
AMERICAN NATIONAL STANDARD

Shaft Alignment Methodology, Part 1: General Principles, Methods, Practices, and Tolerances

ANSI/ASA S2.75-2017/Part 1

Accredited Standards Committee S2, Mechanical Vibration and Shock

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Acoustical Society of America
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Secretariat:

Acoustical Society of America

Approved on June 6, 2017, by:

American National Standards Institute, Inc.

Abstract

This standard establishes methodology consistent with industry best practices for the measurement, analysis, and correction of alignment of shafts on rotating machinery coupled by means of a flexible coupling where such shafts are supported by two bearings in independent, horizontally mounted machine cases. Electric motors driving a pump, fan, or similar machine are examples of this type of machinery. Rigidly coupled machines are outside of the scope of Part 1 of this standard. The methodology addresses conditions for machinery mounting which directly affects shaft alignment, methods for measuring the amount of shaft misalignment, and practices for relocating machine cases to achieve proper shaft alignment. Tolerances are provided in a system of Alignment Quality Grades. Ancillary information for shaft alignment is provided in eight Annexes. Part 2 of this standard provides definitions of terminology unique to the alignment of machinery that has been in common use among engineers and technicians working in the field.

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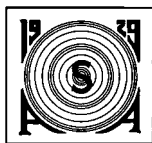
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Contents

1	Scope and purpose.....	1
2	Normative references.....	1
3	Terms and definitions.....	1
4	Safety.....	2
5	Measurement.....	2
5.1	Measurement methods and tools to determine offline shaft centerline positions	2
5.2	Optical methods.....	3
5.3	Measurement repeatability	3
5.4	Factors affecting measurements	3
5.5	Calibration.....	4
6	Factors that influence the response to alignment corrections	4
6.1	Machinery structural supporting system.....	4
6.2	Machinery degradation	7
6.3	Vibration from nearby machinery.....	7
7	Analysis.....	7
7.1	Alignment needs assessment.....	7
7.2	Alignment condition assessment.....	8
7.3	Alignment modeling	13
8	Correcting misalignment conditions.....	13
8.1	Equipment hold-down bolts (foot bolts)	13
8.2	Bolt bound / base bound.....	14
8.3	Controlled movement techniques	14
8.4	Axial spacing or coupling gap.....	14
9	Documentation.....	14
Annex A	(informative) Alignment principles	16
A.1	Shaft centerline geometry.....	16
A.2	Tolerances	18
A.3	Machine casing distortion	19
Annex B	(Informative) Formulas for calculating the moves at the feet from raw readings at the shafts.....	21
B.1	Single unit movement correction mathematics.....	21
Annex C	(Informative) Identifying and correcting pipe strain when performing shaft alignment on pumps.....	24

Annex D (Informative) Offline to running (OLTR) machinery movement	26
D.1 Mechanical changes that may occur quickly from offline to running	26
D.2 Thermal changes that occur slowly	26
D.3 Determining OLTR movement	26
Annex E (Informative) Laser-detector systems	32
Annex F (Informative) Alignment modeling solutions	35
F.1 Alignment modeling basic concept	35
F.2 Practical modeling solutions	35
Annex G (Informative) Repeatability	41
Annex H (Informative) Alignment and machinery installation checklist	42

Tables

Table 1 — Guidelines for levelness, flatness, coplanarity of general process machinery	5
Table 2 — Shaft runout tolerances	6
Table 3 — Shaft-to-shaft alignment tolerances for common RPM values expressed in angle at flex plane	12
Table 4 — Shaft-to-shaft alignment tolerances for common RPM values for coupling span 3 inches or greater, or for couplings with elastomeric CML expressed as offset and angularity	13

