



Fatigue Strength Depending on Position of Transverse Cracks in FCAW Process

The differences in fatigue properties of welds with surface cracks and welds with internal cracks were determined

BY H. W. LEE, S. W. KANG AND J. U. PARK

ABSTRACT. This is a study of fatigue strength of weld deposits with transverse cracks in plate up to 50 mm (2 in.) thick. It is concerned with the fatigue properties of welds already with transverse cracks. A previous study of transverse crack occurrence, location and microstructure in accordance with welding conditions was published in the *Welding Journal* (Ref. 1).

A fatigue crack develops as a result of stress concentration and extends with each load cycle until failure occurs, or until the cyclic loads are transferred to redundant members. The fatigue performance of a member is more dependent on the localized state of stress than the static strength of the base metal or the weld metal.

Fatigue specimens were machined to have transverse cracks located on the surface and inside the specimen. Evaluation of fatigue strength depending on location of transverse cracks was then performed.

When transverse cracks were propagated in a quarter- or half-circle shape, the specimen broke at low cycle in the presence of a surface crack. However, when the crack was inside the specimen, it propagated in a circular or elliptical

shape and the specimen showed high fatigue strength, enough to reach the fatigue limit within tolerance of design stresses.

Introduction

As welded structures become bigger, thick-plate welding becomes more important. Thick-plate weldments have higher cooling rates and greater restraint stresses than thin-plate weldments, making it easier for cracks to occur in the thick welded parts. This is the weakest area because its heating and cooling creates inconsistent microstructure. Safety is very important in this type of weld fabrication. Cracking is not allowed in the weldment, although in some cases certain porosity is allowed.

"Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity," according to AWS D1.1, *Structural Welding Code — Steel* (Ref. 2). "For all other groove welds and for fillet welds, the sum of the visual piping porosity 1 mm ($\frac{1}{32}$ in.) or greater in diameter shall not exceed 10 mm ($\frac{3}{8}$ in.) in any linear inch of weld and shall not exceed 19 mm ($\frac{3}{4}$ in.) in any 305 mm (12 in.) length of weld," the Code continues.

It is well known that porosity has a round edge while a crack is sharp, making it easy to propagate. Crack propagation is different depending on crack size and location. Fatigue in welded structures has been studied extensively, especially with recent developments in fracture mechanics. Research on fatigue crack propagation is also extensive (Refs. 3–6). But in most studies of fatigue, experiments were performed by machined notch or artificially induced discontinuity.

Up until now, few investigations of cracks occurring in the actual structure have been undertaken. In this study, therefore, specimens were fabricated and welded like the actual structure and machined to have transverse cracks on the surface and inside. Fatigue properties, depending on crack location, were then studied, as well as the distance between the transverse crack and porosity.

KEY WORDS

Transverse Cracks
Flux Cored Arc Welding (FCAW)
Weldment Fatigue
Resistance
Preheat
Weldment Fractography
Fatigue Limit
Porosity

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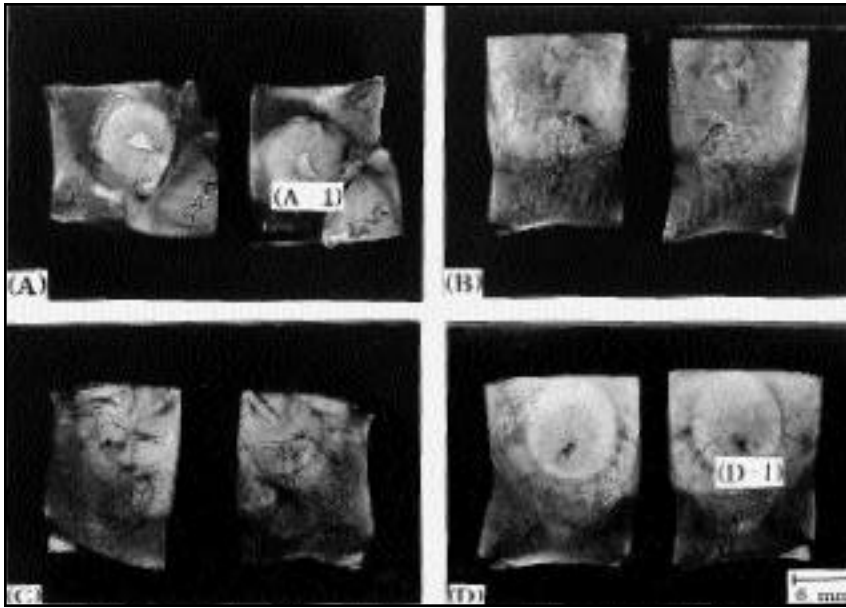


Fig. 8 — Fractured surfaces of specimens with internal cracks after fatigue testing at 35 kgf/mm² stress range (each specimen was overloaded by 35 kgf/mm² stress range in order to fracture the specimen artificially).

