

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

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1. Introduction

- ✓ Background and objectives

2. Geometry and dimensions of C(T) specimen

- ✓ C(T) specimen in ASTM E1921
- ✓ Mini-C(T) specimen

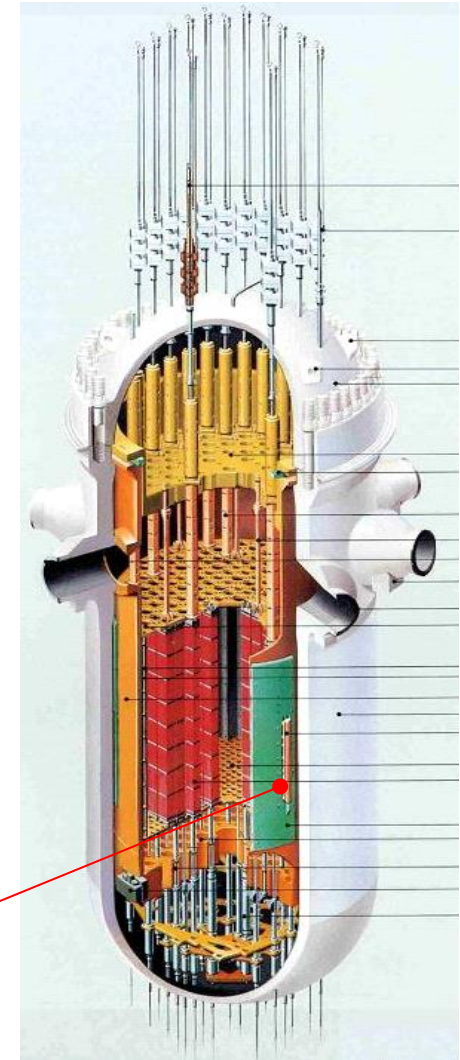
3. Fabrication procedure for Mini-C(T) specimen

4. Conclusions

Background

- Fracture toughness evaluations are essential for structural integrity of irradiated RPVs.
- Fracture toughness data have been obtained through surveillance tests in Japanese PWR plants.
- However, **some plants have a few fracture toughness specimens** because the number of specimens is limited due to capacity of capsule.

Surveillance capsule



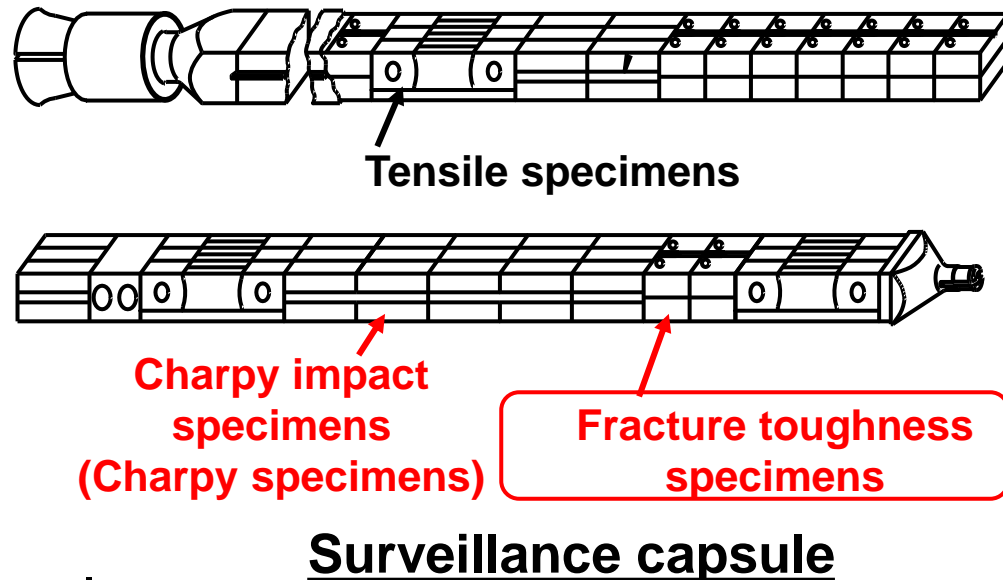
Reactor pressure vessel (RPV) of PWR Plant

Trend in evaluation of fracture toughness

- **Master Curve (MC)** method has become the main stream in evaluation of fracture toughness.
- The MC also tends to be incorporated as the fracture toughness curve used to structural integrity assessment of RPV.
- For the MC method, the minimum number of fracture toughness data is six.
⇒ Some plants need additional fracture data.