Figures

Figure 1 — Standard shim sizes and dimensions	6
Figure 2 — A comprehensive approach to alignment condition assessment	9
Figure 3 — Flex planes, span and coupling mechanical link (CML)	10
Figure 4 — Offset at the midspan and angularity, for horizontal and vertical planes	10
Figure 5 — Misalignment represented as angles at the flex planes: $angle\ A(or\ B) = \frac{offset}{span} \left(\frac{mils}{inch} \right)$	11
Figure 6 — Alignment quality grades illustration	11
Figure A.1 — Offset at the midspan and angularity, for horizontal and vertical planes	17
Figure A.2 — Misalignment represented as angles at the flex planes.	17
Figure A.3 — Shaft centerline positions using orthogonal dimensions.	18

Figure A.4 — Actual misalignment and orthogonal misalignment	19
Figure B.1 — Single unit movement misalignment corrections for the Face – Rim method.	21
Figure B.2 — Single unit movement misalignment corrections for the Reverse Indicator method.	22
Figure B.3 — Single unit movement misalignment corrections for the Double Radial method.	22
Figure B.4 — Single unit movement misalignment corrections for the Shaft to Coupling CML method.	23
Figure B.5 — Single unit movement misalignment corrections for the Face – Face method.....	23
Figure D.1 — Thermal strain equation.....	27
Figure D.2 — OLTR movement on a motor and a pump.....	28
Figure D.3 — Desired offline side view of motor and pump.	29
Figure D.4 — Desired offline top view of motor and pump.	29
Figure D.5 — Sign conventions for OLTR offline values.	30
Figure D.6 — VO-VA offline offset and angularity values.....	30
Figure D.7 — HO-HA offline offset and angularity values.	31
Figure E.1 — Laser, detector, and roof prism method.....	32
Figure E.2 — Single laser, dual detector method.	33
Figure E.3 — Dual laser, single detector method.	33
Figure E.4 — Dual laser, dual detector method.....	34
Figure F.1 — A basic model of a simple motor-pump machine. Foot corrections are shown based on the offset and angularity at the coupling.	35
Figure F.2 — Fan and motor drive system	36
Figure F.3 — Side view alignment model of the fan and motor drive system showing the dimensional information.	37
Figure F.4 — Side view alignment model showing both the offline and running shaft positions.....	38
Figure F.6 — Side view alignment model showing the running shaft positions (red lines), the bore centerline of the fan housing (dashed pink line), the vertical movement restrictions (top edge of translucent orange boundary condition layer), the final desired alignment line (dashed purple line), and the corrective vertical movement solutions.	39
Figure F.7 — Top view alignment model showing the running shaft positions, the bore centerline of the fan housing, the lateral movement restriction, the final desired alignment line, and the corrective lateral movement solutions.	40

Foreword

[This Foreword is for information only, and is not a part of ANSI/ASA S2.75-2017/Part 1 American National Standard Shaft Alignment Methodology, Part 1: General Principles, Methods, Practices, and Tolerances. As such, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the standard.]

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This standard is not comparable to any existing ISO Standard.

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American National Standard

Shaft Alignment Methodology, Part 1: General Principles, Methods, Practices, and Tolerances

1 Scope and purpose

This Standard is the application of alignment concepts concerning relative positions of rotating shafts connected by mechanical means. It contains specific tolerances, factors affecting alignment, and an overview of various measurement methods, following the core technical components of Measure, Analyze, Correct, and Document.

The intended users are craftspersons, front line supervisors, maintenance managers, procedure writers, construction managers, and engineers who design, install, or maintain rotating machinery.

The potential consequences of not following this standard are accelerated wear of machine components (bearings, couplings, and seals), shortened machine life, unscheduled outages, and hazards to personnel.

This standard covers the general configuration of two machines (usually horizontal) and four-bearing systems with rotating shafts. It does not cover vertical machines, strategies for aligning multiple (three or more) machine train systems, large and heavy machines with significant shaft sag, Cardan shaft with universal joints, three bearing machines (diesel generator sets), nor bore alignments. The principles presented here may also be applicable to these other machine configurations.

