Best Practices: Machinery Alignment Shimming

by Alan Luedeking

There is more to proper shimming of a machine for alignment than meets the eye. There are several things you should keep in mind and look out for.

First and foremost, you should be using high quality precut slotted stainless steel shims, such as Lawton Precut SS-304 Shims. If you think cutting your own shims by hand out of cheaper rolls of carbon steel or brass shim stock will save you money, you are very much mistaken. For one thing, you will only be able to cut the thinner thicknesses with scissors or shears; thicker thicknesses (over 0.004") will require the acetylene torch or sawing, which is labor intensive and presents safety concerns. After you have cut your shims by hand, you must take pains to debur them carefully with a ball peen hammer and file. All of this costs you the most valuable commodity of all: time. Moreover, the end result will be fewer available shims resulting in less precise alignments. And, if you are cutting shims by hand, don't forget to budget the time to visit the nurse for a Band-Aid.

ADVANTAGES OF PRECUT STAINLESS STEEL SHIMS

Precut stainless steel shims are:

- Precut: You don't have to hand-cut shims, saving you time.
- Burr-free: This means greater precision in the thickness.
- Accurate in thickness (up to 0.025".)
- Even in the thickness throughout.
- Convenient: Handy carrying cases keep your shims neat and organized.
- Versatile: More thicknesses and sizes to choose from mean you use fewer shims.
- Safe: Safety tab allows for safe manipulation. Never let your fingers get under a machine foot!

Some of these points require further attention, as they have a direct impact on your best practices regime. Let's examine a few of these.

NUMBER OF SHIMS

First, you should never use more than three precut shims under a foot (or four at most) except in exceptional circumstances. The reason for this is that an excess in the net number of shims under a machine foot leads to increased risk of exceeding your allowable soft foot tolerance. You can calculate approximately from a quarter to half a thousandths of an inch (0.00025-0.0005") compression for each airspace under the foot. If you have three shims, you will have four air spaces: Between the underside of the foot and the first shim; between the first and second shim; second and third shim; and third shim and mounting surface. This means that three shims will already inevitably produce about 1 mil (0.001") worth of movement every time you tighten or loosen the anchor bolt. This is due to slight lack of coplanarity between the machine feet and base and in some cases slight bowing of the shims. Add to this the surface contaminants present on both faces of each shim (finger oils, dust, grease, etc.) and the effect can be greater. This is why a tolerance of 2 mils for soft foot is considered standard. In addition, stainless steel can be expected to compress about half a percent of its overall thickness under load, so you can expect a 100 mil shim stack to yield another half thousandths under load. (Contrast this with brass alloys which can yield as much as 6 percent!)

You may think that limiting your shimming to just three shims under a machine foot is unrealistic and unreasonable; however, it is not. Good machine installation practices dictate that a good rough alignment between the machines should not necessitate ever having more than 100 mils worth of shims under any machine foot to achieve final alignment within tolerance. Good quality Lawton precut stainless steel shims come in thirteen thicknesses ranging from 1 mil to 120 mils. These are: 0.001", 0.002", 0.003", 0.004", 0.005", 0.010", 0.015", 0.020", 0.025", 0.050", 0.075", 0.100", and 0.120". With these thirteen thicknesses you can achieve <u>any</u> desired shim thickness from 1 to 150 thousandths with never more than three shims: Examples:

24 = 20 + 4
69 = 50 + 15 + 4
97 = 75 + 20 + 2
149 = 120 + 25 + 4

This means you will actually save money with precut shims, because the greater variety in available thicknesses means you never need to use more than two or at most three shims under a foot. Over time, this adds up to a lot of saved shims. As part of this best practice, it is imperative that you always maintain your shim cases fully stocked; for instance, if you run out of fifteens you will find yourself using a ten and a five, or three fives, which quickly escalates your shim costs and increases the risk of violating the rule of using no more than three shims under a foot.

If you absolutely must shim your machine up by more than 150 thousandths, then go ahead and use four shims; however, if you have to shim up 0.250" or more, then have your machine shop make you a chock (a chock is a shim that is 250 mils or more in thickness) and make sure it is carefully milled flat and coplanar on both faces. Then use three or fewer shims normally on top of this chock to complete the alignment.

ASCERTAINING PRECISION OF SHIMS

Always mike any shim 0.050" or thicker with a micrometer. While Lawton shims are of excellent quality and are even in their thickness throughout, like all commercial precut shims, they are only guaranteed accurate in their marked thickness from 0.001" to 0.025". Thicker thicknesses are always nominal (the way the steel mill rolled the sheet) and should always be miked. For instance 0.075" shims may mike out at 0.078", and 0.100" shims may actually measure 0.104" thick. This does not matter, so long as you know it! Thus, make sure a 0-1" micrometer is a standard part of your alignment toolkit.

