Designation: E1012 – 05

Standard Practice for Verification of Test Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application[1]

This standard is issued under the fixed designation E1012; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Included in this practice are methods covering the determination of the amount of bending that occurs during the application of tensile and compressive forces to notched and unnotched test specimens in the elastic range and to plastic strains less than 0.002. These methods are particularly applicable to the force application rates normally used for tension testing, creep testing, and uniaxial fatigue testing.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E6 Terminology Relating to Methods of Mechanical Testing
E8 Test Methods for Tension Testing of Metallic Materials
E83 Practice for Verification and Classification of Extensometer Systems
E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gauges
E466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
E1237 Guide for Installing Bonded Resistance Strain Gages

3. Terminology

3.1 *Definitions of Terms Common to Mechanical Testing:*

3.1.1 For definitions of terms used in this practice that are common to mechanical testing of materials, see Terminology E6.

3.1.2 *notched section*—the section perpendicular to the longitudinal axis of symmetry of the specimen where the cross-sectional area is intentionally at a minimum value in order to serve as a stress raiser.

3.1.3 *nominal percent bending in notched specimens*—the percent bending in a hypothetical (unnotched) specimen of uniform cross section—equal to the minimum cross section of the notched specimen, the eccentricity of the applied force in the hypothetical, and the notched specimens being the same. (See 11.1.5.) (This definition is not intended to define strain at the root of the notch.)

3.1.4 *reduced section*—the specimen length between the fillets.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *alignment*—the condition of a testing machine and fixturing (including the test specimen) which can introduce bending moments into a specimen during the application of tensile or compressive forces.

3.2.1.1 *Discussion*—This is the overall state of alignment comprising machine and specimen components.

3.2.2 *apparatus*—the components of the machine and fixturing to be used for testing. This includes all components that will be used repeatedly for multiple tests.

3.2.2.1 *Discussion*—While the strain gaged specimen is not used for subsequent specimen testing it is included as part of the apparatus.

3.2.3 *axial strain*—the average of the longitudinal strains measured at the surface on opposite sides of the longitudinal axis of symmetry of the specimen by multiple strain-sensing devices located at the same longitudinal position as the reduced section.

3.2.3.1 *Discussion*—This definition is only applicable to this standard. The term is used in other contexts elsewhere in mechanical testing.

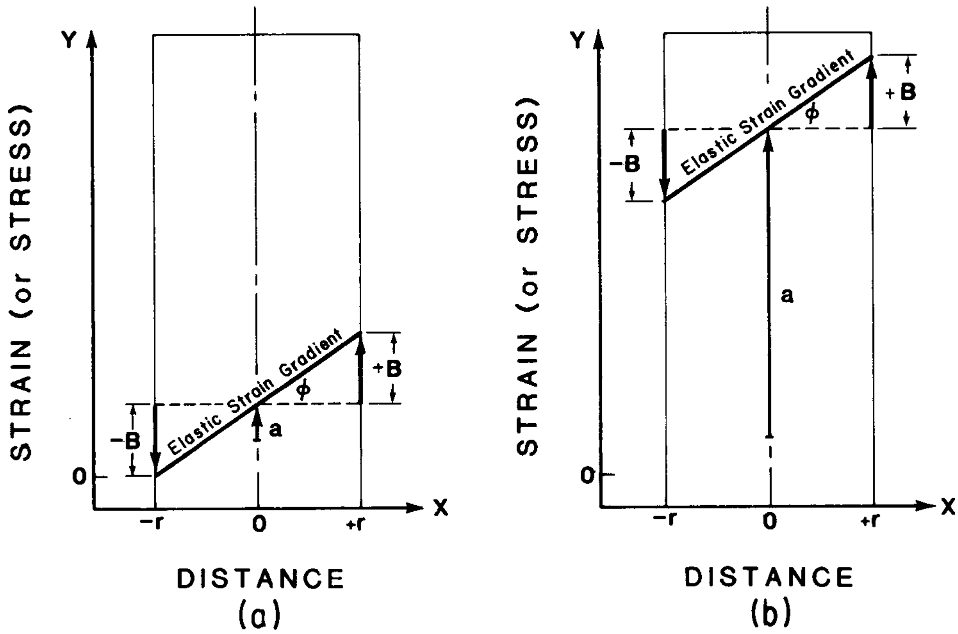
3.2.4 *bending strain*—the difference between the strain at the surface and the axial strain (see Fig. 1). In general, the bending strain varies from point to point around and along the reduced section of the specimen. Bending strain is calculated as shown in Section 11.

