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Mechanical Reinforcement of AISI1018 Steel by a Ni-based Self-fluxing Alloy Coating Applied by Plasma Transferred Arc (PTA)

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Within the manufacturing and repair processes in the mold and tooling industry, joining technologies have a high value because they allow to functionalize and strengthen the surface mechanical properties of the components and thus increase their useful life. However, one of the main drawbacks that arise during a repairing process is the high amount of energy supplied to the component, which modifies the material's microstructure, reduces its mechanical resistance, and causes unwanted fractures [1]. AISI 1018 steel has a wide presence in the tooling industry due to its low cost and good machinability, but it does not meet the necessary mechanical requirements in specialized applications. This work explored an alternative of reinforcing coating for the repair and recovery of molds and tools. A Nickel-based self-fluxing alloy NiCrSiFeB (8Cr, 2.5Si, 2.5Fe, 2B, 0.5C, 84.5Ni. Values in wt. %) was deposited on a low-carbon and low-alloying AISI 1018 steel substrate by using Plasma Transferred Arc technology (PTA). The NiCrSiFeB powder was deposited using WT3500 PTA welding equipment. The coating process parameters were arc current I: 65A, powder feed rate 25 g/min, working distance: 12 mm, carrier, plasma, and shielding gas flow were 2, 4, and 8 slm, respectively. The characterization of the sample was performed in the cross-section around the steel/coating interface. The microstructure, chemical content, and mechanical properties of the samples were measured by SEM, EDX, and Vickers microhardness, respectively. Figure 1a) shows the SEM micrograph around the joining area of the 1018 steel substrate and the coating. A homogeneous region of about 14 µm between the steel and the coating was identified, named interdiffusion zone (IDZ), formed by the γ-Ni phase. The thickness of the IDZ was the same throughout the entire coating. The coating is formed by a mixture region of γ-Ni phase (56.6% fraction) and Ni_3B precipitates (43.4% fraction), which coincides with the findings reported by Mrdak [2]. This author applied a nickel-based alloy by plasma spraying and observed rich zones of γ-Ni and a binary γ-Ni plus Ni_3B region at the beginning of the coating. Figure 1b) shows an inset of the boundary between the base material and the interdiffusion zone. The steel showed a mixture of ferritic and pearlitic lamellar-like microstructures in the boundary with the IDZ and possible lath-bainite structure characterized by parallel fine grains. This microstructure has been observed in austempered heat-treated 1018 steels and is expected to increase the material's mechanical strength [3]. A thin zone of 284 nm was observed free of cementite Fe3C precipitates and γ-Ni phase, named as fusion zone. A zone affected by the heat generated from the PTA was not identified from the analyzed images. Figure 1c) corresponds to a chemical composition analysis using linear scanning performed on the cross-section from the steel to the end of the IDZ, as shown by the dashed red line. During the first 4.8 µm, the steel exhibited Fe content values of about 98% Fe and a small amount of Mn, as expected. A relevant compositional change was observed in the thin melting zone. Fe decreased from 95% to 75%, Ni increased from 1 to 20%, and Cr from 0 to 1%. The most relevant compositional changes were observed along the first 8 µm in the interdiffusion zone. Fe decreased from 75% to 18%, Ni increased from 20% to 70%, Cr from 1% to 8%, Si from 0 to 2%. The Cu content of about 10% was unexpected in the IDZ since this element is not present in the precursor alloy. The Cu appearance in the coating may be associated with contamination from the torch during the process. For values greater than 8 µm, the composition of the elements behaved constantly. Figure 2 shows the microhardness measurements in the cross-section ranging from -1200 µm in steel, 0 µm in the IDZ, up to 1600 µm of the coating. The images of the Vickers indentations in each region help visualize the effect of mechanical reinforcement, as is the case of the IDZ and the precipitates in the coating represented by asymmetric indentations. A SEM inset of the area near the IDZ is shown at the top of the figure. The hardness values observed in the steel are around 200 HV. In the IDZ, a hardness gradient from 203 to 450 HV was observed. This behavior is associated with the reinforcement promoted by the Ni enrichment in the γ-Ni phase. The self-fluxing nickel-based coating presented superior hardness with values around 550 HV. It was noted that the reinforcing agent of the γ-Ni matrix is the Ni_3B precipitates, which presented hardnesses between 550 and 650 HV. In summary, this work reports on the reinforcement of AISI1018 steel by manufacturing a dense nickel-based NiCrSiFeB self-fluxing alloy coating using PTA technology. It was identified that the bond between the steel and the coating occurs through a fusion zone of 284 nm and an IDZ of 14 µm, which exhibits high composition gradients throughout the first 8 µm. The self-fluxing coating is a matrix of the γ-Ni phase with reinforcing Ni_3B precipitates, which improves the surface hardness of AISI1018 steel from 200 HV to 600 HV approximately. The changes in composition and distance along the Steel/IDZ/coating allow calculating concentration gradients that contribute to the understanding of atomic mobility in these self-fluxing alloys deposited on 1018 steel [4].

