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EFFECT OF CRACK ORIENTATION AND WELDING PROCESS ON J-INTRGRAL VALUES

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ABSTRACT

A series of tests was performed with SENB specimens on a Titanium alloy. Results of seven groups of specimens show that the j-integral values of L-T direction specimens are much higher than those of L-S ones. The J-integral values of rolled ring are as : $J_{C-R} > J_{C-L} > J_{L-R}$. And that the J values of welded joint and HAZ are obviously smaller than those of the base metal. It signifies that the welding process can result in a reduced toughness of Ti-alloy and the effect of crack orientation on toughness value is not negligible for engineering applications.

KEYWORDS:

J-integral, Ti-alloy, crack orientation, welding process

INTRODUCTION

J-integral meathd plays a significant role in elastoplastic fracture mechanics. As an important fracture characteristic parameter, it is already well developed and extensively used in engineering prictice[1]. The heat affact zone (HAZ) is in many cases considered to be the most critical part of a welded structure with regard to unstable fracture. It is evident that the designers need to know the fracture toughness of welded joint, HAZ and parent plate as affected by the heat of welding, since the welded metal, the HAZ and the parent material normally have different fracture toughness. Studying the effect of welding process on J-integral value for Ti-alloy has been proved to be very useful for engineering applications. An experimental investigation is therefore carried out in this paper. Besides, the effect of crack orientation on J value is also investigated, because in some materials, such as forging, extrusions or plates, crack orientation can have an important bearing on fracture toughness measured.

EXPRIMENTAL PROCEDURE

material and Specimens

A chinese Ti-alloy plate and rolled ring were used. Their chemical composition is given in Table 1, and the mechanical properties are given in Table 2.

Three-point sigle-edge noched bend (SENB) specimens were used for J-integral tests. The size is shown in Figure1. Based metal, welded joint and HAZ material were used to make different test specimens. Specimens made from the Ti-alloy plate were cut along L-T and L-S direction (see Figure 2). and those made from the Ti-alloy rolled ring were obtained along C-R, R-L and L-R dirrection respectively. (see Figure 3).

