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Application News

Precise Alignment System PAS
Precision Universal Testing Machines AGX™-V2

ASTM E1012–Compliant Tensile Test Using PAS (Precise Alignment System)

Tomoya Matsushita

User Benefits

- Tensile testing can be performed with alignment accuracy compliant with ASTM E1012 by using PAS.
- Data scatter can be reduced by easily aligning the axes of the upper and lower grips.
- Alignment adjustment can be easily performed even after fixtures are removed and reinstalled.

■ Introduction

In the aerospace field, it is required to internationally ensure the quality of parts and materials as well as the reliability of test results. One of the representative frameworks for this purpose is the National Aerospace and Defense Contractors Accreditation Program (NADCAP), which is widely adopted. NADCAP plays an important role in maintaining and improving quality levels throughout the supply chain by establishing common certification standards for special processes and material testing in the aerospace industry.

To obtain and maintain NADCAP accreditation, it is necessary to conduct testing in compliance with specified international standards. In the field of materials testing, tensile testing must be performed using a system configuration that conforms to ASTM E1012. ASTM E1012 emphasizes the importance of minimizing unintended bending stresses on the specimen and explicitly states that tensile tests must be carried out using fixtures that ensure precise alignment of the loading axis[1). Misalignment is a critical factor that can adversely affect test results, and strict control is therefore required in NADCAP-compliant tests. By utilizing the Precise Alignment System (PAS), it is possible to achieve a high level of alignment accuracy in accordance with ASTM E1012. In this Application News, the effect of PAS on improving alignment accuracy is demonstrated through a comparison of test data obtained with and without PAS. In addition, tensile tests of A7075 material were conducted using a system combining the AGX™-V2 precision universal testing machine and PAS, as shown in Fig. 1.

■Precise Alignment System PAS

PAS is designed to minimize slight misalignment of the test axis while performing measurements using strain gauges attached to the specimen. The system consists of an axis adjustment device for alignment control, a strain amplifier for measuring strain, axis adjustment software that displays the measured strain and provides guidance on the amount and direction of adjustment, and a sensor specimen for strain detection. Multiple strain gauges are installed within the sensor specimen. Based on the strain measured by each gauge, the bending strain applied to the specimen is calculated, and the degree of axis misalignment is visually presented on the software window as shown in Fig. 2. The axis adjustment device located at the upper part of the system is equipped with multiple screws for fine adjustment of alignment, enabling precise control of the fixture's horizontal position and angular orientation. In this application, the allowable misalignment tolerance was defined as a radius of 100 µm, and alignment was adjusted so that the test axis fell within this range.

In addition, the grips are required to provide high reproducibility of clamping and minimal deformation under load. In this application, high-precision pneumatic wedge grips were used. These grips enable stable and reproducible clamping by means of pneumatic pressure. The test system combining these grips with PAS is shown in Fig. 3.

Fig. 1 Precision Universal Testing Machine AGX™-V2

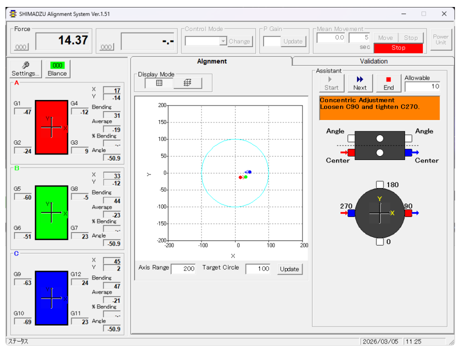

Fig. 2 Operation Window of Alignment Software

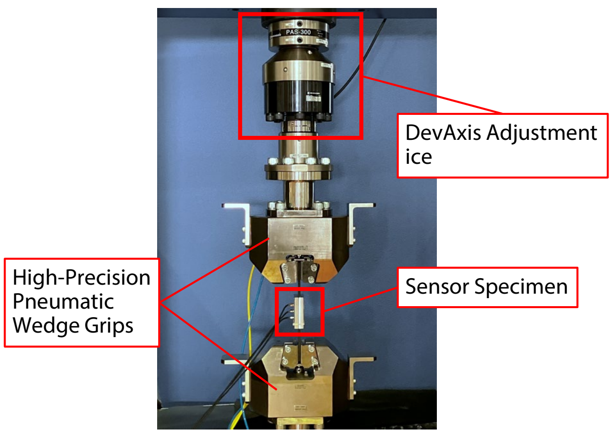

Fig. 3 Testing System

■ Specimens

Table 1 summarizes the specimen information, and Fig. 4 shows an image of a specimen. In this application, A7075 (extra super duralumin), an aluminum alloy widely used in aerospace, automotive, and other industrial fields, was selected. The specimen was prepared in a dumbbell shape, with dimensions conforming to the ASTM E8 Sheet-Type standard (width 12.5 mm)[2].

