Automation of Pre-Cracking Without Additional Sensors for CT Specimens

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1. Introduction

Fatigue pre-cracking is unavoidable to obtain fracture toughness through standard test methods. Several requirements must be satisfied to ensure a sharp and uniform crack front for valid fracture toughness testing.

Two critical factors are essential for developing an automated pre-cracking system. First, the amount of crack growth should be quantified during fatigue cracking. Second, the peak loads of fatigue cycles can be reduced with the corresponding values of the estimated crack length.

In this study, an innovative procedure was developed to compensate for both non-linear machine compliance and brinelling at the specimen load points [1]. This procedure can be used to estimate the crack length using the unloading compliance method without additional sensors, such as a COD gauge.

2. Theory

The unloading compliance method has been well developed and standardized by ASTM standards. Crack lengths can be expressed through a normalized function with specimen compliance, precisely measured using a COD gauge. However, the use of a COD gauge for pre-cracking may not always be available in certain circumstances.

Every test system is equipped with a built-in sensor for measuring the ram stroke or cross-head displacement. However, this signal includes both erroneous system deflection and specimen deflection. System deflection encompasses 1) machine compliance and 2) brinelling at the specimen load points, typically appearing as non-linear.

Fig. 1 illustrates the concept of removing system deflection from the measured load-line deflection. Specimen compliance can be determined from the total load-line displacement if we know the non-linear machine compliance and plastic brinelling.

On the other hand, machine compliance can be determined by using a theoretical specimen compliance with the initial crack length, assuming that plastic brinelling remains constant after some cycles. This assumption is reasonable since peak loads consistently decrease with fatigue cycling during the pre-crack process.

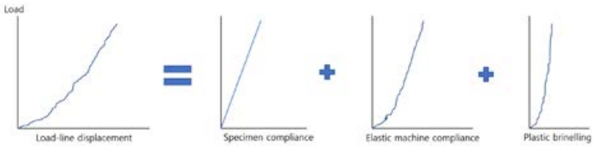

Fig. 1. Constituents of deflections in specimen and test system.

3. System development and test data

A software for test control and crack size determination was developed and implemented on a fatigue machine (MTS FlexTest40). TestSuite MPE [2], the MTS software tool, was used concurrently with user-defined functions written in Python. The software's highlighted feature is its ability to handle non-linearity in machine compliance and the brinelling effect during fatigue cycles.

Fig. 2 illustrates an example of the software development process. The specimen undergoes cyclic fatigue loading for a specified duration and is statically loaded to measure the system compliance. The measured system compliance is then compared to the original system compliance to calculate the current crack length.

In Fig. 3, actual test data is presented, with a comparison to data from the conventional COD gauge. The blue dots in the small box represent cyclic peak loads controlled by the current crack length to maintain the K_{max} envelope of the standard method.

4. Summary and conclusion

The methodology and the software performed exceptionally well in developing the pre-crack automation system without the need for additional sensors. Young's modulus is the sole necessary parameter for the application of this innovative method. The accuracy is nearly comparable to the conventional COD gauge method.

The same methodology was also successfully applied to PCC (pre-crack Charpy) specimens. Additionally, this methodology can be employed for conducting FCGR (fatigue crack growth rate) tests in situations where the COD gauge is unavailable due to restrictions in the test environment.

REFERENCES

[1] K.J. KarisAllen, J.R. Matthews, Journal of Testing and Evaluation, JTEVA, Vo. 22, No. 6 (1994) pp. 581-583

[2] MTS TestSuiteTM. Multipurpose Elite User Guide for Servohydraulic Systems Manual Version 4.7, MTS Manual Part No. 100-401-060D. MTS Systems Corporation; 2021.

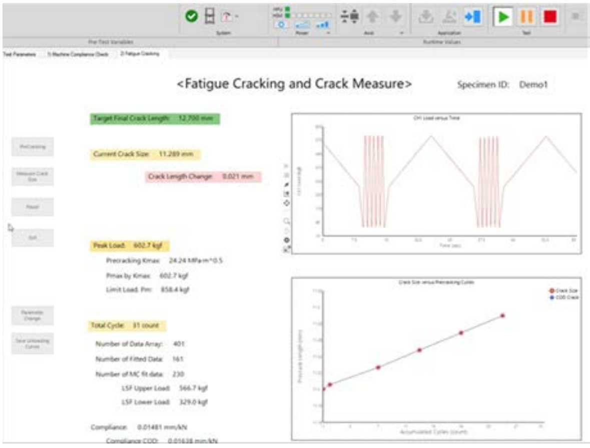

Fig. 2. Developed software to implement the methodology

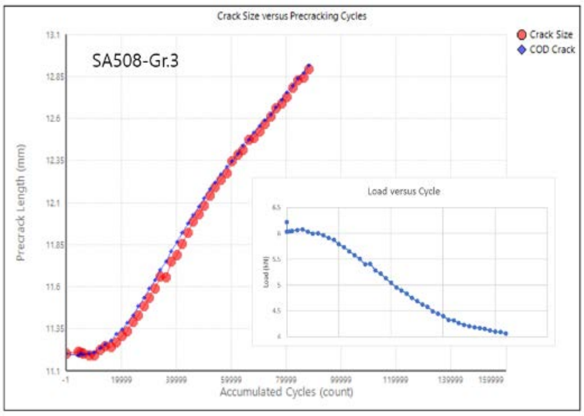

Fig. 3. Pre-cracking results compared to a COD gauge method.