Comprehension of In-Situ SEMTester

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1. Introduction

An in-situ scanning electron microscope (SEM) fatigue testing is proposed to investigate the fatigue crack the crack closure phenomenon within one cyclic loading under plane stress conditions [1]. During the testing, the loading cycle is divided into a certain number of levels. At each level, high resolution images are taken around the crack tip region by SEM. Following this, imaging analysis is used to process these images in order to quantify the crack tip behavior at any time instant. Using an in-situ SEM fatigue testing, crack closure phenomenon is directly observed and measured on SEM image screen phenomenon [2]. The proposed experimental methodology provides a new method for the comprehensive understanding of the fatigue damage accumulation.

2. Methods and Results

The MTI SEM Tester 1000 product is installed and oprating in INL(Idaho National Laboratory) IMCL(Irradiated Materials Characteristics Laboratory) hot cell area on the SEM (JEOL 7600F) equipment. INL IMCL are studying of various mechanical characteristics tests using small specimens. It was investigated that the above product can be used in SEM and EPMA devices operated by KAERI IMEF hot cell. If we could use a SEM Tester product with our SEM instruments in our facility, we would be able to perform tensile, compression, bending, creep and fatigue by the specimen in real time.

The SEMtester line of products is capable of performing tensile, compression, bending, creep and fatigue tests on a variety of materials. Deformation and relaxation behavior can be observed under dynamic or static loading. Optional sample heaters can be used during testing to simulate actual operating conditions. A variety of specimen clamps are available to accept virtually any sample configuration. This versatility makes the SEMtester product line suitable for testing a range of materials. The average resolution of the experimental instrumentation should be in the range of Nanometres to sub-microns which is beyond the theoretical resolution of the optical microscope. SEM is one technique to provide this high resolution during the fatigue testing. Some researchers used the in situ SEM testing to study the crack closure behaviour of small fatigue cracks and the crack growth behaviour. Biallas and Maier reviewed the potential and current limitations of the in situ fatigue testing in an environmental SEM [22]. Most of in situ testing methodologies focus on the observation of crack growth and tip deformation between different cycles, for example, between ten thousand and twenty thousand cycles. Detailed investigations of the crack growth kinetics within one loading cycle are rarely found in the open literature.

1.1 Experimental set-up

An in situ SEM fatigue testing is performed to achieve the high resolution investigation for the hypothesis verification of crack growth kinetics and crack deformation in the vicinity of the crack tip. Some details of the experimental set-up for the in situ SEM experiment are shown in Fig. 1. It consists of a palm-sized tensile stage installed in a field emission SEM (JEOL-7400F). The maximum gage length between mechanical grips is about 27 mm, and the load capacity is 5 kN. The sub-stage is fixed in the SEM and the cyclic loading is applied during the experiment. During the testing, the vacuum level is remained to be less than 9.3 10. MPa [3].

AS shown in Fig 1, the SEMtester Series Tensile Stage can be configured as a bench top tensile stage for use with standard light microscopes. With proper fixtures, the device can also be installed in some electron microscopes. The SEMTester Series of Tensile stages are designed to exert tensile or compressive loads of up to 10kN (2000LBF) on a suitable test specimen. The maximum force that can be exerted varies from model to model.

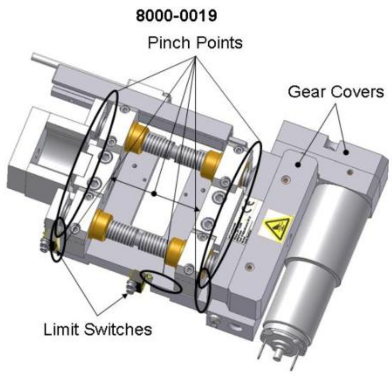

Fig. 1 The SEMTester Series of Tensile stages

Multiple resolution images are recorded during the testing for the measurements of crack length and the crack tip deformation behavior. Since the stage will prevent the coupon from getting closer to the pole piece, the shortest working distance available is 16.5 mm.

In preparing the sample, the piece of sample, scraped by a metal knife, was carefully put on the adhesive carbon tape in the Groove box and dried. Also there is no way to know the direction and location of the specimen. As can be seen in the Fig. 2, In-situ SEM fatigue testing set-up (a) loading stage installed in SEM; (b) specimen installed in loading stage [4].

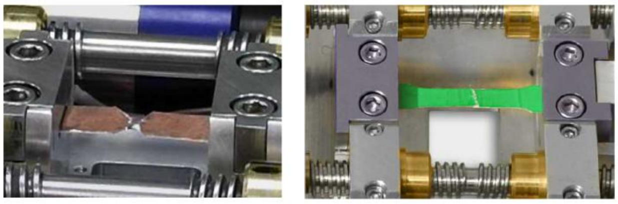

Fig. 2 In-situ SEM fatigue testing set-up

Fig. 3 shows a photograph of a SEMTester installed and operating in the INL IMCL facility. On the photograph of the MTI SEM Tester 1000 in the SEM (JEOL 7600F) equipment installed in the hot cell area is designed to fit the entrance to the SEM equipment. Currently, many researchers have been conducting various studies using SEMTester. Fig. 4 depicts a picture taken from the researcher's paper [5] and the content of the study.

Fig. 3 In-situ SEMTester installed in INL SEM

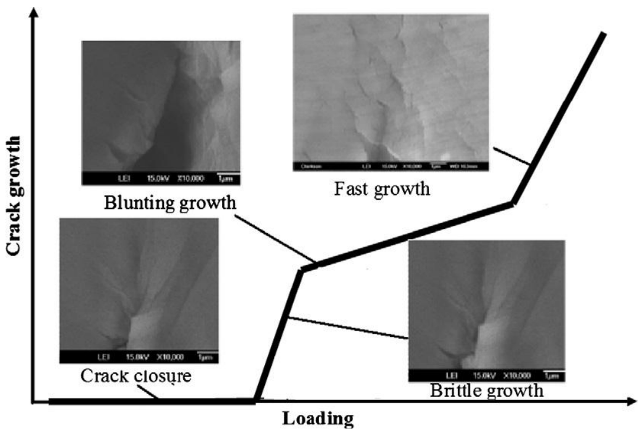

Fig.4 Schematic illustration of different growth mechanism in one loading

As shown a short summary, a multi-mechanism model can be developed based on the proposed experimental study. A schematic plot is shown in Fig. 5. During the initial loading, no crack growth is observed due to the crack closure mechanism. Next, a fast crack growth is observed due to the brittle-like crack growth behaviour right after the crack opening. Following this, a slower crack growth rate is observed due to the crack blunting and plasticity development. Finally, if loading is increased again, micro crack development ahead of the major crack will accelerate the crack growth and eventually break the specimen. This multi-mechanism fatigue crack growth behaviours within one cyclic loading cannot be captured using the cycle-based approach, where the average crack growth per cycle is used.

Conclusion

Survey on whether SEMTester can be installed in SEM and EPMA equipment in KAERI IMEF facility

If this equipment could be install in IMEF facility, it may be a very good option because it can have various advantages such as storing image in real time in a small tensile specimen or performing quantitative analysis test for each part of tensile specimens. Current experimental study focused on the constant amplitude loading and general variable amplitude testing needs further study [6].

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