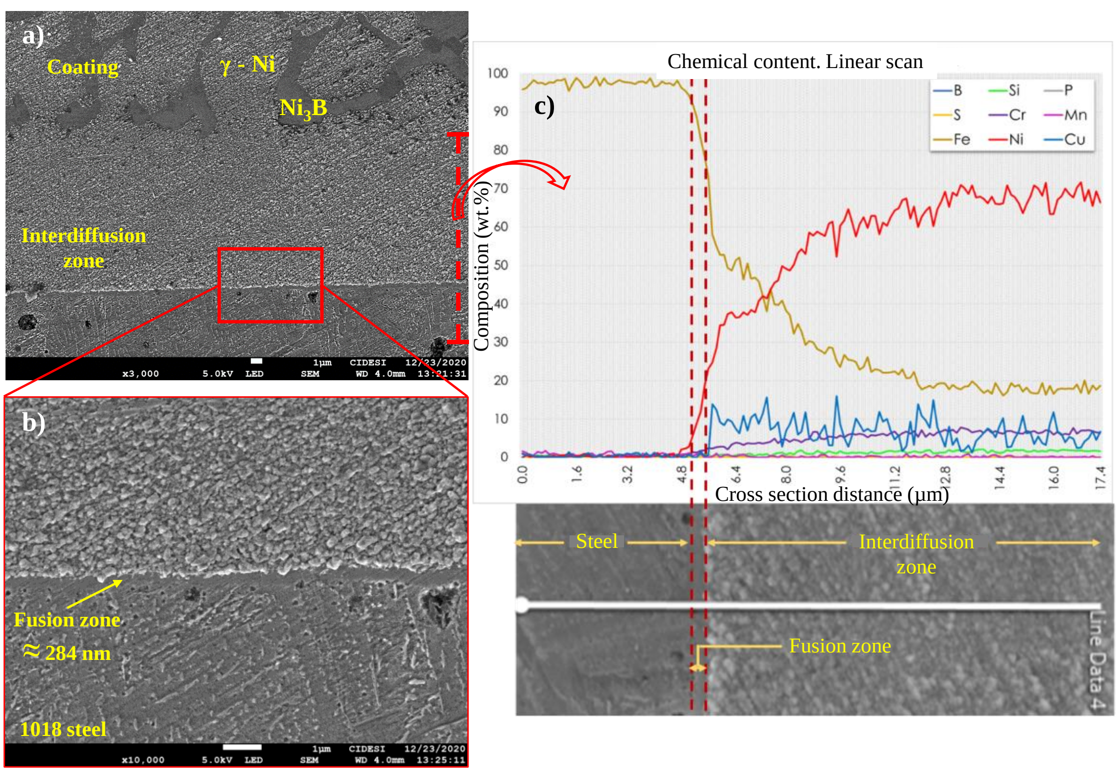

Figure 1. a) SEM micrograph of the cross-section of the steel/coating system. b) inset of the steel/IDZ interface. c) Chemical content profile in the substrate/coating interface.

