Application News

No. i262

Material Testing System

Evaluation of the Bauschinger Effect on a Steel Sheet Specimen Subjected to In-plane Reverse Loading Test

Introduction

From the viewpoint of reducing environmental impacts, the improvement of fuel efficiency and the extension of the driving range of electric vehicles for practical use are key factors for vehicle development. One solution that is expected to be promising is weight saving of the car body. New light-weight high-strength materials such as CFRP are attracting attention while in terms of metal materials featuring good formability, higher strength is being sought for by employing highly tensile materials. In dies manufacturing for presses, the spring-back phenomenon (Fig. 1) is an issue causing forming failures that need to be coped with by trial and error, which requires tremendous time and costs. In recent years, on the other hand, computer aided engineering (CAE) analytical technologies are utilized in various fields to simulate product designs on a computer for reducing the number of times and costs of trial production. Regarding dies manufacturing for presses, simulation is also coming to be used to predict the spring-back phenomenon in die design as an effective tool to achieve drastic cost reductions.

This article presents an example of evaluating the Bauschinger effect on a 1 mm thick cold rolled steel sheet (SPCC) without buckling the sheet, using a Bauschinger effect measuring fixture.

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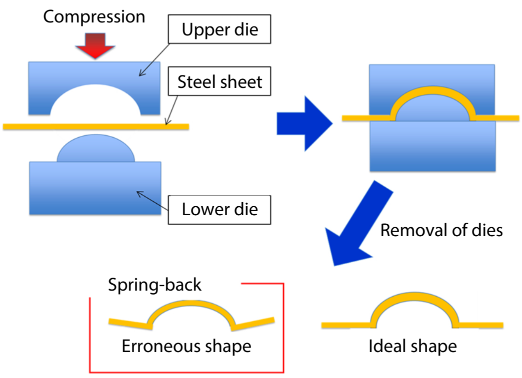

Fig. 1 Spring-back Phenomenon in Steel Sheet Forming

What Is the Bauschinger Effect

The Bauschinger effect refers to a characteristic of metal materials, in which when applying a stress to a plastically deformed metal material in the reversed direction to that applied for predeformation, the absolute value of compressive yield stress σ_{YB} is lower than that of yield stress σ_{YA} at the time of predeformation (Fig. 2). It is known that constructing a material model in consideration of this characteristic enables precise prediction of a spring-back that may occur on steel sheets. Regarding the evaluation of the Bauschinger effect, however, there is no evaluation method established for actual testing because steel sheets easily buckle at the time of compressive loading.

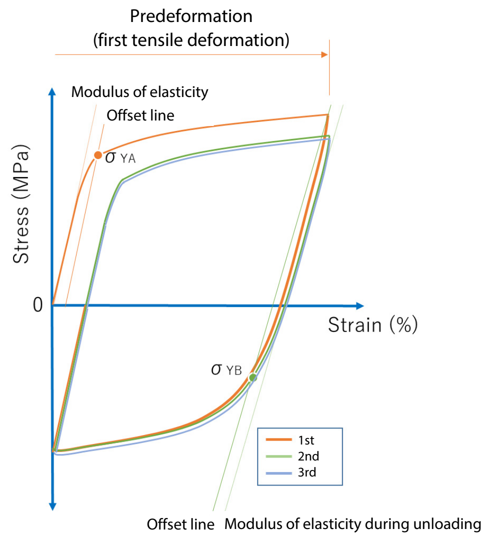

Fig. 2 Conceptual Diagram of Bauschinger Effect Evaluation Results

Conditions and Equipment for Bauschinger Effect Evaluation

Fig. 3 shows the Bauschinger effect measuring fixture. The Bauschinger effect measuring fixture is equipped with a mechanism which prevents buckling of the steel sheet specimen during compression, and the amount of deformation can be measured directly using a contact-type extensometer. Fig. 4 shows the specimen shape and Table 1 shows the test conditions.

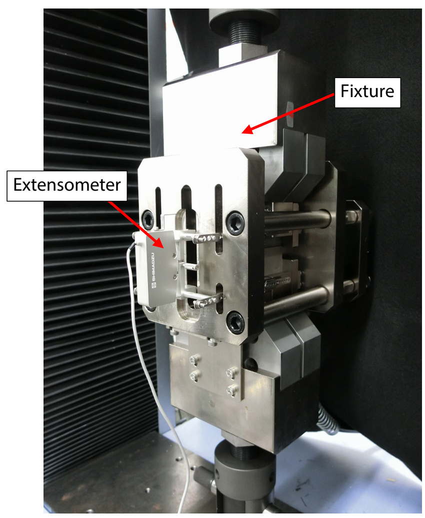

Fig. 3 Bauschinger Effect Measuring Fixture

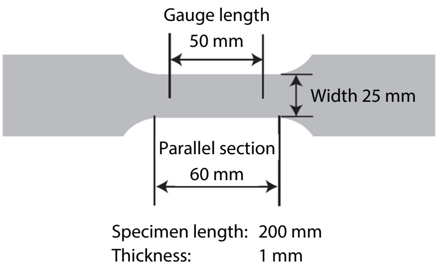

Fig. 4 Specimen Shape (as specified by JIS Z2241 No. 5)