- It is effective to **obtain fracture toughness data using broken halves of Charpy specimens** included in the surveillance capsule.



Objectives

- To make it possible to fabricate C(T) specimen from broken halves of Charpy specimen.

- To develop Mini-C(T) specimen fabrication procedure with sufficient accuracy in hot cell.

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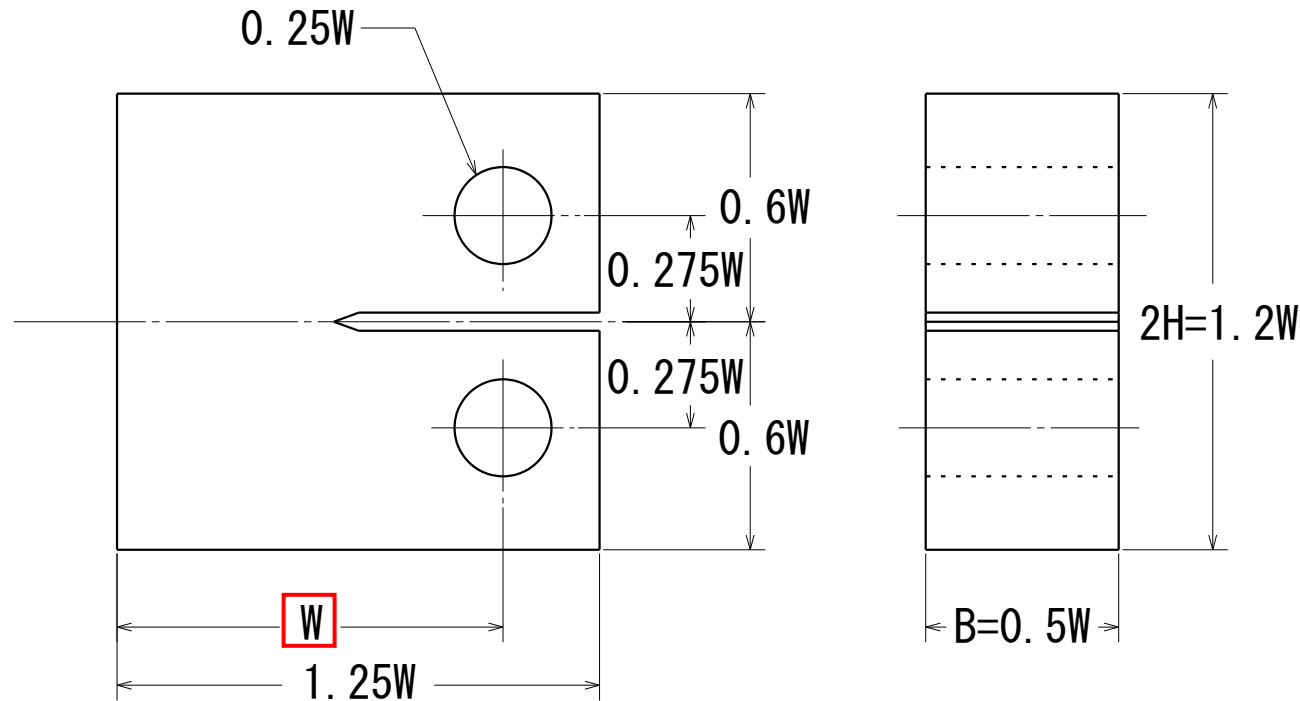
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C(T) specimen in ASTM E1921



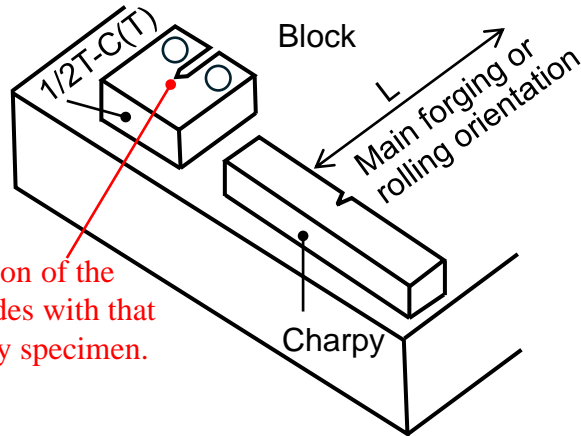
Note 1: Tolerance on all dimensions is $\pm 0.013W$

Note 2: The allowable starter notch height shall be no greater than $0.063W$

Geometry and dimensions of C(T) specimen in ASTM E1921

- **ASTM standard only limits the relative specimen size.**
 ⇒ Miniature C(T) (Mini-C(T)) specimens can be used as is standardized.

