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► BY TIM CROAN

# Top Choices

**Designing and machining top jaws for precision chucking applications.**

Selecting the proper chuck for a precision chucking application* involves more than just thumbing through a catalog and picking out a model that fits the spindle and big enough to grip the workpiece. It takes plenty of forethought, as well as seeking recommendations from the chuck manufacturer about the application.

The design of the chuck's top jaws merit careful consideration, too. Before slapping on a set of soft jaws and boring out some diameter that "looks about right," stop and think about the workpiece and the best way to grip it. Common sense dictates that the massive jaw set needed to restrain a tough steel tractor forging would be inappropriate for the delicate aluminum housing of a camera lens. You also need to think about how you will manufacture the jaws.

This article offers advice about designing and machining top jaws. Many of the tips that follow are valid for numerous makes and styles of chucks, precision or otherwise. Since most chucks use jaws that slide in and out radially, the discussion will focus on them.

## Designing Jaws

During the design and pre-use stage, you need to consider the following: jaw material, jaw length, matching jaw diameter to workpiece size, workpiece loading, corner clearance and gripping force. Let's look at each in order.

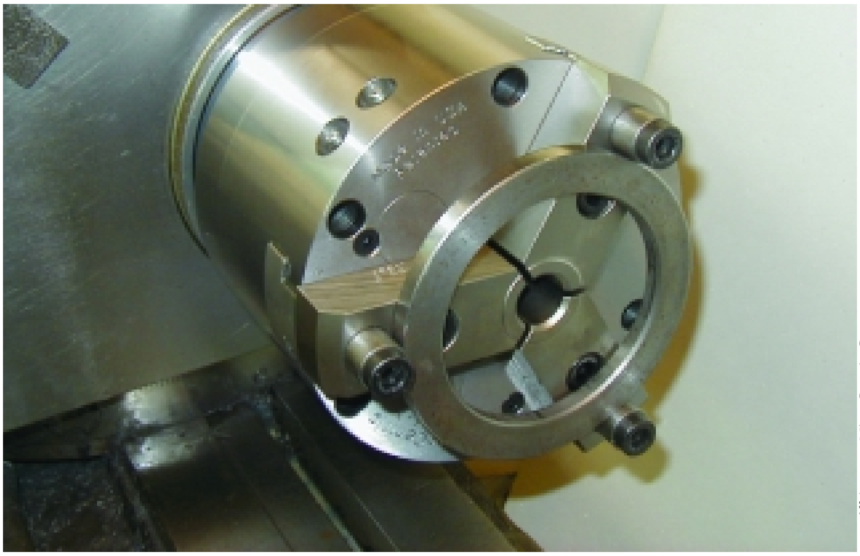
*Jaw material.* The choice of material is usually limited to steel or aluminum. Aluminum is easy to machine, lightweight, which reduces jaw-force loss at higher spindle speeds, and won't scratch most workpieces. The downside is that aluminum jaws lack durability. They frequently need to be rebored during long-run jobs.

Steel jaws can have varying degrees of hardness. They can be readily machined by conventional cutting methods and by grinding or electrical discharge machining. A wire EDM is especially useful in the manufacture of custom jaws, because it lets you take advantage of prehardened jaw blanks. This saves time compared to a conventional machining operation followed by heat treatment.

*Keep your jaws short.* Even in the most scrupulously engineered and assembled precision chuck, there is a certain amount of operating clearance within the chuck's actuating mechanism. Without this clearance, the jaws would fail to operate smoothly, if at all.

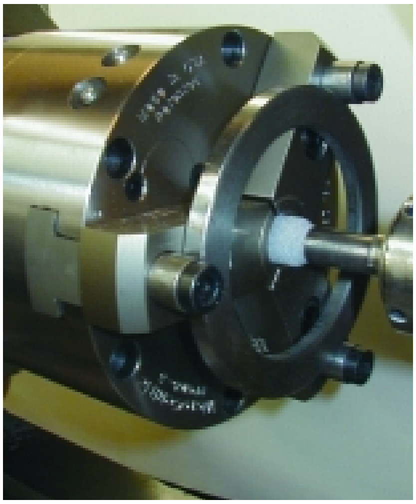
The drawback to internal clearances, of course, is that the jaws are free to move in unwanted directions as pressure is applied to the workpiece. That makes it important to keep the gripping area of the jaws as close to

*Precision chucking is defined as applications in which the part print calls out for 0.0005" or less TIR.



All images: MicroCentric Corp.

