Fixtures for Steambending

Adjustable end-stop and versatile table control breakage, springback

by Michael C. Fortune

Steambending allows me to work with simply curved pieces of wood that I can shape and blend together. Most of the curves I bend happen in one plane and are not exercises in pushing the limits of the process; most of my jobs are multiples, like sets of dining chairs. The trouble with Steambending is the inconsistent and unpredictable results—breakage during the bending and springback afterward.

Since I cannot afford to cut extra blanks in anticipation of rejects, I've had to devise techniques that will ensure uniform results. I also required a high degree of design flexibility, a reasonable rate of productivity, quick set-up time and easy operation by one person, and low capital investment. The system I'll describe is based upon an adjustable end-stop that's attached to the usual steel back-up strap, and a special clamping table to which I can bolt a variety of bending forms.

When I've worked out a design, an integral part of my sequence for building the object is making a complete technical drawing. For Steambending, this provides the length of the blanks to be bent, their cross-sectional dimensions so that I am sure of having enough material to shape and carve around joints, the joinery details and index points for the machine jigs I use, and the size and shape of the bending form itself. The way I work, it is not practical to guess about springback, nor to accommodate each part individually, nor to discard parts that do not match. In some cases, the grain in a bending blank is part of a visual composition and could not be substituted without sacrificing other components as well.

Immersing a straight piece of wood in hot steam plasticizes its fibers. When the steamed wood is bent, the fibers on the inside of the curve are compressed while those on the outside must stretch. Since the wood is much stronger in compression than in tension, a steel back-up strap with fixed end-stops is commonly used to restrain the length of the blank, thus shifting most of the stress into compression. If the strap is too loose, tension failure is the likely result—the wood fibers on the convex side of the bend stretch until they break. If the strap is too tight, the fibers on the inside of the curve may wrinkle and buckle, called compression failure.

In my early experiments, using fixed end-stops on the back-up strap, I got a few pieces of furniture and a large pile of rejected parts. Although I had machined all the blanks to the same length, some of the rejects failed in compression, while others failed in tension. I attributed these inconsistent results to the strap's having stretched during repeated use, and to my having used kiln-dried wood, which could have had such baked-in defects as casehardening or surface checking. The steaming time was also marginally inconsistent, since I put several pieces into the steam box at once, then used them one at a time. Eccentricities that grow into most pieces of wood also contributed to these inconsistent results.

To control these variables, I discarded the fixed end-stops for an adjustable end-fixture that could respond to each blank as the bend progressed. Also, I now use only air-dried wood, which in Ontario ranges in moisture content from 12% to 20% out-of-doors. Since severe bends may require more moisture, say 25% M.C., I may pre-steam the blank for an hour and let it sit in the steam box for a day before bending. I've successfully bent white oak, black walnut, cherry, ash and red oak, but the bending stock must be high quality, straight and free of defects.

Adjustable end-stop—The end-stops on the steel strap are subjected to considerable force as they compress the wood fibers around the bend. The end-stop must accommodate this force. The ones I am now using are shown in figure 1, on the next page, and an earlier version of the adjustable end-stop is shown in the photo. The principal material in both is ¼-in. and ⅜-in. by 2-in. bars of hot-rolled mild steel. My current version is welded from three thicknesses of bar. The adjustable end-stop fixture is not welded to the strap, but is detachable, so it can be mounted on straps that range from 1 in. to 6 in. wide according to the stock to be bent. The bottom of the fixture includes a 45° step that interlocks with a 45° step on the bending strap. A machine screw holds the fixture in place but does not receive any lateral force; if it did, it would quickly shear off. The adjusting thread is ⅝-11 N.C. running through a coupling nut about 2 in. long. The end-stop itself is made of ¼-in. or ⅜-in. angle iron with a short length of black iron pipe welded onto it. The pipe both locates the stop on the threaded rod and reinforces the angle iron. I generally make the stop 2 in. wide, but I add a steel reinforcing plate to the working face of the angle to make it larger than the end of the stock I am bending.