3.2.5 *eccentricity*—the distance between the line of action of the applied force and the axis of symmetry of the specimen in a plane perpendicular to the longitudinal axis of the specimen.

[1] This practice is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.01 on Calibration of Mechanical Testing Machines and Apparatus.

Current edition approved June 1, 2005. Published July 2005. Originally approved in 1989. Last previous edition approved in 1999 as E1012 – 99. DOI: 10.1520/E1012-05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



NOTE 1—A bending strain, $\pm B$, is superimposed on the axial strain, a, for low-axial strain (or stress) in (*a*) and high-axial strain (or stress) in (*b*). For the same bending strain $\pm B$, a high-percent bending is indicated in (*a*) and a low-percent bending is indicated in (*b*).

FIG. 1 Schematic Representations of Bending Strains (or Stresses) That May Accompany Uniaxial Loading

3.2.6 *machine alignment*—the condition of the testing machine and all rigid parts of the load train which can introduce bending moments into a specimen during subsequent force application.

3.2.7 *maximum bending strain*—the largest value of bending strain at the position along the length of the reduced section of a straight unnotched specimen at which bending is measured. (For notched specimens, see 4.9.)

3.2.8 *percent bending*—the bending strain times 100 divided by the axial strain.

3.2.9 *rated force*—a force at which the alignment is being measured.

3.2.10 *specimen alignment*—the condition of the test specimen including the non-rigid parts of the fixturing and the positioning of the specimen within the grips which can introduce bending moments into the specimen during subsequent force application.

4. Significance and Use

4.1 It has been shown that bending stresses that inadvertently occur due to misalignment between the applied force and the specimen axes during the application of tensile and compressive forces can affect the test results. In recognition of this effect, some test methods include a statement limiting the misalignment that is permitted. The purpose of this practice is to provide a reference for test methods and practices that require the application of tensile or compressive forces under conditions where alignment is important. The objective is to implement the use of common terminology and methods for verification of alignment of test machines, associated fixtures and test specimens.

4.2 Unless otherwise specified, axiality requirements and verifications should be *optional* when testing is performed for acceptance of materials for minimum strength and ductility requirements. This is because any effects especially from excessive bending, would be expected to reduce strength and ductility properties and give conservative results. There may be no benefit from improved axiality when testing high ductility materials to determine conformance with minimum properties. Whether or not to improve axiality should be a matter of negotiation between the material producer and the user.

5. Verification of Alignment

5.1 For ease of reference in other practices, test methods, and product specifications, the most commonly used methods for verifying alignment are listed in Section 6.

