SPIRAL CATCHES • COMPLIANT VACUUM CHUCKING SYSTEM • SCALLOP-EDGE BOWLS

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Compliant Vacuum Chucking System

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A new technique, compliant vacuum chucking, enables turning gnarly burls like this without having to cut into the rough surface.

A new technique, which I call *compliant vacuum chucking* (CVC), enables turners to mount and turn burls and other blanks with irregular shapes and voids while leaving the rough surface completely untouched. This new approach combines a few common materials with a conventional vacuum chuck to create a plastic membrane that conforms closely to the shape of the workpiece. It is as if you made a mold in sand or plaster.

Unlike most other methods of mounting wood on the lathe, vacuum chucking does not require cutting or penetrating the wood, once you've made a smooth surface for interfacing with the vacuum chuck. The conventional vacuum chuck resembles a bowl mounted on the headstock spindle with its rim toward the tailstock. A resilient material such as closed-cell foam provides a seal between the chuck and the turning. When the vacuum pump extracts the air from within the chuck, the differential pressure holds the turning in place. For this to work, both the seal against the wood and the wood itself must be smooth and without holes or ripples. If this is not the case, the setup will leak air. The item to be mounted becomes part of the vacuum system.

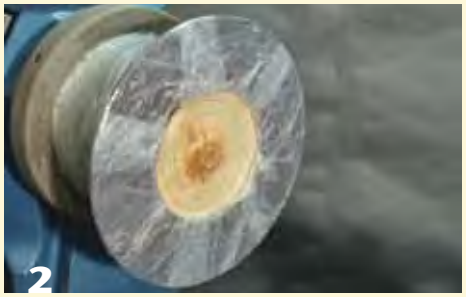
Compliant vacuum chucking does not depend on the smoothness of the blank itself to create a vacuum seal. I got the idea for this system from a technical article about a robotic gripper that presses a bag of granular material around an object. The vacuum compresses the material into a rigid mass that conforms to the object, like coffee vacuum-packed in a bag. The ground coffee is a rigid lump while it is under vacuum but turns into flowing granules when the vacuum is released. This is the basic idea behind the CVC system.

Although compliant vacuum chucking complements the conventional vacuum chuck, it does not replace it. Happily, augmenting a vacuum chuck for this technique doesn't damage it or prevent it from being used conventionally.

I'm using the idea in two ways. The first is a compliant mandrel that molds itself to the shape of the turning, which is then held in place by tailstock pressure (*Photo 1*). This method gives you tool access to most of the exposed face, so you can shape the rim and sides of the blank. The second is a compliant chuck that uses a

1

The compliant vacuum mandrel, with pressure from the tailstock, cradles the burl for rough turning and shaping the outer rim. The mandrel consists of plastic stretch film over a conventional vacuum chuck that is filled with rice.



2

The compliant vacuum chuck uses a force ring to hold the blank around its rim, providing unobstructed access for hollowing. The ring wrapped in shrink film presses the turning into the rice-filled vacuum chuck.

3

To demonstrate the technique, this burl blank is to be turned without damaging the gnarled bottom surface. Like coffee in a vacuum-packed bag, the rice is hardened by the vacuum to the shape of the turning.

force ring to capture the turning by its rim, allowing access to the remaining surface for hollowing (*Photo 2*).

Both the mandrel and the chuck use the vacuum to mold a plastic film covering a granular material (I use rice) so it conforms to the turning. In this system the plastic stretch film provides all vacuum sealing, with the smoothness or soundness of the workpiece playing no role. The system is simple in concept but there are a few details to address in order for the method to work reliably. To demonstrate, I chose a burl with an interesting gnarled outer surface that I wanted to retain without any damage (*Photo 3*). The cut surface was to be smoothed up and hollowed.