**Shown are soft jaws for a precision chucking application.**



Finishing the bore to size, under preload.

## More is sometimes less

Many people believe that if a chuck having two jaws is good, three must be better and six has to be a sure thing. They reason that with more jaws available to contact the workpiece, the "law of averages" will kick in and the part will readily find its "happy home" spot.

The argument has some validity, especially if there is pre-existing sloppiness in the chuck mechanism. The problem, though, is how do you guarantee that all the "slop" will be directed equally toward the chuck's center?

With a precision, self-centering chuck—in which all the jaws are supposed to move toward the centerline simultaneously—it is impractical to expect any more than three jaws to make contact on a given diameter.

Extra jaws—if they contact the workpiece at all—will spread the total jaw-force load over more points. This may help minimize distortion or out of roundness when machining thin-walled parts, but it won't improve concentricity.

Also, don't be too quick to blame the chuck for any out-of-roundness problems—a common complaint leveled against precision chucks. Look at the roundness of your part prior to precision chucking. If you clamp a distorted part, especially one that's thin-walled, the "good" roundness of the chuck jaws may squeeze the part into shape during clamping only to have it spring back when the jaws open.

Be sure to check the spindle bearings, too. Don't expect a 0.0001"-accuracy chuck to make round parts if the headstock sounds like a concrete-mixing truck coming down a dirt road!

—T. Croan

the chuck face as possible. Doing so maximizes rigidity and minimizes the effects of distance as a multiplier of inaccuracy. So, if your part is 3" long and the gripping length is only within the first inch, it makes no sense to use a 4" set of top jaws for the job (assuming tool clearance isn't an issue).

*Matching jaw diameter to workpiece size.* Although it's a hotly debated topic, most chuck makers will agree that the greatest accuracy is achieved when there's a single line of contact between the workpiece and the center of each jaw. This means that for OD clamping, the jaw diameter should be equal to or slightly larger than the maximum tolerance for the part (Figure 1). For ID clamping, the opposite is true: Jaw diameter should equal or be slightly smaller than the minus tolerance of the part (Figure 2).

When the diameter is such that there are two lines of contact per jaw, the gripping force on the workpiece increases but accuracy decreases.

*Workpiece loading.* One often-overlooked factor in precision chucking is the way operators load the workpiece into the chuck prior to clamping. Holding the workpiece straight as the jaws close around it can be difficult when loading by hand. If the part is loaded crookedly, the jaws may not clamp it squarely.

Errors from the workpiece axis being out of parallel to the machine spindle may appear as radial runout in the chuck. In reality, though, the chuck and jaws are not to blame. A solution may be to simply orient one jaw at 6 o'clock and rest the part on it during clamping.

A better solution is to add a simple banking step in the top jaw (Figure 3). Or, you could mount a separate part stop to the chuck body for the workpiece to locate against.

Part stops also prevent axial pushback during machining. In the case of automatic loading, it's usually easier to control the orientation of the workpiece during clamping. And for twin-spindle turning, where work is transferred from one spindle to another, the chance for misalignment is greatly reduced during the second chucking.

*Watch your corners.* Good design practice for any part that will be ground makes allowance for grinding-wheel clearance in corners, as well as the inclusion of radii in corners to minimize cracking during heat treatment. For steel top jaws that are first roughed out and then finish-ground after heat treatment, incorporating these simple features can prevent a lot of grief down the road.

*Gripping force.* Most of us draw on past experiences or trial and error when deciding on the clamping force for a chucked part. Others rely on calculations and formulas involving torque and loads, friction and horsepower, or other parameters. Regardless of the method used, it's advantageous to have some idea of the force needed to hold a workpiece securely when preparing top jaws.

There are two basic ways to enhance

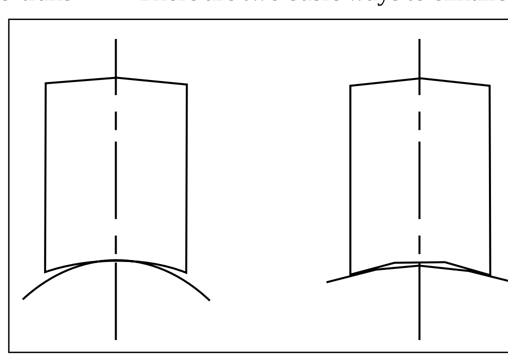


**Figure 1: For OD clamping, the jaw diameter should be such that there's a single line of contact between the chuck and jaw (left). When there are two lines of contact (right), gripping force increases but accuracy decreases.**

