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THE METHOD PROPOSAL FOR CALIBRATION OF THE ALIGNMENT CELL

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Abstract:
The alignment measurements of material testing machines can be made according to ASTM E1012 and ISO 23788 standards. These standards provide information on alignment devices, alignment measurement, and post-measurement calculations. However, they can't make a definition for the calibration of the alignment measuring device. For this purpose, this article has been prepared as a recommendation for the calibration method of the alignment measuring devices and the evaluation after the measurements. In this study, the calibration method of the alignment measuring device is defined and the calculations are given clearly with two different numerical examples.

Keywords: Alignment; calibration method; alignment devices calibration; ASTM E1012; ISO 23788

1. INTRODUCTION

Calibration is the most important way to document that the material test machine achieves regular, accurate, and reliable measurement results. The force calibrations of the material test machines are performed according to ISO 7500-1 or ASTM E4 standards [1], [2]. In addition, the calibration of the extensometer can be performed according to ISO 9513 or ASTM E83 standards [3], [4]. From time to time, the force and the extensometer device have been calibrated. The measurements made on the specified material test machines have been determined to be within the appropriate tolerances, and there are also differences in device dependence. This problem was found to be caused by the alignment problem of the device and the causes of the alignment problems are listed as follows:

- Change the sample holding jaws,
- Use of different and new sample holding jaws,
- Positioning error of the moving table,
- Wear and damage to parts,

For these reasons, alignment problems and deterioration occur in material test machines.

The need for alignment verification of the devices has also been made to identify these problems. In addition, large companies in the aerospace industry and some accredited laboratories want these features of material test machines calibrated because of the importance of the axis.

Details of the alignment measurement and the expected tolerance values are given in the standards ASTM E1012 and ISO 23788, as well as the General Electric company documents S-400 and PRI AC7101 [5], [6], [7], [8], [9], [10], [11], [12]. The alignment measuring device, which is manufactured as described in these documents, determines the deviation rate of the axis from the axis at certain force values of the material tester to be measured. The procedure specified in standard ASTM E1012 is an acceptable method for determining the amount of deviation from the axis of the device measured on material test machines, based on the ASTM E1012 standard.

This is a recommendation document for calibration procedure of alignment measuring devices used in alignment measurements of materials testing machines used for compression and tensile testing. In this study, a proposal has been prepared for the calibration of the alignment measuring device based on verification of strain gauge sensor in EN 12390-4 [13] standard Annex A.3 strain gauge column verification procedure. Formulas and sample calculations according to alignment measuring device types defined in ASTM E1012 and ISO 23788 standards are given below. This study was conducted to investigate the alignment measurements in work package (Task 3.2: Investigation of alignment and non-axial forces) Activity 3.2.4 of ComTraForce project [14].

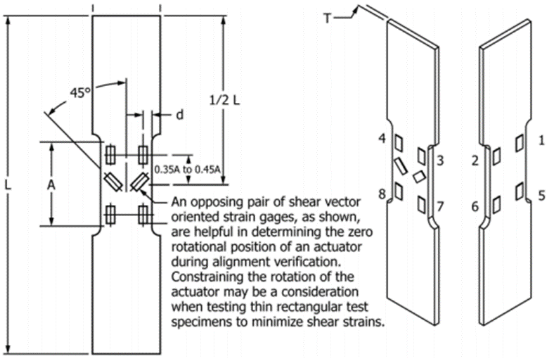
2. DEVICE AND EQUIPMENT

The measure of the alignment and the types of sensors are expressed in the standards ASTM E1012 and ISO 23788. Three types of alignment measurement sensors are defined according to standard ASTM E1012. These are cylindrical, thick rectangles and thin rectangles.

The information of the alignment devices used in the measurements are given below.

