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# 12th Verification of the Charpy Impact Test Machine in IMEF

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## 1. Introduction

Neutron radiation embrittlement of reactor vessel steels is one of the key parameters to limit the lifetime of nuclear reactors. The radiation-induced changes in the impact property of ferritic steels in the reactors have to be monitored through surveillance programs [1]. In order to define the resistance to brittle fracture of a material when a crack is present, the Charpy impact test is done by using a pendulum and basic physics to measure the absorbed energy of a notched specimen. A Charpy impact machine is a major apparatus in the IMEF hot cells of KAERI for testing the irradiated materials [2]. In hot cells, the machine and specimens are handled using manipulators, so the machine is able to be verified indirectly. The IMEF has carried out the indirect verification annually, and the results of the 12th verification test in 2011 are summarized in the paper.

## 2. Experimental

### *2.1 Configuration of Charpy test system*

The Charpy test system in an IMEF hot cell is consisted of an impact machine, a specimen temperature control system and a specimen transferring system, as shown in Fig. 1. The temperature of a specimen is heated by an electrical heater, or cooled by liquid nitrogen gas. The specimen is transferred from a heat/cool to the center of the anvils by a hand-operated-feed assembly.

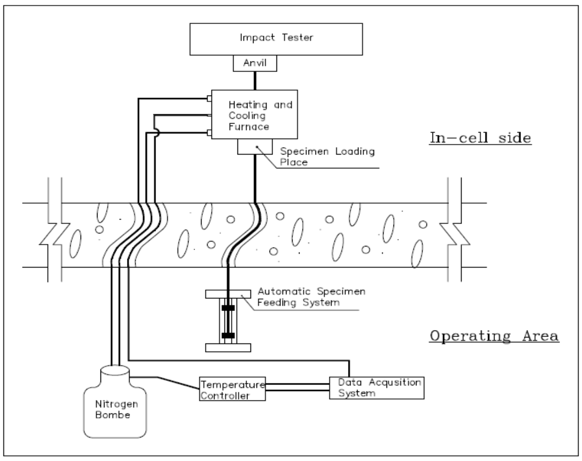


Fig. 1 Configuration of a Charpy test system in IMEF

### *2.2 Positioning attachments of a specimen*

To position a test specimen in the machine, it is recommended that a self-centering tong is used. In hot cell, however, the tong can't be handled by manipulators, so the center-positioning and contacting of a specimen to the anvils is important to produce accurate results by the machine. The IMEF has specially designed an attachment of a specimen to the anvils for positioning the specimen at center and to contact without a gap. The attachment consists of two horizontal push bars and a vertical stopper operated by the pneumatic system [3].

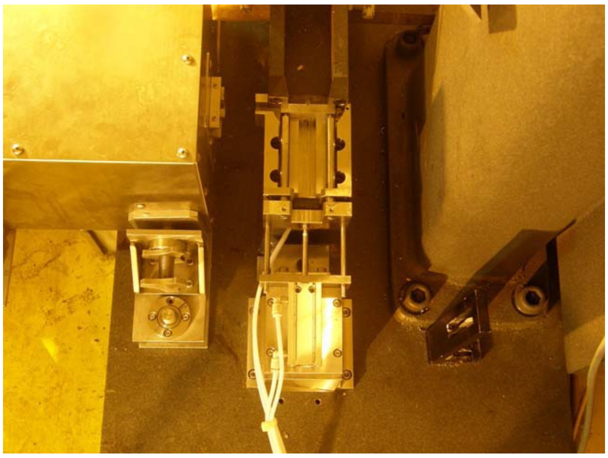

Fig. 2 An attachment for sample positioning at center

### *2.3 Temperature calibration*

The temperature of a specimen was calibrated using Pt-RTDs in the range of -140℃ to 320℃, compared with the temperatures between the RTD inside of the specimen. During the cooling stage by liquid nitrogen gas, the specimen was slightly cooler than furnace, but during the heating stage by an electric heater the specimen showed higher temperature. The test temperature was defined as the temperature inside the specimen.