Table 1 Specimen Information

Material:	A7075 (Extra super duralumin)
Dimensions:	Length 200 × Width 12.5 × Thickness 3 mm

Fig. 4 Image of the Specimen

■ Demonstration of Axis Alignment Accuracy

As shown in Fig. 5, a specimen with a total of eight strain gauges—four attached to each side (front and back)—was prepared. When proper axis alignment is achieved, the strain readings from each gauge ideally coincide during tensile testing. However, when misalignment is present, variations appear among the measured values. In this application, identical tests were conducted using systems with and without PAS, and the variation in strain readings among the gauges at a specified test load was compared. The test procedure is outlined below:

(1) The specimen was gripped using the grips
(2) The specimen was loaded up to 8 kN at a rate of 10 MPa/s
(3) The load was released to approximately 0 N
(4) The specimen was removed from the grips

The above procedure was repeated 10 times using the same specimen. Since 8 kN is within the elastic range of the specimen, unloading enables repeated testing under the same conditions. In addition, strain gauges and a dynamic strain amplifier manufactured by Kyowa Electronic Instruments Co., Ltd. were used in the tests. The specifications of the strain gauges are listed in Table 2.

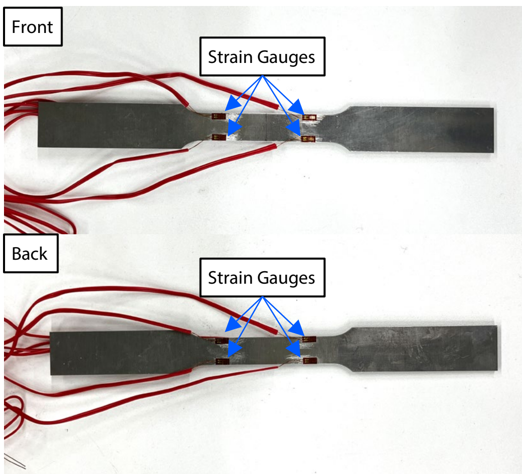

Fig. 5 Image of the Specimen (with 8 Strain Gauges)

Table 2 Specifications of the Strain Gauge

Gauge Length:	2 mm
Gauge Factor:	2.11 ± 1.0 %
Full Scale:	30000 με

■ Demonstration Results of Axis Alignment Accuracy

Figs. 6 and 7 show the load–strain curves. In these graphs, the measured data from two representative strain gauges out of the eight are presented. From these results, it can be seen that the system without PAS exhibits a larger variation in strain. In addition, Table 3 summarizes the coefficient of variation of the eight strain measurements obtained at a tensile load of 5 kN. As shown in Table 3, the system with PAS tends to exhibit lower coefficients of variation across the ten repeated tests. These results indicate that the system with PAS achieves reduced variation in strain measurements, thereby providing higher axis alignment accuracy.

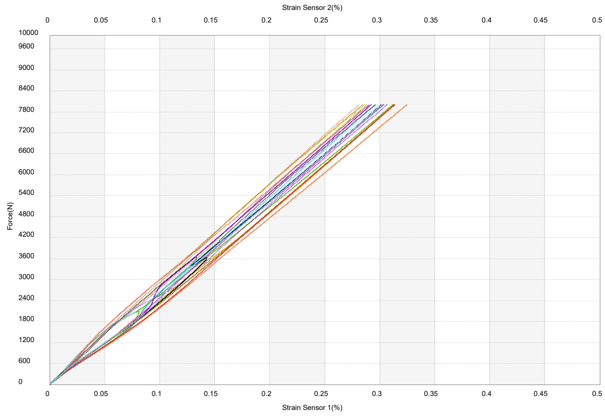

Fig. 6 Force-Strain Curve (without PAS)

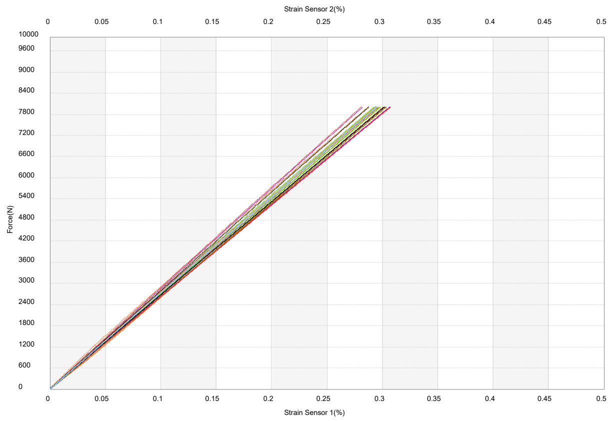

Fig. 7 Force-Strain Curve (with PAS)

Table 3 Coefficient of Variation of Strain Values 1-8 for Each Test (at a Test Force of 5 kN)

Test No.	CoV (%) With PAS	CoV (%) Without PAS
1	2.02	4.10
2	1.92	5.25
3	2.97	11.48
4	3.13	4.10
5	1.37	15.43
6	5.55	5.06
7	4.38	7.54
8	5.23	8.49
9	3.25	6.93
10	3.14	9.57
Average	3.30	7.80

■ Tensile Test

Tensile tests in accordance with ASTM E8 were conducted using a system in which axis alignment accuracy compliant with ASTM E1012 was ensured by PAS. In this application, the "Auto Stress" function of the TRAPEZIUM™X-V software for AGX-V2 was utilized. This function maintains a constant stress rate in the initial stage of the test and automatically switches to an estimated strain-rate control mode once a specified speed threshold is exceeded. Because the strain rate is continuously monitored, excessive crosshead speed—caused by attempting to maintain the stress rate—is prevented.