ASTM E1012 thin rectangular alignment transducer four strain gauges per plane

This type with reduced parallel section length 12 mm or greater, two sets of either three or four gages are acceptable. An additional set of either three or four gauges are common which can be used for further information at the centre of A. If A is less than 12 mm, a single set is sufficient. If additional two gages need to be integrated, they can be positioned at angle of 45°. (See Figure 1 and Figure 2). In contrast to ASTM E1012, ISO 23788 does not include “Configuration of Thin Rectangular Alignment Transducer Three Strain Gauges per Plane”.



An opposing pair of shear vector oriented strain gages, as shown, are helpful in determining the zero rotational position of an actuator during alignment verification. Constraining the rotation of the actuator may be a consideration when testing thin rectangular test specimens to minimize shear strains.

Figure 1: Thin rectangular four gauges per plane - ASTM E1012

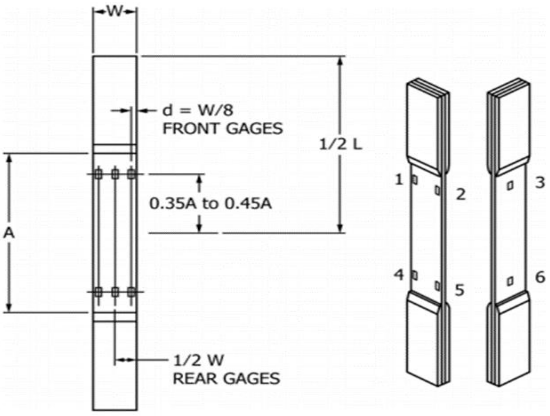


Figure 2: Thin rectangular three strain gauges per plane (used in composite testing) - ASTM E1012

ISO 23788 thin rectangular alignment transducer four strain gauges per plane. Figure 3 is shown as a model for thin rectangular alignment cell four strain gauges per plane. Nominal dimensions can be seen in Tables 3 and 4 of the standard. As stated previously, ISO 23788 does not give a model for three strain gauges per plane.

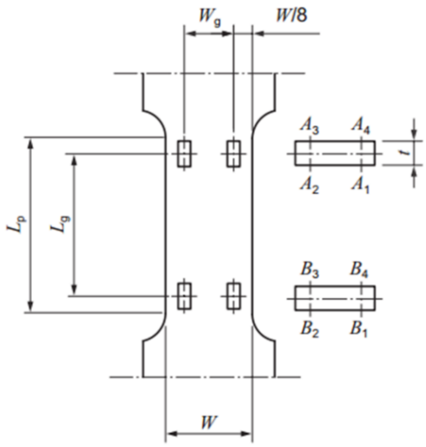


Figure 3: Strain gauge locations on thin rectangular alignment cell - ISO 23788

Reliable measurements depend on all four strain gauges being equally accurate. In order to connect the alignment measuring device to the calibration machine, it should be paid attention to use suitable connection apparatus that does not cause axial misalignment.

3. CALIBRATION METHOD

Describes the properties of EN 12390-4 standard hardened concrete test presses. In order to control the equal distribution of force measurement in this standard, a specially manufactured column-type force measuring device (strain cylinder) is used for measurements as it is seen in Figure 4. This device has four full bridges that can receive four output signals on the same body. The aim of the alignment measuring devices is to check the axis distortion by taking values from three or four different quarter bridge. Due to these similarities, it was thought that the same calibration method could be used in alignment devices.

Describes the strain gauged column verification procedure measured according to EN 12390-4 standard Annex A3. This procedure allows you to check the equilibrium of the output signals from the four measurement points.

In this test, the upper machine plate must be adjusted parallel to the contact surface of the strain cylinder and four series of measurements must be performed with the strain cylinder centrally mounted for each load levels (200 kN, 800 kN and 2 000 kN). After each series of measurements e_1, e_2, e_3 and e_4, the load must be lifted, the strain cylinder must be rotated 90° and the load must be reapplied and more readout kits must be taken. This is repeated at 180° and 270°.