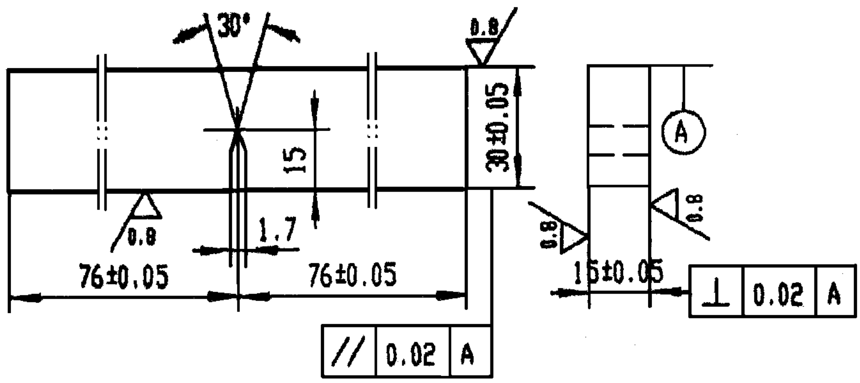

Figure 1: SENB specimen

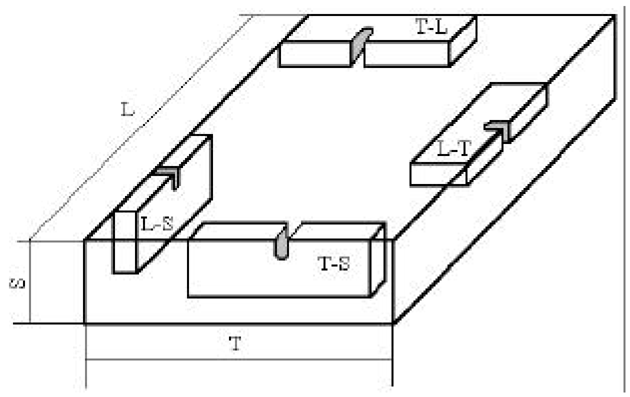

Figure 2: Specimen orientation for a plate

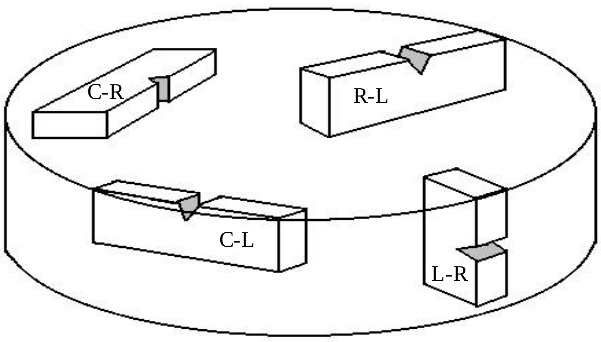

Figure 3: Crack plane orientation for a rolled bar

TABLE 1
CHEMICAL COMPOSITION

	Ti	Al	B	Fe	Si	C	N	H	O
Plate	95.57	4.0	0.005	0.23	0.05	0.025	0.024	0.005	0.084
Rolled ring	95.64	3.975	0.005	0.215	<0.05	0.016	0.023		0.073

TABLE 2
MECHANICAL PROPERTIES

	s_b (MPa)	$s_{0.2}$ (MPa)	$d\%$	E(MPa)	v	a_{KU} (J/cm^2)
Plate	682	605	18.5	1.106×10^5	0.34	74.9
Rolled ring	712	615	16.3	1.310×10^5		71.4

Experimental Procedure

The J-integral tests were carried out on a Chinese WE-30 material testing machine of 300 KN capacity and in accordance with GB2038-91 standard[2]. Specimens have been precracked in fatigue. Load P versus load-point displesment Δ is recorded autographically. After off-loading, specimen crack fronts were marked by re-fatigue and then specimens were broken at low temperture. Crack length a and crack extension Δa measurements were made according to the nine-point-average procedure. A 50-fold enlargement optical micrometer was used to measure a and Δa. All tests were mdae at room temerature, approximately 22-26°C.

The J-integral values were calculated according to the following formula :

$$J_R = \frac{1-v^2}{E}\left[\frac{P_s}{BW^{\frac{1}{2}}}Y\left(\frac{a}{W}\right)\right]^2 + \frac{2U_P}{B(W-a)}$$

RESULTS AND DISCUSSIONS

The exprimental results of J-integral values of seven groups of specimens are shown in Figure 4-10. From Figure 4 and 5, we can see that the J values of L-T direction specimens are much higher than those of L-S ones. It can also be perceived from Figure 8, 9 and 10 that the J values of rolled ring are as follow :

$$J_{C-R} > J_{R-L} > J_{L-R}$$

This means that in Ti-alloy material, crack orientation has an important effect on fracture toughness. It is generally because of inclusions or intermetallic constituents which assist the crack by nucleating voids. Proper design and selection of crack orientation is therefore important for engineering strcture.

Figure 4, 6 and 7 shown that the J values of the welded joint and HAZ are obviously smaller than those of the base metal. it signifies that the welding process can result in a reduced toughness of Ti-alloy. Therefore, the inhomogeneity of the welded joint will bring about a problem in using Fracture Mechanics to assess welded structures. For example, cracks located in the welded joint or HAZ may grow to a critical size and propagate rapidly but then arrest when they enter the parent plate. Likewise, a slow-growing crack in the base metal could suddenly accelerate when entering the welded joint or HAZ.

From our results, we can see that the fracture behaviour of the Ti-alloy is affeted by the welding process and also by the crack orientation. These effects are not negligible for engineering applications.

Because of space limitations, a further analysis and discussion will be conducted in a follow up paper.

