

This document is a summary of recommendations against which to check machinery and rotating equipment

1. Machine Distortion

Flatness

General tolerances on straightness and flatness (values in mm)[1]

Tolerance Class	Straightness and flatness tolerances for ranges of nominal lengths (L)					
	L ≤ 10	10 < L ≤ 30	30 < L ≤ 100	100 < L ≤ 300	300 < L ≤ 1000	1000 < L ≤ 3000
H	0.02	0.05	0.1	0.2	0.3	0.4
K	0.05	0.1	0.2	0.4	0.6	0.8
L	0.1	0.2	0.4	0.8	1.2	1.6

Base plate flatness [2]

Should be levelled longitudinally and transversely to within 200 micrometres per meter for API 610 pumps and to within 400 micrometres per metre for general purpose equipment and ASME pumps (according to API Spec 686)

Pipe Stress

The established practice is for an equipment manufacturer to specify a reasonable allowable piping load and for the piping designer to design the piping system to suit the allowables. Values are often too low to be practical. Could improve machine reliability by having piping engineers work with equipment manufacturers when designing the equipment and determining the allowable pipe stress [3].

Can increase the allowable pipe stress by increasing the strength of the base plate [3].

Referenced standards:

API Standard 610, "Centrifugal Pumps for General Refinery Services," American Petroleum Institute, Washington, D.C.

NEMA SM-23, "Steam Turbines for Mechanical Drive Service," National Electrical Manufacturers Association, Washington, D.C.

API Standard 617, "Centrifugal Pumps for General Refinery Services," American Petroleum Institute, Washington, D.C.

ASME B73.1M-1991, "Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process," American Society of Mechanical Engineers, New York



Soft Foot

Verifying that soft foot had been eliminated [2]

Multiple Bolt- Multiple Indicator Method (Preferred Method)

1. Tighten all of the foot bolts holding the machine in place.
2. Place one dial indicator at each bolt location holding the machine in place. Anchor the dial indicators to the frame or base and place the dial indicator stems as close as possible to the bolt-holds, insure that the stems are touching the top of the feet, and zero the indicators at mid range.
3. Loosen the bolt where the worst soft foot condition existed watching the indicator at the foot for any movement. If more that 2-3 mils of movement is detected, there is probably some soft foot still remaining at that foot but do not do anything yet. Leave the bolt loose.
4. Loosen another bolt watching the indicator at that foot for any movement and also watch the indicator at the first foot for any additional movement. If more than 2-3 mils of movement is detected when this bolt was loosened and if more than 2-3 mils of additional movement is detected at the indicator on the first bolt that was loosened, there is probably some warpage occurring across those two bolts but do not do anything yet. Leave both bolts loose.
5. Continue loosening each of the remaining bolts, holding the machine case, watching the indicators at every loosened bolt, and observing any additional movement. Carefully watch the indicator since each corner may raise or lower as each bolt is loosened, giving you clues as to whether diagonal from warpage or warpage along the side is occurring.
6. Once all of the bolts have been loosened, review what you observed when each bolt was loosened. If only one indicator showed more that 2-3 mils of movement, then there is probably a soft foot condition at that foot only. Remove any soft foot shims under that foot and remeasure four points around that bolt-hole with feeler gauges and install a flat shim or shim wedge to correct the observed condition. If more that 2-3 mils of movement were noticed at several bolts locations, then there is probably a soft foot condition at each of those feet. Remove any soft foot shims under those feet and remeasure four points around those bolt-holes with feeler gauges and install flat shims or shim wedges to correct the observed condition.
7. Repeat the procedure if additional corrections are required.

