Guitar Joinery

The balance between structure and tone

by William R. Cumpiano

The author with apprentice R. Goldberg.

The major problem confronting the guitar maker is how to counteract the structural changes that will occur in his instrument over time. These changes will alter tonal quality and affect the instrument's playability. The builder relies on joinery to counteract these changes.

A strung-up guitar is a structure undergoing constant sizable stress and requiring utmost economy of materials to render it a highly compliant, frequency-dependent vibrating object—that is, with different sections of the guitar vibrating at different but specific frequencies. A successful guitar design must correctly balance an effective structure with an optimum mass to produce an instrument that will project good strong tone for many years without destroying itself in the process. The designer will usually favor good tone and lightness at the expense of rigidity. He will build into the guitar features that anticipate distortion while allowing for repair through its hoped for 100-year life span.

Interestingly, a guitar's tone is expected to mature and decay within a relatively short time, short compared to the maturation span of several hundred years of violins and other bowed instruments. This is because the architecture is different in each case. When a guitar is played, six long strings are pulled up at the center of a wide expanse of very thin spruce of essentially even cross section. In the violin, four short strings are pushing down on a perfectly vaulted cross section of fairly thick and narrow dimension. The guitar body fatigues first, losing power and volume dramatically when its contemporary violin is just passing adolescence.

Guitar assembly methods vary according to how the builder chooses to join neck to sound box. Factors affecting this choice are: the number of instruments to be built simultaneously, the extent of the builder's facilities, his talents, time and profit margin, and his training and accumulated prejudices. Unfortunately, the sense of responsibility of the builder to his creation and his buyer is predominantly absent today, and most mass-produced instruments are designed with only profit in mind.

The selection of the neck/body joint is critical. The primary requirement is rigidity. Also, it must fit at a precise angle. The angle of neck to body determines the height of the strings off the neck and consequently the instrument's playability. Of equal significance is how easily the joint can be disassembled for later readjustment of the angle.

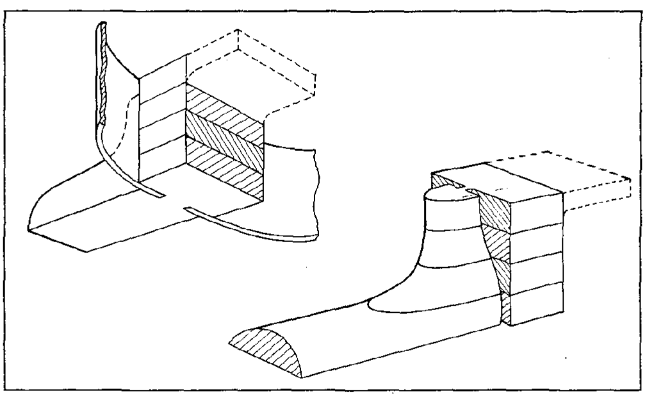
If we accelerate the effect of string tension on an instrument we see the following: As soon as the strings are strung the entire instrument flexes longitudinally away from them, like a wooden bow under a taut cord. Soon the area under the string attachment point at the sound box bellies out as if the instrument were being inflated. Consequently, the previously straight neck is forced into a curve. The fingerboard pushes down toward the sound hole in an effort to resolve the stress. The back of the instrument strains, and the stress causes tension against every inch of its seams. The sides try to flatten out and away from the face, as if the whole system were collapsing into its sound hole.

All of this movement is slowed by the stiffening braces inside the guitar box. A stiffening spline or an adjustable pre-tensioning device running through the center of the neck counteracts its tendency to curve.

The untrained eye will notice only that the strings are gradually moving away from the fingerboard, and that the instrument is becoming progressively more difficult to play. From time to time the guitar must be repaired. Depending on the extent of the distortion, the repair might entail readjusting the pre-tensioning device, filing down the string-to-body attachment, or resetting the neck. The latter involves removing the neck and reattaching it at a new angle to compensate for its distortion and the distortion of the sound box.

Neck/body joints fall into two main categories: those requiring an integral heel and neck block (such as the Spanish method), and those with separate blocks (such as the tapered dovetail and the pinned mortise and tenon). A host of other joints, uncommon in modern guitar making, rely on intricate

The three neck/body joints are, left to right, the Spanish method, the tapered dovetail and the pinned mortise and tenon. The last is shown with its pinning tool.



