ELASTOMERIC COUPLING ALIGNMENT "PRIMER"

1999

MECHANICAL POWER TRANSMISSION ASSOCIATION
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Elastomeric Coupling Division
Technical Information Bulletin

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Introduction

This paper is intended for individuals who need to understand the need for coupling alignment, types of misalignment, factors that affect alignment, and basic practices to achieve alignment of equipment. By presenting basic principals in an organized fashion, it is hoped that one will understand general aspects of coupling alignment. There has been much debate over what is the “theoretical ideal” for coupling selection which many times can relate back to the effects of coupling misalignment on a system. For example, the alignment of one coupling type may be suitable for a certain application. However, when the user switches to a different coupling type and follows the same alignment practices, the user may experience premature machinery problems resulting from unexpected conditions including excessive vibration, heat build up, and loading of bearings on connected machinery. Therefore, it is critical that both the manufacturers of the coupling and the parties that are specifying the coupling understand the system and the effects that alignment will have on the system. Furthermore, the selection process must include variables such as the level of resources available, economic constraints, and machinery accessibility among other factors that play an important role in the task of achieving and maintaining the desired benefits of equipment alignment.

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SECTION I - Common Terms to Know

Flexible coupling
A mechanical fastening device used to connect two shafts for power transmission that accommodates the misalignment between the shafts.

Elastomer
A polymeric material, such as synthetic rubber or plastic, which at room temperature can be stretched at low stress to at least twice its original length and, upon immediate release of the stress, will return to its approximate original length.

Elastomeric coupling
A flexible coupling which uses an elastomer for power transmission between two objects and accommodates misalignment between the axis of rotation of each object through elastomeric materials.

Alignment (of rotating objects)
A measure relating the deviation of the axis of rotation of one object from forming a perfect line with the axis of rotation of another object.

Angular Misalignment
The condition, which exists when the centerlines of connected shafts, are neither parallel nor co-axial.

Offset Misalignment
The lateral displacement in either the horizontal or the vertical plane between non-intersecting axis of connected shafts.

Axial Stiffness
An object's resistance to axial displacement, measured in pounds per inch.

Radial Stiffness
Measure of a coupling's resistance to parallel offset. Measured in pounds per inch.

Power plane (coupling)
Plane at a coupling interface where power is transmitted from one object to another.

Dial Indicator
Gage with a calibrated circular face to provide pivoted pointer readings.

Indicator Sag
Indicator Sag indicates the magnitude of the error of indicator reading due to the weight of the indicator, rod deflection, and possible loose connections

SECTION II – Discussion on Alignment and Permissible Misalignment

Alignment of rotating objects is achieved when the axis of rotation of one object is "in-line" with the axis of rotation of the connecting object. Our concern is aligning machines having a coupling interface that consists of material combinations such as; rubber, steel, plastic, nylon, iron, or an elastomer that is utilized for the connection of these objects. When a coupling is manufactured each of its components has built in tolerances which can effect the ease of installation, resulting forces on connected machinery, heat generation, vibration, and overall life of the connected machinery. Additionally, machining tolerances inherent in machined components make it very difficult for precise alignment. This primer attempts to show that perfect alignment in dynamic situations may be impossible to maintain. However, logistical tactics can be employed to minimize the amount of misalignment and the resulting effects on equipment life.

A couplings permissible misalignment has many defining attributes. Some qualifications include torque transmitted, requirements of connected equipment, rotating speed, duty cycle, heat dissipation and capacity, and coupling type and design characteristics. Couplings allow misalignment in three ways, either from clearances between surfaces allowing relative movement between components, flexing of elements, or a combination of both. The amount of relative motion or flexing of the element ultimately determines the life of the coupling. The heat generation and wear are proportional to the torque transmitted, vibration level, and speed of the rotating objects. Factors such as these force many coupling manufacturers to adjust the amount of permissible angular and parallel offset misalignment as a function of the speed, duty cycle, … when utilizing the nominal torque capacity.

This primer attempts to further emphasize the alignment of elastomeric couplings and the role elastomeric couplings have in misaligned applications. Elastomers generally offer viable solutions for misaligned conditions because elastomers by definition can be stretched to great displacements at very low stress, thereby permitting higher alignment deviations and lower reactionary loads. However, great caution must still be applied to the amount of misalignment because a slightly different elastomeric coupling may offer vastly different permissible misalignment.