The strap is 1/16-in. steel, wide or wider than the stock, and able to take a bend without kinking. Holes are drilled ⅜ in. or ½ in. in diameter on 4-in. centers down the length of the strap, so its overall length can be grossly adjusted by the location of the fixed, hardwood end-stop, which is bolted on. Two holes are drilled through the end-stop for this purpose, with about 1½ in. overhanging on the end that faces the stock and 3 in. on the other end.

Bending table—I used to bend steamed wood around a form clamped to my workbench. To gain mechanical advantage, I attached levers to the end-stop and back-up strap assembly. My body weight was the main force, plus anyone willing to hang on for 15 minutes until the bent part could be removed and clamped to a drying jig. I needed a better way.

The versatile cast-iron table with square holes that welders use seemed appropriate. With this in mind, I fabricated a plywood table 4 ft. by 5 ft. by 3 in. thick to which I could

Michael Fortune, 29, designs and makes furniture in Toronto, Ont. He has also taught at Sheridan College.

Fig. 1: Steambending fixture

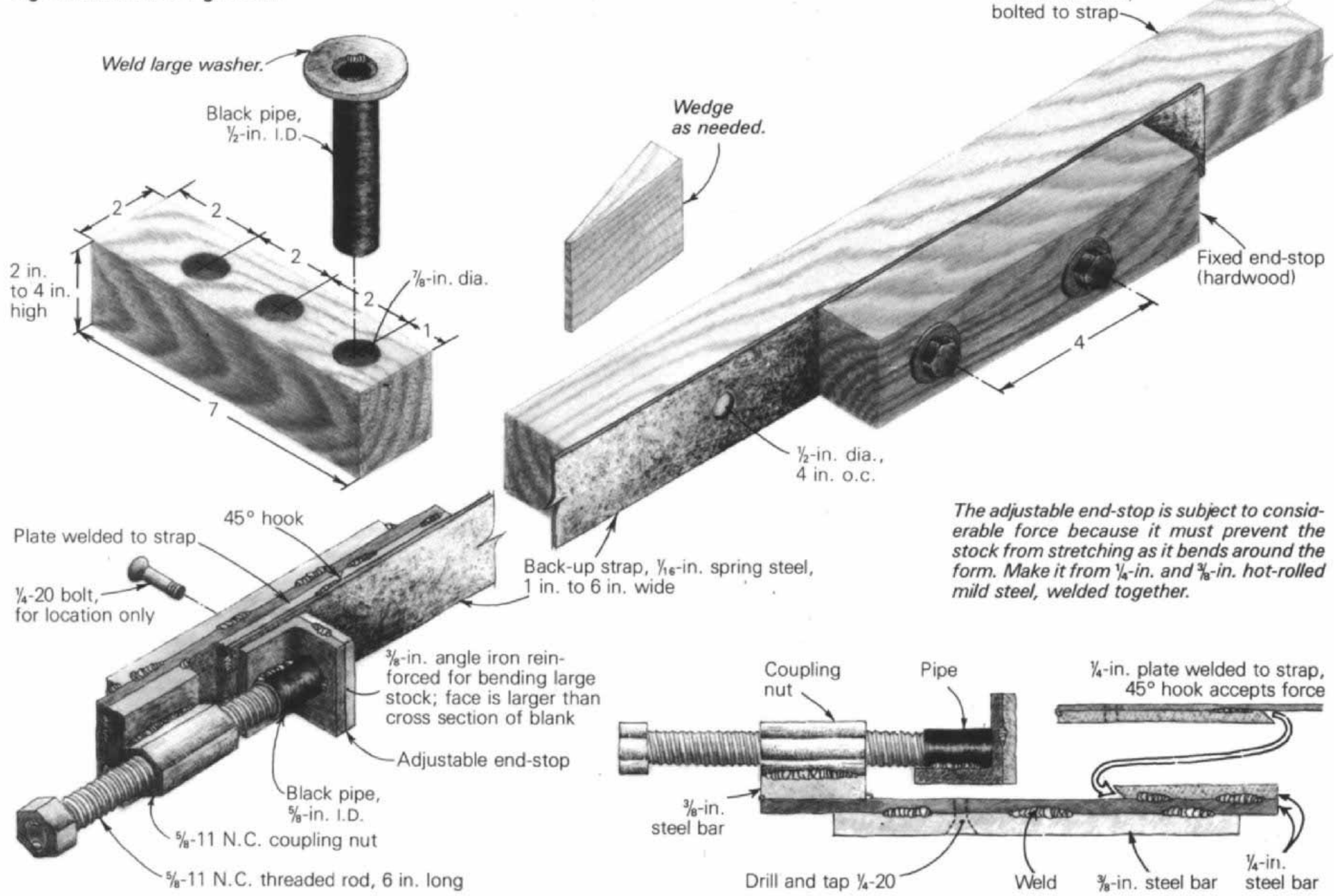
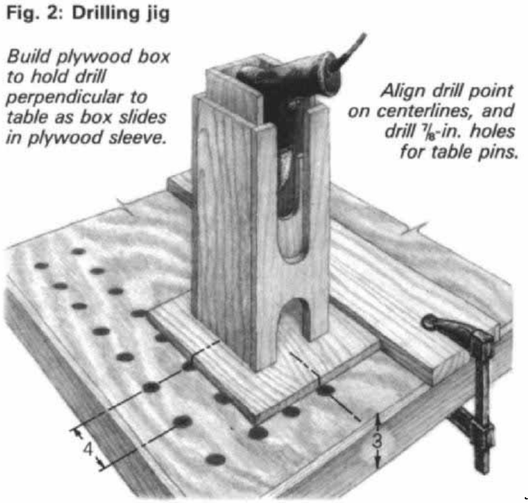
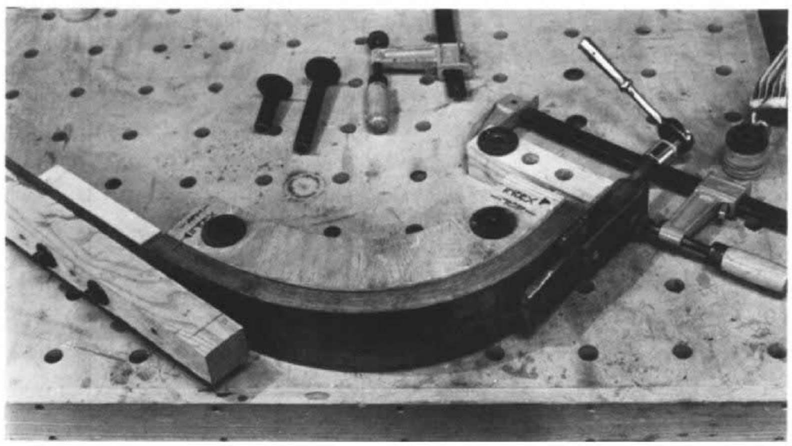


