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Application News

No. i271

Material Testing Machine

Measurement of Paint Bake Hardening of Metals Conforming to JIS G 3135 Annex A

Introduction

Automobiles have become an indispensable part of our daily lives, but in recent years, application of various materials such as carbon fiber reinforced plastic and high tensile strength steel has been studied with the aim of reducing auto body weight in order to improve fuel economy and reduce CO_2 emissions, and many such materials have been applied practically.

However, the required material properties differ in each automotive component. In particular, materials with high dent resistance, i.e., resistance to depressions caused by impact by small stones or other objects that bounce up during travel, is demanded in doors, hoods, and other outer panels. Increasing the contents of carbon and nitrogen to increase yield strength are effective for improving dent resistance, but press forming becomes difficult, and the forming defect called "surface deflection" increases. On the other hand, in order to improve formability and secure high surface accuracy, soft materials with low yield strength are required.

Bake-hardening steel sheets (BH steel sheets) are used to satisfy the mutually-contradictory requirements of high formability and high dent resistance. BH steel sheets are a type of steel sheet that is soft and has high formability at the time of forming, and then hardens when dried with heat (baked) in the subsequent painting process.

This article introduces an example in which tests were conducted in accordance with JIS G 3135 Annex A in order to obtain the paint bake-hardening amount (BH amount) of SPCC, SPFC590, and SPFC1180 steels.

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Paint Bake-Hardening Amount Calculation Method

Fig. 1 shows the image of measurement of the BH amount as provided in JIS G 3135 Annex A, together with the terminology. The BH amount (σ_{BH}) is evaluated by the amount of rise in yield stress when heat treatment corresponding to the baking finish process is performed with a steel material to which prestrain has been applied. The measurement procedure is shown below.

(1) Perform a tensile test at a speed of 10 to 30 MPa/s, obtain the prestrain (work hardening) stress R_{WH} when the total elongation of the specimen reaches 2 %, and then release the force.

(2) Conduct heat treatment of the specimen in (1) at 170 °C for 20 min, then air cooling.

(3) Obtain the strain aging yield stress R_{SA} by conducting a tensile test of the specimen which was heat-treated according to (2). $\sigma_{BH} = R_{SA} - R_{WH}$.

In this test, processing to calculate the numerical values obtained by two tensile tests is necessary. With the conventional method, σ_{BH} could not be calculated using software alone. However, Shimadzu TRAPEZIUMX-V materials testing software enables calculation of the value of σ_{BH} by reading past test results. In this experiment, the test results when prestrain stress was measured were read from the test results of the strain aging yield stress measurement, and σ_{BH} was calculated in the software.

Test Conditions

Table 1 and Table 2 show the test conditions and specimen information respectively. For comparison, three tests were carried out with each of three types of steel, SPCC, SPFC590, and SPFC1180, and the average values were obtained. Fig. 2 shows the condition of JIS Test. In these measurements, the tests were carried out using Shimadzu hydraulic flat grips, which feature strong gripping force, in order to conduct the test of the high strength SPFC material without slipping in the grips.

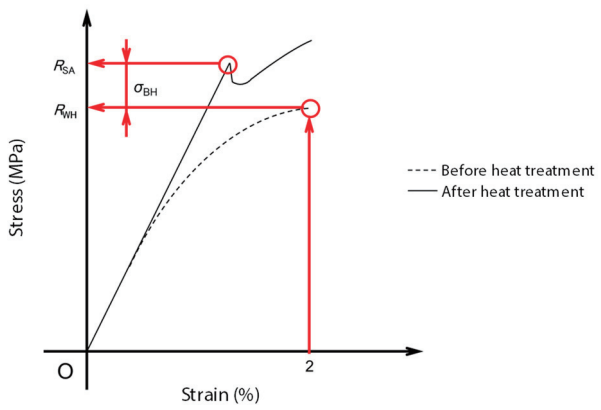

Fig. 1 Image of Measurement by JIS G 3135

Table 1 Test Conditions

Instrument	: AGX™-100kNV
Load cell	: 100 kN
Test jig	: 100 kN hydraulic flat grip
Grip face	: Single-side file-teeth grip face for flat grip
Extensometer	SSG50-10H
Software	TRAPEZIUMX-V single
Test speed	10 MPa/s (load until extensometer output of 2 %)
Heat treatment conditions	: Heating at 170 °C for 20 min, followed by air cooling

Table 2 Specimen Information

Specimen types	: SPCC, SPFC590, SPFC1180
Number of specimens	: 3 specimens/type
Specimen geometry	: No. 5 dumbbell (JIS Z 2241)
Original dimensions of parallel portion	: Width 25 mm × thickness 1 mm