Importance of Alignment

The primary goal of aligning equipment is to increase the life of the connected machinery and its associated components.

Some of the effects on misaligned equipment include:

1. Material fatigue
    - Size and shape, frequency of flexing, ambient temperatures, and the ability of the material to absorb and/or transfer heat effect material life.

2. Excessive Vibration (See MPTA publication on "Balancing Primer", 1998)

- Excessive vibration due to a misaligned condition results in exponentially greater forces on connected machinery.
- Flexing elements are forced to absorb energy created from machinery vibration.
- Bearings and shafts of connected machinery are forced to absorb vibratory forces.

3. Premature seal failure
   - Seal material, much like elastomeric coupling elements, is forced to flex repeatedly causing heat build-up and potential premature failure.

4. Loading of connected machinery
   - The combined loading due to axial and radial forces induced by misalignment is proportional to the element size and stiffness.
   - The L_{10} bearing life is inversely proportional to the cube of the force created.

The ultimate goal of spending capital on setting up and maintaining equipment is to increase equipment life, reduce downtime, and reduce operating costs leading to increased efficiencies and profit levels. Qualified systems personnel must determine the machine train characteristics and individual component attributes to determine the allowable alignment deviation that is still within compliance of individual manufacturer's recommendations to achieve these goals.

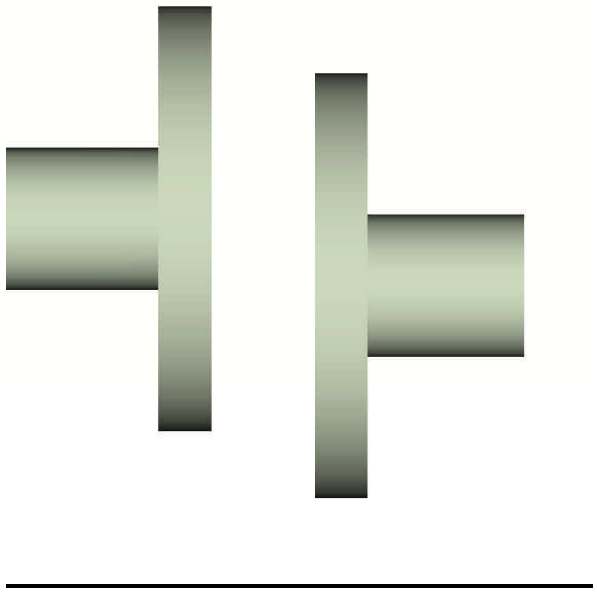
Alignment Considerations

<u>System and machinery characteristics that influence alignment considerations include:</u>

- Operating temperatures of system and thermal changes
- Mounting surfaces – single or multiple bases, flexible mounts, flatness of base, and base rigidity
- Number of pieces of connected machinery that require alignment and determining which component will be fixed.
- Bearing supports – number of supports, locations of supports, and distances from power transmitting elements
- Condition of equipment– shaft/bore clearances, bent shafts, worn bearings, …

SECTION III – Types of Misalignment

PARALLEL OFFSET MISALIGNMENT

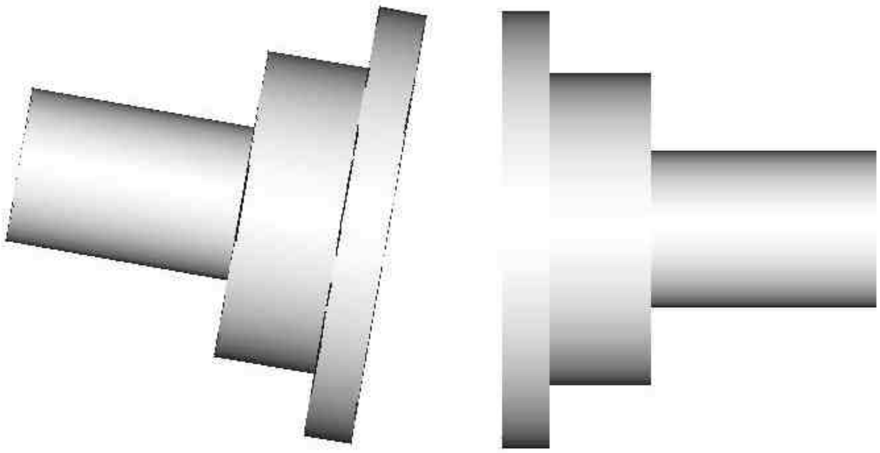


Parallel Offset misalignment is when two objects are parallel but not in the same plane. The two types of parallel offset are horizontal and vertical. The magnitude of the misalignment is the deviation from one datum axis to the other.