The purpose of this standard is to establish guidelines of acceptability for alignment of rotating machinery. The guidelines are based on industry best practices and experience gained in reliability. The requirements and recommendations placed here are intended to result in consistent and uniform final operating conditions at the machine.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI/ASA S2.75-2017/Part 2 – Shaft Alignment Methodology, Part 2: Vocabulary

ANSI/ASME B4.1-1967 (R2009) Preferred Limits and Fits for Cylindrical Parts

ANSI/ASME B17.1-1967 (R2013) Keys and Keyseats

ISO 21940-32:2012 Mechanical vibration – Rotor balancing – Part 32: Shaft and fitment key convention

3 Terms and definitions

For the purposes of this standard, the terms and definitions in ANSI/ASA S2.75-2017/Part 2 apply, in addition to the following:

3.1 radial measurements

A measurement taken perpendicular to the axis of rotation

3.2 axial measurements

A measurement taken parallel to the axis of rotation

3.3 OLTR (offline to running machinery movement)

The amount to which the centerline of a machine shaft moves from the ambient temperature and stopped condition to the normal speed, load, and temperature state

4 Safety

All persons and parties involved, at minimum, must remain vigilant and comply with applicable national, regional, local, and corporate safety rules, policies, and directives.

5 Measurement

The measurements described here are mechanical in nature and describe the geometric features that define and affect shaft alignment. There are many types of rotating machine systems and all parameters cannot be fully identified. Below is a list of what should be measured on typical systems, where applicable, to understand the existing conditions and how to proceed.

1. Base flatness and level
2. Shaft runout
3. Coupling runout
4. Pipe and conduit strain
5. Soft foot
6. Offline To Running (OLTR) machinery movement
7. Shaft centerline to shaft centerline

These parameters and applicable tolerances are defined in this section along with acceptable measurement methods.

5.1 Measurement methods and tools to determine offline shaft centerline positions

Acceptable electronic measurement tools to determine offline shaft centerline positions may include: laser-detector systems, dial or digital indicators, and linear or rotational encoders. Annex E contains information on the basic operating principles of laser-detector systems.

Acceptable mechanical measurement tools to determine offline shaft centerline positions may include: micrometers, calipers, feeler gauges, taper gauges, and dial indicators.

The chosen tool(s) shall measure either two radial measurements, one radial measurement and one axial measurement, or two axial measurements. Several combinations of the above orientations are possible. Annex B contains illustrations showing some of these measurement methods.

Ideally both shafts should be rotated with the coupling disengaged. The second choice would be to rotate both shafts with the coupling engaged. The third choice would be to rotate only one shaft. The least desirable choice is to rotate neither shaft.

5.2 Optical methods

Optical methods of performing measurement of a rotating shaft are considered possible, however, not practical. Optical methods of measuring machine case position are effective for determining OLTR data. Optical tooling can be used to measure levelness, flatness, and coplanarity of baseplates.

5.3 Measurement repeatability

Alignment measurements shall be repeatable. Repeatability shall be verified during initial alignment and final alignment.

During the final measurement, a deviation in repeatability of less than 0.03 mm (1 mil, 0.001 inch) shall be demonstrated to determine conformance to this standard.

The machine system and measurement fixture may exhibit some hysteresis during the first measurement cycle. Therefore, it is advisable to discard the first measurement cycle.

A deviation of less than 10 percent of the total excursion is desirable when taking initial measurements when some gross misalignment is present. Subsequent measurements should also improve with 0.03 mm (1 mil, 0.001 inch) repeatability specified to be the requirement to satisfy the tolerances in this standard.

Repeatability and calibration are separate and independent concepts. Calibration is an inspection and adjustment of the measurement device compared to a known reference; it is a verification that the displayed results are correct. Repeatability, on the other hand, is an inspection of the secure installation of the measuring device on the machine shafts, the variability of the machine when the shafts are manually turned, and the mechanical integrity of the machine itself. Repeatability may also be affected by the skill of the person in taking readings.