William Cumpiano was a furniture designer/draftsman who turned luthier seven years ago. He builds, repairs and teaches at his studio in North Adams, Mass.

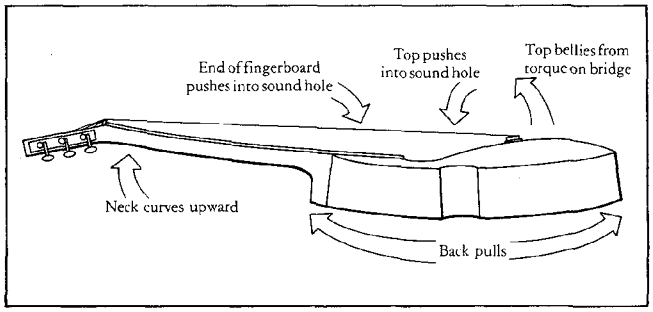
and contrived systems—threads, screws, cams, hooks, wedges and inserts—to hold the neck to the body. Some are bizarre and fascinating; most have been relegated to the dustbin of history.

Some instruments such as the early lutes, citterns and gitterns of medieval times were carved from a single billet of wood, but the oldest surviving assembly technique is the Spanish method. It has outlived all the others because it is simple and adaptable to hand building. It is used by novice and master alike, by hand builder as well as machinist, because it requires less accuracy than the others and does the job as well. Its major shortcoming is that it cannot be undone for resetting, and so it is only used responsibly on instruments with low-tension strings, or short strings and thus short necks. A skilled person can sometimes reset Spanish-method necks, or compensate for body/neck distortion by relying on some arcane tricks of his trade.

In the Spanish method, the instrument's sides are let into slots cut into the neck. The portion of the neck inside the instrument is kept massive and rectangular for ample gluing surface to lock sides, top and back together, and the portion left outside is whittled into the graceful triangulation called the heel.

If you are an experienced hand builder or a well-tutored novice contemplating building a single instrument, you may use the Spanish method/free assembly. You will build the guitar from its face upwards, piece by piece like a Tinkertoy. Start with the guitar face upside down, with its internal bracing members looking up at you. Attach the slotted neck, also upside down. The sides, previously bent, are let into the slots, glued to the face one by one, and carefully lined up with the template outline scribed on the face. The far ends of the sides are both attached to a tail block, similar to the neck block. The back closes the sound box, completing the main structure of the instrument—sound box and neck are locked together rigidly and permanently.

If you need to build several identical instruments, or if your skills are not up to the demanding task of aligning the sides with a template mark on the face, you might choose the variation of the Spanish method that requires an elaborate exterior mold. The mold is a clamping/centering device. You begin by gluing together the sides, slotted neck and tail block. The mold keeps these pieces in place while the glue sets. The product is a neck attached to a guitar-shaped hoop. Then affix the face, and lastly the back. The result is a closed sound box and cantilevered neck, just as in the free assembly. What remains to be done is to attach the fingerboard to the



An exaggeration of structural distortions that will occur in time.

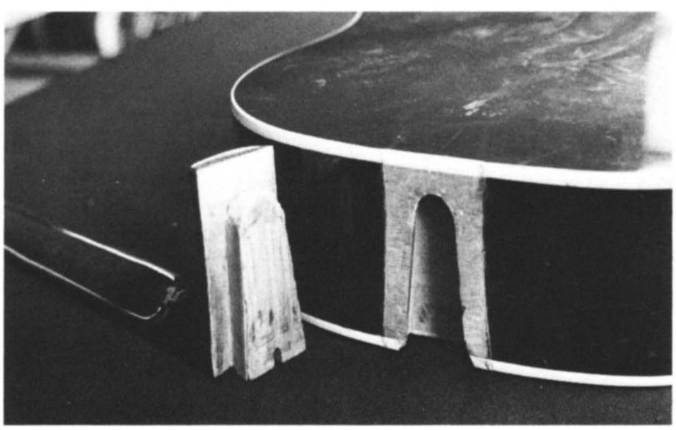
neck, and trim and finish the instrument.

