10.2 DEVELOPMENT OF A NON-CONTACT STRAIN MEASUREMENT SYSTEM FOR POST IRRADIATED TENSILE TESTS AT HIGH TEMPERATURES—H. Sakasegawa, T. Kato, H. Tanigawa (National Institutes for Quantum and Radiological Science and Technology), and Y. Katoh (Oak Ridge National Laboratory)

OBJECTIVE

The objective of this work is to develop a non-contact strain measurement system for post irradiated tensile tests at high temperatures. In past post irradiated tensile tests, strain was calculated from the cross head displacement and the obtained value included deformation other than specimen gage deformation, including specimen shoulder, fixture, and machine frame deformations. This is because it is hard to utilize conventional strain gages used for full size specimens due to the small specimen gage section. This work is part of the U.S. Department of Energy – Japan National Institutes for Quantum and Radiological Science and Technology fusion materials collaboration.

SUMMARY

Appropriate stress strain curves were obtained applying the non-contact strain measurement system developed in this work and the system specifications were selected. Two marks were painted on the specimen gage using a mixture of paste and fluorescent powder which can be used in high vacuum at high temperatures. UV light illuminated these two marks and clear contrast was obtained to measure the distance between marks using a video camera. This system can be used for post irradiated tensile tests at high temperatures in hot cells.

PROGRESS AND STATUS

Introduction

Post irradiated tensile testing is the most fundamental method used to evaluate mechanical properties after irradiation. In past research, changes in material strengths such as yield and ultimate tensile strength after irradiation have been measured without problems, but it has been hard to obtain accurate strain measurements. This is because specimen size is often too small to utilize the conventional strain gages used for full size specimens. Cross head displacement has alternatively been used to obtain strain. This strain calculated from cross head displacement generally includes deformation in specimen shoulders, fixtures, and tensile test machine frames in addition to the deformation in the specimen gage. In the current design activity for fusion blankets using reduced activation ferritic/martensitic steel structural material, it is desired to obtain more accurate strain. This is because significant irradiation embrittlement accompanying irradiation hardening has been observed within a few dpa at temperatures less than about 573K, which is near the lower operation temperature of the Japanese water cooled blanket design [1]. In particular, the uniform elongation of F-82H was almost zero after irradiation [2]. It is indispensable to accurately evaluate the irradiation effect on ductility for the design activity and the application of F-82H as the blanket structural material.

Experimental Procedure

In this work, we defined the specifications of a non-contact strain measurement system that can be used at room and high temperatures. The specification for room temperature was confirmed at ORNL and that for high temperatures was developed and finalized at QST in Japan.

Results

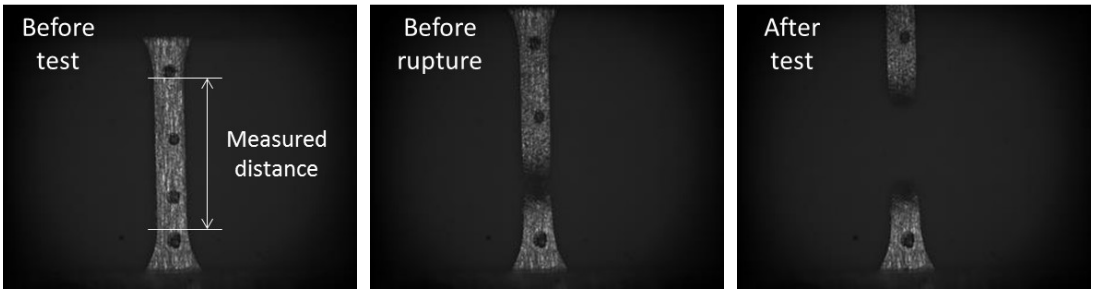
Table 1 shows the specification of the noncontact strain measurement system developed in this work. The controller, video camera, and lens specifications are the same for both room and high temperatures, but light and paint specifications are different.