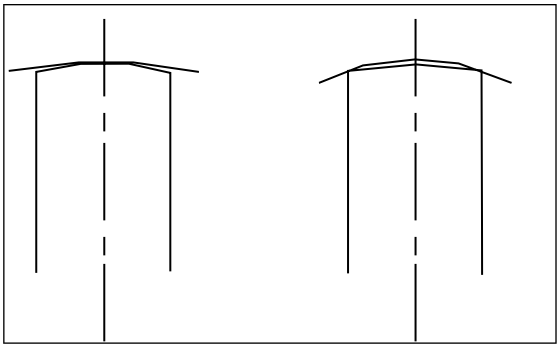


**Figure 2: For ID clamping, jaw diameter should equal or be slightly smaller than the part's minus tolerance (left).**

a chuck's ability to resist torque on the workpiece. The first is to increase the point load each jaw exerts on the part by jacking up the air or hydraulic pressure. The second is to increase the coefficient of friction between the jaw and workpiece.

Increasing the chucking force is not always the best answer, as there is an inverse relationship between high chucking pressure and accuracy. Most times when pressure increases, the chuck's clamping mechanism is strained and it distorts. This degrades accuracy.

If your operation requires high clamping force and high precision, consider having a gritty carbide coating applied to the contact areas of top jaws. It will allow the chuck to operate at a reasonable pressure while still maintaining a solid "bite" on the part.

Several companies offer this coating service at a reasonable cost. Typically, the price of the treatment will be less than 10 percent of the total jaw set's cost. A 1- to 2-week lead time is needed for the treatment and jaws can be recoated.

If you're pressed for time, a careful sandblasting of the holding area will yield similar results. However, the

## Preload, trim the fat

Once top jaws are designed, it's essential that they be preloaded prior to finish boring. Even the best precision chucks have some operating clearance; preloading takes up these clearances and replicates the stresses jaws will experience.

Prestress jaws in the same direction and at the same pressure they will encounter during actual clamping. Various preloading methods involve the use of loading pins, plugs and rings.

The preloading method chosen will be dictated by workpiece shape, direction of clamping and the accessibility needs of the finishing tools. Sometimes you have to get creative, but the best methods generally involve the application of the preload at the point where the initial contact occurs between the jaw and workpiece.

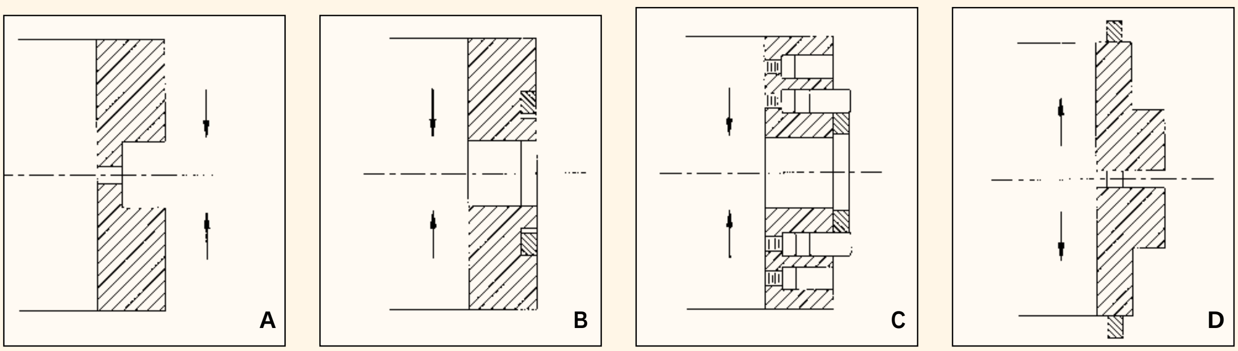
For OD clamping, this is usually at the top of the jaws, away from the chuck face. As pressure is applied, the natural tendency is for the jaws' bottoms to continue moving toward center after they contact the workpiece. This causes the top to open up, allowing the part to wobble. Because of this, it's a bad idea to have the bottom of the jaws unsupported, especially as the jaws become very tall relative to their radial length.

Try to have as much of the workpiece buried inside the jaw as possible, with even contact top and bottom. Leaving relief in the middle one-third of the clamping length helps ensure this condition.

The problem also can be countered—and used to advantage—by grinding a slight amount of back taper into the jaws during the finish-machining step. This way, contact at the top is guaranteed first, for good accuracy, followed by the jaw bottoms "squeezing in" to support the rest of the workpiece.

