Miniature C(T) Specimen Fabrication for Reutilization of Surveillance Tested Materials

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Irradiation embrittlement of the Japanese reactor pressure vessel (RPV) is monitored by the tests on the specimen of the RPV material irradiated based on the surveillance test program. Lately, the Master Curve (MC) approach has become the main stream in fracture toughness evaluation.

However, the number of specimens is limited due to capacity of a surveillance capsule. Because some plants have few fracture toughness specimens contained in the surveillance capsules due to capacity and the minimum number of fracture toughness data for the evaluation by the MC method is six, sufficient fracture toughness data could not be obtained.

Therefore, it is expected to obtain additional fracture toughness data using broken specimens of irradiated materials after Charpy test. It is effective in extension of fracture toughness database to utilize broken halves of Charpy specimen because a large number of Charpy specimens are generally contained in the surveillance test capsule.

Specimen reconstitution by welding can be a candidate to solve this problem. However, it requires specific equipment and time-consuming machining operations for welding. Furthermore, only one three-point specimen can be made from a broken half of Charpy specimen to avoid the heat affected zone due to welding.

As an alternative to specimen reconstitution by welding, fracture toughness test using 0.16T-C(T) (Mini-C(T)) specimen, which has dimension of 4×10×10mm, is available without welding, and moreover four Mini-C(T) specimens can be taken from a broken Charpy specimen.

In this study, machining process in hot cell was considered in order to make it possible to fabricate Mini-C(T) specimen for irradiated materials with sufficient accuracy. And, the Mini-C(T) specimen fabrication technique from a broken half of Charpy specimen used in the surveillance test, was established.

Mini-C(T) fabrication from a broken Charpy specimen

***Geometry and dimensions*.** Figure 32 illustrates C(T) specimen design are recommended in the ASTM E1921 (American Standard for Testing and Materials, 2018; Miura & Soneda 2010). Because the ASTM standard do not limit the available specimen size, small size C(T) specimens including Mini-C(T) specimens can be used.

The Mini-C(T) specimen slit orientation is the same as the crack propagation direction of the Charpy specimen, so that 1.25 W defined in Figure 32 is 10mm for the Mini-C(T) specimen as shown in Figure 33. Central Research Institute of Electric Power Industry (CRIEPI) has developed a MC based fracture toughness evaluation method for the Mini-C(T) specimen (Yamamoto et al., 2012; 2013; 2015) and verified applicability of the Mini-C(T) specimen to the MC evaluation has been studied in a series of international round robin test programs coordinated by CRIEPI. In these programs and the related studies, it was demonstrated that the reference temperature (To) can be determined by the Mini-C(T) specimens without any specific difficulties for the unirradiated RPV base metals.

For the above reasons, Mini-C(T) was adopted as specimens taken from broken halves of Charpy specimen.

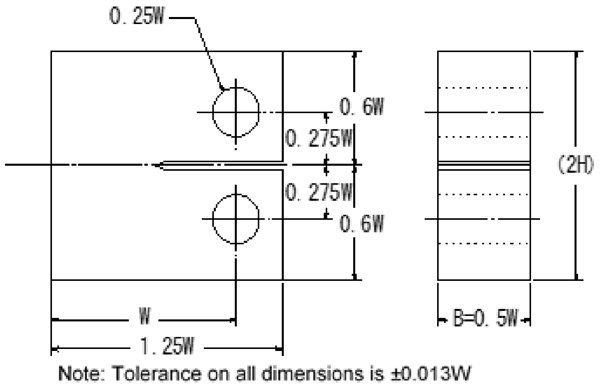

Figure 32: Geometry and dimensions of C(T) specimen in ASTM E1921[1].

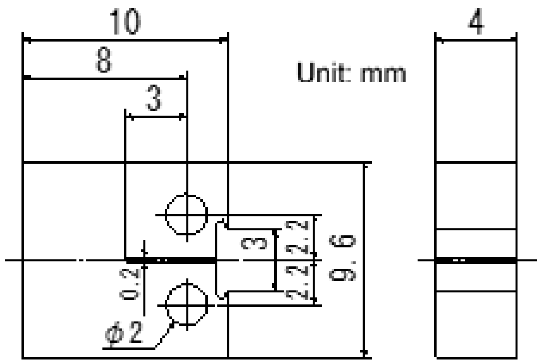

Figure 33: Geometry and dimensions of Mini-C(T) specimen.