2. Shaft Alignment

- Laser measuring resolution down to 0.001mm, therefore could measure tolerance to 0.001mm if using high powered lasers to measure alignment [4]

Tolerances for Long span equipment [5]

Speed	Maximum offset (in)	Maximum offset (mm)	Angularities (in/in) or (mm/mm)
High Speed Equipment	0.001 to 0.002	0.025 to 0.05	0.0005
Low Speed Equipment	Greater than 0.005	Greater than 0.127	Up to 0.003

Shaft Alignment Tolerances (Short couplings)[6, 7]

RPM	EXCELLENT				ACCEPTABLE			
	Offset		Angularity		Offset		Angularity	
	mils	mm	mils/in	mm/mm	mils	mm	mils/in	mm/mm
600	5.0	0.127	1.0	0.001	9.0	0.229	1.5	0.0015
900	3.0	0.076	0.7	0.0007	6.0	0.152	1.0	0.001
1200	2.5	0.064	0.5	0.0005	4.0	0.102	0.8	0.0008
1800	2.0	0.051	0.3	0.0003	3.0	0.076	0.5	0.0005
3600	1.0	0.025	0.2	0.0002	1.5	0.038	0.3	0.0003
7200	0.5	0.013	0.1	0.0001	1.0	0.025	0.2	0.0002

Shaft Alignment Tolerances (Spacer couplings)[6, 7]

Angularity (Angles a and b), or Projected Offset (Offset A, Offset B)

RPM	EXCELLENT		ACCEPTABLE	
	mils/in	mm/mm	mils/in	mm/mm
600	1.8	0.0018	3.0	0.003
900	1.2	0.0012	2.0	0.002
1200	0.9	0.0009	1.5	0.0015
1800	0.6	0.0006	1.0	0.001
3600	0.3	0.0003	0.5	0.0005
7200	0.15	0.00015	0.25	0.00025

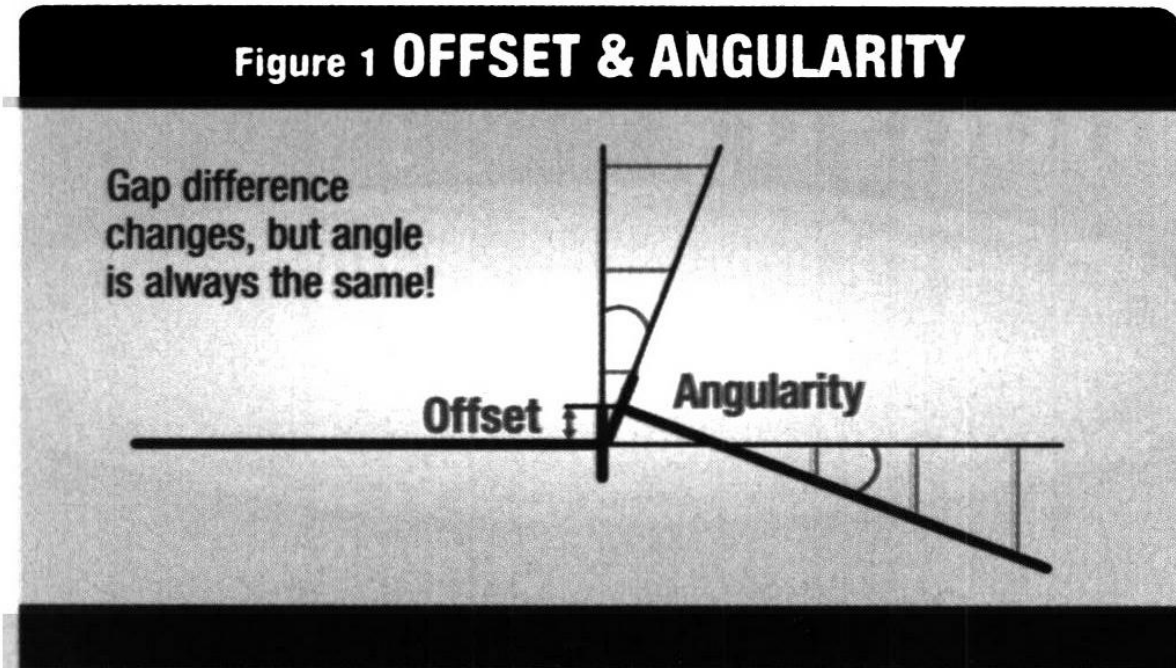


Figure 1: Offset and Angularity [7]

Tolerances of various couplings [8]

