# Pump Rebuilding and Balancing (Part One)

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**This two-part article features the tricks of the trade for pump rebuilding and balancing.**

Pumps and pump systems are unique, engineered products that require specialized knowledge in all phases of repair, rebuilding and balancing. When pumps fail, costs add up quickly for repairs, replacement parts and plant downtime. Costs for lost production alone can add $5,000 to $200,000 per hour to the total cost of a pump failure.

## Pump Maintenance: The Importance of Balancing

Regular maintenance will extend the useful life of pumps and reduce the risk of expensive pump system damage. Balancing, a key component of a quality maintenance process, can be used to improve plant reliability records.

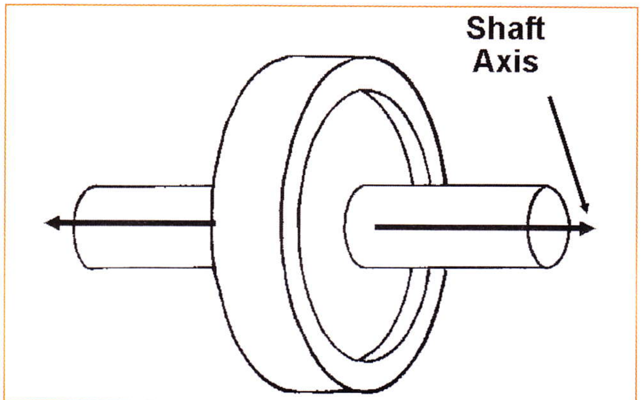
Pump users may label a problem as misalignment, bad bearings or overheating, but the root cause is often unbalance in a component or pump assembly. Unbalance causes vibration and heat buildup, which result in bearing failure.

Some dangers for unbalanced pumps include:

1. Shaft deflection—a bent shaft or uncontrolled resonance can result in deflection and damage to the entire system
2. Excessive, unacceptable vibration
3. Mechanical seal/mechanical packing failures
4. Catastrophic bearing failures
5. Seizing—In many pumps, clearances are so close that if the impeller is not well balanced, the vibration could cause the rotating assembly to deflect enough to seize

## Practical Balancing of Pump Systems

To clarify the balancing process, we will describe it from the perspective of alignment. Balancing involves aligning the geometric center with the mass center. The geometric center (manmade) is the center of the rotating shaft and pump impeller assembly. The mass center is the center the assembly tries to rotate around naturally. The pump impeller would spin around this axis if it were thrown through the air like a Frisbee. These two centerlines are never perfectly aligned. The distance between the centerlines is called *displacement*. Standard tolerances for displacement can be 0.0006 in, 0.0002 in or 0.0001 in. The tolerance is set based on the usage, quality grade and RPM in use.




Shaft axis

To convert the displacement to a balance tolerance, simply multiply it by the part's weight. For example, a 10 lb impeller would have an unbalance tolerance of 0.03 oz-in: **10 lb x 16 oz/lb x 0.0002 in = 0.03 oz-in.**

A 50 lb impeller would have an unbalance tolerance of 0.15 oz-in: **50 lb x 16 oz/lb x 0.0002 in = 0.16 oz-in.** The balancing machine will tell the operator how much material to remove and where to balance the part below tolerance and reduce the displacement between centerlines. This will more closely align the geometric center and the mass center.

One standard procedure in some shops trying to simplify their balancing is setting one balance tolerance for all their parts—for instance, balancing all parts down to 0.1 oz-in. The balance tolerance is the same for all their parts, but depending on the weight of their parts, the alignment or displacement is different.

For the same 10 lb and 50 lb parts mentioned above, the operator would spend more time balancing the 50 lb part (trying to hold an alignment or displacement of 0.0001 in), and the 10 lb part would be completed more quickly (holding a displacement of only 0.0006 in). To attain the same quality for all parts, the correct procedure is to balance all parts to the same displacement, for example to 0.0002 in, if they have the same RPM and usage.