Materials for compliant vacuum chucking

- A conventional vacuum chuck, about the same size or a bit larger than the object to be supported
- Plastic stretch film (This material comes in rolls; I use 5" (13 cm) and 20" (50 cm) widths. Office supply stores sell it for wrapping and bundling items to be shipped.)
- Rice, sand, or other clean granular material
- Several cloth bags (*See Materials notes sidebar*)
- Filter to prevent rice from going into spindle, made from coffee-filter paper and screen wire
- Thin plywood, Formica, or Masonite to make the force ring. (The protective ring can be of cardboard.)
- Miscellaneous heavy rubber bands and tape

The compliant vacuum chuck requires two widths of stretch film, plus a plywood force ring. The standard vacuum chuck mounted on the carving stand is filled with rice. The burl turning at right is partly complete thanks to the compliant vacuum mandrel.

Making the compliant mandrel

Start with a standard vacuum chuck about the same size as the blank to be held and put a filter over the hole going into the spindle (*Photo 4*). To make the filter, I drilled four ½" (13 mm) holes in a PVC cap and covered them with a filter made from a layer of screen wire covered with a layer of coffee-filter paper. The screen wire goes toward the spindle so it can support the filter paper. Seal the entire edge of the filter with thick CA glue. Position the chuck with the rim facing up and fill it with clean rice (*Photo 5*). With experience, you will learn what level of rice works best for the blank at hand.

To create an airtight membrane that will completely enclose the rice and chuck, wrap several loose layers of the wide plastic film across the face of the mandrel in different directions and trim as needed. Next wrap the narrow plastic film clockwise around the chuck, making several tight turns to seal the wide wrap. Do not wrap the wide film tightly against the rice but leave room for movement (*Photo 6*). Be sure that there are two or more layers of film over the rice where the turning will be placed. Cut the film free from the roll and, moving in a clockwise direction, hand-smooth the plastic film onto the chuck and rice. The layers of film will stick together to form the airtight membrane. Always wrap and smooth clockwise so the film won't unwrap when the lathe runs.

Some blanks need additional support around the rim of the chuck. Plan for it by wrapping a layer or two of film around the chuck with the top edge protruding a couple of inches above the rim. You can put more rice inside this collar of film for additional support (*Photo 7*).

Mount the assembly of the rice, chuck, and film onto the lathe spindle (*Photo 8*). Bring up the tailstock to help press the ▸

4

The vacuum chuck is ready for filling with rice. The white dome in the center is a 2" (5 cm) PVC pipe cap fitted into a groove cut into the base of the chuck. It has four ½" holes drilled around the perimeter to allow airflow into the spindle. A shopmade filter keeps the rice out of the spindle.

5

Grains of rice poured into the chuck will support the plastic film and the burl blank. The vacuum will draw the loose grains into a solid mass.

6

Wrap plastic stretch film around and over the surface of the rice and the chuck. Wrap the film in a crisscross pattern so it overlaps and covers all surfaces. The film stretches and clings to itself and the chuck, forming a vacuum-tight seal.

Wrap a couple of layers of film that extend up beyond the rim to help nestle extra rice around the burl later in the process.

Mount the completed compliant vacuum mandrel assembly onto the lathe spindle. You might need Teflon tape on the spindle threads for a good vacuum seal.

Press the burl blank into the plastic film and the rice. The compliant surface molds itself to fit the surface of the burl. Bring up the tailstock to help position the blank and hold it in place.

Removing the burl while leaving the vacuum switched on reveals how the film and rice conformed to its gnarly surface.

Advantages of compliant vacuum chucking

- Almost any shape blank can be mounted on the lathe without using glue, turning a tenon, inserting screws, or otherwise cutting into the wood.
- It allows mounting and turning items too small for conventional vacuum chucks.
- The system is insensitive to holes, perforations, or imperfections in the workpiece, and the region where the force ring contacts the turning may be irregular in shape.
- Only the plastic stretch film provides all vacuum sealing.
- The system is scalable to a wide variety of turning projects.

turning blank into the plastic film and work it down into the rice (*Photo 9*). To properly position the blank, make sure it rests completely on plastic-covered rice. If the workpiece contacts the rigid chuck surfaces, it may be difficult to position and it could wear a leak through the film. If you do get a leak anywhere, repair it with additional layers of stretch film while the vacuum is still applied. The vacuum gauge will show when the leak has been repaired.