For each load level, calculate the average e_m value of the strain readings at four measuring points e_1, e_2, e_3 and e_4, and the R_n from $(e_\mathrm{n} - e_\mathrm{m})/e_\mathrm{m}$ strain ratio for each measurement point, where this is the stress at the most considered measurement point.

The mean strain rate is calculated from the strain rate at each measurement point from the four measurement point series. Values must be within the limits specified in EN 12390-4.

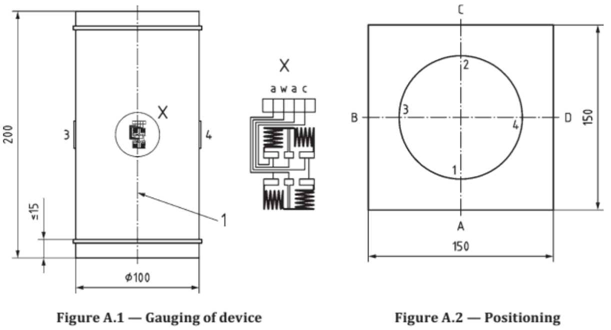


Figure A.1 — Gauging of device

Figure A.2 — Positioning

Figure 4: The shape of column-type force measuring device (strain cylinder)

4. MEASUREMENT AND CALCULATION ERROR

A procedure similar to the EN 12390-4 standard was determined for the calibration of the alignment measuring device. The alignment measuring device is connected to the appropriate calibration device via the required connection apparatus. Firstly, two or three preloads are required. Then, the force is applied in two series incremental directions. The capacity – time graph is shown Figure 5. It is recommended to take force steps in the series in 50 %, 62.5 % and 100 %. Then, the position of the alignment measuring device is rotated 180° to reconnect and the same actions are applied. The results are evaluated by calculating the parameters defined below from the obtained results. The limit values of acceptance for alignment uniformity are also defined in Table 1.

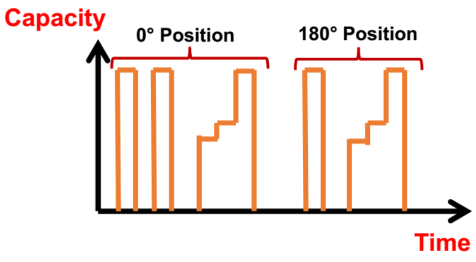


Figure 5: Alignment device verification measurement sequence shape

The measurements and the formulas to be used are summarised as follows:

1. Axial strains are measured and calculate average strain

e_1, e_2, e_3 and e_4: the measured strains at the four locations and the subscript indicates the order around the strain-gauged alignment transducer:

$$a = \frac{(e_1+e_2+e_3+e_4)}{4} \text{ or } a = \frac{(e_1+e_2+e_3)}{3} \tag{1}$$

2. Calculate strain ratio:

$$R_{n1} = \frac{e_1 - a}{a} \tag{2}$$

$$R_{n2} = \frac{e_2 - a}{a} \tag{3}$$

$$R_{n3} = \frac{e_3 - a}{a} \tag{4}$$

$$R_{n4} = \frac{e_4 - a}{a} \tag{5}$$

3. Rotate 180° and record data.

4. Calculate strain ratio component due to misalignment in the machine:

$$R_{n1,\mathrm{mc}} = \frac{R_{n1,0°} + R_{n1,180°}}{2} \tag{6}$$

$$R_{n2,\mathrm{mc}} = \frac{R_{n2,0°} + R_{n2,180°}}{2} \tag{7}$$

$$R_{n3,\mathrm{mc}} = \frac{R_{n3,0°} + R_{n3,180°}}{2} \tag{8}$$

$$R_{n4,\mathrm{mc}} = \frac{R_{n4,0°} + R_{n4,180°}}{2} \tag{9}$$

5. Calculate the average value of each step

$$\bar{R}_n = \frac{R_{n1} + R_{n2} + R_{n3} + R_{n4}}{4} \tag{10}$$

Table 1: Alignment cell requirements

Measurement step		**Limits of acceptance for alignment uniformity**
με	**% capacity**	$\bar{R}_n$
1 000	50	± 0.02
1 250	62.5	
2 000	100	