5.4 Factors affecting measurements

There are several factors that affect the accuracy of the shaft centerline position measurements obtained with either electronic or mechanical measurement tools and methods. The object of shaft alignment is to align the shaft rotational centerlines. If a shaft is not rotated, the true centerline of rotation of that shaft may not be determined if shaft or coupling hub runout issues exist. Shaft runout can only be detected by rotating the shaft; thus if it is impractical to rotate a shaft, errors from shaft runout cannot be detected or eliminated. To eliminate the runout effect, the measurement device shall be maintained at the same angular position on a shaft or coupling hub when rotating the shafts.

When shafts are coupled and rotated together, gross amounts of misalignment may force a shaft to be in a position inside a journal bearing where it would not normally run. For shafts supported in either journal or rolling element bearings, gross amounts of misalignment may elastically bend the shafts resulting in erroneous results. When axial measurements are made and shafts are rotated, any axial movement of the shaft can result in errors. Various methods of indicating or minimizing axial shaft movement can eliminate such error in most cases.

All measurements produce an offset relative to some distance. For radial measurements the relative distance is the separation between measurement points. For axial measurements the relative distance is the radius at which the measurement is made. The greater the distance, the greater the precision of the measurement.

Any mechanical brackets that span across a flexible coupling may be subject to bracket sag. The effect of bracket sag should be measured and the necessary compensation applied to the readings. Bracket sag affects readings taken on shafts oriented perpendicular to the lines of gravitational force. The common technique for measuring bracket sag is to mount the bracket and measuring tool assembly on a rigid shaft

of similar diameter as it would be configured across the coupling. By rotating the rigid shaft and noting any deviation of readings on both sides and the bottom, the bracket sag effect can be measured and hence compensated.

Straightedges, feeler gauges, gauge blocks, and calipers have been used successfully under ideal conditions, but are subject to variability that limits accuracy needed to meet tolerances stated in this standard. These tools are acceptable for initial “rough” alignment work and can meet the tolerances in this standard but it depends heavily on the care, skill, and aptitude of the alignment technician.

5.5 Calibration

Dial indicators, feeler gages, and straight edges do not need to be periodically checked for accuracy. Dial indicators, however, shall operate freely and not stick or bind. Micrometers and calipers require periodic calibration. Laser, electronic, and optical systems that transduce the physical measurement parameter into different proportional values shall be periodically compared to a reference standard to verify measurement accuracy according to manufacturers’ recommendations.

6 Factors that influence the response to alignment corrections

6.1 Machinery structural supporting system

The base shall be inspected for damage, integrity, corrosion and stability. The foundation should provide a mass large enough to hold the machinery in a stable position and absorb normal vibration from the machinery during operation. The machinery may be supported on a contiguous baseplate or on separate soleplates, chock plates, or on a structural frame. For land-based rotating machinery drive systems, there is frequently a desire and or requirement that the structure the machinery is attached to be level, flat, and coplanar. The contact surfaces should be measured for levelness, flatness, and coplanarity using precision levels, optical alignment tooling, or laser-detector leveling tools. For small bases (i.e., less than 4 feet in length and width), straightedges and precision levels may be used to measure.

Non-coplanarity, levelness and flatness can be accommodated with corrective shimming methods, as provided in the section on shims. In severe cases, machining may be necessary.

Corrosion or fretting damage cannot be corrected with shims, and machine feet or base pad surface reconditioning may be required to restore flatness.

NOTE 1 It is understood that the alignment technician may not have the opportunity to inspect the base with the machine units removed thus making this a subjective judgment. This inspection is still valuable information for analysis and documentation.

NOTE 2 It is recommended that rotating machinery bases be grouted for stability.

NOTE 3 The alignment technician has little control of the base design. The technician should be alert to possible flexibility in the support structure that can amplify resonance or vibration and affect the repeatability of the measurements.

6.1.1 Level

Level describes the condition of being in a horizontal plane in relation to the earth’s surface. Although not a requirement, it is a recommendation that, when applicable, all machine bases be installed level to a horizontal plane, as a common reference.

