Compound-Angle Joinery

The Chair

The side-rail to rear-leg joint on a Chippendale chair—and many other types of chairs—must account both for the trapezoid-shaped seat and for the cant angle of the leg, making it necessary to cut and use a compound-angle tenon.

BY WILL NEPTUNE

For me, chairs are easily the most satisfying projects to build, but students often are puzzled by the compound-angle joinery between the legs and seat rails. I learned how to draft, lay out and cut these joints when I was a furniture-making student years ago, and now I teach it at North Bennet Street School. Once you answer two critical questions—"Where do the layout lines come from?" and "How do I get the layout lines on the wood?"—you'll see that cutting these joints isn't all that hard. What's more, once you understand how to cut compound-angle joinery, cutting joinery with a single angle becomes simple.

Recently, I built a set of Chippendale chairs. Most Chippendale chairs—and a lot of other styles of chairs—have rear legs that cant inward as they go toward the floor but front legs that are perpendicular to the floor line. Although this design lends a refined sense of upward motion to a chair, it also introduces a fussy situation when it comes to joining the rail to the back leg. To allow for the cant of the legs and the trapezoidal shape of the seat, most of the time you'll have to cut compound-angle tenons between the legs and seat rails.

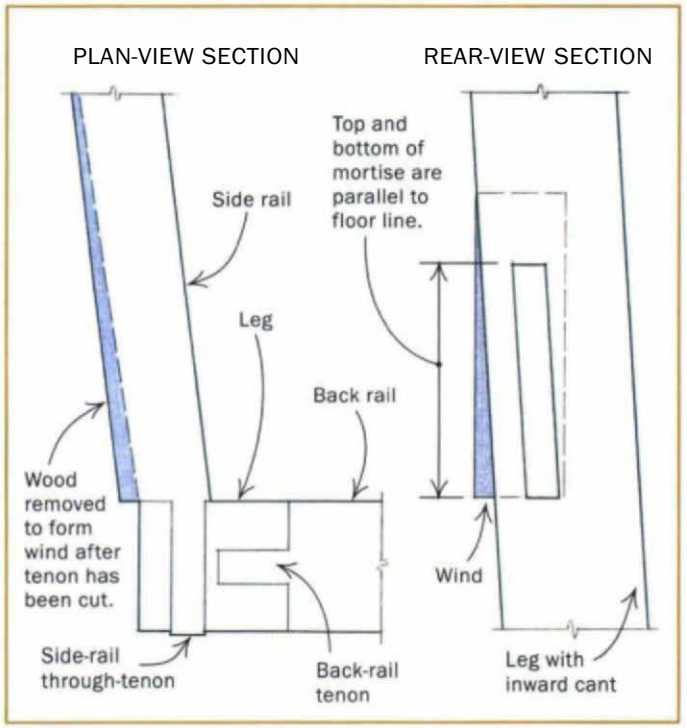
It is tempting to angle the mortises, in either the plan or elevation, to simplify the tenon problem. In the first case, the mortise would angle in the plan view at the

FEDERAL PERIOD

In the high style. *Made by Steve Brown, this heart-back Hepplewhite design has curved seat rails and more complex shaped legs, but the leg-to-rail joinery is the same as the Chippendale chair above.*

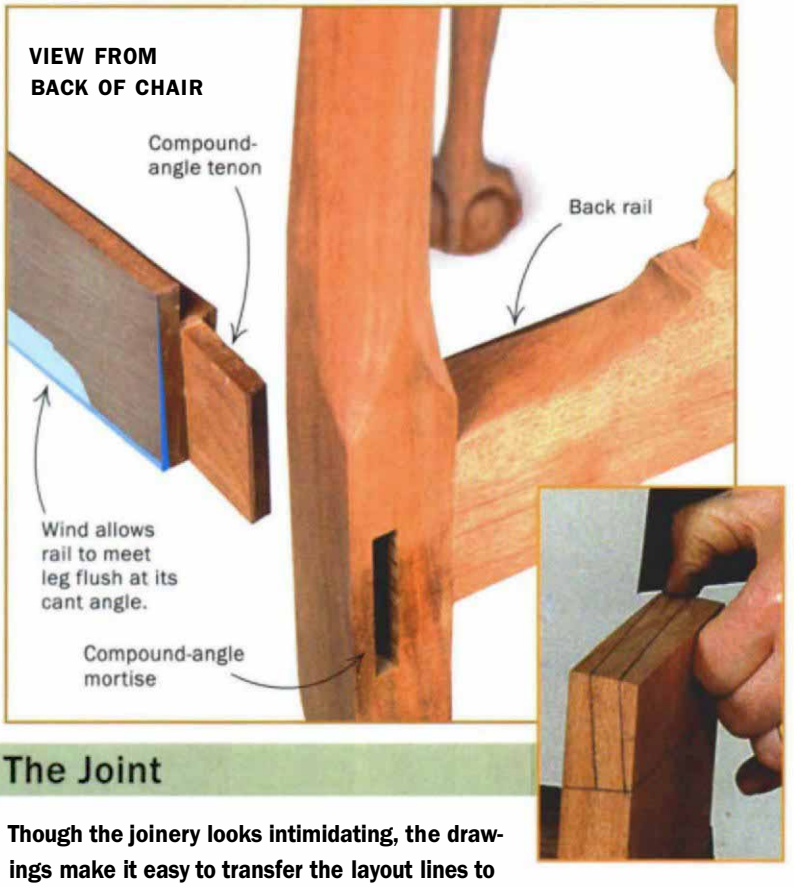
Photos, except where noted: Michael Pekovich; this page and facing page (bottom): Lance Patterson

