The Relationship of Fatigue and CTOD about E43 Steel
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Abstract. Because of the inevitable defects inherently exist in the bridge steel structure, the steel E43 specimen was under fatigue and CTOD (Crack tip opening displacement) test. The results provide an experimental base and computing foundations for the bridge steel-using. This paper studies the CTOD fatigue precracking experiment on steel E43.

Introduction
With the rapidly growth of Chinese construction, people use so many kinds of material, especially metal material, we frequently encountered sudden break phenomena, they are usually much lower than the bearing capacity in the design. Fatigue failure has been considered one of the main failure forms of various engineering structures, since the steel structure since the birth of the fatigue crack initiation, stable propagation structure, and finally lead to the failure of engineering structures of the case occurred frequently. Because of the sudden occurrence of the fracture event, it often leads to very serious consequences.

Long span steel structure bridge is a typical welding structure, because of its structural shape. It has complex working conditions and large stress concentration. Under the action of external loading, the welding defects, welding residual stresses and the uneven microstructure and properties of joints lead the phenomenon of brittle fracture is easy to occur. At present, a large number of steel structures have entered into late stage of service, in order to increase economic benefits, save resources, these structures will continue to be used for a long time. Therefore, how to obtain the toughness accurately and ensure the safety of steel structure is very important in Engineering. A large number of experimental studies have shown that steel for bridge. In addition, CTOD fracture toughness is a useful tool to evaluate the resistance of steel and welded joints. The important parameters of brittle fracture characteristics can be used to evaluate the brittle fracture resistance of steel.

CTOD (crack tip opening displacement) refers to the relative distance between the two points of crack tip after the cracked materials suffer from open load. The larger CTOD means the fracture roughness of materials is stronger but less CTOD shows a weaker fracture roughness. CTOD fracture roughness technology is widely adopted by the main developed countries. Based on CTOD (crack tip opening displacement) test data of 6 thick steel plates, this paper aims to study fracture roughness of thick steel and estimate fracture roughness of engineering structures.

Specimen and Specimen Preparation
The high strength steel plate specimen which is produced by Wuhan Iron and Steel Company Limited has been adopted in this experiment. According to British standard of BS7448, the three-point bending standard sample was made. The parent metal is based on BS7448: 1991-Part1 Method for Determination of KIC, Critical CTOD and Critical J Values of Metallic Materials and the welding joint and HAZ (Heat Affected Zone) are based on BS7448: 1997-Part2 Method for Determination of KIC, Critical CTOD and Critical J Values of Welds in Metallic Materials.

We practiced linear cutting and processing on CTOD test specimen in accordance with standards; then process the opening in the single side of the sample to make the opening directed in the thickness direction; the third step, we use JXG-200 high frequency fatigue testing machine to make the fatigue crack, finally, we employed material testing machine to get CTOD value.
The experiment operated referring to British Standard. The test was performed on a computer control hydraulic universal material testing machine using a single specimen method. The CTOD value of the E43 steel was measured using a straight three-point bending test. The cross-section of the sample is 2B×B-shaped. The notch orientation is NP direction, where N is perpendicular to the weld direction and P is parallel to the weld direction. The actual thickness of the standard sample after machining was 38 mm, and a CTOD toughness test at normal temperature was performed on the manual arc welding joint of E43 high strength steel in accordance with the specification BS7448. The CTOD test used a standard three-point bending specimen with unilaterally prefabricated fatigue cracks. Three specimens are taken from each of the base metal. The CTOD test uses a standard three-point bending specimen with unilaterally prefabricated fatigue cracks. Three specimens are taken from each of the base metal. According to the BS7448 specification, the formula, the stress intensity of a material was calculated and the crack opening displacement was gotten.

**Test Results and Discussion on CTOD Value and Fatigue**

Table 1. The fatigue crack growth of H44.

| Specimen’s number | Specimen’s thickness (mm) | Fatigue crack’s minimum propagation extent (mm) | Fatigue crack’s maximum propagation extent (mm) | Fatigue crack’s propagation extent mean value (mm) |
|-------------------|--------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| H44-1             | 37.97                    | 4.280                                       | 5.440                                       | 5.250                                       |
| H44-2             | 38.04                    | 4.670                                       | 5.270                                       | 5.010                                       |
| H44-3             | 38.01                    | 4.160                                       | 5.200                                       | 5.110                                       |
| H44-4             | 38.09                    | 4.880                                       | 5.120                                       | 5.190                                       |
| H44-5             | 38.07                    | 4.720                                       | 5.560                                       | 4.960                                       |
| H44-6             | 38.05                    | 4.710                                       | 5.250                                       | 4.870                                       |
| Cycle average number N | 36000                  |                                             |                                             |                                             |

Table 2. CTOD value of H44.

| Specimen’s number | Specimen’s thickness (mm) | $\delta_e$ | $\delta_p$ | $\delta_u$ | $\delta_m$ |
|-------------------|--------------------------|----------|----------|----------|----------|
| H44-1             | 38.01                    | 0.065    | 1.175    | —        | 1.240    |
| H44-2             | 38.03                    | 0.067    | 0.923    | —        | 0.990    |
| H44-3             | 38.02                    | 0.060    | 0.951    | —        | 1.011    |
| H44-4             | 38.05                    | 0.050    | 0.009    | 0.059    | —        |
| H44-5             | 38.05                    | 0.060    | 0.931    | —        | 0.991    |
| H44-6             | 38.04                    | 0.068    | 0.901    | —        | 0.969    |

The fatigue test value was shown in Tab1, and the CTOD value is shown in Tab 2. The fracture surface of ductile failure specimen is shown in Fig.1. The test result show us that CTOD test destruction critical states of thick steel plate have one phenomenon: ductile instability fracture and the critical value depends on actual situations. According to allowable value specified by BS7448, the fracture toughness of the structure meets the standards. As the test results show in the tab 1, the CTOD test results of the parent metal test specimen sample under 20°C, among which $\delta_u$ and $\delta_m$ are respectively brittle instability CTOD value and maximum load CTOD value. The CTOD value of the test specimen is only related with elasticity Component $\delta_e$ and plastic Component $\delta_p$.
Figure 1. The fracture surface of ductile failure specimen.

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