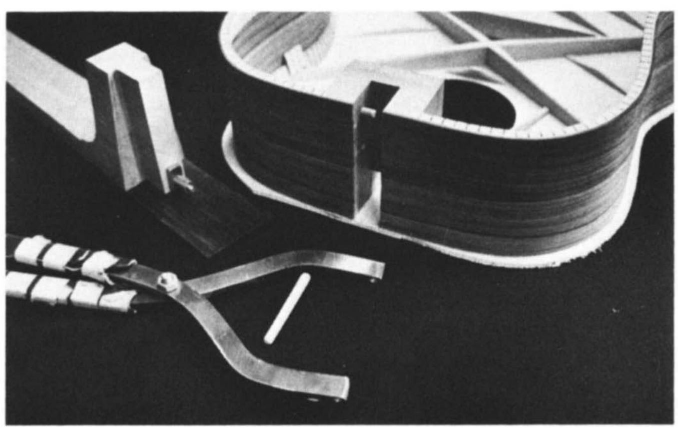
The tapered dovetail neck/body joint is the most common production joint. It is also used by many hand builders, but it requires skill with a backsaw and chisel to make the necessary angled cuts. In a factory setup, jigs and hold-downs allow the mating pieces to be cut with an overhead router and a dovetail bit.

The tapered dovetail joint consists of a separate neck block inside the body, exposing a dovetail cavity, its least width pointing down to the back of the instrument. A matching male counterpart behind the heel of the neck slips into the body and down, forming the precise body/neck angle that yields accurate string height. If you've done any woodworking you can see why this joint is more popular with machinists than with hand builders. Yet some hand builders feel it is the supreme neck/body joint.

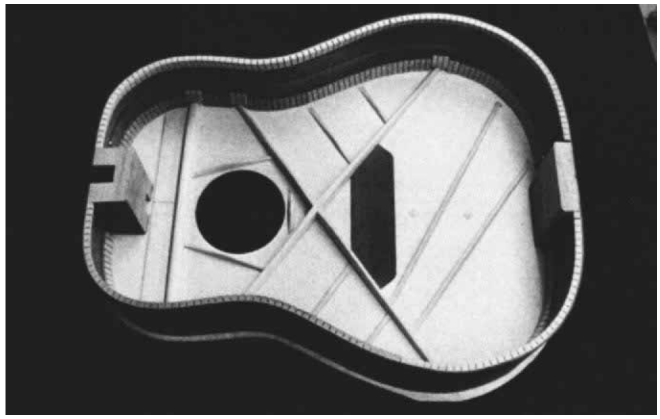
The pinned mortise and tenon has a vertical mortise exposed on the outside of the sound box. The mortise mates perfectly with a vertical tenon on the neck behind the heel. Whether machined or hand-built, it is simpler to construct than the tapered dovetail with its double-angled cavity. However, the right angles must be perfect if the instrument is to fit together properly.

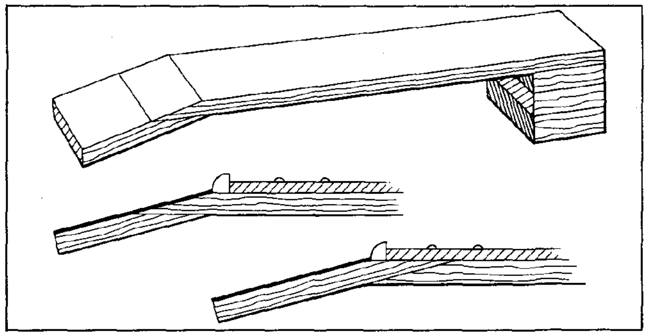
Two tapered hardwood dowels just long enough to pass through the neck block pin the neck tenon to it. Pre-drilled holes in the neck block and neck tenon are taper-reamed to match the pin, so that as the pin is pushed through, it tightens. The holes in the tenon are minutely offset to those in the block, so that as the pin is forced through, it draws the neck tightly against the body. After the neck and body are completely finished and polished, the pinning is done with the aid of a homemade steel pincer called a pinning tool. It is manipulated through the sound hole, its pincers grabbing the