Tailstock support is essential to press the workpiece into the vacuum-hardened rice; there is no direct vacuum drawing the burl toward the headstock. When the bottom of the blank is irregular, as with the burl in the photos, its shape holds it in place (*Photo 10*). When the bottom of the blank is relatively smooth, you can add stability by using a vacuum chuck large enough to bed the blank deeper into the rice.

The final positioning of the blank within the compliant mandrel takes some experimenting. When you start to apply a small vacuum, the plastic film will begin to compress the rice. When you rotate the spindle the rice will shift, providing slack for adjustment. By tweaking the vacuum level, you can keep the rice compliant so that you can push it around like putty. Be sure to keep the tailstock and live center tightly pushing the blank into the rice. When satisfied with the position of the blank, apply full vacuum.

Verify that the turning is securely held by the mandrel without any movement. The initial application of the vacuum will tend to pull the rice away from the surface of the turning blank. If unacceptable movement is detected, reduce the vacuum (to around 5" Hg) low enough for the rice to be pliable. Tighten the tailstock and rearrange the rice as needed to provide proper support then apply full vacuum. As discussed in the safety sidebar, you can tape a protection ring over the plastic film to reduce the risk of damage.

Slowly ramp up the lathe's speed and have fun shaping the rim and perimeter of the blank. It may be necessary to leave the rim thicker than normal since you need to have a surface for the force ring later. On some projects, after using the compliant vacuum chuck to hollow out the interior, I returned to the compliant vacuum mandrel, remounted the turning and continued to work on the rim and walls.

Rice was used with this compliant vacuum mandrel and chuck but other granular materials may work also. Experiment with clean sand, plastic pellets; I did not succeed with ground coffee, however. The main criteria are that the granular material must compress and interlock within the plastic sheeting when a vacuum is applied, unpack and flow freely when the vacuum is released, and it should not contain a lot of fine particles or dirt.

Fine particles can collect on the filter, pack up, and restrict the flow of air.

Making the compliant chuck

The compliant vacuum mandrel is useful for initial roughing and shaping the rim and perimeter of your turning blank without damaging the other surfaces. To complete the turning, convert the mandrel into a chuck that will hold the turning by its rim, allowing full access for hollowing and finishing (*Photo 11*).

The compliant chuck uses the same basic materials as the mandrel, with the addition of a plywood force ring. The force ring will be on top of the blank, but under the plastic sheeting, to hold the turning in place (*see Materials sidebar*). Size the force ring center hole to overlap the outer rim of the turning blank. The surface the force ring touches does not need to be continuous, smooth, or flat. Under load, the force ring may bend and crack, which is okay as long as it continues to hold the turning and does not cause any vacuum leakage. Trace the force-ring's center cutout onto the burl's rim to confirm this is the area you want to hollow out (*Photo 12*). The drawn circle will help you position the blank later.

When the blank is mounted in the compliant vacuum chuck, you will not have access to the outer surfaces. Therefore, make a sketch with measurements to help plan the depth and shape of the interior. As before, position the vacuum chuck facing upward partly filled with rice. Place several layers of wide plastic stretch film on your work surface. You're going to need enough film to extend down over the sides of the vacuum chuck after wrapping around the blank and up through the force ring (make it big, it can be trimmed later). Place the turning on the center of the layered film. Place paper clips at several locations around the perimeter of the ▸

The compliant vacuum chuck retains the turning with a plywood force ring wrapped in plastic stretch film. The vacuum pulls the force ring and the turning into the rice-filled mandrel.

Materials notes

Plastic Stretch Film

While developing the compliant vacuum chucking system, I experimented with the plastic stretch film in other applications. With porous wood that leaks excessive air, wrapping it with the stretch film (or with plastic wrap from the kitchen) can significantly reduce the leakage. It is not necessary to leave the area to be turned uncovered, because a sharp bowl gouge will cut easily through the film. In one case, when I mounted a freshly turned crab apple bowl on a conventional vacuum chuck there was enough leakage through the wood that I could only achieve 4" Hg. When I covered the entire bottom of the bowl with plastic food wrap, the vacuum increased to 19" Hg. Using a sharp bowl gouge, I trimmed off the tenon and shaped the bottom of the bowl. I did not remove any of the film but just cut through it while shaping the wood.