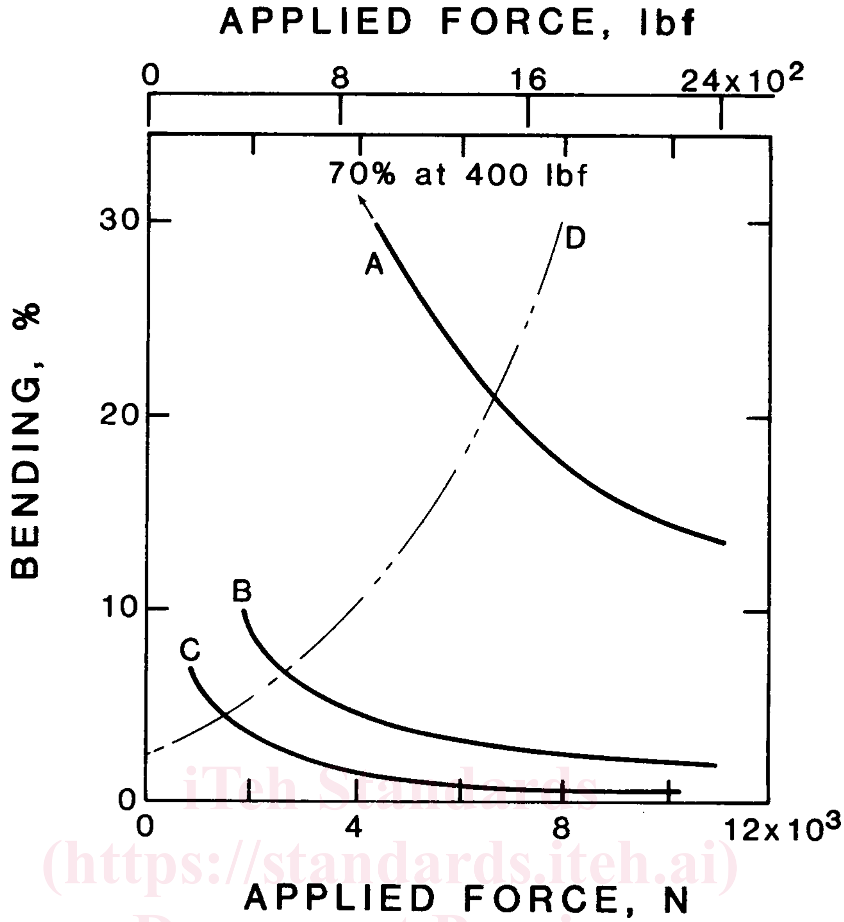
5.2 A numerical requirement for alignment should specify the force, specimen dimensions, and temperature at which the measurement is to be made. An alternate method employed when strain levels are of particular importance may be used as described in Practice E466. When this method is used, the numerical requirement should specify the strain levels, specimen dimensions and temperature at which the measurement is to be made.

5.2.1 The force at which the bending strain is specified may be stated in terms of a yield strength or other nominal specimen stress.

NOTE 1—For a misaligned load train, the percent bending usually decreases with increasing applied force. (See Curves A, B, and C in Fig. 2.) However, in some severe instances, percent bending may increase with increasing applied force. (See Curve D in Fig. 2.)

5.3 Alignment requirements and results can refer to either an overall test machine capability or to a specific test. This distinction should be noted in the results.

5.3.1 Verifications of overall test machine capability should be made using a specimen and apparatus made to a similar



NOTE 1—Curve A: Machine 1, threaded grip ends **(11)**
NOTE 2—Curve B: Machine 2, buttonhead grip ends **(11)**
NOTE 3—Curve C: Machine 3, grips with universal couplings **(7)**
NOTE 4—Curve D: schematic representation of a possible response from a concentrically misaligned load train **(16)**

FIG. 2 Effects of Applied Force on Percent Bending for Different Testing Machines and Gripping Methods

design and of similar materials as those that will be used during testing, except that any specimen notches may be eliminated. The same specimen may be used for successive verifications. The materials and design should be such that only elastic strains occur at the rated force. In cases where the expected test specimen material is not yet known, use good engineering judgement to select a specimen made of a commonly used material for verification.

NOTE 2—To avoid damage to the verification specimen, the sum of the axial strain and the maximum bending strain should not exceed the elastic limit.

5.3.2 Verifications of specific specimens that are to become test specimens following the alignment procedure shall be made on the specimen to be tested just prior to or during the testing without removing the specimen from the testing machine or making any other adjustments that would affect alignment during the period between verification and testing. These type of verifications provide the best measure of the true bending strain in a specific test specimen.

