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The corrosion resistance of TIG welds of lean duplex stainless steel UNS S82441 after different surface finish treatments

Z. Brytan*[1], J. Niagaj[2a], M. Król[1b]

[1] *Mechanical Engineering Faculty, Institute of Engineering Materials and Biomaterials, Division of Materials Processing Technologies, Management and Computer Techniques in Materials Science, Silesian University of Technology, Str. Konarskiego 18a, 44-100 Gliwice, Poland,*
[2] *Institute of Welding, Str. Bł. Czesława 16-18, 44-100 Gliwice, Poland*

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Abstract.
The duplex stainless steels composed of two-phase microstructure of austenite and ferrite are very attractive constructional materials for use in petrochemical, pulp and paper, pharmaceutics industry, off-shore constructions as well as bridges and civil engineering structures. The duplex stainless steel type UNS S82441 is one of the recently developed and introduced to the steel market grade of a lean duplex stainless steel. The basic characterization of welded microstructures and their corrosion resistance plays an important role in understanding of overall alloy performance in welded structures. The results of pitting corrosion resistance of the welded joints of lean duplex stainless steel UNS S82441 were studied in as welded conditions and after different mechanical surface finish treatments applied in industrial post welding surface cleaning.
This paper discusses the results of microstructure investigations and pitting corrosion resistance of the welded lean duplex stainless steel UNS S82441, studied according to ASTM G48, where autogenous TIG welding process was applied using different amounts of heat input and shielding gases like Ar and Ar-N_2 and Ar-He mixture.

Keywords: lean duplex stainless steel, TIG, heat input, residual stress, surface finish treatment

1. Introduction

In recent years, the development in duplex stainless steel alloys is mainly focused on optimisation of their corrosion resistance and mechanical properties. The superior mechanical strength of duplex stainless steel compared to single phase alloys (austenitic and ferritic) benefits of lighter construction design. The standard duplex stainless steel grade UNS S32205 (22%Cr, 5%Ni, 3%Mo) applied in many industrial branches have been successfully replaced from the decade by cheaper, but still resistant lean-duplex grades, where the duplex grade UNS S32205 where over specified in term of corrosion resistance. The lean-duplex stainless steel contain lower nickel content and increased manganese comparing to standard duplex grade what brings the highest price stability (no influence of nickel price variability). One of the most popular lean-duplex stainless steel grades of composition 21%Cr, 1.5%Ni, 0.5%Mo and 2-6%Mn (UNS S32101, UNS S32202, UNS S82011) are mainly intended to substitute austenitic stainless steel alloy AISI 304 and constructional carbon steel (Coudreuse *et al*. 2003). The light-weight

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*Corresponding author, Ph.D., Zbigniew Brytan, E-mail: zbigniew.brytan@polsl.pl
[a] Ph.D., E-mail: jerzy.niagaj@is.gliwice.pl
[b] Ph.D., E-mail: wojciech.pakiela@polsl.pl
[b] Ph.D., E-mail: mariusz.krol@polsl.pl

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construction made of mentioned lean- duplex stainless steel grades have been successfully applied in civil engineering applications like pedestrian bridges, tanks for storage and transportation (road and rail transport) and even potable water tanks (Boillot *et al*. 2014, Peultier *et al*. 2009).

The newly developed duplex grade LDX 2404® (UNS82441, EN 1.4662) creates a linking bridge between standard duplex and lean duplex stainless steel family. The UNS82441 steel contains a higher amount of manganese, but a slightly lower amount of nickel and molybdenum comparing to duplex grade UNS S32205. In turn, compared with the lean duplex steel S32101, new grade S82441 contains less manganese, but more chromium, nickel and molybdenum (Canderyd *et al*. 2012). The lean duplex stainless steel with a composition containing approximately 24% Cr and 3.5%Ni, 1.5%Mo and 3.0%Mn has strength and corrosion resistance superior to that of Cr-Ni austenitic stainless steel Type 304L and comparable to molybdenum alloyed grades like AISI 316L. High mechanical strength, corrosion resistance and good toughness and together with good weldability make lean duplex stainless steel family a good choice for load-bearing applications (Anbarasu *et al*. 2016).

One of the most important features of virtually all high-alloy steels, including duplex stainless steel, which determine the success of their use in industrial practice is not only suitable corrosion resistance of the base material, but also of their welded joints. The welding process of duplex stainless steel can cause many precipitation phenomena occurring in the weld metal as well in the heat affected zone. Those changes can significantly influence on both corrosion and mechanical properties of the component in working conditions. For lean duplex, as well as duplex grades it is essential to ensure an adequate amount of austenite in the weld metal and heat affected zone, in order to ensure adequate balance between austenite and ferrite phase. The second important factor that should be taken into consideration during welding of such alloys is to avoid the precipitation of detrimental phases such α' ferrite responsible for the effect of "the 475°C embrittlement", carbides M_7C_3, $M_{23}C_6$, nitrides Cr_2N, CrN, π and a number of intermetallic phases like the sigma phase σ, chi χ , R, τ , G, ε, that affect on the deterioration of corrosion resistance and decrease in the toughness of welded stainless steels (Calliari *et al*. 2011, Fang *et al*. 2010, Straffelini *et al*. 2009, Wei *et al*. 2009, Liu *et al*. 2008, Ramirez *et al*. 2003, Hsieh *et al*. 2012).

One of the main problems concerning duplex stainless steels is a proper ferrite-austenite ratio, that can change due to rapid cooling associated with weld thermal cycles resulting in excessive content of ferritic phase. The predominance of ferrite in the weld resulting in the loss of strength and increased susceptibility to intergranular corrosion. The weld microstructure and the austenite to ferrite ratio are largely influenced by welding heat inputs and the cooling rates from welding temperature. Consequently, a careful balance of heat input and cooling rates must be selected in order to achieve a favourable phase balance and avoid the formation of a coarser grained microstructures in the weld (Lippold *et al*. 2005). The key issue is also a proper post-welding treatment focused on the cleaning of welded joints, performed to ensure a good corrosion properties. The heat tint caused by thickening of the surface chromium oxide layer formed alongside weld during welding is always a preferred place where corrosion can develop (Wickstrom *et al*. 2015).

The presence of residual stresses deriving from mechanical surface treatment can influence on the corrosion resistance of the treated surface. The stress level in the superficial layer as well as the stress gradient may influence on overall corrosion resistance of each phase separately and entire duplex microstructure. The X-ray diffraction technique is widely used for the determination of residual surface stresses (Kim *et al*. 2015, Nam *et al*. 2011, Mochizuki *et al*. 2007, Monin *et al*. 2014). One of the main advantages of diffraction methods is the possibility to obtain separate measurements for each phase of the material, so for ferrite and austenite, separately. Regarding duplex stainless steel the X-ray diffraction techniques were usefully applied to evaluate residual stresses in welded joints (Dakhlaoui *et al*. 2006).

2. Experimental procedure

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