- Horizontal offset can be characterized as the side to side misalignment as viewed when looking from the top of the coupling towards the baseplate below.
- Vertical offset can be characterized as the up and down misalignment as viewed from either side of the coupling.
- The amount of parallel offset that a coupling can accommodate is proportional to the distance between power planes.

Whether a coupling can accommodate parallel offset misalignment is a function of the number of flexing planes, internal clearances between coupling components, radial stiffness of torque transmitting element.

ANGULAR MISALIGNMENT

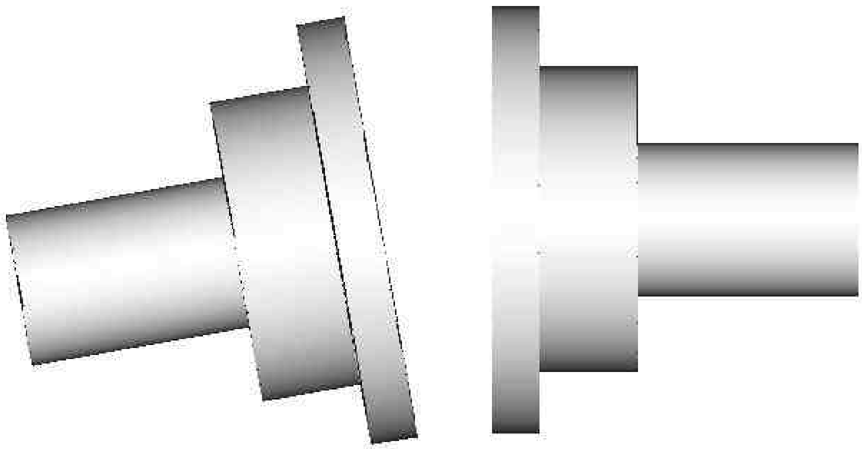


Angular misalignment is when the datum axes of two objects are neither parallel nor co-axial. There are two types of angular misalignment, horizontal and vertical. The amount of misalignment can be calculated from indicator readings taken and related to the angle between datum axes. Angular misalignment can be further distinguished from offset misalignment by the relevance of reference locations such as indicator positions and foot mounting locations. Angular misalignment varies at different measurement locations and these locations must be accounted for, whereas offset misalignment is the same.

- Horizontal angular misalignment is determined as viewed when looking from the top of the coupling towards the baseplate below.

- Vertical angular misalignment is determined as viewed from either side of the coupling.

PARALLEL OFFSET & ANGULAR MISALIGNMENT



Combined Misalignment includes horizontal offset, vertical offset, horizontal angular, and vertical angular misalignment.

The combined alignment tolerance must be determined by coupling type and according to the coupling manufacturers maximum permissible misalignment.

SECTION IV – Comparison of Alignment Methods

Our discussion will show the methodology behind three of the most common methods of machinery alignment. The methods are the straight edge method, reverse rim alignment method, and the rim and face alignment method. As mentioned earlier, the goal is to increase equipment life, reduce downtime, and reduce operating costs leading to increased efficiencies and profit levels by aligning equipment. There must be a coordinated effort between equipment manufacturers to determine if the alignment method chosen will lead to the system reliability to meet this goal. Brief descriptions of three methods are shown below.

Straight Edge/Feeler Gage Method

A method of alignment in which a straight edge and/or feeler gages is used to determine the amount of angular and offset misalignment that is present between two datum axes. The advantage of this method is that alignment is quick and no specialty tools are required.

