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ASSESTMENT OF FRACTURE BEHAVIOR OF DISSIMILAR WELDING OF INCONEL 600

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ABSTRACT

Inconel 600 is a nickel-based superalloy mainly used in chemical, petroleum, energy and aerospace industrial processes; in applications such as processing plants natural gas, capacitors in the treatment of fatty acids in food storage tanks at elevated pressure, among others. As components are subjected to cyclic load fluctuations during their lifetime, where a crack microscopic scale can nuclear, followed by growth at a macroscopic level and finally causing material failure.

There are important parameters which play a significant role in the fatigue strength of components, as is the case of a welded joint; e.g. microstructure, heat treatments, geometry, stress concentrators, surface finish even environmental conditions. The main objective of this study is to investigate and to analyse the fatigue life of test pieces of dissimilar welding of Inconel 600 (IN600) on arrival condition and heat-treated for a period of 100 h and 300 h has 700°C with filler material ER-310, with simple preparation V through Gas Metal Arc Welding processby through bending tests at three points with to $\Delta\sigma$ between 300 and 600 MPa.

The use of such filler material is justified, because the Inconel is a relatively expensive alloy and a material with good properties can be used in conditions of lower risk to reduce costs such as stainless steel as the AS-310.

Through fractography analysis, different areas characteristics of a fatigue failure were determined. Similarly using a scanning electron microscope, it can perform a more detailed failure initiator, fracture surface analysis, and determination of the susceptible region.

KEY WORDS: *Inconel 600; dissimilar welding; fatigue.*

INTRODUCTION

Inconel 600 is a nickel superalloy base, widely used in industry; mainly in applications such as processing plants natural gas, capacitors in the treatment of fatty acids in food storage tanks at elevated pressure, among others. As components are subjected to cyclic load fluctuations during its lifetime, where a crack can nuclear microscopic scale, followed by growth at a macroscopic level and finally causing material failure.

Fatigue may be defined as a deterioration under repeated cycles of stress or strain, leading to a progressive cracking until produces failure in the material. The number of load cycles that can be expected during the lifetime of a component may oscillate depending on the material and operating conditions [1].

Cracks, are generated are known discontinuities, defects in materials, therefore, in the period of crack initiation, fatigue phenomenon of surface material [1]. The importance of the material surface is essential for the study of fatigue life, since most of the components in service have irregularities showing significant influence that affects the fatigue strength of the material.

The machining of the material, and integrity, such as cavities, microcracks, residual stresses; are known to play a key role in performance, particularly under high cycle fatigue [2]. Previous studies show that the onset of fatigue cracking occurs due to the accumulation of damage by plastic deformation. This damage is manifested in persistent slip bands (PSB), intrusions or extrusions in the external surface of fatigued samples. The start of fatigue cracks occurs to over the PSB or intrusions that are joined together and lead to material failure [2], because the slip is not a reversible process resulting from strain hardening or by the formation of an oxide layer.

The start of a process of crack growth is very important in the analysis of the fatigue life, covering much of the same to failure, although often this process is not very relevant, because it material already has type crack defects, which, interested growth thereof.

Although the start transition to crack growth is not well defined; because such change depends on microstructural barriers, which depend on each material. Know the start period is completed, when the growth of microcracks, longer depends on the surface condition, and passes the resistance to crack growth is controlled by the growth rate of material [3].

Fatigue occurs at a stress level below the elastic limit, by thus no plastic deformation is observed on the surface and is called high cycle.

The main objective of this study was to research and analyze the fatigue life of test pieces of dissimilar welding Inconel 600 in arrival condition and aged for a period of 100h and 300h with filler material ER-310, with dimensions of 6x6x100 mm, by a bending test at three points.

MATERIALS AND METHODS

Plates of 6.35x74x150mm (thickness, length and width respectively) of Inconel 600 were welded on arrival condition and Inconel 600 heat treated at 700°C for 100 h and 300 h, with preparation in simple V without bead by the Gas Metal Arc Welding process.

The tests were performed in a configuration of three-point bending test in a servohydraulic Instron machine 8801, as shown in Fig.1.

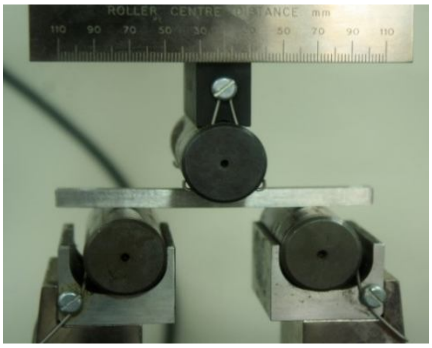


Fig. 1. Configuration of the three-point bending test.