5. NUMERICAL EXAMPLES

An example calculation for a thin alignment measuring device microstrain is tabulated below. Firstly, the alignment device is positioned on the calibration machine. After the jaws are closed, data is taken and approximately 1 000 $\mu\varepsilon$, 1 250 $\mu\varepsilon$, and 2 000 $\mu\varepsilon$ values are obtained. Then, the alignment measuring device is rotated 180° and positioned, and data are taken similarly (Table 1). The data are tared (Table 2) and strain ratio values are calculated (Table 3). Finally, the uniformity values are calculated (Table 4) and compared with the limit value given in Table 1. In this way, it is checked whether the alignment measuring device provides the accepted uniformity value.

Table 2: Axial strain data

Pos.	**Steps / με**	**Ch. 1 / με**	**Ch. 2 / με**	**Ch. 3 / με**	**Ch. 4 / με**
0°	Free	-0.702	-1.146	-0.11	0.78
	Grip	1.55	-0.22	-0.15	0.15
	1 000	1 061.0	1 060.3	1 056.9	1 058.4
	1 250	1 248.9	1 250.7	1 247.0	1 246.8
	2 000	2 045.0	2 062.0	2 058.0	2 044.0
180°	Free	-1.25	-1.89	1.47	2.01
	Grip	2.88	-2.66	-0.59	1.92
	1 000	1 063.2	1 057.4	1 055.9	1 061.8
	1 250	1 246.0	1 250.7	1 247.4	1 242.8
	2 000	2 044.0	2 064.0	2 057.0	2 045.0

Table 3: Tared (zeroed) strain data

Pos.	**Steps / με**	e_1 / με	e_2 / με	e_3 / με	e_4 / με	a / με
0°	Free	-0.702	-1.146	-0.111	0.776	-
	Grip	0.00	0.00	0.00	0.00	0.00
	1 000	1 059.44	1 060.55	1 057.00	1 058.22	1 058.80
	1 250	1 247.35	1 250.92	1 247.15	1 246.65	1 248.02
	2 000	2 043.45	2 062.22	2 058.15	2 043.85	2 051.92
180°	Free	-1.25	-1.89	1.47	2.01	-
	Grip	0.00	0.00	0.00	0.00	0.00
	1 000	1 060.33	1 060.10	1 056.45	1 059.88	1 059.19
	1 250	1 243.12	1 253.36	1 247.99	1 240.88	1 246.34
	2 000	2 041.12	2 066.66	2 057.59	2 043.08	2 052.11

Table 4: Evaluation of strain ratios from equations (2) to (5)

Pos.	**Steps / με**	R_{n1}	R_{n2}	R_{n3}	R_{n4}
0°	1 000	0.00	0.00	0.00	0.00
	1 250	0.00	0.00	0.00	0.00
	2 000	0.00	0.01	0.00	0.00
180°	1 000	0.00	0.00	0.00	0.00
	1 250	0.00	0.01	0.00	0.00
	2 000	-0.01	0.01	0.00	0.00

Table 5: Evaluation of uniformity from equations (6) to (10)

Steps / με	**Average strain ratios**				**Uniformity**
	$R_{n1,\mathrm{mc}}$	$R_{n2,\mathrm{mc}}$	$R_{n3,\mathrm{mc}}$	$R_{n4,\mathrm{mc}}$	$\bar{R}_n$
1 000	0.00	0.00	0.00	0.00	0.00
1 250	0.00	0.00	0.00	0.00	0.00
2 000	0.00	0.01	0.00	0.00	0.00

If the alignment measuring device outputs in mV, sample calculations are given in the tables below. The strain data are given in Table 6, zeroed data are given in Table 7 and strain ratio values are given in Table 8. Then the uniformity values are calculated in Table 9.