### *2.4 Verification test*

The Charpy machine in the IMEF shall be verified indirectly annually as recommended by ASME standard test method [4]. The certified values of verification specimens were 100.5J for the high energy level, and

15.5J for the low energy level. Five tests at each energy level were carried out at 40℃, and the average value was calculated to confirm meeting the verification requirements.

## 3. Results

The absorbed energies of verification specimens at high energy level with a certified value of 100.5 J at 40℃ are summarized in table 1. The average value of the five tests was 103.9 J, and corresponded to the certified value of the verification specimens with 3.4 %. The verification requirement is within 5 % of the certified value [4], so the average value results in ensuring the verification requirement at high energy level.

Table 1 Measured values of high energy specimens

| Test Temp. (℃) | Specimen ID | Absorbed Energy (J) | | Lateral expansion | |
|---|---|---|---|---|---|
| | | Measured | Certified | mm | mils |
| 40 | HH120-0600 | 104.8 | 100.5 | 1.16 | 45.7 |
| 40 | HH120-0636 | 103.7 | 100.5 | 1.01 | 39.8 |
| 40 | HH120-0637 | 99.6 | 100.5 | 1.2 | 47.2 |
| 40 | HH120-0638 | 107.3 | 100.5 | 1.2 | 47.2 |
| 40 | HH120-0639 | 104.3 | 100.5 | 1.15 | 45.3 |

At low energy level, the measured values of absorbed energy were summarized in table 2. The certified value of the verification specimens was 15.5 J at 40℃. The average value of the absorbed energy was 15.8 J, and corresponded to the certified value of the verification specimens with 1.3 J. The verification requirement is within 1.4 J. Thus, the average value is determined to ensure the verification requirement at a low energy level.

Table 2 Measured values of low energy specimens

| Test Temp. (℃) | Specimen ID | Absorbed Energy (J) | | Lateral expansion | |
|---|---|---|---|---|---|
| | | Measured | Certified | mm | mils |
| 40 | LL114-0510 | 16.5 | 15.5 | 0.0 | 0.0 |
| 40 | LL114-0150 | 16.3 | 15.5 | 0.33 | 13.0 |
| 40 | LL114-1017 | 18.3 | 15.5 | 0.07 | 2.76 |
| 40 | LL114-1171 | 17.0 | 15.5 | 0.07 | 2.76 |
| 40 | LL114-1725 | 16.1 | 15.5 | 0.27 | 10.6 |

Fracture appearances at high and low energy levels were observed, and lateral expansion measurements were summarized in the tables. Specimens with high energy showed shear lips and protrusion on each side of broken specimens. Conversely, specimens with low energy showed almost flat fracture and little expansion.

HH120-0600 LL114-1725

Fig. 3 Fracture appearance of broken specimens

## 4. Conclusion

The 12th verification test of the Charpy impact machine in the IMEF was performed using an indirect method with the verification specimens. The average value at 40℃ was determined for the five specimens at high and at low energy levels. The test results corresponded to the certified values of the verification specimens within 1.4 J or 5 %, thus the Charpy impact machine in the IMEF was verified and have continued to operate for impact testing of irradiated materials.

## REFERENCES

[1] ASTM E185, Standard Practice for Design of Surveillance Programms for Light-Water Moderated Nuclear Power Reactor Vessels, ASTM, 2010.
[2] Y.S Choo et al., "Post-Irradiation Examination of Nuclear Fuels and Materials Irradiated Capsule at HANARO in IMEF", Proceeding of KNS Autumn Meeting, Oct.25-26, 2002.
[3] Y.S Choo et al., "Improvement in the Uncertainty for a Remote-controlled Impact Tester in a Hot Cell", Proceeding of KNS Spring Meeting, May 26-27, 2011.
[4] ASTM E23, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials, ASTM, 2007.