With a value R=0.15 with a distance between supports of 60 mm, with range values Δσ between 300 and 600 MPa was used. The dimensions of the specimens were 60±.10 x 60. ±.10 x 100 mm

Range applied load ΔF was calculated with the following expression valid for the configuration used (bending):

$$\Delta F = F_{\max} - F_{\min} = \frac{\Delta\sigma b t^2}{1.5L} \quad (1)$$

where $\Delta\sigma$: is the stress amplitude, the thickness b, t height and the distance L between the supports.

The values of F_{min}, F_{max} , were obtained depending on the load ratio R used (ratio of minimum load and maximum load); and from these other parameters such as amplitude and medium stress they were obtained.

During such testing the independent variable is the applied stress, being the dependent variable, the number of cycles supported by the specimen.

It is known that stress cycles are characterized by amplitude σ_a , and an average stress σ_m whose equivalent loads for machine configuration, is calculated as:

$$F_a = \frac{F_{\max} - F_{\min}}{2} \quad (2)$$

$$F_{med} = \frac{F_{\max} + F_{\min}}{2} \quad (3)$$

RESULTS AND DISCUSSION

In Fig. 2 shows a curve $\Delta\sigma$ – N with all the results; where the maximum stresses applied were lower than the yield stress of the materials of the joined sheet (522 MPa), which meant that the tests were carried out under elastic conditions. This can be verified in the specimens which do not show considerable residual plastic deformation.

According to the previous results it is observed that both the tests for a $\Delta\sigma$ = 313 MPa and $\Delta\sigma$ = 371 MPa, for which there is no rupture, which means that they would not break even if 10 million cycles were applied (N = 107).

In all other cases, the maximum stresses were higher than the yield stress of the material, which also showed cyclical remanent deformation and forced the ending of the test due to excessive plastic deformation, change in the configuration of the test and operational limitations to continue it.

Some of the specimens, as shown, didn´t show visible defects, while some of the specimens did. Of these three specimens only, the last one showed an intern defect that acted as an initiator and that generated the propagation of a macroscopic crack during the test.

Once the test was completed, the test specimen with defect was finally fractured in order to analyze the fracture surface, which is shown in Fig. 3. It can clearly observe a passing defect of approximately 0.2 mm average depth, and a crack length. final about 1.5 mm average. After this the final area of the fracture is shown.

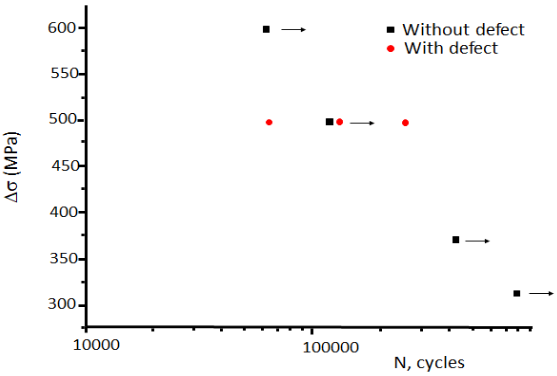


Fig. 2. Curve applied stress – number of cycles without defect (■) and with defect (●).

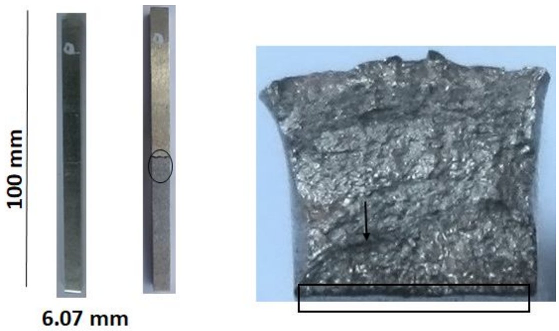
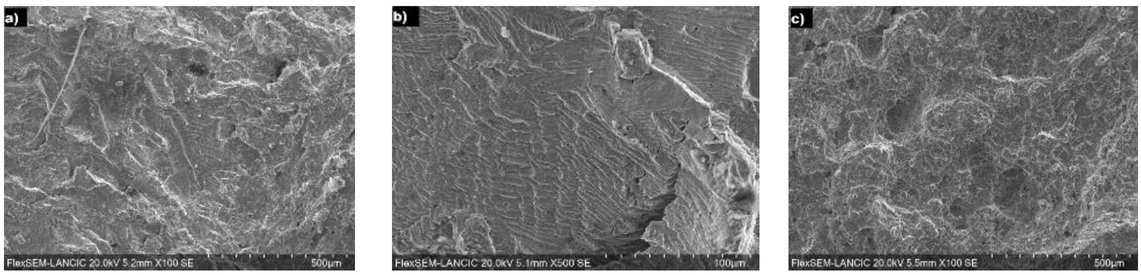


Fig 3. Specimen with defect. Test piece with final crack. Test specimen surface fractured in arrival condition with filler material ER-310.

The microphotography's (fig. 4, 5) for the different fracture surfaces are shown for the different joint conditions of Inconel 600, where planes and regions defined in different directions are observed, in each of them are presented at 100X and 500X the beginning of the crack.