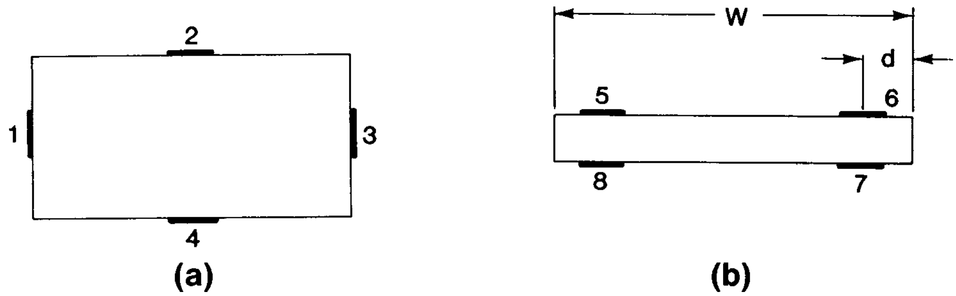
NOTE 3—Maintaining a small force on the specimen between verification and testing may be necessary to retain alignment on test machines with non rigid fixturing.

6. Methods of Verification of Alignment

6.1 Use this method for verification of machine alignment and for measurement of specimen alignment on a particular test or at specified test conditions.

6.1.1 *Machine Alignment*—This part of the method describes the initial alignment of the rigid parts of the fixturing. Machine alignment is initially established when first installing a test machine and when setting up a particular type of rigid fixturing configuration on a testing machine. While it may not change appreciably over time, catastrophic failures in the load train (fixturing or test specimen) or wear may establish the need to measure and readjust the machine alignment. The machine alignment should be performed any time a change in the rigid fixturing is required. Machine alignment is often viewed as a "coarse" alignment.

6.1.2 *Specimen Alignment*—This part of the method describes the positioning and subsequent alignment of the specimen and all the non-rigid fixturing in the load train. It requires the use of either a strain gaged specimen of specific geometry or a mechanical alignment fixture that uses other types of displacement gages to measure the strain applied to the specimen. The strain-gaged specimen is discussed in Section 8.



NOTE 1—*w* equals width of specimen.
NOTE 2—*d* equals distance from edge of specimen to centerline of strain sensor.

FIG. 3 Locations of Strain Sensors on Specimens of Rectangular Cross Section (Numbers Indicate Positions of Strain Sensors)

The mechanical alignment fixture is described in Section 7. A description of the type of alignment measuring configuration (that is, strain gaged specimen or mechanical alignment fixture) should be included in the report. Strain gaged specimens usually provide better resolution of strain readings, particularly at low levels, than do alignment fixtures so they are more commonly used for this method of measurement. Specimen alignment is often viewed as a "fine" alignment.

7. Apparatus

7.1 When multiple strain sensors are used as in 6.1.2, specimen size limitations may dictate the use of electrical resistance strain gages rather than extensometers or alignment fixtures employing mechanical linkages. Strain sensors, such as mechanical, optical, or electrical extensometers, as well as wire resistance or foil strain gages, can provide useful displacement data. The sensitivity of displacement measurement required by an applicable standard or specification depends on the amount of bending permitted.

7.2 For verification using an alignment fixture as in 6.1.2, a single extensometer of the nonaveraging type may be used by rotating it to various positions around the perimeter during successive force applications and repeating the measurements as described in 10.5. In general, repeated force applications to strain levels approaching yielding are not good laboratory practice because they may affect the subsequently measured results by deforming or fatiguing the specimen.

NOTE 4—Repositioning the extensometer around the specimen does not usually give highly precise and reproducible results, but nevertheless is a technique which is useful for detecting large amounts of bending.

7.3 Mechanical fixturing for measurement of strain on a specimen can be an effective way to measure and allow for in situ adjustments to improve alignment on a test specimen. Fixtures that attach to the specimen shoulders and measure displacements at four equally spaced positions around the circumference of a cylindrical specimen have been effectively used for this purpose. Displacement measurement devices need to have sufficient resolution to detect very small differences in displacements around the specimen. If this method is used these displacements must be converted to strain before applying the bending calculations. Strain should be calculated using an effective gage length as described in ASTM E21.

NOTE 5—When multiple extensometers are used, the strain may be determined by arithmetically averaging outputs. Electrical outputs are thought to be more accurate and reproducible than mechanical outputs.