Reverse Rim Alignment Method

A method of alignment in which two dial indicators are used, one of which is mounted on a revolved feature of the driven equipment and the dial indicator pointer extends to a revolved feature on the driving equipment. The other dial indicator used is mounted exactly in reverse of the first indicator. The objects are then rotated simultaneously about the datum axes in order to obtain the amount of deviation between the datum axes. The readings are then recorded and the amount and type of corrections to align the datum axes is calculated using either mathematical formulas or graphical plots.

Rim and Face Alignment Method

A method of alignment in which a dial indicator or a set of dial indicators is used to align two datum axes. One indicator is mounted on a revolved feature of the driven equipment and the dial indicator pointer extends to a revolved feature on the driving equipment. The other indicator is mounted to the driven equipment and extends so that the dial indicator pointer extends to the face of a revolved feature on the driving equipment. The readings are then taken and the amount and type of corrections to align the datum axes is calculated using either mathematical formulas or graphical plots.

Laser Alignment

Laser optic alignment devices use a laser beam and information is fed to a microprocessor to indicate adjustments that need to be made. The advantage of laser alignment is speed of alignment and precise alignment. The drawbacks are cost of alignment equipment and training required. This primer will focus on dial indicator and the straight edge methods of alignment.

Section V - ALIGNMENT

A Starting Point

Find out system characteristics
- Obtain drawings and installation bulletins
- Thermal characteristics
- Facts on connected machinery
- Type of coupling and installation facts on coupling

Checks and Measures
- Measuring equipment calibrated
- Check bores and keyways
- Check all dimensions that will ensure coupling will mate properly to equipment
- Ensure that readings are taken from a good clean surface with minimal runout
- Check that bolt, shims, … that protrude from mounting bases will not interfere with coupling guards
- Check for soft foot, insufficient foundation strength, loose foundations or supports
- Determine component spacing
- Make rough alignment, if possible

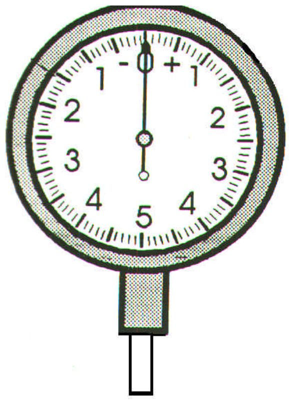
Determine tools needed and the process to follow:
- The tools that are accessible
- Obtain any tools and/or hardware needed
- Where the equipment will be assembled
- Determine if all the parts required are at the site
- Determine locations and accessibility for mounting of hardware
- May want some type of mirror to view indicate in hard to read areas

Common Tools Required (dependent on alignment method employed)

- Dial indicator with desired mounting hardware
- Shim kit
- Micrometers, Precision straight edge, feeler gages, levels
- Lifting and moving aids – jacking bolts, pry bar, adjustment hardware, rubber mallet, and hydraulic lift, … depending on the size of equipment, accessibility to power, working environment and other factors.

Understanding a dial indicator

Reading a Dial Indicator



A Dial Indicator reads parallel to its stem (plunger)
Increments shown represent .001", one full revolution = .100"

- A positive reading indicates that the plunger is pushed inward and the dial rotates in a clockwise manner, thus indicating a positive reading.

- A negative reading indicates that the plunger is extended outwardly and the dial rotates in a counter clockwise manner indicating a negative reading.

- Dial indicators have many different face designs and maximum indicator travel. It is important to become familiar with the dial indicators and other measuring devices that you are going to use.