Mini-C(T) specimen (1/2)



The following is required as geometry and dimensions for the Mini-C(T) specimen taken from a broken half of Charpy specimen.

【Requirements for Mini-C(T) specimen】

- The geometry and dimensions satisfy ASTM standard.
- The dimensions is as large as possible.



In order to satisfy requirements, **10mm** was adopted as 1.25W (defined in ASTM E1921)

for the Mini-C(T) specimen.

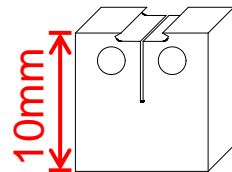


Image of specimens taken from block in surveillance program

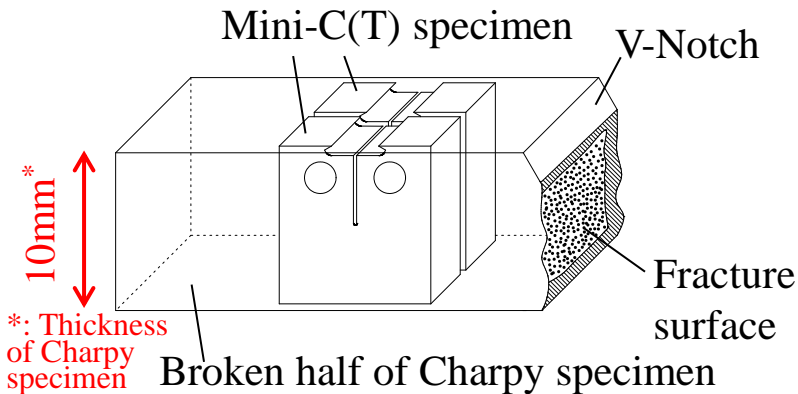
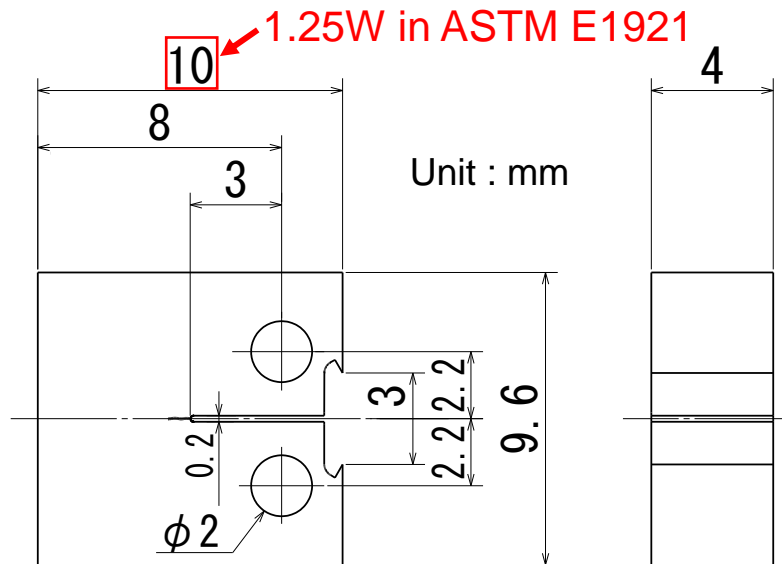


Image of Mini-C(T) specimens taken from a broken half of Charpy specimen

Mini-C(T) specimen (2/2)



Geometry and dimensions of Mini-C(T) specimen

- In recent years, Central Research Institute of Electric Power Industry (CRIEPI) has developed the MC method for the Mini-C(T) specimen as a method of fracture toughness evaluation.
- CRIEPI has verified applicability of the Mini-C(T) specimen for **unirradiated materials** to the MC method in a series of international round robin test programs coordinated by CRIEPI.
 - ⇒ In order to verify applicability for **irradiated materials**, it is necessary to develop Mini-C(T) fabrication procedure in hot cell.

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Accuracy of machining

Dimensional tolerances of C(T) specimen specified in ASTM E1921-18

Specification in ASTM E1921	1/2T-C(T) specimen	Mini-C(T) specimen
$\pm 0.013W$	$\pm 0.33\text{mm}$	$\pm 0.1\text{mm}$

Note: The allowable starter notch height is no greater than $0.063W$ (0.5mm for Mini-C(T) specimen).