Careful tenon layout is the key to cutting and mastering this intimidating joint



The Drawing

I teach students to lay out this joint with only two partial drawings—a plan (overhead) view at the bottom edge of the side rail and a front elevation view. This article will show you that simple drawings are all you need to know to cut this joint.



The Joint

Though the joinery looks intimidating, the drawings make it easy to transfer the layout lines to the rail. Once the layout lines are in place, it's simply a matter of cutting the joint—by handsaw, bandsaw or other means.

seat-frame trapezoidal angle. In the second case, the mortise could be cut square to the back rail in front elevation to correct for the cant angle. Both of these moves force you to shorten the back rail tenon, which would weaken this critical joint.

Both historically and for chair making today, I think compound-angle tenons represent the best possible technical solution to this problem. Once you have a system for laying out these joints, cutting them is not that difficult.

Draw simple elevation and plan views

No matter what style chair you're building, there are two angles to consider: the cant of the leg, seen in a front elevation, and the seat-frame trapezoidal angle, seen in a plan (overhead) view. Start by doing a partial drafting job, just enough to get the information you need for layout.

First draw the leg from a front view and show the mortise. The mortise in the rear leg should be as far to the outside of the leg as possible without sacrificing the thickness of the mortise walls. The mortises can be cut square and slightly short in length, then chiseled to the correct angle at the top and bottom, making the mortise a parallelogram. Cutting a mortise in the shape of a parallelogram not only helps you register the rail, because it makes the rail's top and bottom edges parallel to the floor line, but it also makes the through-tenon look better from the back of the chair.

Transferring information from the elevation, draw the sections of the leg at the bottom of the rail. Then you can draw the side

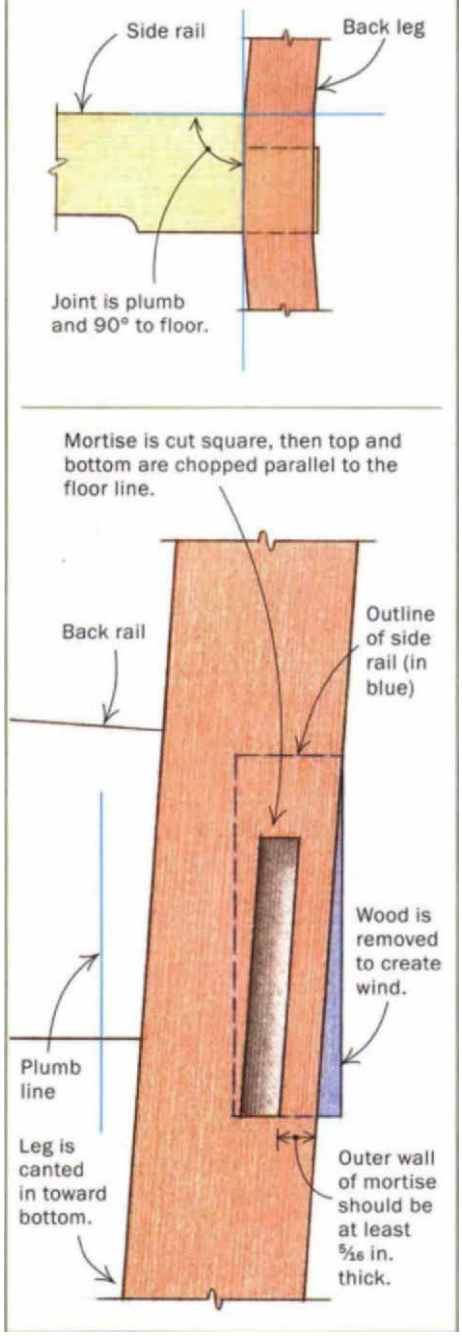
COUNTRY CHIPPENDALE

In any style. *Made of curly maple, Mary Conlan's Chippendale chair of simpler form is built using the same leg-to-rail joinery as a more flashy, high-style chair.*