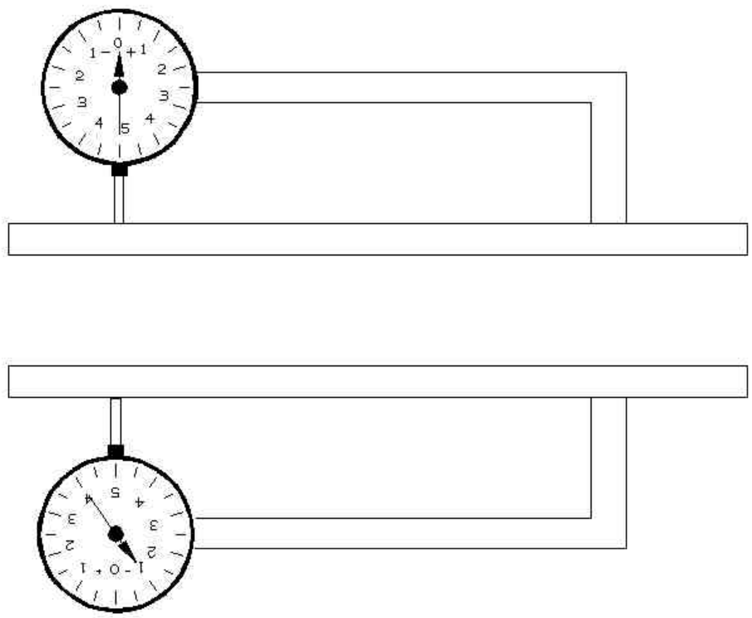
- For the case where a dial indicator is mounted on the driven equipment and the plunger touches a surface on the driving equipment. A positive value of the difference between the top and bottom readings would indicate that the plunger is depressed greater at the top, thus the axis of the driving equipment (indicator plunger contacts this equipment) is higher than the driven equipment.

Other Helpful Hints when using a Dial Indicator

- Adjust indicator face to zero. Rotate shaft one complete revolution and note the maximum positive or negative value. Return the shaft to location of maximum value and readjust face to zero.
- Rough align equipment to ensure that equipment to ensure that equipment alignment is within the indicator total travel.
- Make sure that supporting hardware is reliable and rigid. Areas of attachment should be large enough for indicator supports and clean for mounting.

Calculating Indicator Sag

- Determine amount of indicator sag before beginning. (See method below)



Example above shows the indicator reading zeroed in the 12:00 position
And an indicator reading of -.010 in the 6:00 position

- The amount of indicator sag is determined by clamping the indicator to a rigid bar and rotating the bar 180 degrees from top to bottom. The difference in the top and bottom readings is the amount of sag. In the above example, it should be noted that the amount of sag is .010 and any future bottom measurements adjusted accordingly.

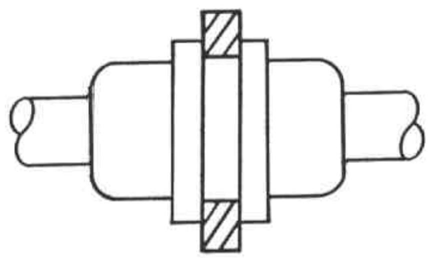
Understanding and calculating runout

Any surface that is going to be utilized for alignment purposes should be checked for runout. The amount of runout can vary greatly due to manufacturing processes and design tolerances. Therefore, to accurately align two pieces of equipment one must first make sure the surfaces that are being used as references are clean and manufactured to an acceptable limit to achieve the desired alignment.

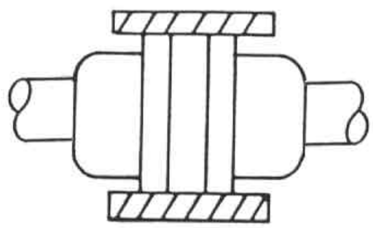
- Mount the dial indicator on the driven equipment with the indicator extending so that the plunger/stem is on the surface that will be used for alignment. Rotate the equipment that the indicator plunger is contacting one complete revolution-making

- note of the maximum indicator reading. Zero the indicator at the location of the maximum reading. Repeat the previous step and record the total indicator runout of the driving equipment. The readings should be reviewed to ensure that a good-machined surface is being used and that the equipment falls within the manufacturers tolerances.
- Remount the indicator on the driving equipment and repeat the above process to get the runout of the driven equipment.

Straight Edge / Feeler Gage Method of Alignment



Step 4: Measure between flanges



Step 6: Straight edge over flanges

STEPS

1. Take rough alignment check with straight edge to determine which unit to align and which unit to fix. The unit with the higher shaft centerline should now be fixed.
2. Complete rough alignment of the unsecured unit by setting up the proper gap and using a straight edge to roughly align the unit in both the horizontal and vertical directions. Shims may be required.
3. Tighten the equipment down to the foundation or baseplate assembly.
4. Mark both pieces of equipment for the 12:00, 3:00,6:00, and 9:00 positions.
5. Use either calipers or feeler/block gauges to record the distance between flange ends in the 12:00 and 6:00 locations (Do not rotate the equipment). The (2) measurements should be taken at approximately the same distance from the flange diameter and the diameter noted. These measurements will be used to determine the correction required for angular misalignment.
6. Vertical parallel misalignment is determined by placing a straight edge across the two pieces of equipment at the 12:00 and 6:00 locations. Again, the equipment should not be rotated.