Fig. 2: Drilling jig





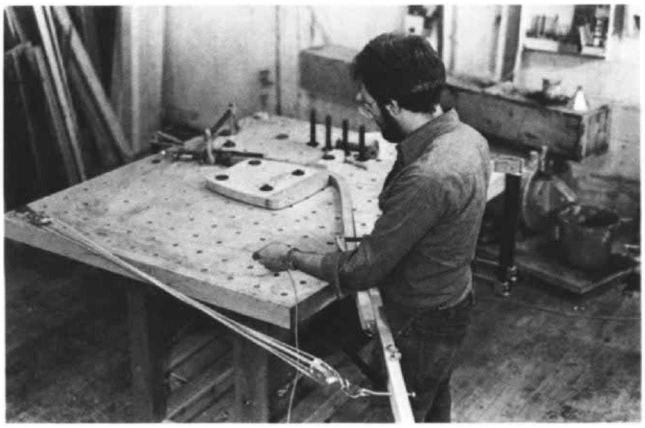
Bend has been levered from fixed-stop end, left, by block and tackle (not visible); adjustable end-stop is clamped to block at right, which is attached to the table by one pin. Strap and stops pivot away from the form for easy insertion and removal of stock.

fasten bending forms. My table was laminated from four sheets of ¾-in. plywood, hardwood ply for the faces and floor sheathing for the core. Not having a veneer press, I laminated the sheets one at a time, using wood screws to provide clamping pressure. I removed the screws before adding the next layer, so I could drill holes anywhere in the table without hitting embedded hardware. For design flexibility, I drilled a regular pattern of ⅞-in. holes through the table, and holes in my bending forms and adjustable end-stop fixture. These accommodate short lengths of iron pipe, ½-in. I.D., which act as locating pins. They can handle the substantial shear forces of the bending process and have a large washer welded to the top for easy insertion and removal. Half-inch bolts pass through the table pins to secure the bending forms and adjustable end-stop fixture to the table.

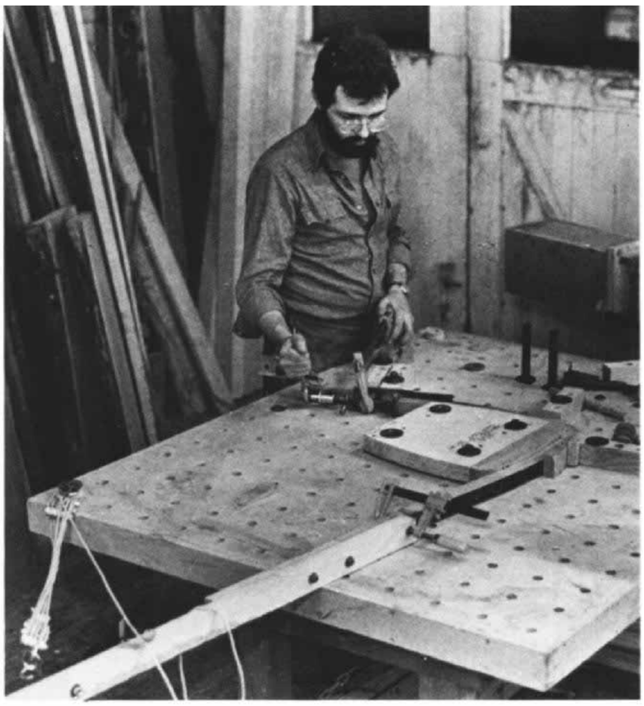
To drill perfectly perpendicular ⅞-in. holes through the large table, I constructed a tight-fitting box around a ½-in. hand drill. It slips into a sleeve mounted on a square of plywood, as shown in figure 2.

The pattern of holes eliminates the need for large, reinforced bending forms, because most forms can be bolted to the table at several points. I prefer plywood forms, as the less dense core of particleboard will crush after repeated use. I cut the inside shape of the form parallel to its face so that clamps can be applied wherever they might be required.

The photo, above, shows how I mount the assembly. Note



Above, Fortune begins to pull in the block and tackle for the first bend of a chair seat. The stock is first steamed in the plywood box in the background; steam is generated by a salvaged boiler containing a 4.5-kilowatt immersion heater. Below, with the first corner turned, Fortune slackens off the adjustable end-stop before levering the wood around the second bend.



Walnut dining chair, one of a set of eight with dining table, has steambent arms and rear legs, laminated back slats.

David Allen

that the adjustable end-stop is at the starting point of the bend, and the fixed stop is at the free end of the blank. The adjustable end-stop is clamped to a wooden block, which in turn is located on the table by a table pin and a bolt. This arrangement allows the strap with both end-stops to pivot away from the form for quick installation of the heated blank, and easy removal of the bent piece. Index marks can be made on the form and transferred to the bent piece for later reference when machining joints. A dozen wooden clamping blocks, drilled with ⅞-in. holes, will come in handy, as they can be bolted down anywhere and wedged against the bent blank.

The final piece of the assembly is a lever bolted to the back of the bending strap at the wooden fixed-stop end. It provides mechanical advantage and supports the blank, which otherwise might compress locally or overturn off the strap. The lever reaches several inches beyond the stop toward the blank (see figure 1). It can be clamped to the blank here if trouble starts to develop, then the clamp removed when the blank is bent close to the form. A block and tackle can be attached to the lever at its far end, for additional leverage. This can be tied off in mid-bend, freeing the operator to adjust the end-fixture or to place clamps. A marine hardware spring-loaded cinch would be useful here too.