MARKING AND QUALITY OF SHIMS

Always prefer precut stainless steel 304 shims whose thickness and size are indelibly etched upon them. This is a sign of a best quality shim (such as the Lawton brand), and avoid using cheaper brands that only ink their shims or worse, punch stamp them with the thickness marking. Punch stamping a marking on shims ensures that they are not flat, resulting in a leaf spring effect under the machine feet that contributes to a "squishy foot" soft foot. Also, cheaper shims usually have raised knife edges (burrs) along their edges, because they are not tumbled after being stamped out of the sheet, and the dies used to stamp them out are not sharpened often enough. This too results in a shim of inaccurate thickness producing a squishy soft foot, and also constitutes a safety hazard for the millwright who is not using safety gloves. In the end cheaper shims always end up costing you more than good quality shims, given the increased labor costs from repeated adjustments of the machine position and greater downtime resulting from their inaccuracies, as well as presenting potential handling safety hazards.

SHIMMING TECHNIQUE

Always sandwich your thinner shims between thicker ones to protect them. In fact, if you have to shim 26 thousandths, choose to use a 20 and two 3's rather than a 25 and a 1 alone.

Always insert your shims until they touch, and then withdraw them slightly. This way you know for sure that you are not letting the slot of the shim get caught in the threads of the anchor bolt.

Always handle your shims by grasping them at the safety tab (see Figure 1); *never* let your fingers get under a machine foot while the machine is being pried up or lifted!

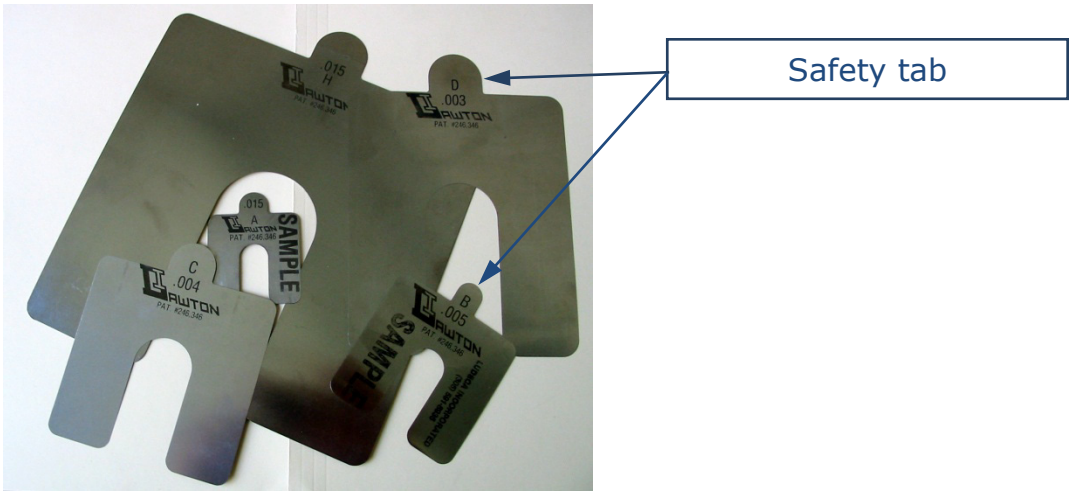

Fig. 1

SHIM SIZES

Precut stainless steel shims come in several standard industry sizes, as pioneered by Lawton Industries many years ago: These are:

- Size A: 2" × 2" with a $^{5}/_{8}$" slot
- Size B: 3" × 3" with a $^{13}/_{16}$" slot
- Size C: 4" × 4" with a 1¼" slot
- Size D: 6" × 5" with a $1^{5}/_{8}$" slot
- Size G: 7" × 7" with a 1¾" slot
- Size H: 8" × 8" with a 2¼" slot

Lawton has published a chart of horsepower ranges and motor frame numbers associated with the different sizes of shims. See Figures 2 and 3 below.