In recent researches about nickel based alloys using careful examination reveals that crack nucleation and propagation in the early state of deformation occur preferentially along slip bands. Crack nucleation can also form from carbides precipitating during the cyclic loading; the carbide precipitates are continuously generating some discontinuity at the interface between slip bands and carbide precipitates and at the location of carbide precipitates within the grain boundaries [4].



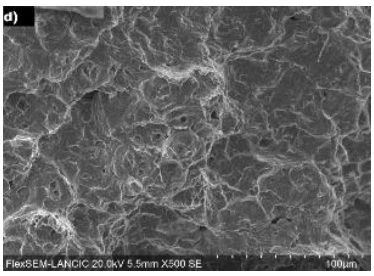


Fig. 4. Microfractographies of the dissimilar welding of IN600. Surface in arrival

As seen in Figures 4 *a* and 4 *b*, once cracking has started, the cracks propagate way transgranular. In Figure 4 *b* striations are observed, which are often noticed with the presence as the crack grows steadily, which indicate increasing levels of plasticity [4].

The same for the Figures 5 *a* and 5 *b* In the case for the Figures 4 *c*, 4 *d*, 5 *c* and 5 *d*, the fracture is ductile, which means that the fracture surface tends to become more ductile and softening with increasing number of cycles to failure [4, 5].

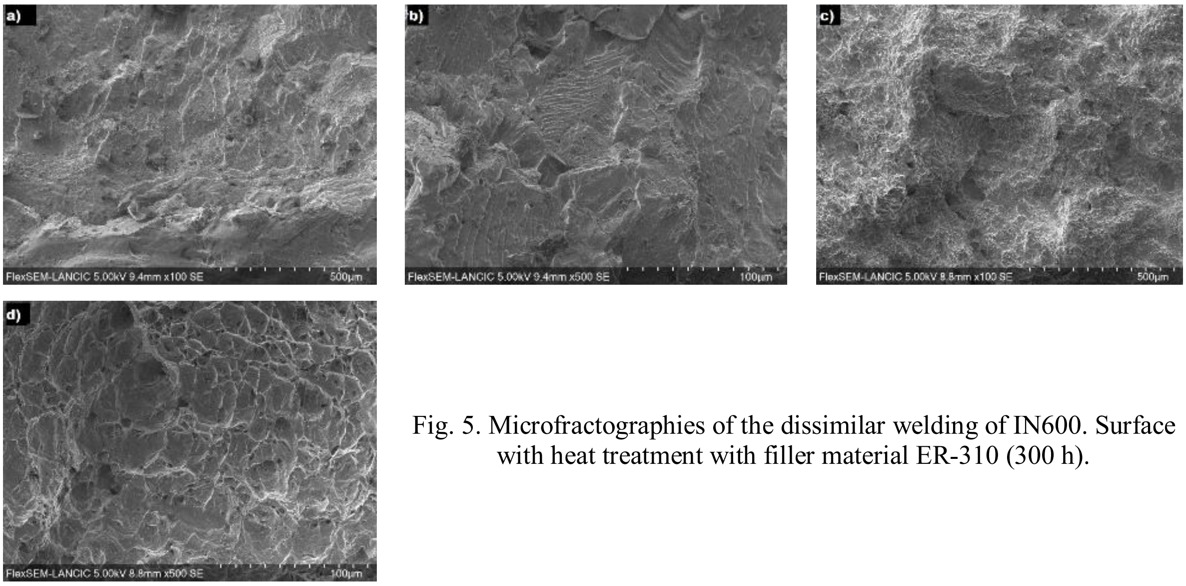


Fig. 5. Microfractographies of the dissimilar welding of IN600. Surface with heat treatment with filler material ER-310 (300 h).

Fig. 5 *a* shows the starting area of the crack. Fig. 5 *b* and 5 *c* show in greater detail an area near the crack initiation, which shows separate and staggered planes, which are commonly known as cleavage [6].

In the case of Fig. 5 *d*, the final fracture zone is presented, which its appearance indicates that the final phase of the fracture was caused by plastic collapse [6].

CONCLUSIONS

According to the results for $\Delta\sigma$ = 500 MPa for the based material -based material and based material – welded material -300 h conditions, there would be no significant difference, with respect to the microstructural conditions, previously studied; since under fatigue the behavior is similar. However, there are several factors that do not allow us to infer important conclusions, among which are the small dimensions of the specimens, the type of load (bending, with important gradients for such small thickness and high nominal voltages), and a curve $\Delta\sigma - \mathrm{N}$ associated with the very flat base material, close to the yield stress.

Through the fractographic analysis, the different characteristic zones of fatigue failure were determined as well as with scanning electron microscopy. It is of utmost importance to consider the gloss that this type of discontinuity has, since a greater quantity and size significantly reduces life to fatigue.

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