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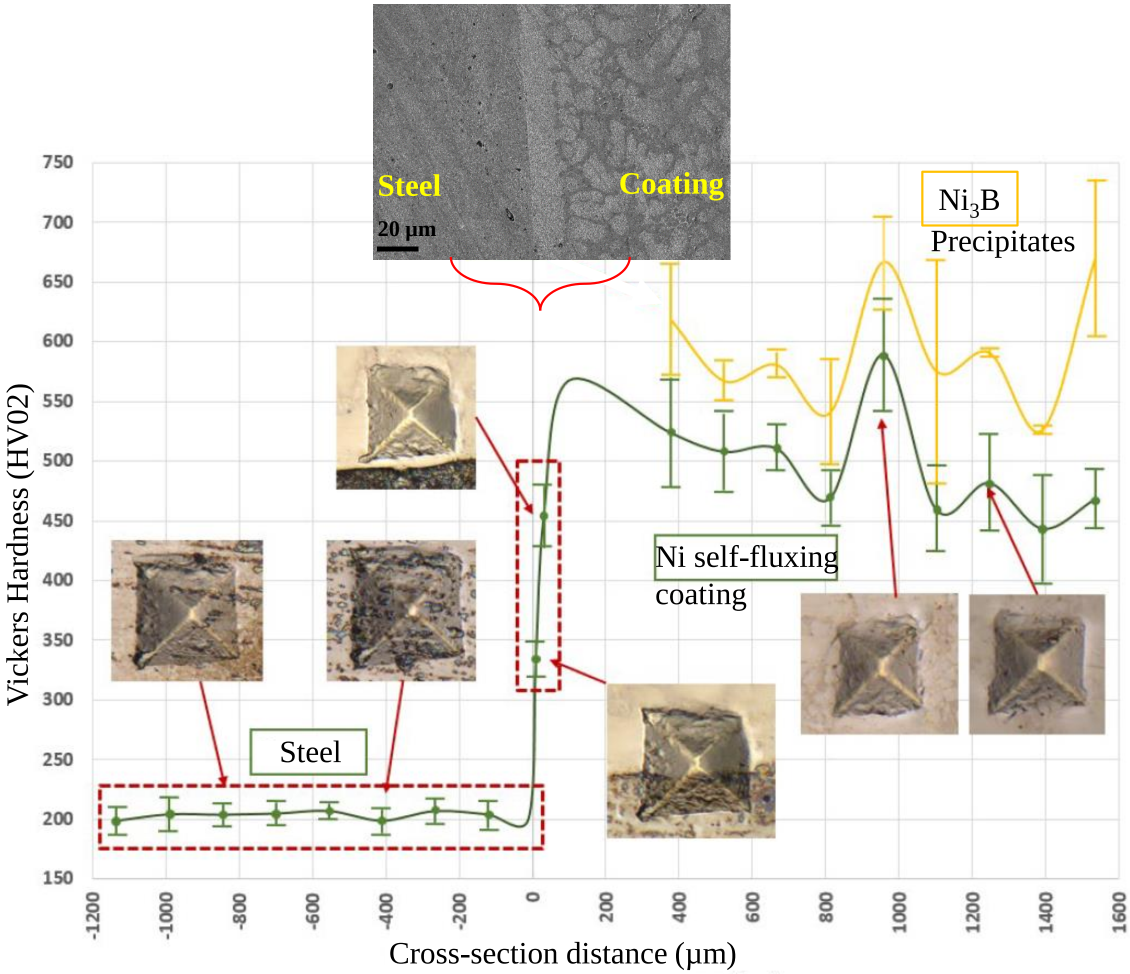

Figure 2. Micro Vickers Hardness measurement of the steel/coating cross-section.

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