7.4 *Additional Machine and Fixturing Considerations*:

7.4.1 Poorly made components and multiple interfaces in a load train can cause major difficulty in attempting to align a test system. All components in the load train should be machined within modern machine shop practices with attention paid to perpendicularity, concentricity, flatness and surface finish. The number of components should be kept to a minimum.

7.4.2 Situations can arise where acceptable alignment cannot be achieved for a given machine, fixturing and specimen. In these cases, redesign and fabrication of any of the components may be needed to achieve acceptable alignment.

8. Test Specimen

8.1 This practice refers to cylindrical specimens, thick rectangular specimens, and thin rectangular specimens. The actual specimen geometry is dictated by the test standard to be used. These specimens are usually hourglass shaped with a reduced gage section, although other specimens such as those used for compression testing are acceptable.

8.2 This practice is valid for metallic and nonmetallic test specimens.

8.3 Quality of machining of test specimens is critical. Important features include straightness, concentricity, flatness, and surface finish. In particular, specimens used for compression testing may be of the type that uses two parallel plates to apply compression to the ends of the specimen. In these cases, the parallelism of the specimen ends is extremely important as described in ASTM Method E9.

8.4 The design of a strain gaged specimen should follow the same guidelines as design of standard test specimens. For static (tensile, compressive and creep) testing, specimens conforming to Test Methods E8 are appropriate. For fatigue testing applications, specimens conforming to ASTM E606 are appropriate. The strain-gaged specimen should be as close dimensionally to the expected test specimens as possible so that the same grips and fixturing to be used during testing will be used during alignment. The material used for the strain-gaged specimen should be as close as possible to expected test specimen materials. If the expected test material is not known, it is acceptable to use a specimen of a common material that has similar elastic properties to expected test materials. The alignment specimen should be carefully inspected and the dimensions recorded prior to application of the strain gages.

8.5 Strain Gages should be selected that have known standardized performance characteristics as described in Test Methods E251. Strain gage manufacturers provide detailed information about the strain gages available. Gages with gage lengths of approximately 10 % of the reduced section of the specimen or less should be selected. The gages should be as small as practical to avoid any strain averaging effects with adjacent gages. Temperature compensated gages that are all of the same type and from the same batch should be used.

8.6 Strain gages should be installed according to procedures outlined in Guide E1237. A commonly accepted method is to make precision shallow longitudinal marks by scribing where the strain gages are to be applied. The gages are then applied with the scribe marks as the longitudinal axis. This can also be used to mark the transverse axis. This method has the added benefit that the gage placements can be inspected at any time after the installation. Note that surface preparation is often required for mounting strain gages that can have an influence on subsequent mechanical properties. For this reason, the strain gaged specimen should not be expected to supply standard mechanical properties as a normal test specimen would.

8.7 Strain gages are to be arranged in at least two sets of four with each set mounted on one of two strain measurement planes. For cylindrical specimens, the gages are equally spaced at 90 degrees to one another around the circumference of the specimen. For thick rectangular specimens (that is, those with width to thickness ratios of less than three), gages are to be mounted in the center of each of the four faces. For thin rectangular specimens (that is, those with width to thickness ratios of three or larger), the gages are to be mounted on the two larger faces in pairs of back to back sensors that are equidistant from the specimen center line. Strain gage placement is shown in Fig. 3 for rectangular specimens. The sets of gages are to be spaced at a distance of 0.75× the reduced section length with each set positioned equidistant from the longitudinal center of the specimen.

NOTE 6—While the maximum bending strain is usually best measured using gages placed near the ends of the reduced section, a third set of gages located at the geometric center of the reduced specimen may also be used.

NOTE 7—For thick rectangular specimens, the differences in adjacent dimensions of the gage section can lead to differences in the sensitivities of gages on these surfaces. This in turn can lead to difficulties in making adjustments to bring a test setup into good alignment.

NOTE 8—Arrays of three gages at 120 degree spacing on cylindrical specimens are acceptable if there is a compelling reason to use this configuration. Caution should be taken with this configuration as adjustments to the test machine and fixturing become more complicated and less intuitive. In addition, it is more difficult to detect a malfunctioning gage.

