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A Practical Method to Compensate the Machine Compliance for Simple Tensile Tests Without Extensometer

Bong-Sang Lee* and Min-Chul Kim

Materials Safety Research Div., KAERI, Daejeon 34057 Korea
**Corresponding author: bongsl@kaeri.re.kr*

1. Introduction

Tensile testing is a fundamental step to obtain mechanical properties of metallic materials, including the yield strength, the tensile strength and ductility. ASTM E8 standard method describes a standard procedure to conduct tensile tests and to evaluate the test data. While test laboratories have referred to the ASTM E8 standard method for determination of the tensile properties, all requirements of the standard procedure cannot be simply fulfilled in every situation.

In many cases, an appropriate extensometer may not be available for testing due to various limitations even though the standard requires using it. In fact, many laboratories measure the machine displacement (LVDT or Stroke) instead of the specimen elongation with extensometer. Therefore, the measured stroke displacement should be convertible to actual specimen elongation by any method. Since there is no standard procedure to convert the machine displacement data into the equivalent extensometer data, the elongation values are often dependent on the test laboratory.

In this paper, a tentative method and the related analytical procedure will be proposed to accurately determine the specimen elongation from simple tensile testing in case that an appropriate extensometer is not available.

2. Observations from common tensile tests

Fig. 1 shows typical tensile curves obtained from a standard test by using an extensometer and from a simple test by using the machine stroke. Horizontal axis represents the specimen elongation determined between the extensometer gage length positions or the stroke displacement. Vertical axis represents the applied load.

In order to convert a tensile curve into an engineering stress-strain curve, the X-axis values have been divided by an initial gage length (extensometer gage length) or a uniform gage length of the specimen. The Y-axis values are divided by the initial area of the specimen gage section. Therefore, the curve shapes do not change even after converting.

Then, Fig. 1 reveals that the tensile curve from a simple test must be different from the standard test and that curve should be corrected by any means to obtain more reliable result equivalent to the standard test.

The tensile curves in Fig.1 may be divided by three regions which have different characteristics.

I) Elastic region: A steep rise in load proportional to specimen elongation occurs until yielding. Deformation in the gage section is dominantly linear elastic. For the stroke displacement in simple tests, additional displacements are also included from the grip joint and the machine compliance.

II) Work hardening region: A moderate rise in load occurs after yielding until maximum load. Deformation of specimen is homogeneously plastic. For the stroke displacement in simple tests, additional displacement comes from the machine compliance. The machine compliance displacement is elastic and increases with load increase.

III) Load drop region: Load drop is accelerated after necking at the maximum load point until fracture of the specimen. Deformation of specimen is localized and mostly confined within the gage section. For the stroke displacement in simple tests, additional displacement also comes from the machine compliance. However, the elastic machine compliance displacement decreases with load drop.

3. A tentative method to compensate the machine compliance effects for simple tensile tests

It can be assumed that the nonlinear grip joint displacement ends at a certain amount of loading. After that point, all extra displacement can be treated as machine compliance effect which is practically linear elastic. Therefore, a tentative procedure for analysis of a simple tensile curve is to be proposed as below.

1) A linear fit line is determined to have the maximum tangential slope within the stage of elastic region.

2) The tensile curve lower than the intercept of the linear fit is modified by a backward extrapolation of the linear fit line.

3) The linear fit line represents the summation of the specimen compliance and the machine compliance that is kept constant during a test. A theoretical value of the specimen compliance can be found from a literature and usually very small compared to the machine compliance. So, the machine compliance can be approximated from the test data itself without any other complicated procedure.

4) From the modified tensile curve, the specimen plastic tensile curve is reproduced by extracting the machine compliance displacement at each load level.

5) In order to convert the plastic tensile curve into a plastic stress-strain curve, the plastic elongation values are divided by the uniform section length until the maximum load and are divided by the gage length after the maximum load point.

6) Finally, a small effect from theoretical compliance of the specimen is added to the plastic strain values at each stress level.

4. Results and Discussion

Fig. 2 compares the stress-strain curve estimated by the proposed method for a simple stroke test with the stress-strain curve directly obtained from a standard test with extensometer. In fact, the two curves came from a single test while two different displacement values were simultaneously measured. The specimen was a standard ASTM rod type with a gage length of 25mm and a uniform section length of 32mm.

The proposed method worked very well for an RPV steel. The method will be further verified for other materials and other geometries.

5. Conclusion

A tentative method was proposed to compensate the machine compliance effects practically for simple tensile tests without extensometers. The method worked very well for an RPV steel to improve the accuracy of simple test results. It will be useful for circumstances where a standard testing with an extensometer cannot be practical. It is necessary to compare more experimental data from different materials and geometries.

REFERENCES

[1] ASTM Standard E8, Standard Test Methods for Tension Testing of Metallic Materials

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[3] KS B 0802, 금속재료 인장시험 방법

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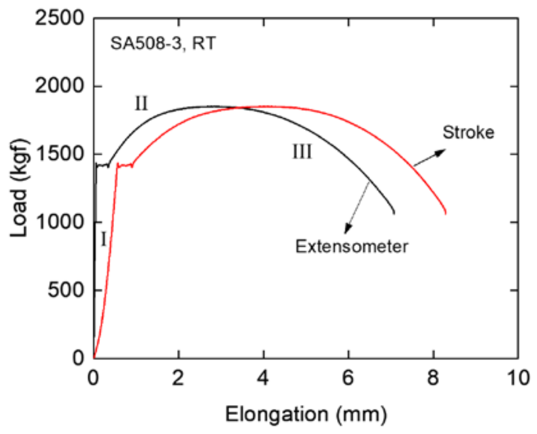

Fig. 1. Typical tensile test curves from common tests

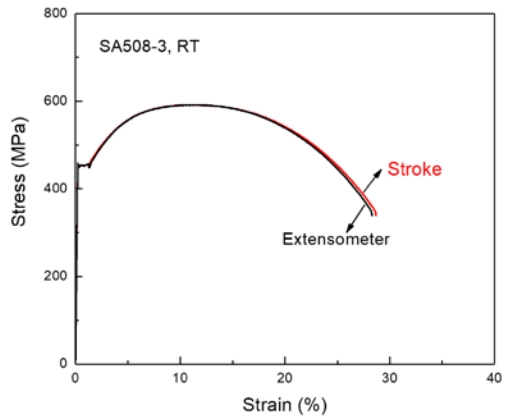

Fig. 2. Comparison of the stress-strain curve compensated by the proposed method with the standard test result