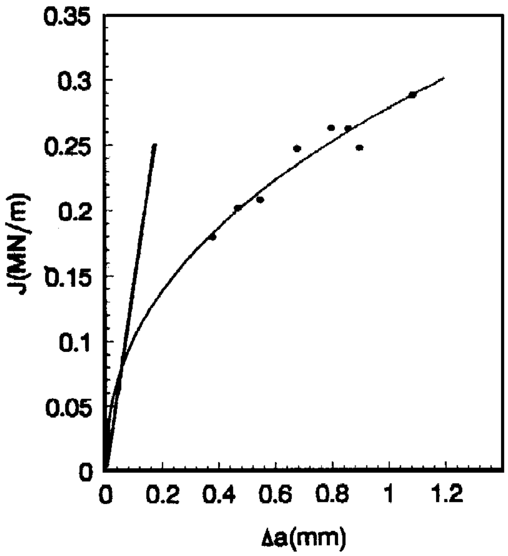

Figure 4: J vs a of base metal plate(L-T)

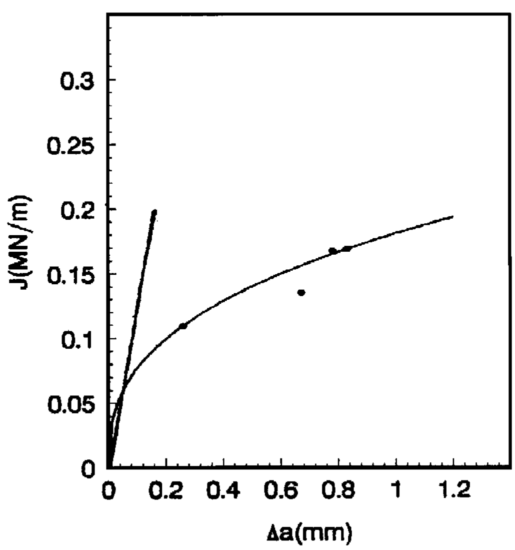

Figure 5: J vs a of base metal plate(L-S)

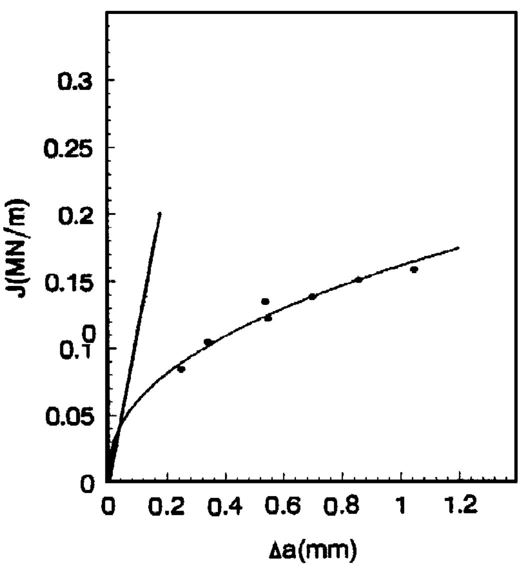

Figure 6: J vs a of HAZ plate(L-T)

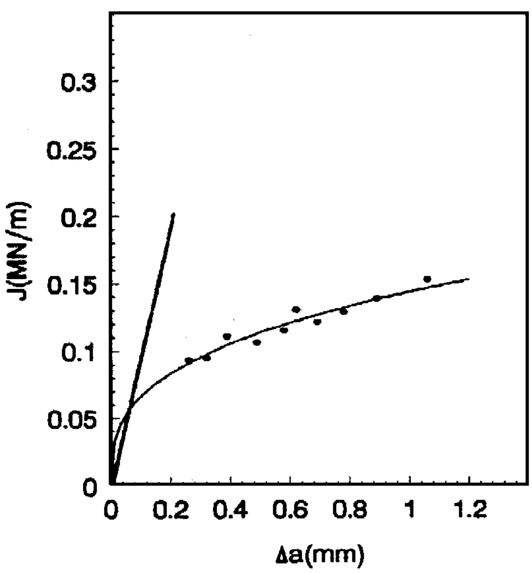

Figure 7: J vs a of welded joint plate(L-T)