Drawings: Vince Babak

LAYOUT AND CUT THE MORTISE

Set the mortise to the outside of the leg as far as possible, taking care to see that the outer mortise wall is at least 5/16 in. thick for strength. Lay out and cut the square mortise parallel to the side of the leg. Then chop the top and bottom of the mortise parallel to the floor line, making the mortise a parallelogram. The rail joins squarely to a flat section of the leg; cut a wind to keep it flush.



rail and its angle. Notice that the side rail must be thick enough to allow wood for the top outside corner as well as the bottom inside corner, as seen in the elevation drawing on p. 61. I also like to have extra rail thickness to allow for a shoulder at the bottom inside corner.

First draw the line representing the outside face of the rail blank and its angle. Here I'm assuming that the outside face of the rail lands flush to the top of the leg, but you could leave a shoulder if your design calls for it. Then draw a parallel line showing the bottom inside face of the rail, choosing a rail thickness that will allow for an inside shoulder of 1/16 in. to 1/8 in.

As a last check, draw a detail of the top section of the leg in plan view. I draw this as if the leg mortise runs all the way up to the top edge of the side rail. Extend the line that represents the outside face of the rail back through the leg to be sure that the tenon lies within the thickness of your rail.

This construction has the side rail forming a simple angle, which leaves wood sticking out from the canted leg on the outside. These surfaces will be reconciled by fairing a wind into the outside face of the rail once the joinery has been cut. The front end of the rail is left alone for the leg joints, so the rail starts plumb at the front and develops a wind that becomes the cant angle of the rear leg.

To show this, draw a dotted angled line from the bottom outside corner of the rail out toward the rail's front end. This transfers the information from the elevation onto the plan view (as in the drawing on p. 61). The plan view is simplified but contains all of the crucial points seen in the elevation. These two drawings provide the information necessary for laying out the joint.

Follow the drawings to lay out the joint

To make the layout easier, I pretend the mortise is extended up to the rail's top edge. Once the tongue of the tenon has been cut using the method of your choice, it will be easy to shoulder down the tenon to match the real mortise (see p. 64).

Extend the lines of the mortise opening up to where the edge of the rail will land. From the bottom inside corner of the mortise, square up a line to the top edge of the rail. Where these three lines cross the top rail edge will become the source of the layout information.

The important thing to realize is that the information seen here is true only at one location along the rail: the plane of the shoulders (see the plan view on p. 61).

On the inside face of the rail, square a line across that shows the correct shoulder location, measured in from the end. Here I've left extra length for later cleanup. Then, using a bevel gauge set to the seat angle, run the shoulder lines across the top and bottom edges of the rail. These should then connect with another square line, up from the outside face of the rail, describing the plane of the shoulders. Your drawing should now show the location of the tenon at this plane (see the drawing on p. 64).

CHIPPENDALE

One joint, many chairs. *No matter what kind of chair you're building, if your back legs are canted and your seat is trapezoidal, you'll need to use compound-angle tenons to join them, as was done with this Chippendale chair by Rich Heflin.*

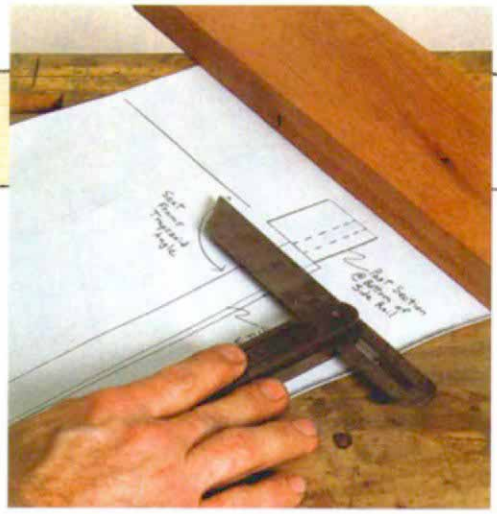
Working from the elevation drawing, set a marking gauge to *x* and mark this distance across the top and bottom shoulder lines, measuring from the inside face of the rail. From the mark on the top edge, use a pair of dividers set to the distance *y* to make another mark along the shoulder. The new mark on the top edge and the first mark on the bottom edge locate the inside cheek of the tenon. From these marks, transfer the size of the mortise to locate the outside tenon cheek.

