

A Study of Compact Test and Stress Intensity Factor on Developed Welded Duplex Stainless Steel

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ABSTRACT: The purpose of this study is to subject the DSS to thermal ageing (TA) temperatures such as 475°C respectively and for the further study TIG welding is carried out in a view to understand how exactly the thermal ageing is influencing the degree of brittleness in developed welded DSS of TA475. Compact test examination was carried out for developed welded TA475 in which the investigation helps to find the severity of brittleness. The results obtained from the compact test conclude that the grade TA 475 exhibits better mechanical properties due to lack of ferrite, carbide precipitation and irregular grain orientations. This paper relates the study of compact test (test for stress intensity factor, K_{IC}) on the selected developed welded TA 375.

KEYWORDS: Duplex Stainless Steel (DSS), thermal ageing, brittleness, precipitation, compact test.

I. INTRODUCTION

The duplex stainless steel (DSS) family was introduced commercially about 1920's mainly intended for the pulp and paper industry. Original duplex Alloys suffered from brittleness and low ductility. A second generation with improved Weld-ability, mainly due to higher additions of nitrogen, was developed in the early 80's. Duplex Stainless Steels are extremely corrosion resistant, work hardenable alloys. Their microstructures consist of a mixture of austenite and ferrite phases. This two-Phase structure of ferrite and austenite combines the beneficial effects of the phases and allows the steel to obtain high strength (ferrite) and toughness (austenite) even at low temperatures.

II. RELATED WORK

There are five types of specimens (Fig.1.) that are permitted in ASTM standards that characterize fracture initiation and crack growth (stress intensity factor, K_{IC}). Although no single standard follows all five configurations, and the configuration available are,

- Compact Test Specimen (CT)
- The Single Edge Notched Bend (SENB)
- The Arc-shaped Specimen (AS)
- The Disc-shaped Specimen (DS)
- The Middle Tension Specimen (MT)

A) Each specimen configuration has three important characteristics:

- The crack length (a)
- The thickness (B) and
- The width (W)

In most cases, $W = 2B$ and $a/W = 0.5$.

B) Testing requirements: In order to obtain fracture toughness parameters, it is essential that fracture toughness satisfies three requirements:

1. The specimen geometry must be such that K_{IC} can be estimated with sufficient accuracy.
2. The value of the load and the crack length at the onset of cracking must be measured accurately.
3. Pre cracking must be done so as to ensure that the crack introduced into a sharp one.

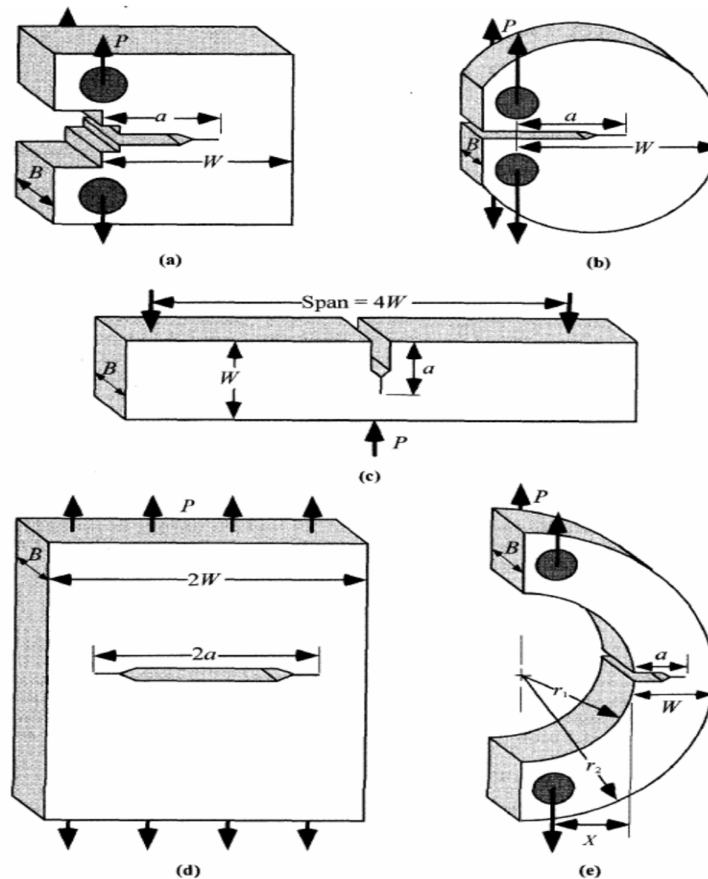


Fig.1. five types of specimens that are permitted in ASTM standards that characterize fracture initiation and crack growth

C) Constraints on specimen dimensions: Specimen plate thickness B , crack length a , and width W as shown in fig.1 must satisfy the following requirements,

$$B \geq 2.5 \left(\frac{K_{IC}}{\sigma_{ys}} \right)^2 \quad \text{for plate thickness}$$

$$a \geq 2.5 \left(\frac{K_{IC}}{\sigma_{ys}} \right)^2 \quad \text{for crack length}$$

$$W \geq 5.0 \left(\frac{K_{IC}}{\sigma_{ys}} \right)^2 \quad \text{for width}$$

Where σ_{ys} is the usual yield stress of the material.