Table 1 Test Conditions

Testing System	: Shimadzu's Autograph AG-50kNXplus precision universal testing instruments
Fixture	: Bauschinger effect measuring fixture
Sinking comb pressure	: 5 MPa
Extensometer	: SG-50-50 (dedicated to the Bauschinger effect measuring fixture)
Test speed	: 1 mm/min
Software	: TRAPEZIUM X (control)
Stress reversal strain	: ① 0 % ⇆ 1 % ② 0 % ⇆ 2 % ③ 0 % ⇆ 5 %
Number of cycles	: 3

Stress - Strain Diagram at Stress Reversal

Fig. 5 shows the stress - strain curves obtained by applying three different strains to the specimen. It is found that with the SPCC material used in this test, the upper yield point appears at the time of predeformation.

Consequently, in order to evaluate the Bauschinger effect, we offset the modulus of elasticity during unloading by –0.5 % to obtain the compressive yield stress σ_{YB}, and calculated the Bauschinger stress σ_B from the difference in absolute values between yield stress σ_{YA}, which is the strength at the upper yield point in predeformation, and compressive yield stress σ_{YB} (see Fig. 2 for details). The characteristic values obtained by this test are given in Table 2.

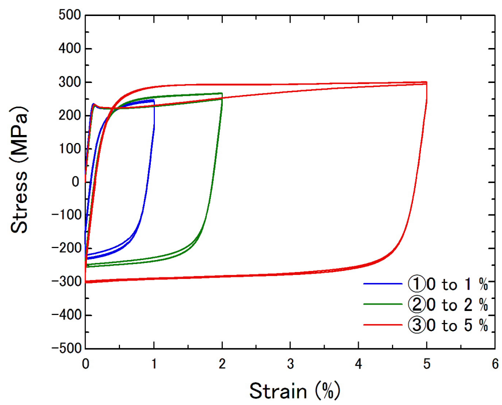

Fig. 5 Repeated Stress - Strain Curves

From Fig. 5, we found that in the course of repeated tensile-compressive deformation of a specimen, the stress amplitude at the second time was higher than that at the first time and was almost equal to that at the third time. In addition, the stress amplitude is correlated positively with the tensile-compressive deformation cycle, and this suggests the dependence of the stress amplitude on the cyclic strain width. Table 2 indicates that a greater strain to the specimen results in a smaller modulus of elasticity during unloading modulus of elasticity during unloading ③ < ② < ①). The reason why the modulus of elasticity during unloading is small is conceivably that the linear area appearing immediately after the reversal of stress generated an essentially non-linear response, so we can say that this value is greatly dependent on the strain. Furthermore, compressive yield stress σ_{YB} is larger as the induced strain is greater. The specimen used in this test shows a negative correlation to the strain induced by the Bauschinger stress σ_B (Fig. 6).

Table 2 Characteristic Value

Characteristic Value	Condition ①	Condition ②	Condition ③
Modulus of elasticity at predeformation (GPa)	214.7	201.3	216.7
Modulus of elasticity during unloading (GPa)	180.6	164.0	154.0
Upper yield stress σ_{YA} (MPa)	235.3	230.3	233.2
Compressive yield stress σ_{YB} (MPa)	–175.1	–185.7	–204.3
Bauschinger stress σ_B σ_{YA}-|σ_{YB}|	60.2	44.6	28.9

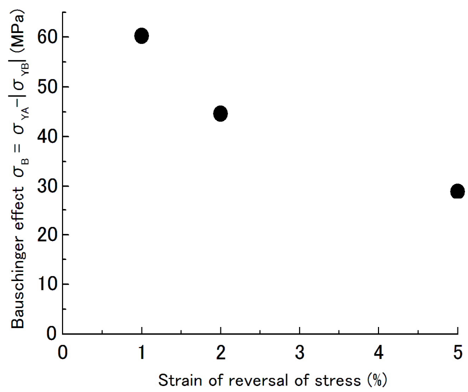

Fig. 6 Relation between Bauschinger Stress σ_B and Stress Reversal Strain

Conclusion

By using Shimadzu's Autograph and a Bauschinger effect measuring fixture, the Bauschinger effect on a steel sheet can be evaluated without buckling the specimen.

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