Rice

I've been using rice as the granular material and I've left it out in the open so it shows in the photos. What the photos don't show is the rice explosion that can follow a cut in the plastic film. I soon learned to confine the rice in loose cloth bags. The key is to choose a flexible cloth that is light enough to allow easy passage of air, but fine enough not to leak rice. The bag should be large enough to be only half full, and you can use more than one bag to fill the chuck. Although the bags make it more convenient to manage the rice, gaps between bags might put the unsupported film at risk of rupture.

Force Ring

The vacuum causes a differential pressure between inside and outside the chuck, pushing the plastic inward and pressing on the force ring, which in turn generates a significant force to hold the blank in place. The force ring can be made of any smooth, thin, and rigid material, such as plywood, Formica, or high-density fiberboard.

Assume the vacuum generated is 18" Hg (small leakage), which will produce a differential pressure inward of about 9 psig. The force ring is 4¼" in diameter with a 2"-diameter hole. The resulting area of the force ring A is the area of a 4¼" disc minus the area of a 2" disc, so A = 11 square inches.

force = area × pressure, f = 11 × 9 = 99 pounds

That is the force the ring is using to press the turning blank into the chuck. Want more force? Make a larger force ring. The force produced depends entirely on the area of the ring, not on the size of the workpiece nor of the vacuum chuck itself.

When a blank leaks air, try placing plastic food wrap over it. Before applying the film to this green-turned crab apple bowl, the vacuum level was 4" Hg; with the film smoothed out and taped down at the edges, it increased to 19" Hg.

Loosely confining the rice in cloth bags makes it easier to handle and less of a mess in the event of membrane failure.

Place the force ring over the burl to verify its size, position it, and trace its inner cutout onto the wood. This will help you align the setup later.

Spread out and crisscross several layers of 20" stretch film. The paper clips on the perimeter will help manage it later.

Gather the large square of film around the turning blank and hold it with a rubber band.

Place the wrapped burl on top of the rice-filled chuck and slip the force ring down over the film and onto the rim of the blank. Add rice as needed around the blank.

Remove the rubber band and spread the film down and around the vacuum chuck.

Smooth the plastic stretch film around the sides of the vacuum chuck, and hold it in place with a rubber band. Trim the film to the rubber band.

plastic film; they'll help you handle the film later (*Photo 13*). Pull the plastic up over the blank, gathering it together and holding it with rubber bands or tape (*Photo 14*).

Settle the wrapped turning into the rice that's inside the chuck. The deeper you insert the turning, the better the rice can support it. Place the force ring down over the gathered plastic onto the rim of the turning blank (*Photo 15*). The film is now between the force ring and the blank. Check the level of the rice. It should come close to the force ring but not support it. Carefully remove the rubber bands holding the plastic and fold the plastic down over the force ring and over the edge of the chuck (*Photo 16*). The paper clips will help you separate and smooth out the film; leave a little slack in the plastic to help you reposition the blank. The surface to be hollowed and shaped should be exposed in the center, but surrounded by the force ring and plastic film. Use a large rubber band to hold the film in place against the side of the chuck. Use scissors to trim the film about halfway down the chuck's side. Smooth out the film with your hand. Using the narrow plastic stretch film, wrap around the chuck in a clockwise direction, covering from the hub and extending slightly past the rim of the chuck. Cut off the film and smooth it down (*Photo 17*).

Reviewing, the plastic film is under the turning, wraps around the side, over the top edge, up through the force ring, out over the ring's rim and then down onto the sides of the chuck. When the vacuum is applied, the rice conforms to the base of the turning blank to support it and the force ring is pushing the blank inward. Verify that the space immediately below the force ring is open so that it can be pulled down on the blank by the applied vacuum. If the film contacts the underside of the force ring or gets in between the ring and the chuck rim, it may interfere with the vacuum. Wrapping the film in the clockwise direction ensures that, when the lathe is running, the air does not catch any free ends causing the film to unwrap (*Photo 18*).