D) Specimen Size:

1. Specimen plate thickness, B = 6.35mm
2. Crack length, a = ($a_{notch} + a$)
3. Machined notch length, a_{notch} = 8.25mm
4. Pre-crack length, a_p
5. Width, W = 25.4mm
6. Pin hole diameter, d = 6.35mm
7. Height, h = 30.48mm

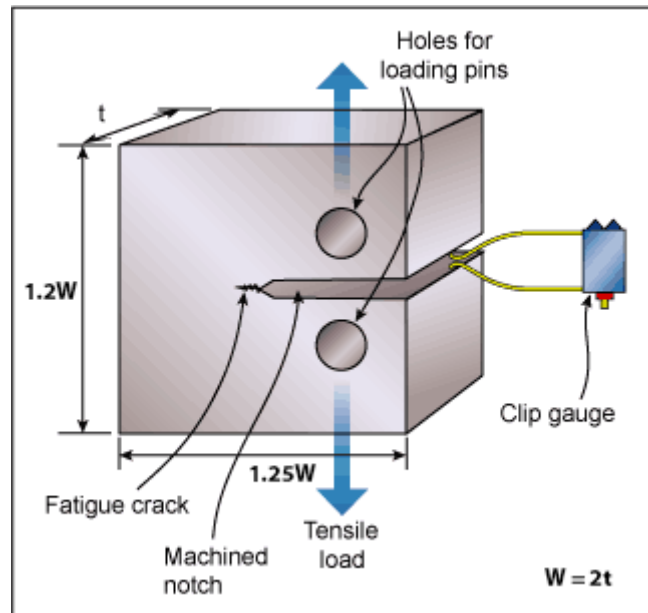


Fig.2 Dimensions of CT specimen as per ASTM E399-90 standard used for K_{IC} test

Fatigue Pre-Cracking and Measuring Crack Length

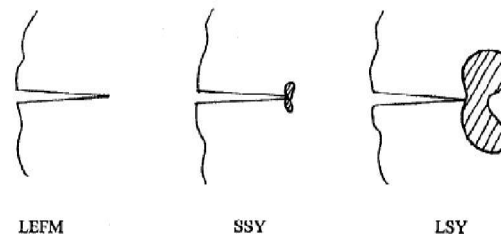


Fig.3. Fatigue Pre-Cracking a Fracture Mechanics CT Specimen

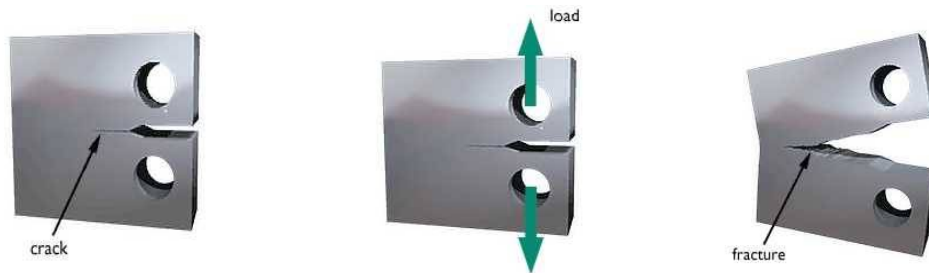


Fig.4. CT specimen before and after failure results

Fig.2. illustrates the pre-cracking procedure in a typical specimen where a fatigue crack initiates at the tip of a machined notch and grows to the desired size through careful, control of the cyclic loads.

The fatigue crack must be introduced in such a way that it should adversely influence the toughness value that is to be measured. Cyclic loading produces a crack of finite radius with a small plastic zone at the top. When contains strain hardened material and a complicated residual stress distribution. In order for a fracture toughness to reflect true material properties, the fatigue crack must satisfy the following conditions.

1. The crack tip radius at fatigue must be much larger than initial radius of the fatigue crack.
2. The plastic zone produced during fatigue cracking must be small compared to the plastic zone at fracture.

Each of the various fracture testing standards restrictions on fatigue loads, which are designed to satisfy the above requirements. In K_{IC} tests, the maximum K during fatigue loading must be no greater than the particular fraction of K_{IC} . The maximum fatigue load is defined as a fraction of the load at ligament yielding. Of course one can always perform fatigue pre-cracking well below the allowable loads in order to gain additional assurance of the validity of the results, but the time required to produce the crack increase rapidly with decreasing fatigue loads.

III. EXPERIMENTAL RESULTS

The results of the fracture toughness test conducted with the aid of servo- hydraulic UTM for the ASTM E399 standard CT specimen were presented in this section. The load versus COD curve associated with each trial is also shown graphically.

TABLE 1
Results of compact test specimen geometric conditions

Sample	W mm	B mm	a_0 mm	a_p mm	a mm	a/W mm	f(a/W)	P_q KN	P_{max} KN	K_{IC} MPa√m	K_{max} MPa√m
DSS	24.4	6.35	7	4.48	11.48	0.541	8.34	5.04	5.50	36.24	37.35

Sample	σ_{ys}	a mm	a/w mm	B mm	a_0 mm	W mm	f(a/W)	$P_{max}/P_q \leq 1.10$
DSS	484	11.48	0.451	0.014	0.014	0.541	8.34	1.09

Notations used:

W = Distance from the centre of the loading holes to the edge of the specimen, mm.

a_0 = Initial machined notch length, mm.

a_p	= Fatigue pre-cracking, mm.
a	= total crack length, mm.
P_{max}	= Maximum load, KN.
P_Q	= Load at which K_{IC} is calculated, KN.
B	= Thickness, mm.
K_{IC}	= stress intensity factor calculated at critical load P_Q , $MPa\sqrt{m}$.
K_{max}	= Mode I failure toughness, $MPa\sqrt{m}$.

IV. CONCLUSION

The plane strain fracture toughness test have been conducted for Duplex stainless steel (DSS) to evaluate its crack resisting capability, whose values was found to be $K_{IC} = 36.24 MPa\sqrt{m}$ and $K_{max} = 37.85 MPa\sqrt{m}$.

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