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Fundamentals of Shaft Alignment

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Performing correct shaft alignment saves time and money. Misalignment is the most common cause of machine vibration. Understanding and practicing the fundamentals of shaft alignment is the first step in reducing unnecessary vibration, reducing maintenance costs, and increasing machine uptime. Every alignment should be performed from start to finish using the same fundamental process. Once you employ this process into all shaft alignments the average time spent on an alignment will go down and the quality of the alignment will go up.

Shaft alignment is an essential component of plant maintenance, but safety is the first thing to think about before any alignment begins. All equipment that is to be aligned must be locked out and tagged out. The locks and tags should not be removed until all persons working on the equipment are finished. Every individual should be responsible for their own lock and tag.

Cleaning up is an important step when performing an alignment, and I'm not talking about your hands. The twenty to thirty minutes that is spent cleaning up the machines before the alignment will save an hour and a half at the end. So break out the wire brushes and solvents and clean up the machines to be aligned. Make sure all dirt, grease, and rust are removed from the base and the machine feet. If there are any rusty shims, replace them. Even make sure that there isn't any foreign object trapped under the machine (this has gotten me into trouble before). After all contact surfaces between the base and the machine are clean we can move on.

All hold down bolts to the machine should already be loose from cleaning. Notice if there are any obvious gaps between the machine feet and the base. If there are any gaps, fill them. Don't worry right now if any of these gaps appear to be uneven, we will take care of that later. Once you are satisfied with cleanliness of the contact surfaces and all of the gaps are sufficiently filled, you can tighten the hold down bolts.

Now is the time to decide which machine is going to be moved and which machine is going to remain stationary. This is almost always decided by which machine is **not** going to be moved. Sometimes it is like deciding between the lesser of two evils. There are some questions to ask to help make this decision easier. Is one machine heavily piped in? Is one machine much heavier than the other? Does one machine have no access to its feet? If there is no clear answer to any of these questions then just pick up one machine to be movable, if it doesn't work out you can always start over.

Does the machine have a rigid or a flexible coupling? If it is flexible, great, you will have no problem taking accurate misalignment readings with a variety of methods. For rigid couplings, there is one of two ways to get accurate misalignment readings. The bolts in the coupling can be loosened to the point that each shaft will move about its own centerline of rotation. This can not always be accomplished, the bolts may be too short to loosen sufficiently or there may be some other obstruction preventing the coupling from coming apart. If this is the case, the coupling must be completely separated in order to take misalignment readings.

Once all misalignment can be exhibited at the coupling, the misalignment can be measured. The methods to measure misalignment vary widely. I would highly recommend using a laser alignment system to measure misalignment. They are extremely accurate, versatile, and easy to set up, and provide results fairly free of human error. Don't get me wrong, you can perform an excellent shaft alignment using dial indicators, but it requires much more training and will take much longer to complete the alignment. Given the choice I would rather drive a Dodge Viper than a Model T.

Whatever alignment tool is chosen to perform the alignment, it must now be bracketed to the machines. The bracketing chosen will depend on many different variables. Are the shafts rotatable? Are the shafts coupled together? Are there obstructions during rotation? The bracketing and measurement method chosen are a subject for an entirely different article. For right now I will just say, acquire misalignment readings at the coupling as accurately as possible.

The misalignment readings are comprised of the four elements of misalignment: vertical offset, horizontal offset, vertical angle, and horizontal angle. Sometimes offset is described as parallel misalignment and angularity is described as gap at the coupling diameter. Whatever the terminology, it is all misalignment. From these misalignment readings we can determine the proper feet correction to make in order to improve the misalignment at the coupling. These moves are comprised of a vertical move on the drive end and non drive end feet and a horizontal move on the drive end and non drive end feet. All moves made at the feet are made in order to improve the coupling misalignment. Don't ever loose sight of this during the alignment.

When moves at the feet are made, all vertical corrections should be made first and the horizontal corrections are made second. This is because any vertical corrections are going to affect the horizontal position. The easiest way to make horizontal corrections is with jacking bolts. If you don't have them, install them, you will thank me later. The proper procedure to make the corrections is to take measurements, make vertical corrections, then take measurements, and make horizontal corrections. Notice that measurements at the coupling should be taken after each move is made. This is because the previous set of readings is invalid after each move is made. The first set of feet corrections is just a rough alignment. The rough alignment is only meant to get the feet corrections to within .025”.

After the rough alignment is completed the soft foot correction can begin. A soft foot is not necessarily at the feet. The definition of soft foot is actually a machine frame distortion. This is anything that causes the machine frame to distort. The condition of soft foot is most commonly caused by the following ailments: one or two feet being out of plane with the other feet, one or more feet being angled, or pipe strain. Often a combination of these problems exists. It can be very difficult and time consuming to correctly diagnose and correct a soft foot. An entire week long course could be devoted to soft foot diagnosis (and is). All I will say for right now is do whatever is necessary to correct the soft foot. The soft foot is akin to internal misalignment; until the internal misalignment is corrected the shaft alignment will only solve part of the problem. A general rule is to keep any foot deflection to within .002”.

Final alignment should now be performed to within an acceptable tolerance. This tolerance will usually come from the machine or coupling manufacturer or some other in-house specifications. Wherever the tolerance comes from it is important to use it. By this, I mean your tolerance is there to protect the machinery and help the personnel that align the machine. You will never be able to remove all of the misalignment that exists. Even if your measurement device reveals a zero for each parameter of misalignment, a tool with higher resolution will show that some misalignment still exists. Because of this state of imperfection that we must live with, it is necessary to use a tolerance. I like to think of a tolerance like the end zone in football. Whether the ball is caught at the front, back, side, or middle of the end zone it is a touchdown. As long as your shafts are aligned to within the specified tolerance, your alignment is done. There is no reason to waste time continuing the alignment in order to get a displayed .000” for all values.

Now that the machines are aligned within acceptable tolerance, the hold down bolts should be torqued to the proper amount. Take a final set of alignment readings, just to make sure that nothing moved and for documentation. Remove the measuring device, perform any necessary reassembly on the coupling, and remove the lock and tag. Congratulations, you are done.

About the Author

Damian Josefsberg is an applications Engineer for Acquip, Inc. He currently performs service work and teaches training classes. He has performed numerous laser shaft alignments, bore alignments, diaphragm alignments, machine train alignments, and thermal growth monitoring studies. He has performed internal and shaft alignments on compressors, gearboxes, motors, pumps, and turbines. Damian has provided plant maintenance support for the power, oil and gas, pulp and paper, food processing, automotive manufacturing, pipeline, and marine industries.

Damian has a degree in Mechanical Engineering from Florida Tech. He is also certified in vibration analysis and on several laser alignment systems.