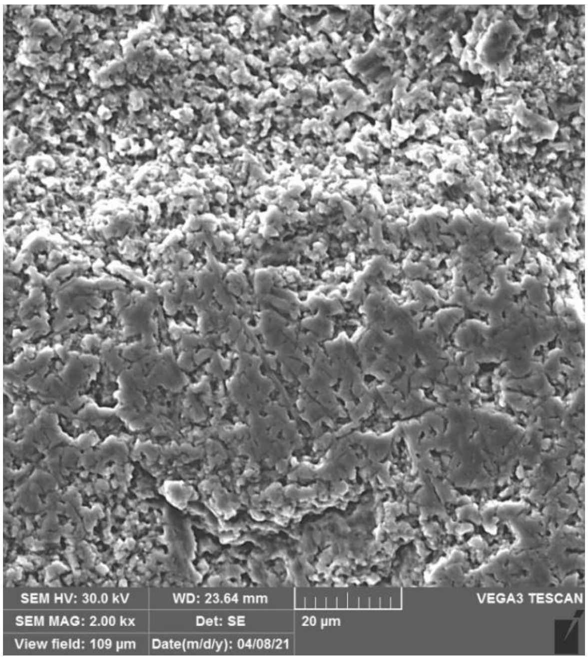
Number of layers	30 min	75 min	120 min	165 min
3				
4				

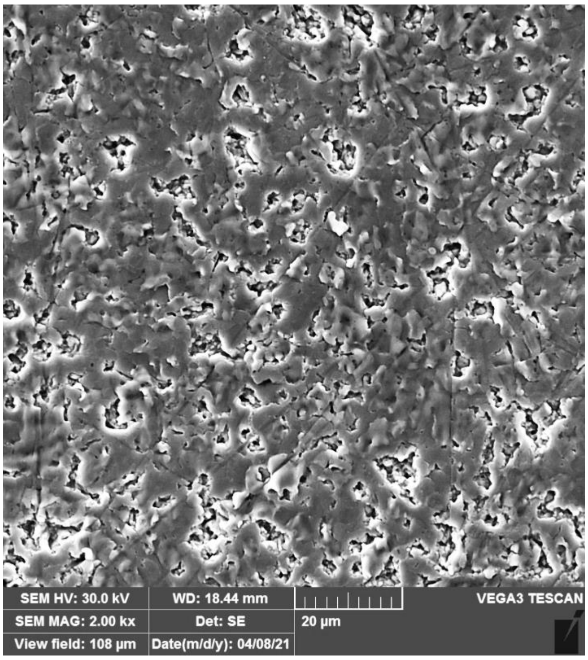
Figure 4 Macroscopic aspect of the sample surface after each period of cavitation attack

4.2. Topography of surfaces eroded by cavitation

In **Figures 5 a** and **5 b** are shown the SEM images of the samples surface with 1 deposited layer and 3 deposited layers, respectively, which were tested by cavitation erosion for 165 minutes. In both situations, carbide particles were preferentially removed as a result of initial deformation and crack generation at the particle-austenitic matrix interface. As a consequence, this plastic deformation causes the initiation and propagation of fatigue microcracks, which ultimately lead to fatigue failure and material erosion.



a)



b)

Figure 5 SEM images of cavitated surfaces: a - 1 layer deposited; b - 3 layers deposited

5. CONCLUSIONS

TIG welded Corodur 65 layers help to increase the surface strength of X2CrNiMoN22-5-3 stainless steel subjected to solution treatment at 1060 °C, cooled in water.

Compared to the base metal, as number of deposited layers (from 1 to 3) increases, there is a decrease of 4.01 - 8.1 times in mass loss and a reduction of 3.9 - 7.7 times in erosion rate.

As a result of the dilution of the filler material with the base metal when depositing a single weld layer, the amount of carbides formed is somewhat lower, the hardness has slightly lower values and consequently the resistance to cavitation erosion will be slightly lower.

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