Table of Shim Sizes & Horsepower Ranges				
	SIZE A	SIZE B	SIZE C	SIZE D
Shim dimensions:	2" × 2" × $^{5}/_{8}$"	3" × 3" × $^{13}/_{16}$"	4" × 4" × 1¼"	6" × 5" × $1^{5}/_{8}$"
H.P. Range Approx.:	0.25 to 15	10 to 60	50 to 200	150 to 1,000

Fig. 2

NUMERICAL LISTING FOR CORRESPONDING MOTOR FRAME NUMBERS							
2" x 2" x 5/8"		3" x 3" x 13/16"		4" x 4" x 1-1/4"		6" x 5" x 1-5/8"	
SIZE A MOTOR FRAME NUMBER		**SIZE B MOTOR FRAME NUMBER**		**SIZE C MOTOR FRAME NUMBER**		**SIZE D MOTOR FRAME NUMBER**	
42	184	66*	325	203*	408	502	681
48	185	253	326	204*	409	503	682
56	186	254	327	224*	443	504	683
143	187	255	328	225*	444	505	684
145	188	256	329	363	445	506	685
162	189	257		364	446	507	686
163	1810	258		365	447	508	687
164	213	259		366	448	509	688
165	214	283		367	449	582	689
166	215	284		368	504*	583	
167	216	285		369	505*	584	
168	217	286		403	506*	585	
169	218	287		404	507*	586	
1610	219	288		405	508*	587	
182	2110	289		406	509*	588	
183		323		407		589	
		324					
						** Denotes Old Frame Number*	

Fig. 3

Alternatively, choose your shim size more by the slot size than by the foot's surface area. It is a myth that you have to support the entire surface area of the machine foot with the shim. You only need to support the load zone around the anchor bolt. Most machine feet are made much larger in surface area than what is strictly necessary to support the mass of the machine and its operational load stresses. So, if a machine foot is too large for a given size of shim but the shim adequately supports the load zone around the hole in the foot, you do not have to worry if the outer edges of the foot overhang the shim a bit— that is perfectly okay.

Figure 4 shows an example of how *not* to shim a machine: Too many shims were used and the shims do not support the load zone of the machine foot around the anchor bolt! In addition, the Size A shim used on top of the stack is too small for a motor of this size. When the anchor bolt of this foot is tightened, the foot will be stressed, distorting the machine frame and altering the internal alignment of the bearing bores, as well as affecting the airgap between rotor and stator. Note too that the motor was painted *in situ*, covering the shims and jackscrews in paint, and also allowing paint to go under the foot.