6.1.2 Flatness

Flatness describes the conditions of surface irregularities of a contact surface, foot or base pad. These surfaces may be bowed, crowned, or twisted which will affect how much surface area is making contact between the base and the machine feet. It also describes a condition where corrosion or fretting has damaged the surface of the foot or pad.

6.1.3 Coplanarity

Coplanarity describes the condition of the machine's supporting systems (i.e., bases) contact surfaces, foot pads, and soleplates, etc., being in the same plane (coplanar) with each other or of being parallel with no angularity. For example, when a machine is placed on these surfaces, all feet of the machine case are in full contact and bear proportional load. The extent to which machine case feet, when placed on the base, do not bear proportional load is referred to as non-coplanarity. Non-coplanarity is a common cause of soft foot and the associated problems.

6.1.4 Level, flatness, and coplanarity limits

The base should provide a flat surface for each foot and coplanarity between the feet to avoid distortion to any machine case that rests on the base. For new machine installations, or whenever a machine case is removed from the base, the level, flat, and coplanarity specifications in Table 1 should be met. Corrections for coplanarity can be made with shims.

Table 1 — Guidelines for levelness, flatness, coplanarity of general process machinery.

Machinery type	Recommended levelness	Recommended foot flatness	Coplanar surface deviation (shimmed)
General process machinery up to 400 kW or 500 HP	$\leq 0.8 \mu\text{m/mm}$ ($\leq 10 \text{ mils/ft}$)	$\leq 0.4 \mu\text{m/mm}$ ($\leq 5 \text{ mils/ft}$)	$\leq 50 \mu\text{m}$ ($\leq 2 \text{ mils}$)
General process machinery 400 kW or 500 HP or above	$\leq 0.4 \mu\text{m/mm}$ ($\leq 5 \text{ mils/ft}$)	$\leq 0.2 \mu\text{m/mm}$ ($\leq 2 \text{ mils/ft}$)	$\leq 50 \mu\text{m}$ ($\leq 2 \text{ mils}$)

6.1.5 Shims

The area of the shim should not be smaller than 80 percent of the area of the machine foot where it is to be placed. It is recommended to accurately measure the thickness of shims that are greater than 0.5 mm (0.020 inches). It is also recommended to accurately measure the entire shim stack to verify total thickness.

Shims should be in clean, smooth condition. Used shims should be discarded if damage is evident.

No more than 5 total shims shall be placed under any machine case foot, excluding the shims to correct angle foot conditions. No more than 1 of those shims shall be less than 0.08 mm (0.003 inches) thickness. The sum of the three thinnest shims shall be 0.25 mm (0.010 inches) or greater.

Standard shim sizes are illustrated in Figure 1. It may be necessary to field fabricate shims from rolled or flat shim stock. Care must be taken to keep fabricated shims uniform in thickness without burrs or raised edges.

Metric			
Designation	L (millimeters)	W (millimeters)	S (millimeters)
A	50	50	15-25
B	75	75	25-35
C	100	100	35-45
D	125	125	40-55
English			
Designation	L (inches)	W (inches)	S (inches)
A	2	2	0.625-0.750
B	3	3	0.875-1.250
C	4	4	1.25-1.50
D	5	5	1.50-1.75
E	6	6	1.75-2.25
H	8	8	2.50-3.25

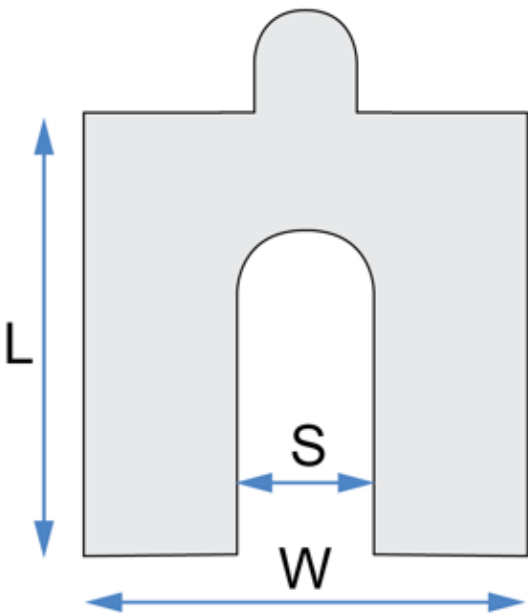


Figure 1 — Standard shim sizes and dimensions

6.1.6 Shaft runout

The shaft shall not exhibit TIR (Total Indicator Reading) greater than the limits of Table 2. The shaft should be straight along its exposed extension in accordance with Table 2.