NOTE 9—Geometry and dimensions of test specimens taken from different product forms are described in the Test Specimen section of Test Methods E8.

9. Calibration and Standardization

9.1 All conditioning electronics and data acquisition devices used for the determination of testing system alignment shall be calibrated where applicable. The calibration results shall be traceable to the National Institute of Standards and Technology (NIST) or another recognized National Metrology Institute.

9.1.1 Calibration of strain gaged specimens is very difficult and is not required by this standard. However, great care should be taken in the manufacture of strain gage specimens used for the determination of alignment. With the exception of cases where the gaged specimen is bent, the sources of measurement error due to individual gage misalignment and differences in gage sensitivity can be minimized by acquiring rotational and repeatability data runs.

9.2 Extensometers should be verified in accordance with Practice E83. Typically extensometers that meet the ASTM classification B-2 are adequate for most determinations of alignment.

9.3 Strain gages should conform to the requirements of Test Methods E251.

10. Procedure

10.1 Temperature variations during the verification test should be within the limits specified in the methods or practices which require the alignment verification.

10.2 *Machine Alignment*—This section describes the initial alignment of the rigid parts of the fixturing. Machine alignment is usually established when setting up a particular type of rigid fixturing configuration on a testing machine. While it often does not change appreciably over time, shock from catastrophic failure in the load train (within the fixturing or test specimen) or wear may establish the need to measure and readjust the machine alignment. Before continuing with subsequent fine alignment activities, one should always be sure that the machine alignment is acceptable.

10.2.1 Inspect all tooling for the ability of the force bearing surfaces to properly mate with one another and with the alignment specimen and subsequent test specimens. This includes but is not limited to concentricity, perpendicularity and parallelism measurements. Other measurements may be needed for specific types of grips and tooling. Re-machine specific parts of the fixturing if necessary.

10.2.2 Assemble the rigid portion of the fixturing, and inspect the position of the tooling on one end of the specimen attachment point with respect to the position of the tooling on the other end of the opposite specimen attachment point. This is often done with a dial indicator setup that allows the user to establish both linear (concentric or parallel) and angular differences between the centerlines of the tooling on each end of the specimen attachment points. Fig. 4 illustrates linear (concentric and parallel) and angular differences between the tooling on the two ends of the rigid portion of the test machine. Special alignment fixtures may also be employed. Specific tolerances are beyond the scope of this standard, but should adequate alignment be unachievable, misalignment of these components may be the reason. Test machines that allow the user to adjust the position of the normally fixed crosshead should be set up in the position that will be used during testing. Movement of the normally fixed crosshead during testing can affect alignment results. If moving the normally fixed crosshead during routine testing (that is, between specimens) is needed, the inspection should be performed several times to assure that movement can be made and the crosshead repositioned to the same location without appreciably affecting alignment.