The bending process—Before bending, make sure that all forms, fixtures and clamps are in place. Set the steamed blank (steam an hour for every 1 in. of thickness) in the strap, making sure it's in line with the strap and with both end-stops. Tighten the threaded rod on the adjustable end-fixture. I use a ratchet, tightening until it's secure, then giving it another half-turn. This should flatten any kinks out of the strap.

The photos at left show a U-shaped bend around a chair-seat form. The first curve and first corner can be bent without backing off the adjustable fixture. However, upon approaching the second corner, the straight portion of the blank will start to arch away from the strap or to deform in an S-shape. I loosen the fixture just enough to relieve the excessive compression forces that have built up. The second bend can then be made.

I've found that springback can be minimized by leaving the bent part to cool on the form for 15 minutes, bathed in a slow stream of compressed air. Then it's quickly transferred to a setting jig of the same shape as the form before it has time to spring back. It is clamped there, and left for a week or preferably two weeks. The setting jig should be wide enough to accommodate all the parts being bent; clamps spanning the bend will maintain the distance between the ends of the blanks but do not help to maintain the shape. I accommodate the setting time by proceeding with other parts of the job according to my drawings.

It's important to allow the bent fibers to relax, and the wood to reach moisture equilibrium with the atmosphere. Since pieces may come out of the strap at 20% moisture content or higher (for severe bends), they must dry slowly, else they'll check. This problem is acute when bending red and white oak. I cover the setting jig with a blanket to restrict air flow for a few days, and this seems to control the problem. □

Further Reading

"Steam Bending," W.A. Keyser, *FWW* #8, Fall '77, pp. 40-45.
"Michael Thonet," John Dunnigan, *FWW* #21, Jan. '80, pp. 38-45.
Wood Bending Handbook, W.C. Stevens and N. Turner. Woodcraft Supply, 313 Montvale Ave., Woburn, Mass. 01888, $9.35, 110 pp.

Bending with Ammonia

by Bill Keenan

Consider the possibilities if wood were as pliable as leather. Form could be added to the beauty of wood without having to use subtractive methods of shaping. With this in mind, Huff Wesler, at the University of Wisconsin's Art Department, has experimented with wood that is plasticized by immersion in gaseous anhydrous ammonia. After exposure to the ammonia, wood can readily be coaxed into fantastic forms.

The underlying principle of this process is not hard to understand. A solvent applied to the wood diffuses into the cell-wall structure. The bonds that clamp the wood's microscopic components together are disassembled. The wood becomes flexible, and when bending force is applied the components are physically displaced. As the solvent diffuses out of the wood, these microscopic cell components bond together in their new positions. The piece regains its rigidity in the new shape, like hair after a permanent-wave treatment.

Steam has traditionally been used to soften wood, but ammonia plasticizes the fibers more quickly and more completely; yet ammonia is not so strong that it will dissolve cell tissue as might a stronger solvent. Only the cell components are separated, allowing movement with minimal bending stresses.

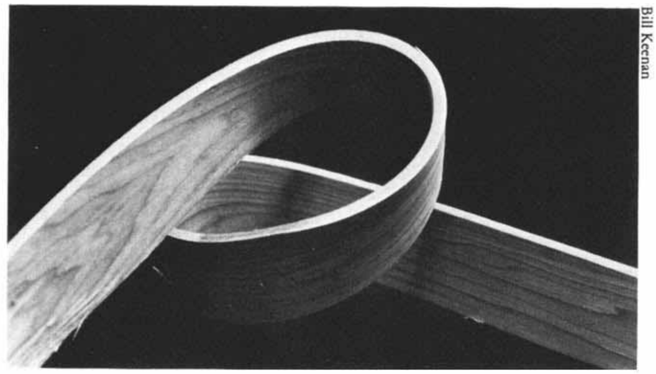
The process Wesler uses derives from research conducted over the past 15 years at Syracuse University, and commercial applications of it are covered by a number of U.S. patents. It's important to note that anhydrous ammonia (anhydrous means without water) is chemically pure NH_3, whereas household ammonia is a dilute solution of ammonia gas in water. Experiments with household ammonia will not bend wood.