With the chuck assembly mounted on the lathe spindle, bring up the tailstock live center to help hold and position the turning blank. With the tailstock tight, position the turning by rotating the spindle, pushing the blank into place, and modulating the vacuum so the rice complies (*Photo 19*). When you get it right, apply full vacuum to hold the blank in place. It is okay if the force ring touches the rice, so long as it continues to hold the blank. Check the blank for movement and adjust as necessary. Tape a protection ring over the plastic and turn the wood as you normally would, taking light cuts (*Photo 20*). Be sure to monitor the vacuum gauge just in case you nick the plastic or otherwise develop leakage.

Be sure that all surfaces that make contact with the plastic film do not have sharp edges or points. If these cannot be removed by sanding, then reinforce the film with more layers or with tape. The rice provides support for the plastic film and a conforming base to hold the

turning. Too much rice could hang up the force ring, preventing it from applying enough force. Too little rice could allow the plastic film to balloon inward and burst. Experience will help you adjust the rice levels correctly.

Mounting small objects

With small objects, the forces generated by a conventional vacuum chuck may be too low to be useful. For example, an object with a diameter of 2" will have an area of 3.14 square inches. Using a vacuum level of 20 in. Hg gives approximately 10 psig.

force = area × pressure = 3.14 × 10 = 31.4 pounds

This small force cannot reliably hold the workpiece onto the conventional vacuum chuck. The compliant vacuum chuck breaks this barrier, because the force increases along with the size of the force ring (*see Materials sidebar*). In this example, making the force ring 4" in diameter with a 1.5" diameter hole for the 2" object gives an area of 10.8 square inches. Using the same 20" Hg vacuum:

force = area × pressure = 10.8 in^2 × 10 psig = 108 pounds

More than enough, an increase of three times over the conventional chuck.

How well does it really work?

I've done enough work with the compliant vacuum chucking system to believe it is reliable for jobs like the ones described here. It's very flexible and it can manage irregular shapes, so long as they don't fall though the force ring. I hope other turners will add further refinements and improvements. Using compliant vacuum chucking, I mounted and shaped the burl into a bowl without gluing, cutting, or drilling into surfaces other than those that were intentionally hollowed. The bottom gnarled surface was untouched and undamaged. I have turned many projects successfully, including natural edge bowls, and I have developed several techniques to help accurately position turnings in the chuck. I am learning something new every time I use this system. ■

Safety

Working with chunks of rapidly spinning wood on the lathe is inherently dangerous. Always wear a faceshield and breathing protection. Compliant vacuum chucking is a new concept without a lot of experience. So far, the failure modes of losing vacuum and tool catches seem to be less dramatic than with conventional vacuum chucks. However, a major cut through the plastic can cause an interesting dispersion of rice everywhere, along with launching of the turning blank. I recommend taping a protection ring of cardboard or plywood onto the plastic to reduce the risk of nicking the plastic film.

A protective ring taped onto this compliant vacuum chuck protects the plastic film from accidental cuts by the turning tools.

Don't rely on the vacuum gauge—also check the plastic film to verify that it is tightly pressed against the rice and turning blank. If the granular material contains fine particles, they can build up against the filter and block airflow from small punctures and cuts. Consequently, the actual vacuum within the chuck can be less than shown on the gauge, which may lead to inadequate support.

References:

- "Understanding—and Improving—Vacuum Chucking Systems," John I. Giem, *AW,* vol 26, no 1.
- "Universal robotic gripper based on the jamming of granular material," Eric Brown and others, proceedings National Academy of Science, November 2, 2010, vol. 107, no. 44, 18809–18814.

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Mount the assembly on the lathe spindle and smooth everything down tight to seal the vacuum chuck. Smooth clockwise so the lathe doesn't unwind anything.

Bring up the tailstock for support and position the blank so the pencil line aligns with the force ring. Slowly turn on the vacuum and readjust as needed.

Using light cuts, hollow out the blank and sand it, being careful not to damage the plastic film.