Fabrication procedure for Mini-C(T) specimen

Four miniature C(T) specimens were machined from a broken half of Charpy specimen as shown in Figure 34, so that the orientation of the crack coincides with that of the Charpy specimen. According to the ASTM standard, dimensional tolerances are defined by the ratio to the specimen width W as shown in Table 2. This means that the dimensional tolerances for Mini-C(T) specimen are severe compared with larger specimen. For this reason, because fabrication of specimen seems to be difficult in hot cell using the limited existing equipment, it is important to establish procedure for Mini-C(T) specimen fabrication.

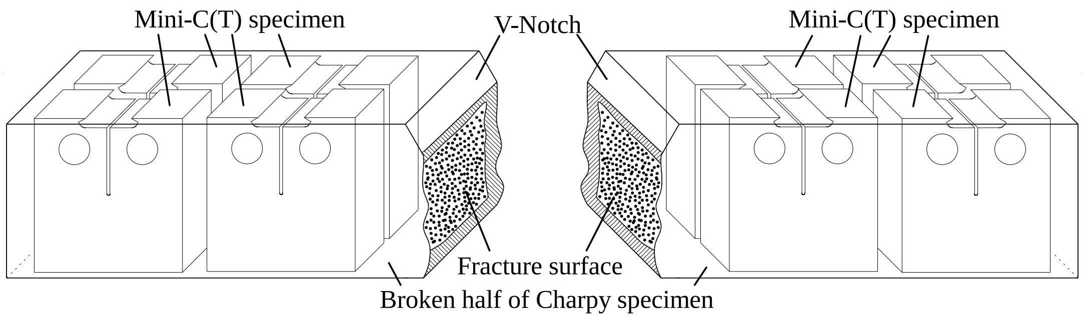

Figure 34: Orientation of Mini-C(T) specimens machined from broken halves of Charpy specimen.

Table 2: Dimensional tolerances of C(T) specimen specified in ASTM E1921.

Specification in ASTM E1921	Mini-C(T) specimen	1/2T-C(T) specimen
±0.013W	±0.1mm	±0.33mm

In order to fabricate Mini-C(T) specimen in high accuracy, the wire cut EDM (electrical discharge machine) was used mainly. Image of machining process for Mini-C(T) specimens from a broken half of Charpy specimen is shown in Figure 35.

【Machining process】

1. Cutting of fracture surface
2. Machining of prepared holes by drill
3. Machining of outline by wire cut EDM

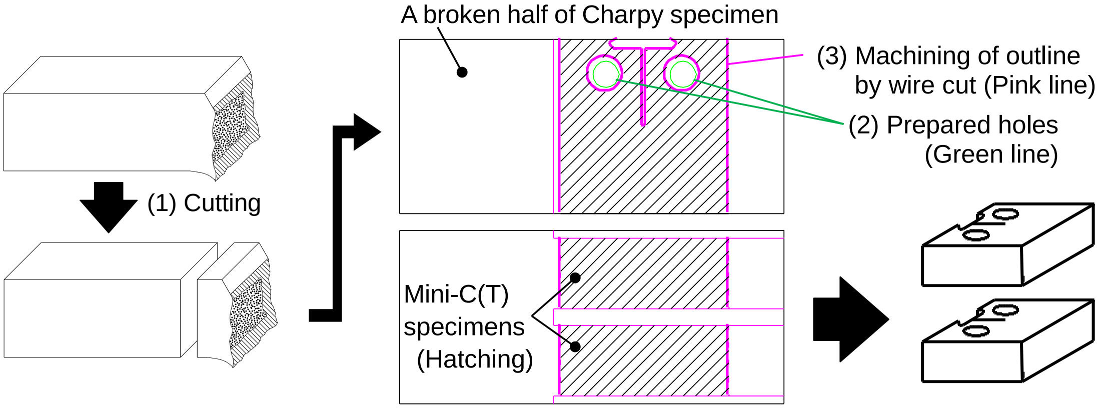

Figure 35: Image of machining process for Mini-C(T) specimens.

Prototypes of Mini-C(T) specimen were machined from a unirradiated material piece, and the prototypes of Mini-C(T) specimen fabricated in radiation controlled area have sufficient accuracy. The procedure established in this study is adopted to Mini-C(T) specimen fabrication from surveillance test materials after Charpy test.

References

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