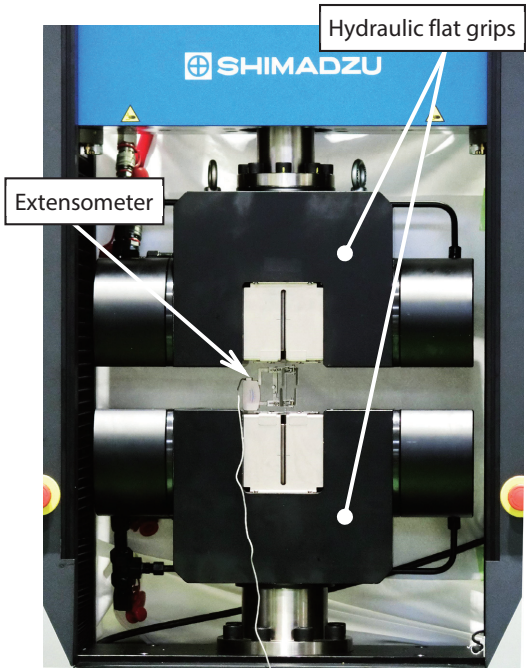

Fig. 2 Condition of JIS Test

Test Results

Fig. 3, 4, and 5 show examples of the test results for SPCC, SFC590, and SPFC1180, respectively. Strain on the horizontal axis is the value obtained by converting the output of the extensometer, and stress on the vertical axis is the value calculated based on the cross-sectional area of the parallel portion before applying prestrain. With all specimens, it can be understood that there are differences in the S-S curves before and after heat treatment. Table 3 shows the measured stress values and the calculated σ_{BH} for each type of specimen. The lowest σ_{BH} was obtained with SPFC590, and σ_{BH} increased in SPCC and SPFC1180 in that order.

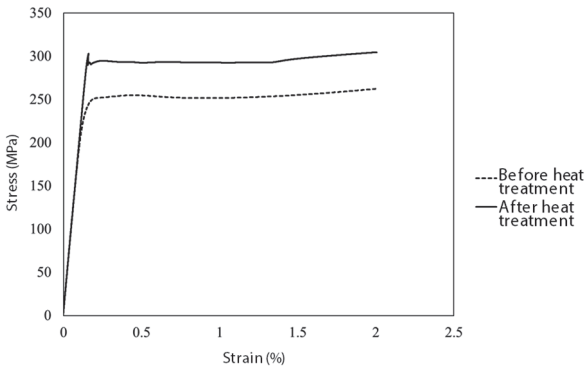

Fig. 3 Test Results of SPCC

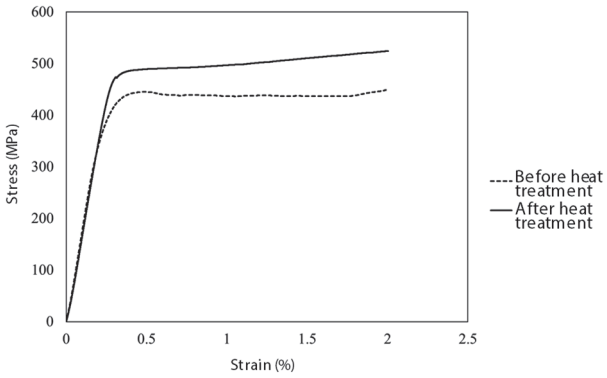

Fig. 4 Test Results of SPFC590

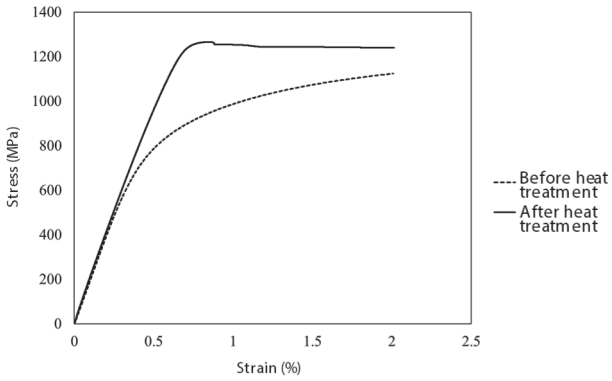

Fig. 5 Test Results of SPFC1180

Table 3 Summary of Test Results (Average of n=3)

	R_{WH} (MPa)	R_{SA} (MPa)	σ_{BH} (MPa)
SPCC	261.0	297.7	36.7
SPFC590	447.4	472.5	25.1
SPFC1180	1119.3	1264.2	144.9

Conclusion

This article introduced an example in which tests conforming to JIS G 3135 Annex A were conducted and σ_{BH} was calculated using Shimadzu TRAPEZIUMX-V materials testing software. In addition to tensile strength, percentage elongation after fracture, elastic modulus, and similar items provided in JIS Z 2241, the value of σ_{BH} becomes an important item in material selection of materials used in automotive outer panels such as doors and hoods.

Calculation of σ_{BH} conforming to JIS G 3135 Annex A is easily possible by using Shimadzu measurement system.

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