Remove any excess jaw mass before putting top jaws to work, and dynamically balance them if they're to be used for high-speed turning.

—T. Croan




**Methods of preloading (arrows represent clamping direction): A) Loading pin at center of jaws. B) Ring inserted into a groove cut into jaw faces. C) Loading ring clamped between pins inserted into holes in jaw faces. D) ID clamping jaws using loading ring around OD of jaws.**

sandblasted area will need to be renewed frequently.

### Ready, Set, Mount

Once the jaw design has been completed, it's time to mount the blank jaws to the chuck and machine the required geometry. Devise a machining sequence that includes three basic steps: a roughing operation followed by some intermediate adjustments and then final finishing to size.

Follow the chuck manufacturer's recommendations for mounting blank top jaws, confirm that the chuck itself is in good working order and that it's mounted securely to the spindle. Use an indicator to check alignment to the spindle centerline on the correct qualified surface. Be aware that not all diameters on the chuck are necessarily concentric, so ask the manufacturer which surface is critical.

Fasten the top jaws to the chuck with high-quality hardware and torque to the correct specs. If the jaws are truly massive, or are rough castings from the vendor that have had minimal premachining, make sure the mounting surfaces between the chuck and jaws mesh correctly before bolting down.

Ensure, too, that the entire chuck and jaw assembly clears all guards, loaders, tool eyes, turret tooling and other machine components. Then start the spindle turning slowly. Take a few light cuts to clean up any irregularities, including where the preloading device will rest (see sidebar, opposite page). Next, bring the jaws into some semblance of symmetry and balance, then check for anything that may have loosened. The one thing you don't want to do is ramp up the spindle and have big lumps of metal fly off it.

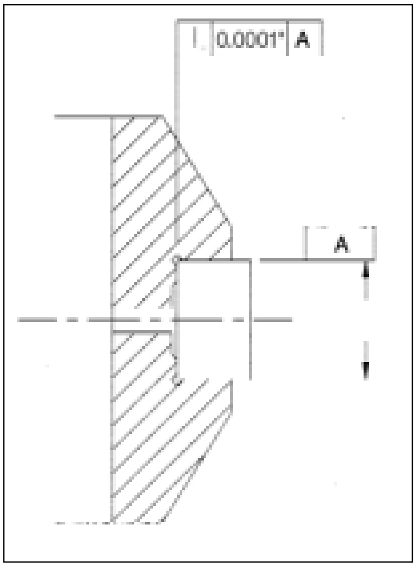


**Figure 3: Machining in a simple banking step helps ensure the part squares up properly during clamping.**

Set the preload device in place and clamp it securely. Begin machining as needed until only enough stock remains to account for heat treatment and finishing operations. Make sure all grinding reliefs and radii are where they belong. At this time, if possible, try to remove unnecessary jaw mass, making sure you don't wipe out any material required by the preload device.

Next, remove the jaws, deburr all surfaces and heat-treat them, if necessary. Confirm that the chuck body hasn't shifted relative to the spindle, and give the chuck a shot of lubricant. Over time, chucks lose a certain amount of clamping force due to internal friction. Proper lubrication is critical with precision chucks because they have such closely fitted moving parts.

A final check then should be made to confirm the flatness of any mounting surface on the top jaw after roughing or heat treatment. This ensures good contact between chuck and jaws, and reduces the possibility of a bowed or crowned top jaw distorting the component upon which it's mounted.

In precision chucking, it is hypercritical to replicate the actual production clamping conditions when finish machining the top jaws. Preload pressure should be adjusted to match the pressure required to machine the workpiece, and the preload jaw force should be in the same direction as the actual clamping.

Remember to use a sharp insert if you're cutting the jaws (or dress your grinding wheel), then finish the clamping diameter. Check the results with a gage pin or mount a sample part in the jaws.

### Ask the Manufacturer

Each manufacturer's chuck behaves a little differently than its competitors', so it's always in your best interest to seek the advice of the company that manufactured yours.

The tips provided in the preceding are proven solutions to common problems encountered when trying to hold "tenths" on concentricity. Hopefully, they will help you avoid pitfalls and produce good parts with a minimum of fussing and head scratching.

### About the Author

*Tim Croan has been involved with machine tools since 1975. He currently is a sales and application engineer at MicroCentric Corp., a Plainview, N.Y., manufacturer of precision workholding systems.*