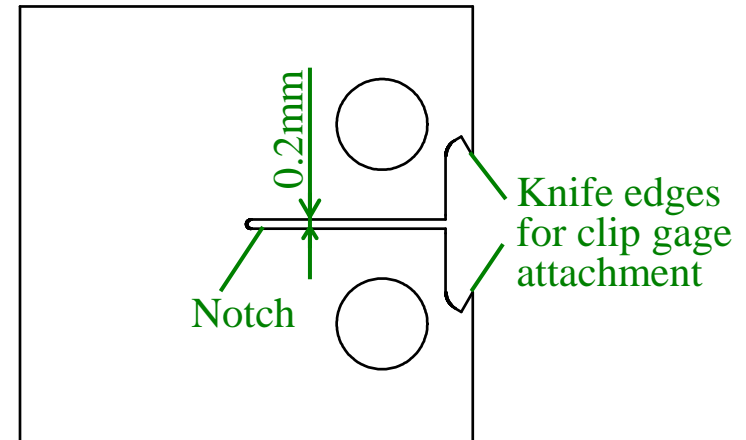
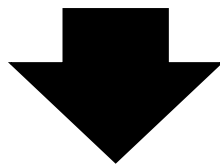
- Dimensional tolerances of C(T) specimen are defined by the ratio to **the specimen width W** .
 - ⇒ **The dimensional tolerances for Mini-C(T) specimen are quite small** compared with larger specimen.

Available equipment in hot cell

- The existing processing equipment for irradiated Mini-C(T) specimen is limited due to capacity of hot cell.

⇒ It is necessary to simplify Mini-C(T) specimen fabrication procedure in order to minimize the number of apparatuses for machining.

- Wire EDM device (wire EDM) is cited as one of apparatuses for machining.
- The Wire EDM has an advantage in fabricating micro and complex shapes in high accuracy, especially for notch and knife edges.



Geometry of notch and knife edges for Mini-C(T) specimen

It is very useful to apply **wire EDM** in Mini-C(T) fabrication.

The procedures for fabrication of Mini-C(T) specimen:

(1) Cutting of fracture surface.

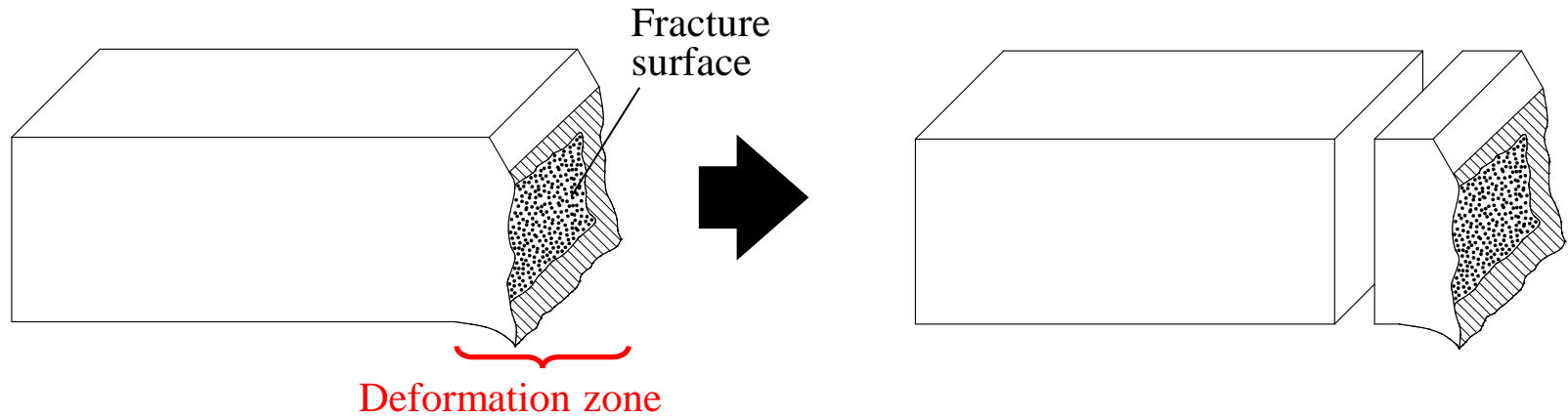


(2) Machining of prepared holes by drill.