We will adjust for the vertical angular misalignment and vertical offset misalignment first since it is easier to control vertical movement than horizontal movement of equipment.

7. The difference in the top reading and bottom reading for the measurement between flanges indicates the magnitude of the angular misalignment. The datum axes of our fixed equipment is considered our reference and we want to align to it. A positive difference between the top and bottom readings indicates that the back feet to the front feet of our non-fixed equipment is sloping upward, thus the back legs need to be shimmed to adjust for this upward slope.

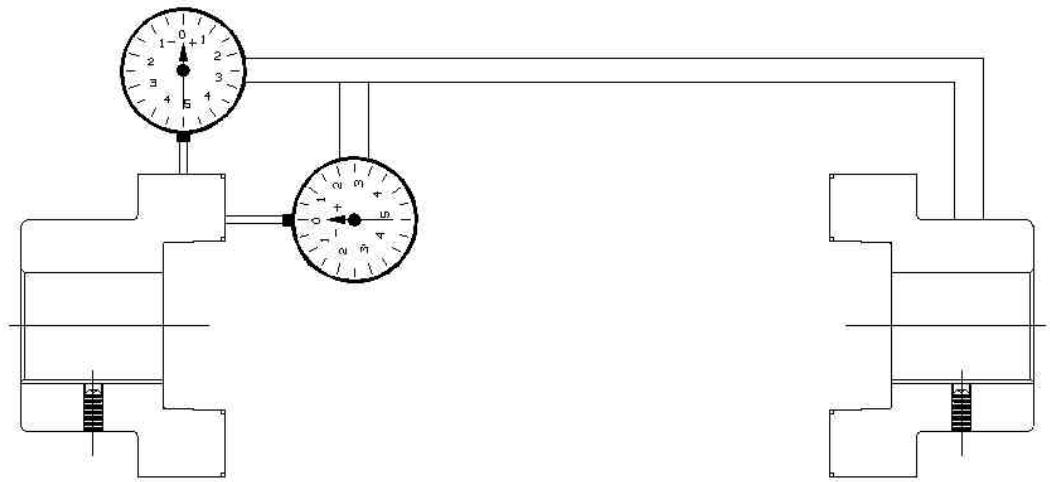
   - Mathematically the angular correction is calculated as follows:
     The angular slope is calculated from simple geometry.
     Top reading – bottom reading/ distance between measurement points = slope between flanges and
     Front foot – Back foot of equipment/ distance between mounting feet = slope of unfixed equipment.
     These two slopes are equal since the flanges are rigidly mounted to the equipment.

     Example: Top reading of 2.010 and bottom reading of 2.00 between flanges on a 10" diameter between measurement points. Distance between mounting holes of equipment is 30". Thus the correction would be (2.010-2.00) / 10 x 30 = .030"

8. Vertical parallel misalignment is simply the difference between the top and bottom readings using a straight edge. The unfixed equipment should be shimmed accordingly.

9. Steps 5-8 should be repeated for the 3:00 and 9.00 readings to adjust for the horizontal angular and horizontal offset misalignment.

Rim and Face Alignment Method



Driving Equipment **Driven Equipment**

A method of alignment in which a dial indicator or a set of dial indicators is used to align two datum axes. One indicator is mounted on a revolved feature of the driven equipment and the dial indicator pointer extends to a revolved feature on the driving equipment. The other indicator is mounted to the driven equipment and extends so that the dial indicator pointer extends to the face of a revolved feature on the driving equipment. The readings are then taken and the amount and type of corrections to align the datum axes is calculated using either mathematical formulas or graphical plots.

