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# Brittle Fracture of Weld T-Joints in Reversed Loading

*K. Azuma and Y. Makino*
Kumamoto University
Kumamoto, Japan

*Y. Kurobane*
Kumamoto Institute of Technology
Kumamoto, Japan

## ABSTRACT

**This paper concerns the assessment of weld defects influencing crack growth and fracture behavior of joints. Welded T-joints made of steel plates, with or without fatigue cracks along the weld toes, were tested in reversed loading to reproduce fractures starting from the weld toes. The effects of fatigue cracks were studied by comparing test and FE analysis results and by looking into the state of stress and strain at the region near the weld toes.**

KEY WORDS: Welded T-joints, Fatigue Crack, Ductile Crack, Brittle Crack

## INTRODUCTION

The Kobe Earthquake revealed that tensile failures frequently started with ductile cracks growing from weld toes. These cracks changed to a fast unstable failure as they grew, when adverse effects were combined. The stable crack growth from the weld toes and its change to fast failure are the subject of study in a series of tests of welded T-joints recently performed by the authors (Kurobane et al. 1997). A welded T-joint configuration was selected because it had the simplest possible form and yet reproduced brittle fracture as observed during the earthquake. Namely, each specimen had a main plate, with a rib plate groove welded at the center of the main plate. Details of specimens are shown later. When a compressive static load was applied to the rib plate, the weld toes sustained large plastic strain. The load was reversed and a tensile load was applied to the rib plate. A ductile crack first appeared in the central region of the main plate along the weld toes. This crack extended stably not only along the weld toes but also in the through thickness direction. Some specimens failed suddenly, at a certain stage, showing an unstable crack extension from the tips of ductile cracks, while the other specimens failed by ductile tear.

A nonlinear finite element analysis was found to accurately reproduce load versus deflection relationships until crack depth reached about 0.5 to 2.5 mm. The initiation of first ductile cracks was found to be predicted by a simple function of stress triaxiality, von Mises' equivalent stress and maximum uniform strain of material (Wang et al., 1996). Ductile cracks therefore gave no appreciable effect on load-deflection curves until they reached about 0.5 to 2.5 mm in depth, as far as they grew stably. After that, the cracks grew rather quickly, leading finally to a ductile or brittle failure. It has been unsuccessful to reproduce load versus deflection curves numerically after cracks grew further.

An attempt was made to evaluate the strength of pre-cracked welded T-joints by means of the failure assessment diagram (FAD). The FAD utilized was a classical CEGB approach (1976) with a modification according to Milne (Bloom 1995). Although the FAD was found to predict test and numerical results very well, several crude assumptions had to be introduced to apply the FAD to welded T-joints. Two important questions were: effects of pre-strain on fracture toughness of material; and effects of ductile crack extensions preceding brittle fracture.

This paper describes further tests on welded T-joints. The test apparatus is improved to permit a reversed loading test. Specimens, with and without fatigue cracks along the weld toes, are fractured by applying reversed loading of one cycle. The weld toes are first strained in compression into plastic region, and then strained in tension until brittle fracture occurs following ductile crack extensions. A nonlinear finite element analysis is performed to compare fracture behavior with the test.

## TESTS ON WELDED T-JOINTS WITH FATIGUE CRACK

Welded T-joints with or without fatigue crack were tested under reversed loading as shown in Figure 1. The Vertical load 'V' was applied to the rib plate by a 100-ton hydraulic ram while both ends of the main plate were fixed to the base of the rig. Loading sequences employed were as follows:

Step 1: A compressive load was applied to the rib plate in the vertical direction until the deflection at the rib plate reached $\delta_{max}$ (see explanation for $\delta_{max}$ below).

Step 2: A tensile load was applied to the rib plate until complete failure.

V-$\delta$ data were converted to V-sin$\theta$ data to compare with the previous test results. The maximum deflection $\delta_{max}$ at the first application of the compressive load corresponds to sin$\theta$=−0.3, which was selected for all tests so that the specimens would sustain tensile failure corresponding to the same $\delta_{max}$ under compression. This was to simulate a similar situation to the Kobe Earthquake, where many connections sustained tensile failures after being strain-cycled in both tensile and compressive directions well into the strain-hardening region.