Table 1. Specification of the non-contact strain measurement systems

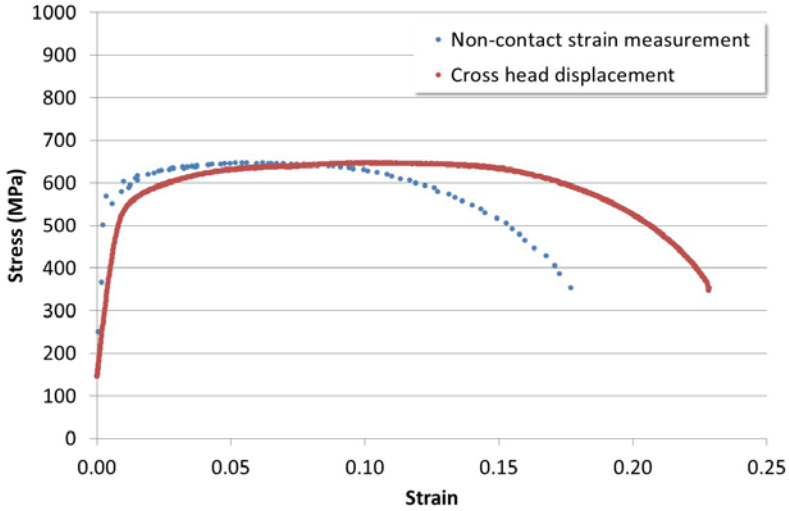
Item	Room temperature	High temperature
Controller	Keyence CV-X292F	Keyence CV-X292F
Video camera	Keyence CA-H2100M	Keyence CA-H2100M
Lens	VST technology corp. VS-TC1-300CO	VST technology corp. VS-TC1-300CO
Light	Keyence CA-DPB2 Blue (Co-axial light)	CCS 165-SHU
Paint	General permanent maker Black (SANFORD Sharpie)	Paste for SEM at high temp. (PELCO High Performance Nickel Paste) and Fluorescence powder (Ohira Seisakusho BLP-02G)

For the room temperature tests, there were not any specific difficulties, because a clear contrast can be easily obtained using a permanent marker and a LED light which is co-axial and easily set in the lens. Figure 1 (a) shows measured pictures taken during a tensile test using the system shown in Table 1. Marks on the specimen gage were clearly seen and the distance between the outer two marks was measured during a tensile test. Figure 1 (b) shows the obtained stress-strain curves. The blue curve was obtained using the non-contact strain measurement system and the red curve was calculated from the cross head displacement (conventional measurement). The red curve tends to show larger strain than the blue curve. This means that the strain has been overestimated and it has included deformation in specimen shoulders, fixtures, and tensile test machine frames as well as the deformation in the specimen gage.

For high temperature tests, there were some difficulties. This is because marks on the specimen gage have to give appropriate contrast to be clearly observed and they have to endure high temperatures under high vacuum. We tried to use a mixture of a paste developed for SEM observation at high temperatures and fluorescent powders to be illuminated with UV light to obtain observable contrast. Since we did not have an appropriate tensile test frame to completely confirm and select the system specification at ORNL, we used tensile test frames at QST in Japan. First, we observed the endurance of the mixture of PELCO High Performance Nickel Paste and fluorescent powder, under vacuum at high temperatures, up to about 573 K and its dependence on the level of vacuum. No specific problems were found. Second, we applied the mixture to a high temperature tensile test at about ~ 523 K using a halogen spot heater in air. (We did not have a high temperature tensile test frame with a vacuum chamber with view ports to test the non-contact strain measurement system.) Figure 2 (a) shows measured pictures taken during the high temperature tensile test. Marks on the specimen gage are clearly seen and the distance between two marks was measured during the tensile test, similar to the case of the room temperature tensile test. Figure 2 (b) shows the stress-strain curves. As also shown in Figure 1, the blue curve was obtained using the non-contact strain measurement system and the red curve shows strain calculated from cross head displacement. The red curve again tends to show larger strain than the blue curve. Larger differences in strain are especially obvious at the beginning of test and this explains why a lower Young's modulus has been obtained when using cross head displacement in past research.