Steps (Always perform alignment checks after mounting bolts are tightened)

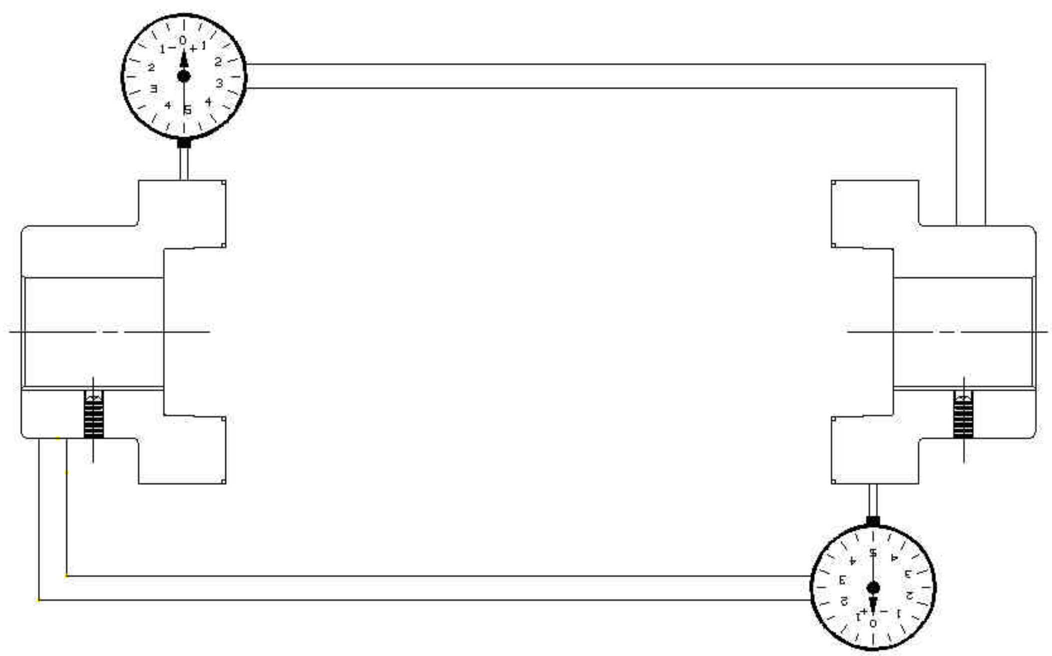
1. Take rough alignment check with straight edge to determine which unit to align and which unit to fix. The unit with the higher shaft centerline should now be fixed.
2. Complete rough alignment of the unsecured unit by setting up the proper gap and using a straight edge to roughly align the unit in both the horizontal and vertical directions. Shims may be required.
3. Zero the dial indicator at the 12:00 position
4. Rotate the driven shaft by 180 degrees
5. A positive value on the face reading means that the back feet of the driving equipment need to be shimmed. The reasoning and the amount of correction can be

calculated using the same methods mentioned under the straight edge/feeler gauge alignment methods.

6. A negative value on the indicator reading from the outside diameter of the part indicated that the driven equipment has a higher centerline, thus the driving equipment should be shimmed as a correction for vertical parallel offset.

7. The previous steps should be repeated for the 3:00 and 9:00 positions to adjust for horizontal parallel offset and angular misalignment.

REVERSE RIM ALIGNMENT METHOD



A method of alignment in which two dial indicators are used, one of which is mounted on a revolved feature of the driven equipment and the dial indicator pointer extends to a revolved feature on the driving equipment. The other dial indicator used is mounted exactly in reverse of the first indicator. The objects are then rotated simultaneously about the datum axes in order to obtain the amount of deviation between the datum axes. The readings are then recorded and the amount and type of corrections to align the datum axes is calculated using either mathematical formulas or graphical plots.

Steps (Always perform alignment checks after mounting bolts are tightened)

1. Take rough alignment check with straight edge to determine which unit to align and which unit to fix. The unit with the higher shaft centerline should now be fixed.

2. Complete rough alignment of the unsecured unit by setting up the proper gap and using a straight edge to roughly align the unit in both the horizontal and vertical directions. Shims may be required.
3. Set the secured equipment dial indicator in the 12:00 position and zero
4. Set the unfixed equipment dial indicator in the 6:00 position and zero
5. Rotate both shafts by 90 degree increments and record readings
6. Record the distance between indicator plungers
7. Record the distance between the unfixed equipment indicator plunger and the front foot bolt center
8. Record the distance between bolt centers.

The readings can then be used to graphically calculate the adjustments or mathematically calculate the magnitude and direction of the corrections as mentioned previously.

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