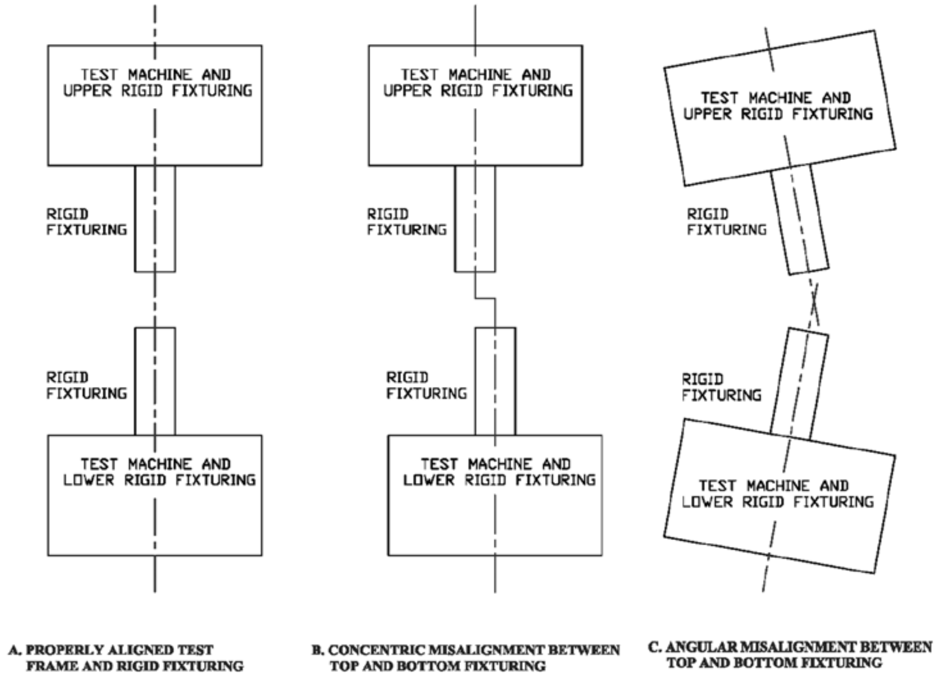


FIG. 4 Illustration of Test Machine Frame and Fixturing (A) Properly Aligned (B) With Concentric Misalignment and (C) with Angular Misalignment

10.2.3 Adjust the position of the tooling on one end of the specimen attachment point with respect to the position of the tooling on the other end of the opposite specimen attachment point to minimize the perpendicularity and the concentricity (cylindrical specimens) and parallelism (flat specimens). This may require loosening the attachment hardware of the fixturing of one end, tapping or shimming it into position and retightening it. Alignment adjustment fixturing is commercially available to facilitate this often-tedious process.

10.3 *Specimen Alignment*—This section describes the positioning and subsequent alignment of the specimen and all the non-rigid fixturing in the load train. It requires the use of either a strain gaged specimen of specific geometry or a specialized alignment fixture that uses other types of displacement gages to measure the strain applied to the specimen. The strain-gaged specimen is discussed in Section 8. The specialized alignment fixture is described in Section 7.

10.3.1 Inspect any tooling not already inspected as in 10.2.1 (the non-rigid parts of the assembly). Establish the position of the specimen for fixturing setups with non-rigid members by assembling the inspected parts of the load train. Connections, including the specimen should fit smoothly together with no extra play. Re-machine specific parts of the fixturing if necessary.

10.3.2 Mark the position of any portion of the fixturing that will be moved (that is, unthreaded or otherwise repositioned) during the course of normal testing relative to the fixed portion of the fixturing. This is to assure that the components can be put together the same way each time.

10.3.3 Inspect cylindrical specimens for concentricity and perpendicularity between gage section and loading surfaces. Inspect flat specimens for parallelism and perpendicularity between the gage section and the gripping surfaces. This is most often done using a machinist microscope or an optical comparitor. Other measurements may be needed for specimens of unusual configuration. Document results.

10.3.4 If a strain gaged specimen is to be used, select a suitable specimen based on inspection results and apply strain gages as described in Section 8. Since this can be a time consuming and expensive process it is best to have this step planned out well in advance of needing the strain gaged specimen.

10.3.5 Install the strain-gaged specimen or the specimen and the alignment fixture into the assembly. Zero the strain readings with no force applied to the specimen. It is best to do this with the specimen unattached from one of the sets of grips. The act of gripping a specimen on both ends can be enough to introduce unwanted bending.

10.3.6 Attach the specimen to the remaining grip.

10.3.7 Apply a small force to make sure all sensors are reading properly and then remove the force (see Note 3).

10.3.8 Plan the force application cycle such that the machine applies the maximum force expected during routine testing, unless this force induces plasticity in the test specimen. If the maximum expected test force is enough to induce plasticity in the test specimen, apply only enough force to well describe the alignment within the elastic region of the specimen. The actual force level in these cases should be agreed upon with the customer and well documented. This may be a tensile force, a compressive force, or both. The force may be applied either manually or automatically.

10.3.9 Apply the force cycle while recording strain measurements continuously if the recording equipment has the capability. If this is not possible, at least ten discrete points