Table 6: Axial strain data

Pos.	**Steps / ratio of app. force**	**Ch. 1 / mV**	**Ch. 2 / mV**	**Ch. 3 / mV**	**Ch. 4 / mV**
0°	Free	0.121 30	-0.813 00	-0.572 90	0.994 60
	Grip	0.000 00	0.000 00	0.000 00	0.000 00
	50%	-0.544 37	-0.525 80	-0.542 47	-0.559 57
	62.5%	-0.677 03	-0.654 14	-0.672 70	-0.693 95
	100%	-1.109 28	-1.080 86	-1.101 22	-1.127 75
180°	Free	0.121 30	-0.813 00	-0.572 90	0.994 60
	Grip	0.000 00	0.000 00	0.000 00	0.000 00
	50%	-0.550 79	-0.580 52	-0.568 75	-0.538 68
	62.5%	-0.667 90	-0.702 59	-0.690 44	-0.655 55
	100%	-1.096 10	-1.137 31	-1.131 14	-1.090 07

Table 7: Tared (zeroed) strain data

Pos.	**Steps / ratio of app. force**	e_1 / mV	e_2 / mV	e_3 / mV	e_4 / mV	a / mV
0°	Free	0.121 30	-0.813 00	-0.572 90	0.994 60	-
	Grip	0.000 00	0.000 00	0.000 00	0.000 00	0.000 00
	50 %	-0.544 37	-0.525 80	-0.542 47	-0.559 57	-0.543 05
	62.5 %	-0.677 03	-0.654 14	-0.672 70	-0.693 95	-0.674 46
	100 %	-1.109 28	-1.080 86	-1.101 22	-1.127 75	-1.104 78
180°	Free	0.121 30	-0.813 00	-0.572 90	0.994 60	-
	Grip	0.000 00	0.000 00	0.000 00	0.000 00	0.000 00
	50 %	-0.550 79	-0.580 52	-0.568 75	-0.538 68	-0.559 69
	62.5 %	-0.667 90	-0.702 59	-0.690 44	-0.655 55	-0.679 12
	100 %	-1.096 10	-1.137 31	-1.131 14	-1.090 07	-1.113 66

Table 8: Evaluation of strain ratios from equations (2) to (5)

Pos.	**Steps / ratio of app. force**	R_{n1}	R_{n2}	R_{n3}	R_{n4}
0°	50 %	0.00	-0.03	0.00	0.03
	62.5 %	0.00	-0.03	0.00	0.03
	100 %	0.00	-0.02	0.00	0.02
180°	50 %	-0.02	0.04	0.02	-0.04
	62.5 %	-0.02	0.03	0.02	-0.03
	100 %	-0.02	0.02	0.02	-0.02

Table 9. Evaluation of uniformity from equations (6) to (10)

Steps / ratio of app. force	**Average strain ratios**				**Uniformity**
	$R_{n1,\mathrm{mc}}$	$R_{n2,\mathrm{mc}}$	$R_{n3,\mathrm{mc}}$	$R_{n4,\mathrm{mc}}$	$\bar{R}_n$
50 %	-0.01	0.00	0.01	0.00	0.00
62.5 %	-0.01	0.00	0.01	0.00	0.00
100 %	-0.01	0.00	0.01	0.00	0.00

6. CONCLUSIONS

Alignment is a measurement required by the aviation industry with a special device. Alignment measurements are described in ASTM E1012 and ISO 23788 standards. However, since the calibration of the alignment measuring device is not explained in detail in these standards, this study was carried out.

In this study, it has been tried to create a recommendation document for the calibration procedure of the alignment measuring devices used in the alignment measurements of the material testing machines. This work is also performed for the EMPIR - ComTraForce project activity number 3.2.4. This document has been prepared with the aim of being useful in current and future studies in force metrology.

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