Table 2 — Shaft runout tolerances

Shaft runout tolerance	Shaft diameters up to and including 160 mm (6.25 inches)	Shaft diameters over 160 mm (6.25 inches)
Standard	50 μ m (2 mils) TIR	75 μ m (3 mils) TIR
Precision	25 μ m (1 mil) TIR	25 μ m (1 mil) TIR

6.1.7 Coupling hub runouts

The condition of the coupling is not relevant to any rotating centerline measurements since that method detects the rotating shaft centerlines directly. The lack of good coupling geometry can affect vibration and wear; however, it does not affect the measurement of shaft centerlines.

The geometric condition of the coupling does affect the face and rim measurement process if the shafts are not rotated together. That is, if the coupling is disconnected and the dial indicator measures on the coupling as one shaft is rotated and the other shaft is not, then the dial indicator tip rides on the surface of the coupling and irregularities in its shape corrupts the measurement.

NOTE 1 One technique to avoid this error when using dial indicators is to rotate both shafts together (even though they are disconnected) and take every measurement with the dial indicator tip located on the same point at each measurement position.

It is the responsibility of the alignment technician to determine the condition of the coupling surfaces with both axial and radial runout measurements, if both shafts are not rotated together, and to determine if the final aligned condition of the machine centerlines defined here are obtainable. Coupling face and outside diametrical runout tolerances are not applicable to shaft centerline alignment.

NOTE 2 Coupling to shaft fits are not addressed in this standard. Refer to manufacturers' recommendations or ANSI/ASME B4.1.

NOTE 3 Key and keyway fits are not addressed in this standard. Refer to ANSI/ASME B17.1 and ISO 21940-32.

NOTE 4 Non-concentric bores and non-perpendicular faces affect the wear and vibration during operation, but the shafts can be aligned to be collinear.

6.1.8 Pipe strain, conduit strain, duct strain, and other external forces

External forces from piping strain, flange strain, conduit strain, attached ductwork, etc., applied to machine cases subject to shaft alignment tolerances, shall not be sufficient to cause changes in the shaft alignment of magnitude greater than 50 micrometers (2 mils) vertical or horizontal measured at the coupling.

6.2 Machinery degradation

Machines which require alignment corrections may have additional mechanical faults which will affect the alignment process. Extended operation with significant misalignment, unbalance or other machinery fault often results in excessive clearances, looseness, bearing damage, and related ancillary faults that cause non-repeatability in the shaft alignment measurements. Any such ancillary faults should be corrected before proceeding with the shaft alignment process.

6.3 Vibration from nearby machinery

Measurement systems are sensitive to vibration. Running machinery in proximity to the equipment being aligned nearby may impose vibration into the shaft alignment measurement process, distorting results or possibly preventing electronic systems from operating properly.

7 Analysis

There are two general situations where decisions are made concerning shaft alignment. The first is a broad overview of the machine system to determine the alignment needs. The second is an assessment of measurement data as compared to tolerances to determine if the system alignment is acceptable.

7.1 Alignment needs assessment

All new machine system greater than 3.75 kW (5 HP) shall be adequately aligned prior to being placed into service. However, it is recommended that all rotating machine systems be aligned.

Whenever a machine is moved—i.e., unbolted from its support structure—the shaft alignment shall be verified for compliance to this standard prior to being placed in service.

Whenever a machine system experiences unacceptable wear or vibration, misalignment should be considered as a possible root cause or contributor. If warranted, verification of the alignment could be