(3) Machining of outline by wire EDM.
(After this step, the fatigue precracking is conducted.)

(1) Cutting of fracture surface:



Cutting image of fracture surface from a broken half of Charpy specimen

- Charpy specimens have **deformation zone** after Charpy impact test.
- The deformation zone affect attachment to the wire EDM.

⇒ In order to remove deformation zone from a broken half of Charpy specimen, **cutting is conducted near fracture surface.**

(2) Machining of prepared holes by drill:

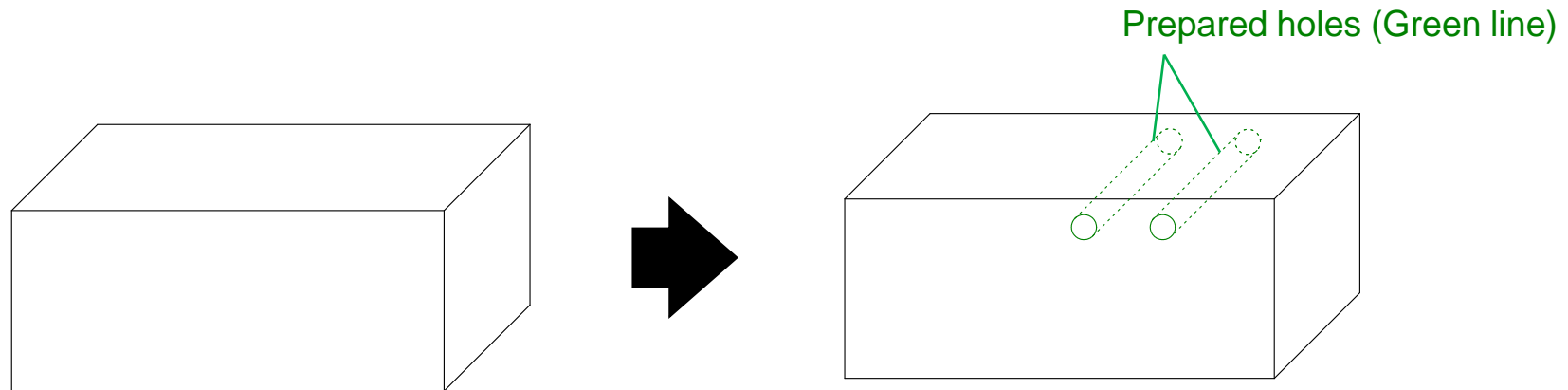


Image of machining by drill

- Mini-C(T) specimen have two holes for attachment of loading pins.
- However, it is impossible to drill holes by only using the wire EDM.
⇒ Thus, **two holes are prepared using drill** in advance of fabrication by the wire EDM.

(3) Machining of outline by wire EDM:

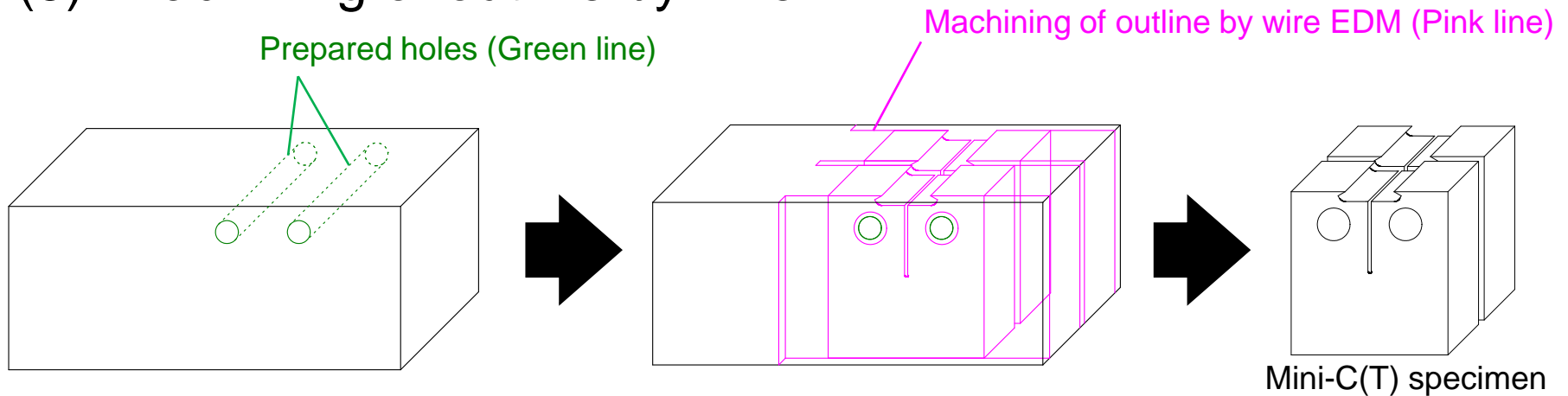


Image of machining by wire EDM

- Mini-C(T) specimens were machined from pieces of unirradiated materials.



