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Failure analysis of a safety equipment exposed to EAF environment

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ABSTRACT

The aim of this work was to determine the causes of failure of a safety system for the inspection of a crane used to load an Electric Arc Furnace (EAF). This system is composed of an assembly of cords and tensioners where the technicians are hooked in order to perform the crane system maintenance in safety conditions. This system, made of AISI 316 stainless steel, failed after few service months.

In this work, the causes of failure have been investigated by means of microstructural and morphological characterizations of the failed components. In particular, a morphological and chemical analysis has been firstly performed by SEM + EDXS. Later on, a deep microstructural investigation of the failed components was performed in order to highlight possible weak points in the materials microstructure.

The analyses showed that the components underwent to a severe Stress Corrosion Cracking (SCC) stimulated by the presence, in the working environment, of atmospheric condenses together with high chlorides containing EAF dusts.

1. Introduction

The austenitic stainless steels are materials prone to Stress Corrosion Cracking (SCC) in Cl^- containing environments, as well described in the literature [1–13]. The SCC frequently initiates by pits formation in components subjected to stresses that could also be internal such as those deriving from cold working. These pits usually act as local stress raisers that favor the crack formation, then propagation is speeded up by the corrosive process [1–4,6–13]. The crack nucleation is thus stimulated by the presence of Cl^-, high temperature and metallurgical heterogeneities (sigma phase, delta ferrite, etc.) [1–13].

The literature is rich of case histories concerning fractures of austenitic stainless steels working in aggressive environments. These failures are reported occurring in many different technological fields (nuclear power, oil and gas or steel making plants etc.) [4–13]. Considering the environment, most of these failures have occurred in the presence of high chlorides containing media.

In the present work, the failure of a safety system for the inspection of a crane installed to load an Electric Arc Furnace (EAF) has been investigated (Fig. 1a). This system is also made of cords and tensioners giving a sort of stiffness to the structure. The cords are strands of AISI 316 stainless steel wires cold drawn, while the tensioner is an AISI 316 hot stamped component that has been machined after the stamping process.

The system has been designed to bear the static loads (the tensile force needed to give stiffness to the structure) and some dynamic loads that are usually given by the vibrations induced by the crane operations and by the operators hooked to this system of cords, in order to perform the maintenance of the crane under safe conditions.

The use of stainless steel components in steel making plants was recently increasing for many applications at both room and high

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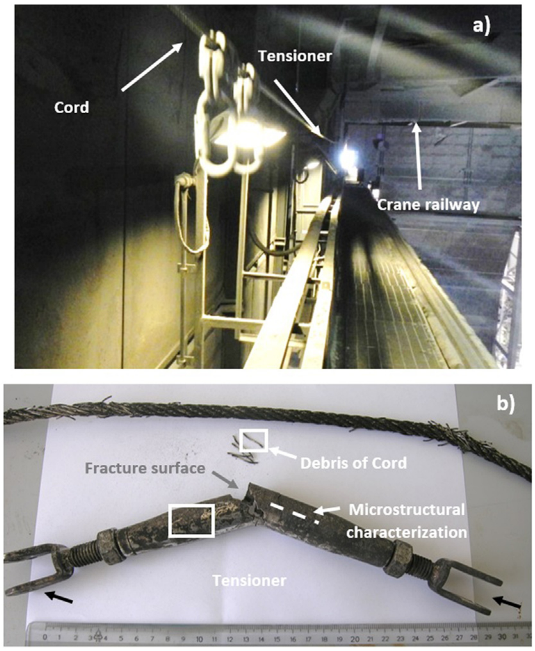

Fig. 1. image of the safety system, a) as installed in the steel making plant (the tensioner position is indicated in the picture) and b) the broken components (tensioner + cord). The squares indicate the regions of top view SEM analysis. The dotted line indicates the section for the microstructural analysis. The black arrows indicate the regions of cord-tensioner connection.

temperature such as: flare tips, tubes, mechanical elements, machine covers, etc.) [14–17]. Therefore, in order to resist to a fast degradation due to the harsh environment composed by EAF dust, the system components have been designed in austenitic stainless steel. In fact, during low alloyed steel making operations, in particular when the furnace is extracted from the hood, EAF dust can leach from furnace and the climate variables such as humidity and temperature can favor the formation of condenses on the component. It is well known that the components close to the EAF could be subjected to the deposition of dust containing high amount of chlorides, sulphides and of low melting point metals that evaporated during the EAF process [18–22].

Unexpectedly, the components studied in this experience already failed after a service life of about 2 months instead of a foreseen life of more than 3 years. As the components were yearly inspected to guarantee a safe use of the system, the failure was noted because some tensioners presented showy cracks and the cord showed a progressive detachment of some wires of the strand. It is to remark that the tensioner did not show a complete failure but only a deep crack inducing a not correct movement the system. On the other hand, it is likely that some small wires of the cord failed before the tensioner, because of the different dimension of the components.

The aim of this work is to find the causes of failure of these components by means of laboratory investigations in order to prevent the unexpected failure of the component and increase the reliability of the component.

2. Material and methods

The AISI 316 stainless steel components analyzed in this experience are shown in Fig. 1b). These components have been first visually inspected in order to determine macro details to be further analyzed. A sample of the dust deposited on the components was analyzed by SEM + EDXS using a Zeiss EVO 40 + INCA X sight equipment. The fractured surfaces of the tensioner and of a wire were also analyzed by SEM + EDXS in order to analyze the fracture morphology and to determine the failure mechanism. After surface cleaning in ultra sound bath (using ethanol as cleaning bath), SEM + EDXS analyses were performed on the components surface (white rectangles in Fig. 1b) in order to determine possible damages caused by the interaction with the environment. For both the components, some samples have been extracted in longitudinal direction in order to determine both the microstructure and the origin of possible internal defects. In the case of the cord, some debris of the strand were used, while for the tensioner the sample was extracted by refrigerated abrasive wheel cut. These samples were embedded in epoxy-resin, grinded and polished in order to obtain a mirror-like surface and then etched by acetic glyceregia (15 ml HCl, 10 ml HNO_3, 10 ml acetic acid, 3 drops glycerine) for 60 s in order to evidence the microstructure. The samples were analyzed by light microscope (Olympus GX71) and Vickers microindenter (3 HV2 indentations for each sample in the material bulk). In particular, the wires underwent to microhardness measurement along the centerline. On the other hand, the microhardness on the tensioner have been performed in longitudinal section along the whole wall-thickness of the component. The same samples (cord and tensioner embedded in epoxy resin) used for the microstructural characterization underwent to SEM + EDXS analysis in order to determine both the chemical composition of the alloy and the internal defects.