Coupling types	Angular misalignment		Max. parallel offset		Max. Axial freedom	
	inches	mm	inches	mm	inches	mm
Elastomeric						
Jaw	1.0	25.4	0.015	0.381	0.028 - 0.31	0.711 - 7.874
Curved jaw	0.9 - 1.3	22.9 - 33.0	0.008 - 0.086	0.203 - 2.18	0.023 - 0.181	0.584 - 4.597
Donut	3.0	76.2	0.06 - 0.08	1.524 - 2.032	0.18 - 0.4	4.572 - 10.16
Pin & bushing	5.0	127	0.01 - 0.05	0.254 - 1.27	no rating	no rating
Shear type donut	1.0	25.4	0.01 - 0.062	0.254 - 1.575	0.125	3.175
Corded tire	4.0	101.6	0.125	3.175	0.25	6.35
Bonded tire, urethane	4.0	101.6	0.188	4.775	0.125	3.175
Jaw in shear	2.0	50.8	0.03 - 0.047	0.762 - 1.194	0.031 - 0.063	0.787 - 1.6
Gear w/ elastomer	2.0 - 5.0	50.8 - 127	0.016 - 0.032	0.406 - 0.813	0.04 - 0.375	1.016 - 9.525
Metallic						
Gear	1.5	38.1	0.005 - 0.032	0.127 - 0.813	0.125 - 1.0	3.175 - 25.4
Grid spring	0.25	6.35	0.012 - 0.022	0.305 - 0.559	0.125 - 0.25	3.175 - 6.35
Disk	0.5	12.7	0.009	0.229	0.009-0.4	0.229 - 10.18
Wrapped spring	3.0 - 4.0	76.2 - 101.6	0.008 - 0.044	0.203 - 1.118	0.01 - 0.04	0.254 - 1.016
Three link disc	6.0	152.4	0.12 - 0.35	3.048 - 8.89	0.09 - 0.25	2.286 - 6.35

3. Shaft Condition

Straightness

General tolerances on straightness and flatness (values in mm) [1]

Tolerance Class	Straightness and flatness tolerances for ranges of nominal lengths (L)					
	$L \leq 10$	$10 < L \leq 30$	$30 < L \leq 100$	$100 < L \leq 300$	$300 < L \leq 1000$	$1000 < L \leq 3000$
H	0.02	0.05	0.1	0.2	0.3	0.4
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Circular run-out

General tolerances on circular run-out (values in mm) [1]

Tolerance Class	Run-out tolerance
H	0.1
K	0.2
L	0.5

(According to ISO 1101)

Roundness/Circularity

General tolerances have been established as equal to the diameter tolerance or circular run-out tolerance, whichever is smaller [1].

Cylindricity

Consists of three components; circularity, straightness and parallelism. Each component is controlled by its own tolerance and there are currently not enough measured values to create general cylindricity tolerances [1].

Parallelism

The Parallelism tolerance is defined as the greater of the straightness or size tolerances [1].



References

1. Henzold, G., *Handbook of Geometrical Tolerancing*. 1995, West Sussex: John Wiley & Sons.
2. Piotrowski, J., *Shaft Alignment Handbook*. Third ed. 2007: CRC Press.
3. Bloch, H.P., *Improving Machinery Reliability*. Vol. 1. 1998.
4. Support, M. *Shaft Alignment Systems*. 2005 [cited 2009 25th November]; Available from: http://www.machinesupport.com/english/laser_alignment_systems.html.
5. Sullivan, R., *Shaft alignment over long distances*. *Plant Engineering*, 1995. **49**.
6. Bloch, H.P., *Update your shaft-alignment knowledge*. *Chemical Engineering*, 2004. **111**(9).
7. Luedeking, A., *Why Alignment?* *Power Engineering*, 2008. **112**(7): p. 96.
8. Kevin, R., *Keeping an eye on alignment*. *Plant Engineering*, 2006. **60**(3): p. 71.

You can learn a lot more about rotating equipment health management with the 4-day [Rotating Machinery Maintenance and Reliability Training Course PowerPoint Presentation](#) available to buy at the Lifetime Reliability Solutions online Web store.