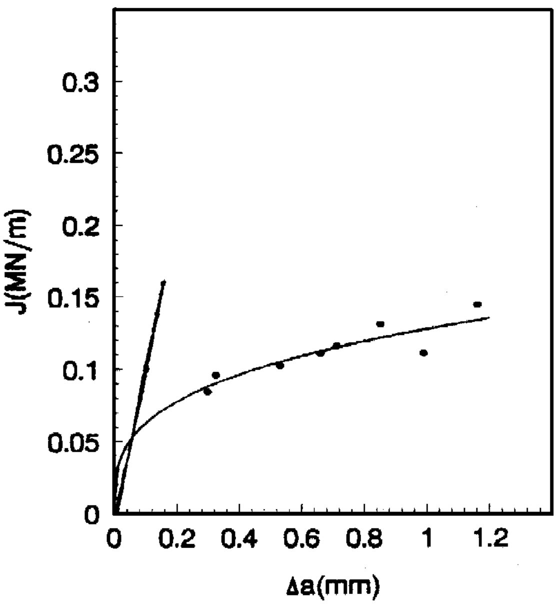

Figure 8: J vs a of rolled ring (C-R)

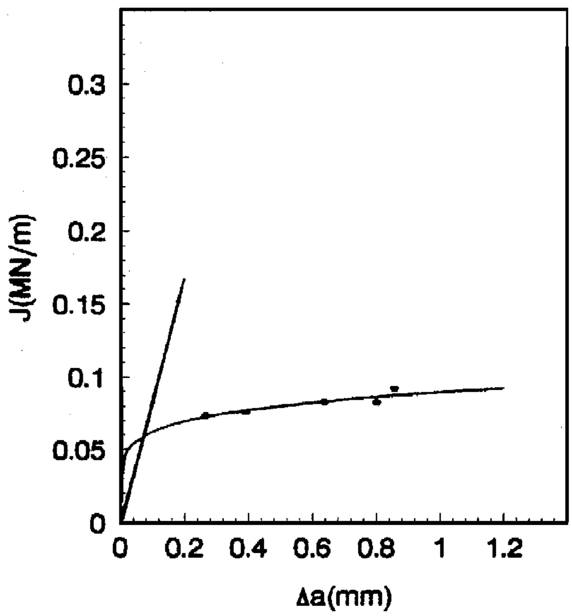

Figure 9: J vs a of rolled ring (L-R)

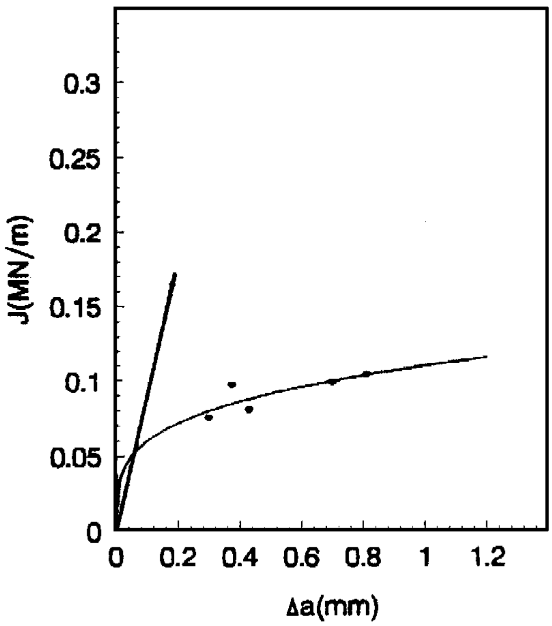

Figure 10: J vs a of rolled ring (R-L)

CONCLUSIONS

Crack orientation has an important bearing on fracture toughness. The J-integral values of Ti-alloy plate specimens taken along the L-T direction are much higher than those taken along the L-S direction. And the J values of rolled ring Ti-alloy are as follow:

$$J_{C-R} > J_{R-L} > J_{L-R}$$

The welding process can result in a reduced toughness of Ti-alloy. The J-integral values of the welded joint and HAZ are obviously smaller than those of the base metal.

REFERENCES

1. Stanley, P.*Fracture Mechanics in Engineering Practice*, Applied Science Publishers Ltd, London, 1977.
2. *Standard Method of J-integral Testing, GB2038-91*, The Chinese Standard Institution, 1991.