Runout in the shaft is a cause of unbalance in the assembly that also relates to alignment. A shaft that has runout of 0.001 in will hold the impeller off-center by 0.0005 in. This defeats the purpose of balancing down to a displacement of 0.0002 in. Depending on the direction, the mass center of the impeller may now be 0.0003 in to 0.0007 in away from the geometric (rotational) center. To hold a tighter balance tolerance on an impeller, shaft runout should also be reduced below the desired balance tolerance.

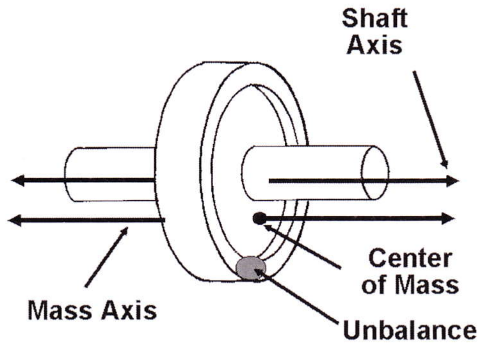
One frequently asked question on balancing is "How can I still have vibration after balancing my pump impeller down to 'zero'?" Remember, to maintain the level of unbalance in the impeller, the alignment met on the balancing machine must be maintained in the assembly. Assuming that the balancing machine is calibrated and operating correctly and there are no other outside causes of the vibration (resonance), it usually means the alignment (displacement) has changed during assembly. The pump impeller is mounted differently on the shaft, the shaft has runout, a key has been added that was not accounted for during balancing, or the bearings have a different centerline. Many shops balance not only the components, but also the whole assembly for this reason.

## Understanding Resonance in Rotating Machinery

One of the dangers of vibration in a rotating machine is resonance. For example, a typical vertical pump with a motor and a base or support on which the pump is mounted can be considered a vertical reed, or cantilever beam, which is anchored at the lower end to an infinite mass and free to move at its top end. If such a reed or beam is plucked at the top end, it will vibrate at its natural or resonant frequency like a reed in a Frahm tachometer. This natural frequency is an inherent property of the system or assembly rather than of any individual component.

If the system resonant frequency, or CPM (cycles per minute), is numerically close to the operating speed of the pump motor (RPM), excessive vibration will probably occur even though the equipment is well balanced. Even a small amount of unbalance in the motor or driven equipment will cause the system to vibrate at operating speed, and the magnitude of this vibration for a given amount of unbalance is greatly amplified if the resonant frequency approaches operating speed. It is desirable to have the system resonant frequency (CPM) numerically at least 25 percent above or below the operating speed of the pump motor (RPM). For a 1,200 rpm motor, the system resonant frequency should be above 1,500 cpm or below 900 cpm.

Resonance can happen at various speeds. If unbalance exists in a part, resonance will likely happen at least once during run-up, as the machine approaches or passes through its critical




Mass axis

speeds. Even after balancing down to required tolerance, a small amount of residual unbalance may remain. Balancing the part ensures that if resonance occurs, it will happen only in the speed range above or below the machine's operating speed.

Stable, continuous operation of a motor and its load at a low vibration level can be obtained only when the system resonant speed is well removed from the operating speed. To stop resonance from occurring during run-up or at operating speed, there are three primary ways to change the resonant frequency:

1. Stiffen the mount or supporting structure
2. Use a larger shaft
3. Stiffen the housing (by adding ribs or thickening housing walls)

Some field modifications can be made to allow system operation at speeds too close to the resonant frequency; however, balance refinement is not a desirable permanent solution for excessive vibration caused by system resonance. While vibration of the motor and the pump running close to the system resonant speed or frequency can be reduced by precision balancing at the installation, it may prove impossible to balance equipment well enough to reduce vibration to an acceptable level. Furthermore, a bearing replacement, a shift in alignment, pump wear or some other component change may destroy the precision balance and allow excessive vibration to occur again. It may also be possible that the resonant speed will be shifted closer to operating speed by a change in foundation bolt tension or some other similar change.

However, it is imperative that the machines be as closely balanced as is practical to at least offset any possibilities that may develop in a pumping system.

*Part Two will feature a case study on the repair and rebuilding process of a feed water pump.*

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