This may sound confusing, but all you're doing is converting the cant angle to a rise/run problem. The rail width is the run, and *y* is the rise. The reason for the initial marking gauge line is that it's more difficult

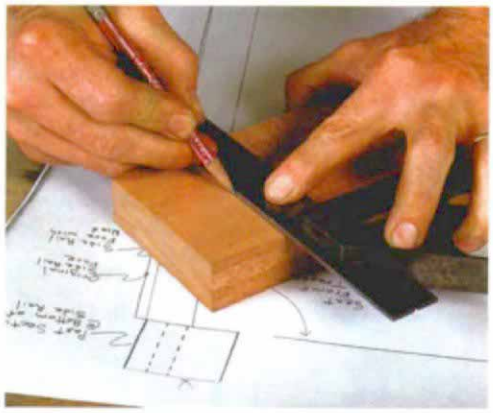
Photo, this page (right): Lance Patterson

CONSIDER LENGTH AND SEAT ANGLE WHEN LAYING OUT TENON SHOULDERS

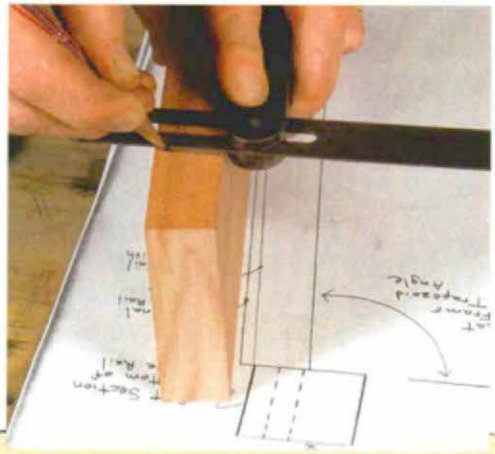
While the joints at the front of the chair are simple angles, compound-angle joints are required where the side seat rail joins the back leg. Use simple full-sized drawings to determine the angle of the top and bottom tenon shoulders at the back of the seat rail. Then transfer measurements from the drawings to the rails.



1. Full-sized drawings help you avoid errors. *Working from a full-sized plan (overhead) view, set the bevel gauge to the angle between the back rail arid side rail on the seat frame.*



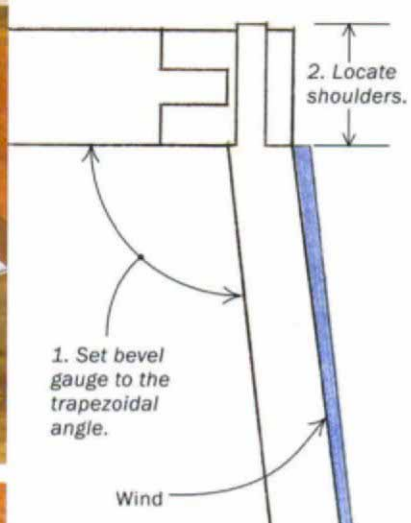
2. Marking the first face. Set *the side rail into place over the drawing (make sure there's enough stock for the full tenon). Make a tick mark on the bottom inside corner of the side rail, and pencil in the shoulder line on the inside face.*



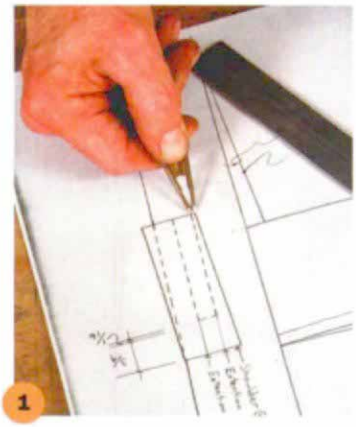
3. Locating the top and bottom shoulders. *Register the bevel gauge against the line for the inside shoulder, then mark the bevels at the top and bottom of the rail. Check that your angles match those in the drawing.*

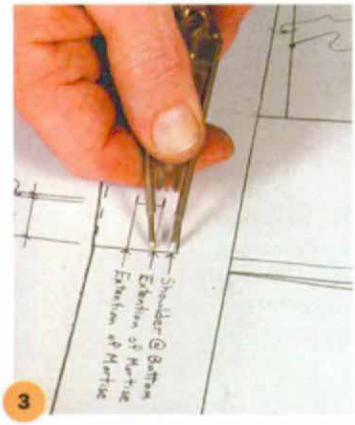
4. Knife marks are more exact. *Once the tenon shoulder has been correctly marked, knife-mark the lines on all sides of the rail. The knife marks provide a specific line to pare or shoulder-plane to.*