The test conditions are summarized in Table 4, and test setup is shown in Fig. 8.

Table 4 Test Conditions

Testing Machine:	Precision Universal Testing Machines AGX-V2
Load cell Capacity:	250 kN
Software:	TRAPEZIUMX-V (Single)
Jig:	High-Precision Pneumatic Wedge Grips
Extensometer:	Strain Gauge (Gauge Factor 2.11)
Test Speed:	V1: 10 MPa/sec (until the actual speed exceeds V2) V2: 50 %/min

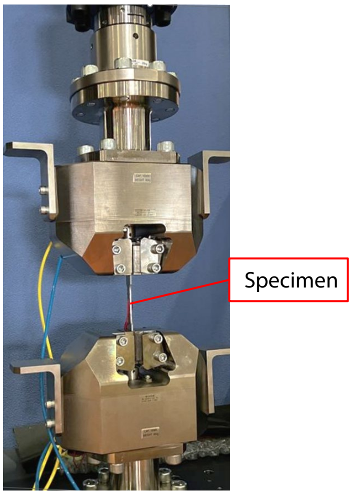

Fig. 8 Image of Tensile Test

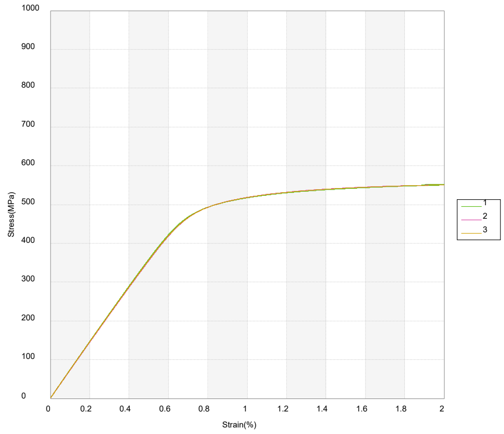

Fig. 9 Tensile Test Result up to 0.2 % Strain (n = 3)

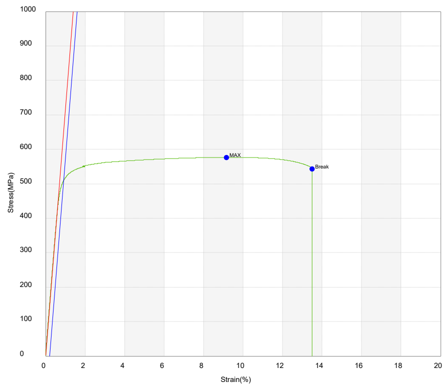

Fig. 10 Tensile Test Result up to Failure (n = 1)

Table 3 Tensile Test Results (Mechanical Properties)

Specimen No.	Elastic modulus (GPa)	0.2 % Proof stress (MPa)	Tensile strength (MPa)
1	70.91	508.6	578.0
2	71.02	509.4	578.7
3	70.80	511.2	579.1
Average	70.91	509.7	578.6
Standard deviation	0.109	1.36	0.581
CoV (%)	0.154	0.267	0.100

■ Test Result

The test was performed with n = 3. Fig. 9 shows the tensile test results up to 2 % strain (n = 3). As seen in Fig. 9, the three stress–strain curves are in close agreement. Fig. 10 presents the tensile test result up to failure (n = 1). As a representative example, the stress–strain curve of one specimen is shown. The red line indicates the elastic modulus line, and the blue line represents the proof stress line. From these results, the elastic modulus, 0.2 % proof stress, and tensile strength of the A7075 specimens were calculated. Table 3 summarizes the tensile test results (mechanical properties) for each specimen. As shown in Table 3, the tests were conducted with high reproducibility.

■ Conclusion

In this application, the PAS axis alignment system—capable of ensuring alignment accuracy in accordance with ASTM E1012—was introduced, and the difference in alignment accuracy with and without PAS was demonstrated through experimental results. The results confirmed that the use of PAS improves axis alignment accuracy. Furthermore, tensile testing of A7075 was carried out using PAS, and the elastic modulus, 0.2 % proof stress, and tensile strength were successfully measured with high reproducibility.

References

1) ASTM E1012-14

2) ASTM E8-16a

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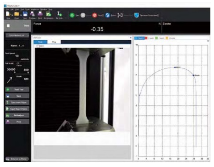

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