(a) Measured picture

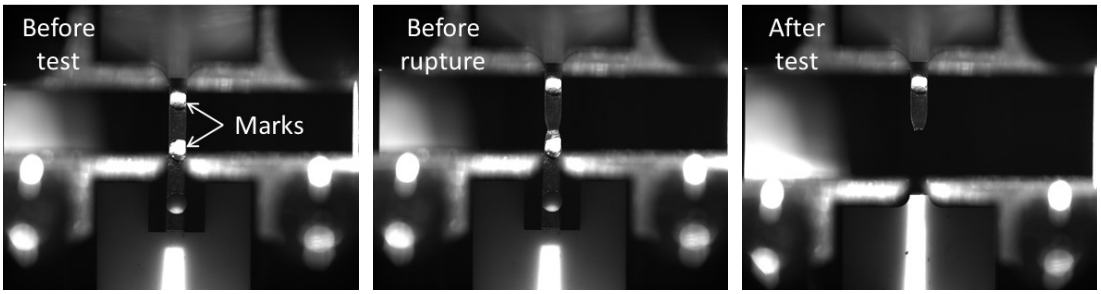


(b) Stress-strain curve

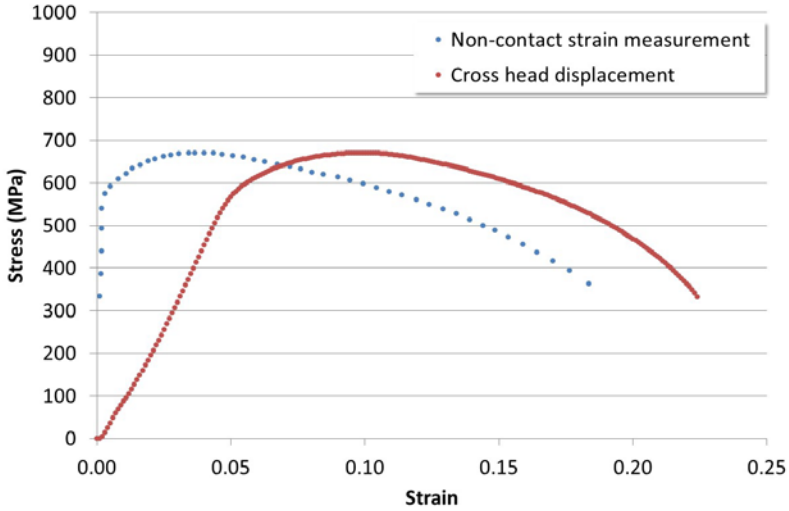
Figure 1. Room temperature tensile test result (F-82H IEA heat, SS-3 type specimen).

It should be noted that the number of points in the blue curves are less than in the red curves for both Figures 1 (b) and 2 (a). This is because the image capture rate was low, about a few seconds per image. The image capture rate depends on specifications and conditions of video camera, image resolution, and data transfer speed. In our latest tests, we obtained a 0.5 seconds per image for 2432 x 2050 image resolution (five million pixels) and it gives a number of points comparable to the conventional measurement.

Based on this work, we will finalize the specifications of a system which can be used for the high temperature tensile tests in Cell 1 in ORNL Building 3025E.



(a) Measured picture



(b) Stress-strain curve

Figure 2. High temperature tensile test result (F-82H BA12 heat, SS-J3 type specimen).

Acknowledgements

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References

[1] K. Tobita et al., J. Nucl. Mater. 386-388 (2009) 888-892.
[2] For example, T. Hirose et al., Fusion Materials Semi-annual Progress Report, DOE/ER-0313/46, (June 30, 2009) 72-78.