SECTION AT RAIL BOTTOM

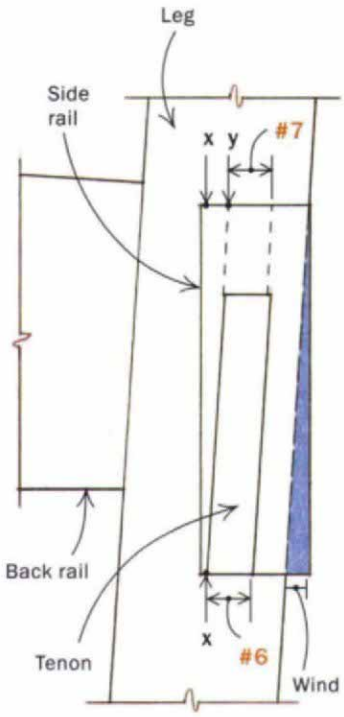


CAREFULLY LAY OUT THE ANGLED TENON ON THE STOCK





Laying out and cutting angled tenons is a methodical process, but it's not a difficult one. Work from simple but accurate drawings and mark out each measurement from a single reference line on both the top and bottom of the tenon.



1. *Use a simple elevation drawing, as seen from the front of the chair, and set dividers to x—the distance from the bottom inside corner of the rail to the inside corner of the tenon.*

2. Set a *marking gauge to the distance* x between *the inside face of the rail and point* x *and scribe a line across the top and bottom shoulders from the inside face of the rail.*

3. *Set the dividers to the distance between* x *and* y.

4. Use the *divider setting from step 3 to locate point* y on the top *edge of the rail, measuring from point* x.

5. *Set the dividers to match the mortise width on the rear leg of the chair itself.*

6. *From point* x *on the bottom of the rail, transfer the width of the mortise.*

7. *With the dividers still set to the mortise width, measure from point* y to *mark the tenon width at the top of the rail.*

8. *Tenon cheeks are marked perpendicular to the shoulder line by registering a square against the bevel gauge—which is still set to the trapezoidal seat angle.*

9. *After the top and bottom of the tenon have been marked, use a straightedge to connect the points and complete the layout.*

10. *After knife-marking the shoulder lines, cut the tenon and shoulders with a backsaw, then trim to fit.*

to measure from a corner using dividers. The goal here is not just to get a tenon that fits—the rail should also land on the post at the correct location and project at the trapezoidal angle.

Once the base of the tenon has been located, the plan view (see p. 61) shows the next move. The tenon is simply square to the shoulder. Clamp the bevel gauge to the rail and square all four tenon marks out to the end of the rail. Once you've connected these lines across the end grain and knife-marked the shoulders, layout is complete, for now. Once the tenon cheeks and the side shoulder have been planed, the top shoulder can be marked out and cut. After fitting the tenon, mark the wood to be faired directly from the leg (see the photos at right).

Take it slow. *The author uses a shoulder plane to trim the cheeks, checking the tenon frequently against the mortise until he has a tight fit. He then trims to the layout lines with a shoulder plane.*

MARKING OUT THE WIND

Once the tenon has been cut and fitted, dry-fit the joint tightly and mark out the section of the rail that needs to be planed away. Notice that there is no material removed at the front of the rail.

Establish layout lines. *Connect the bottom line of the wind with the bottom front corner of the rail. Planing to this line gives you an even wind and lets the rail meet flush at both the front and back legs.*

Make practice cuts in scrap before cutting the real joint

One very direct way of cutting a compound-angle joint is with a handsaw. First the cheeks would be sawn in the ordinary way. The only tricky part is remembering that the shoulder cuts are at different depths on each edge. Begin sawing with the shallow edge facing you, and avoid cutting into the tenon.

A bandsaw is good for cutting the cheeks, too. Setting the table for the cant angle (remember to keep track of lefts and rights), you can follow the cheek lines on the top edge and the blade will follow the cant angle on the rail's end.

The tablesaw can probably get you closer and thus avoid a lot of cleanup with hand tools, but the explanation is a story all by itself (for more on this technique, see Master Class on p. 108).

Whatever method you use, lay out with pencil first and confirm that you have things correct. Often, the cant and seat angles are close enough that it's easy to grab the wrong bevel gauge during layout. The shoulder won't look bad, but the front legs will be way off. It's also possible to get the lefts and rights mixed up and lay out the correct angle in the wrong direction. These mistakes make for a long day, so when in doubt, mill a practice rail and check both your layout and cutting method. Once the joinery for the back end of the chair has been cut, the simple angles on the front ends of the rails will seem easy. □

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