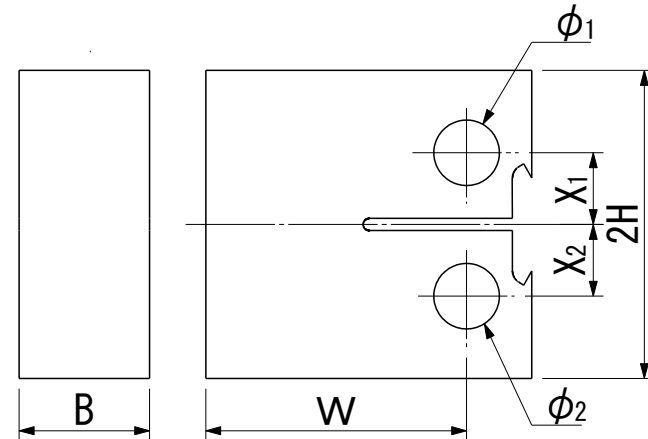
After the machining,
in order to examine the accuracy of machining,
the principal dimensions for the prototypes of Mini-C(T) specimen
were measured.

An example of principal dimensions for the prototypes of Mini-C(T) specimen

Unit : mm

ID Number for prototype	Thickness B	Width W	Height 2H	Pinhole Dia., Φ_1	Pinhole Dia., Φ_2	X_1	X_2
	4 ± 0.1	8 ± 0.1	9.6 ± 0.1	$\Phi 2 \pm 0.1$	$\Phi 2 \pm 0.1$	2.2 ± 0.1	2.2 ± 0.1
P-1	4.04	8.00	9.61	2.01	2.01	2.20	2.20
P-2	4.03	8.01	9.62	2.01	2.01	2.20	2.20
P-3	4.04	8.02	9.61	2.01	2.01	2.20	2.20
P-4	4.03	8.01	9.60	2.01	2.01	2.20	2.20

- The prototypes of Mini-C(T) specimens fabricated in hot cell have **sufficient accuracy within the dimensional tolerances specified in ASTM E1921.**



In conclusion, **the developed procedure for Mini-C(T) specimen fabrication from surveillance test materials after Charpy test has been adopted.**

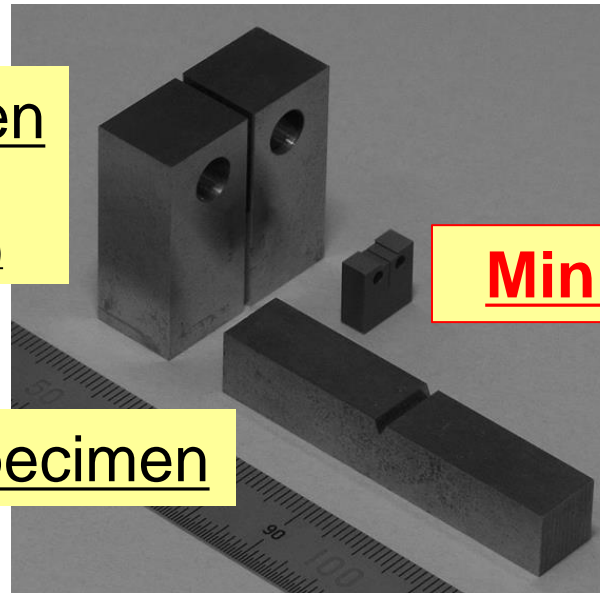
- The Mini-C(T) specimen fabrication procedure from a broken half of Charpy specimen was developed.
- The prototypes of Mini-C(T) specimen fabricated in the hot cell have sufficient accuracy in dimensional tolerances specified in ASTM standard.

1/2T-C(T) specimen

(Conventional specimen
on surveillance test program)

Charpy specimen

Mini-C(T) specimen



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for your attention