The guitar's braces help control structural distortion while "disciplining" flex and thereby determining tonal quality. The large, flat brace at the left counteracts the top's tendency to split from differing expansions of top and fingerboard. The thicker brace next to it supports the end of the fingerboard. The three short braces around the sound hole restore rigidity where the hole was cut out. The X-brace is the main support for the top, the fan braces above and below support the outer edges. The patch to the right of the X increases the mass for the bridge attachment. The two diagonal braces control the top's flexibility and therefore its frequency response. The small cross-grained diamonds reinforce the book-matched seam of the top. In the drawing, at the left the headstock veneer reinforces the joint; at the right the fingerboard acts as a reinforcement, commonly found on banjos.





neck block and pin, forcing one into the other when its lever arms are squeezed. A small light bulb inside the body illuminates the process. To remove the neck, the action of the pinning tool is reversed with the help of a small metal dowel inserted into the small end of the pin hole. Pressure on the tool pops the pin out. Removing the neck becomes a fifteen-minute affair, instead of the hours-long job of undoing a tapered dovetail.

With the tapered dovetail and the pinned mortise and tenon, the neck and body are constructed, trimmed, and often even finished separately. The production advantages are obvious. Parts can be conveniently stacked, and the often laborious pre-finish and post-finish sanding at the heel/body juncture in the Spanish method is no longer necessary. The result is a clean, finished joint at the end of the line.

I have often participated in lively discussion with hand builders who eschew these two-piece systems. They feel that something intangible is lost when they work long hours on an object that only at the very last moment becomes a guitar. They feel, understandably, that they can retain a subtle connection with their creation through the entire process only if it is guitar-like from a very early stage in its construction. However, the more pragmatic realize the superiority of the dovetail and pinned mortise and tenon, when it comes to building a salable product that can be guaranteed over the long run.

The pinned mortise and tenon is highly efficient and practical. Its use is not widespread and when it is found, it is on instruments coming from small shops that specialize in individually handcrafted instruments. I have found some controversy about its use. Some people are just prejudiced in favor of the other methods; others legitimately feel that in time the pins may shrink and loosen, or that its rigidity and impact resistance is inferior. And although it is easier to disassemble for resetting, very few repair people are familiar with it, let alone possess the special pinning tool necessary to dismantle and reassemble it. However, I prefer this last joint. It is neat and foolproof, and I have yet to see it come undone when it wasn't supposed to. On the other hand, I have repaired dozens of tapered-dovetail instruments whose necks had slipped due to glue failure or inaccurate fitting. I feel free to guarantee the pinned mortise and tenon on my instruments, since if worst comes to worst, repairs can be made with a minimum of fuss and time.

The rest of the joints in the instrument are simple glue joints with two exceptions: a lap joint on the X-brace found under the top, and the headstock-neck joint. The purpose of the top braces is not exclusively structural. The top braces control the amount of flex and movement in the top and determine each instrument's vibration characteristics. The guitar box is not only a sound amplifier, but more importantly a sound modulator. Nowhere on the instrument is the balance of mass and structure more finely determined than at the top braces. The size, shape, weight and placement of these braces determine the flex and vibration of the top, thus modulating the sound and giving a guitar its characteristic tone. The angle of the lap-jointed X-brace determines the size of the resonating "working area" (the circular lower portion of the guitar top, which has the bridge as its approximate center) and thus influences the tone; it must be accurately laid out and cut for the instrument to produce the desired sound. All these braces counteract the effects of string tension.

Another important joint is where the headstock meets the neck. On mass-produced instruments, this is usually not a joint at all, but a one-piece neck blank bandsawn from a single billet of hardwood, often Honduras mahogany. A one-piece blank can be made quickly, but it is wasteful of stock and relatively weak, with its short grain in the angled headstock. A better possibility is the composite neck blank. A scarf joint at the bend reinforces the headstock because the long grain follows the shape, and the built-up heel eliminates the need for thick stock.

The sheer economy of all these methods has always intrigued me. They have been refined and perfected over a period of 500 years, and may never be superceded. A musical instrument, like an airplane or a racing bicycle, owes its success to the dictum "less is more" (but not too much less!). Its components must be pared away, thinned out, made so economical that all that remains is its essence: the absolute minimum that will allow it to function properly. Anything more gets in its way. In this process you also end up with something that happens to be a thing of beauty.