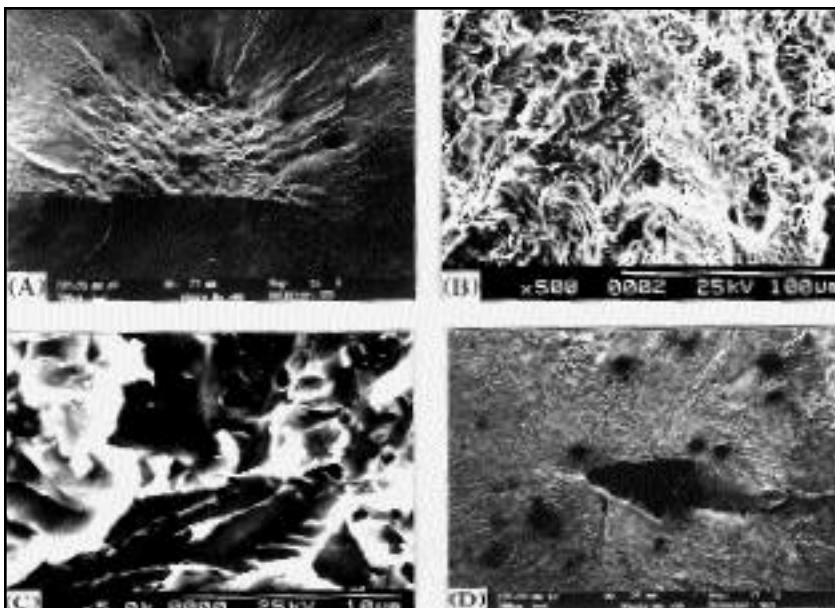


Fig. 9 — SEM morphology of cracks and porosity. A — Crack (16X); B — crack (500X); C — crack (5000X); D — porosity (17X).

2) Specimens with internal cracks showed superior fatigue strength, enough to reach fatigue limit under designed stress. Propagation mode showed a circular or elliptical morphology.

3) Specimens with internal cracks and porosity showed fatigue fracture at the large cross-sectional area of the porosity. Therefore, it appears the cross-sectional area of a discontinuity has greater effect on fatigue strength than its shape.

References

1. Lee, H. W., Kang, S. W., and Um, D. S. 1998. A study on transverse weld cracks in thick steel plate with the FCAW process. *Welding Journal* 77(12): 503-s to 510-s.
2. *Structural Welding Code — Steel* (ANSI/AWS D1.1-98). American Welding Society, Miami, Fla., pp. 175-180.
3. Tsay, L. W., Chen, T. S., Gau, C. Y., and Yang, J. R. 1999. Microstructure and fatigue

crack growth of EH36 TMCP steel weldments. *International Journal of Fatigue* 21, pp. 857-864.

4. Lu, B., Zheng, X., and Li, D. 1993. Fatigue crack initiation and propagation in butt-joint weld of an ultrahigh-strength steel. *Welding Journal* 72(2): 79-s to 86-s.

5. Zhang, M., Yang, P., and Tan, Y. 1999. Micromechanisms of fatigue crack nucleation and short crack growth in low carbon steel under low cycle impact fatigue loading. *International Journal of Fatigue* 21, pp. 823-830.

6. Forman, R. G. 1972. Study of fatigue crack initiation from flaws using fracture mechanics theory. *Eng. Fract. Mech.* 4, pp. 333-345.

7. Yurioka, N. 1995. A chart method to determine necessary preheat temperature in steel welding. *Journal of Japan Welding Society*, pp. 347-350.

8. *Boiler and Pressure Vessel Code*, Section XI. 1995. American Society of Mechanical Engineers, pp. 20-23

9. Dreng, T., Robakowski and Dreng, and Scierski, J. M. 1987. *International Conference on Fatigue of Welded Constructions*. England, Welding Institute, pp. 445-456.

10. Lee, H. W., and Kang, S. W. 1997. A study on transverse weld cracks in 50-mm thick steel plate with the SAW process. *Journal of Japan Welding Society* 15(4): 563-573.

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