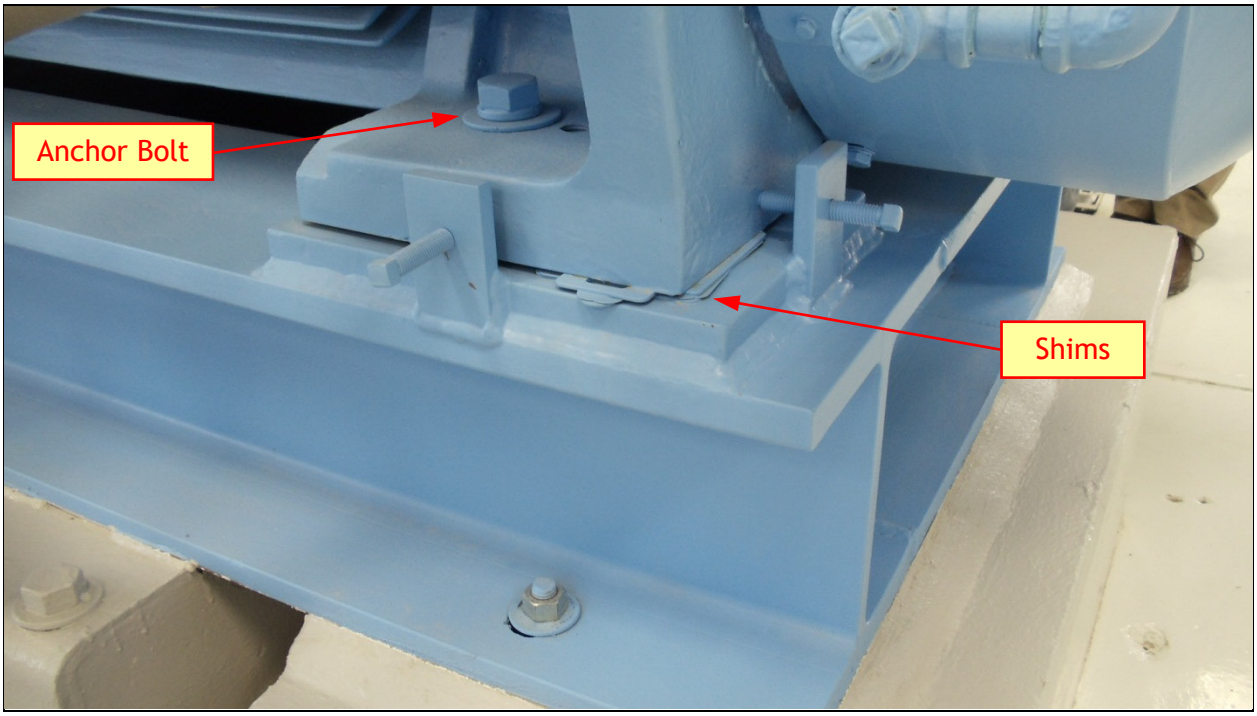

Fig. 4: How *not* to shim a machine

If existing standard shim sizes cannot properly fit a given machine foot, or you cannot accommodate the anchor bolt(s) or the load zone, custom shims in any shapes and sizes can be easily supplied by Lawton Industries, in any desired material (SS-304, Monel, etc.) at a lower cost and higher precision than they can usually be made in-house. Do not hesitate to contact LUDECA for help with this.

UNUSUAL CIRCUMSTANCES: STEP-SHIMMING

Sometimes a machine will have feet that are significantly angled with respect to the contact surface of the baseplate or soleplate supporting them. This can be caused when the feet are accidentally bent, or when the machine is "rolled" to accommodate a horizontal misalignment problem (definitely *not* a best practice!) Tightening the anchor bolts under these conditions would force the feet flat to the base and thereby distort the machine, increasing the radial load on the bearings, affecting airgap clearances between internal components, and placing undue stress on the feet or other machine parts. How to solve this problem? The best way of course would be to remachine the baseplate, soleplate or undersides of the machine feet in such a way as to eliminate the lack of coplanarity; however, this may not be practical or economical to do. This leaves us with the only other solution possible: step-shimming.

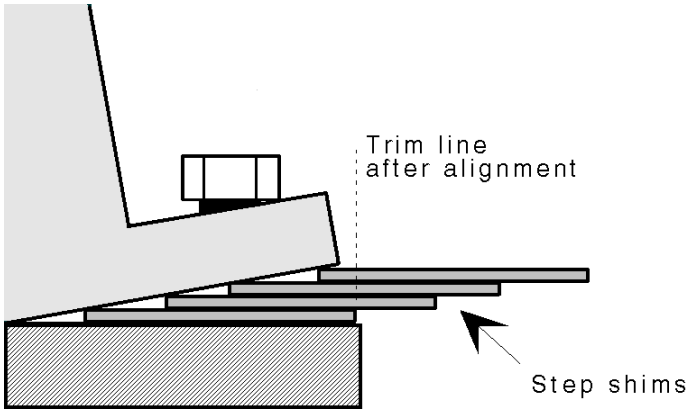

Fig. 5

Step-shimming requires several thinner shims to be carefully inserted between the foot and its support surface in such a way that they are offset from one another in step fashion, so as to fill the tapered gap between the underside of the foot and its support plane as evenly as possible (see Figure 5.) This may require you to use more than three shims overall, but, as with everything, there is always an exception to the rules, and here the benefits outweigh the disadvantages. Soft shims that mold themselves to the uneven opening under the feet are *not* recommended; they allow the machine casing to distort when the feet are tightened before they set and harden, thereby resulting in an undesirable strained condition of the machine frame.

To step shim correctly choose a thickness of shim that will allow you to stack several of them (not more than four though!) in such a manner as to fill the uneven airgap between the underside of the foot and its support surface (including any shims already there for the alignment of the machine) as evenly as possible. Mike the largest airgap and divide this gap by five. This will reveal the ideal thickness of shim to use for the steps. For instance, if you must fill a 20 mil tapered air gap, dividing this gap by five yields an ideal step shim thickness of 4 mils. Use four 4-mil shims to fill the gap as evenly as possible.

Step shimming works well since the angles involved are sufficiently small as to fall well within what is known as the 'swedge' angle for the coefficient of friction of the materials involved. This means that the shims will tend to remain in place when the anchor bolt is tightened rather than "squirt out" like watermelon seeds. Once the step shimming task is complete and the machines are aligned with all anchor bolts tight, do not neglect to trim off the excess part of the shims protruding out from the edge of the machine foot so as to prevent possible injury.

Although not elegant, this solution is expedient, easy and economical, and will prevent a much more serious machine distortion problem, allowing your machines to run satisfactorily until your next major outage when you can schedule the time and resources to fix the problem in a more permanent manner. ▣