Ammonia vapors are extremely dangerous to the eyes and lungs, and this process releases quantities of these noxious fumes. A fume hood and goggles are essential parts of the apparatus. The original Syracuse experiments were conducted atop a tall building, where strong winds carried the fumes away. Despite the awful vapors, Wesler believes the process holds real potential for the craftsman and sculptor.

He built a treatment chamber (see drawing at right) for introducing ammonia into wood; using parts acquired from ordinary plumbing suppliers and stainless-steel fittings from dairy suppliers, he spent under $1,000. The unit was welded together to withstand a pressure of 800 PSI as a safety measure. Pure, anhydrous ammonia at room temperature and at approximately 130 PSI pressure is used in the chamber.

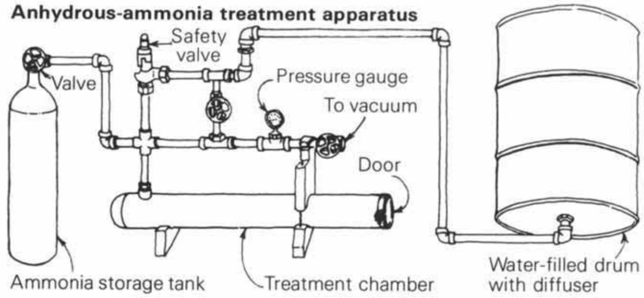
The first step in treatment is selecting the right piece of wood. In general, woods good for steambending are also good for ammonia bending. Certain species work better than others; oak works well whereas maple does not. Bending stock should be straight-grained and flatsawn. Surface irregularities and such defects as knots should be avoided, because they tend to concentrate stress. Moisture content of the wood is also important. Wesler prepares his bending stock in a plastic enclosure into which moist heat is fed, like a steam room. The stock stays there for about a month, until its moisture content is raised to an optimal 20%.

The rest is simple. In a demonstration, Wesler places a ¼-in. thick hickory board in the treatment chamber and exposes it to the gaseous ammonia for about 45 minutes. Exposure time varies according to thickness and species of wood. Generally, an hour per ¼-in. thickness is adequate. When he



After plasticizing in anhydrous ammonia, the ¼-in. stock above was easily bent into a pretzel shape.

Anhydrous-ammonia treatment apparatus



removes the piece, it's soft and ready to be shaped. Watching the piece being twisted into a pretzel shape reminds me of the delight I got as a child from watching a chicken bone that had been rubberized in a pressure cooker and was being flexed back and forth.

The bending rate can mean the difference between success and failure. If the piece crumples or kinks along its concave face, bending should be halted for about 30 seconds to allow the wood to flow. But there is also a time constraint, as the wood will begin to stiffen in about 15 minutes.

Ammonia-treated wood requires significantly less force to bend than steam-treated wood. Pieces ¼ in. thick can be bent by hand and then restrained by taping or clamping. There are other methods of bending, such as form bending, for which a mold is required. A pipe makes an excellent form for a helix or circle. Thicker pieces require a bending strap.

Once the bending is completed, the piece is dried until it reaches equilibrium with surrounding humidity conditions. A temperature and humidity-controlled drying room is best, but air-drying works well too. Warping and distortion can be controlled by leaving restraints on the piece until it is dry. This may take from hours to weeks, depending on the size and type of wood, and on the drying conditions.

Following exposure to ammonia, wood is changed in several ways. It is often denser and harder than before, a condition you can augment by compressing the wood while it is still soft. The color of the wood usually darkens slightly, but this can be an asset, as some plain woods come to life. Color change can be prevented with a sulfur-dioxide pretreatment.

There are a lot of variables involved in plasticizing wood, but the results are worth the trouble. The ease with which ammonia-treated wood can be bent, molded, embossed, densified or any combination of these processes offers a new horizon for the wood craftsman.

Bill Keenan is a woodworker and forester in Milwaukee, Wisc.