BSBAR001.DOC

SPRINGING THE BASSBAR

The bassbar has not had the attention given to it as the soundpost has. It is understood to have been absent in early instruments [1] and after being introduced, gradually increased in size to its present form. The bassbar is tapered at each end to increase its flexibility. It is placed beneath the bass foot of the bridge on the inner surface of the top plate and aligned along the violin a distance from the centreline proportional to the respective width of the upper and lower bouts. The bassbar does not admit of much variation; it has been placed on the centreline of experimental instruments [2] and varied in shape. It is supposedly installed to support the downbearing of the bridge due to the string tension. It is also thought to maximise the area of the top plate that moves in phase at the lower end of the range of the violin where the "breathing action" predominates and monopole radiation is important for maximum output. The bassbar has another function, one that would be difficult without it. When the plates are tuned by whatever method, it allows the detuning that occurs when the ff-holes are cut to be reversed. When ff-holes were used instead of a "rose", to increase the flexibility of the top, the plate tuning was lowered. It could be restored by raising the stiffness lost and allowing some adjustment. This may have been the more important function of the bassbar. An example using figures for a free top plate mode 5 is; plate tuned, 377 Hz; ff-holes cut, 311 Hz; bassbar added and tuned, 376 Hz. The bassbar in another sense is a form of "strutting" as used in the guitar. Only one attempt [3] is known where it has been used in this way. There is a controversy attached to the fitting of the bassbar. This concerns whether it should be sprung when gluing it in place. The logic behind this idea is that "prestressing" will counter the force applied through the bass foot of the bridge and thus prevent the depression in the top often found in old violins, especially those with thin tops.

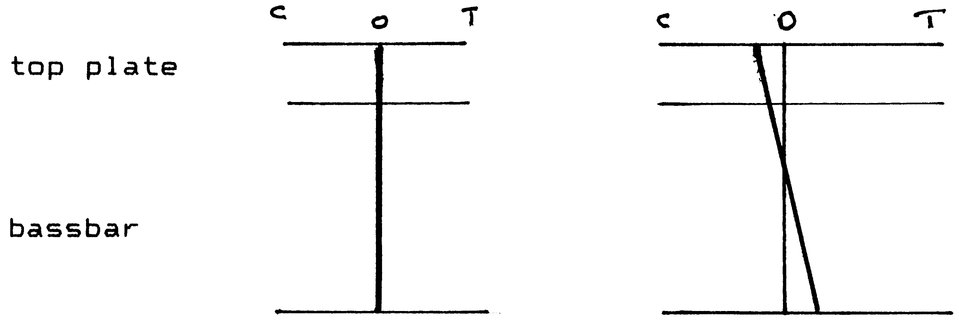
There are two uncertainties associated with this. One is whether the prestress introduced will be permanent. Wood is viscoelastic and will undergo permanent deformation under stress which may seriously change a preexisting stress pattern. Deformation of the violin body is not unknown. The other uncertainty is what is the force to be supported and how big is the force introduced by the springing operation. Rule of thumb methods only can be used.

From an overall look at the violin and the forces that are sustained by the structure, it is clear that the forces resisting the string tension must be well below those needed to deform the structure. The tensile strength of spruce in the longitudinal direction of the grain is about 100 MPa (maple is similar) and the limit of proportionality about 75 MPa. The working stresses are about one tenth of this with associated strains of 0.05%. Wood being visco-elastic will slowly deform umder a constantly applied load. From the general state of violins over 250 years old that show little deformation suggest the stresses are indeed low. The strength in compression is about one third that in tension; the wood structure deforms by buckling. There is therefore something to be gained by tensioning the back to lower the compressive forces in the top. Gadd [4] carried out some relaxation tests on Sitka spruce with bending stresses 2 and 4 times the expected working stresses. He found 60% relaxation at room temperature after 5 years. However, the test was a constant strain test. As the structure relaxed the level of stress decreased. This is not the situation in the violin where the stresses are maintained.

The problem is indeterminate. Approximate numbers can be obtained by applying simple beam theory and assuming a simple geometry and force conditions. To a first approximation, the arching of the top can be neglected and the bassbar treated as a simple rectangular beam. In the figures stress varies between tension (T) and compression (C). No magnitudes are implied although the difference across the glueline is thought to be maintained in some cases.

CASE 0.

Clearly the case when the bassbar is shaped and glued in without springing would be expected to be simple. There would be no built in stresses and under load the bassbar and the region of the top plate in its vicinity might behave as a simple beam to a first approximation. If this is the case the stress distribution under load in the unstressed case would be superimposed on the other cases with built in stress patterns to obtain the final situation under load.



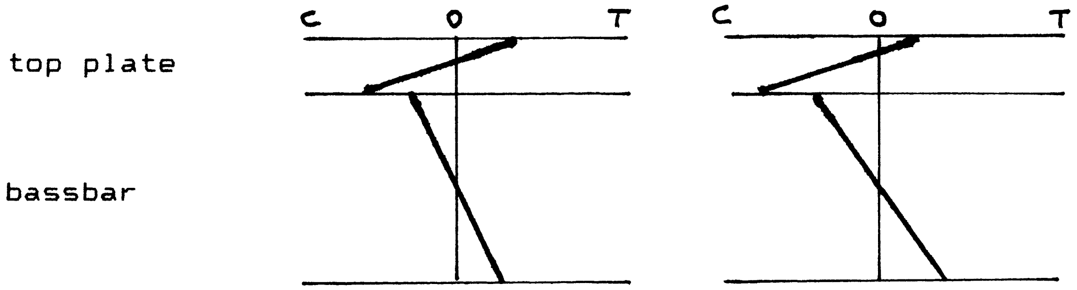
clamped and glued

under load

Figure 0. Stress distribution for case 0.

CASE 1.

As am example, a beam 0.270 m long with a cross section 17 x 10^{-3} m by 6 x 10^{-3} m assumed to be simply supported at the ends with a central load. (In fact the support and the load would be distributed over the glued length of the bassbar.) For a maximum deflection of 0.75 x 10^{-3} m the load for spruce (E_L = 10 x 10^9 Pa) is about 45 Kg. This deflection might be that expected after springing 1.5 mm at each end allowing relaxation after gluing to the top. The load equivalent to this net deflection is about 10 times the estimated load at the bass foot of the bridge. The technique of springing the bassbar by shaping the bar so that the ends are forced against the inside of the top for gluing, causes a mutual deformation of both the top and bassbar during clamping, the relative amount depending on the respective stiffnesses of the two parts. Thus the two surfaces glued together are in compression while the outer surfaces of the top and bassbar are in tension. The stress difference across the glue line is assumed to be maintained during any subsequent working and loading. The relative stress levels will be governed by the stiffness of the two members. If the stiffness is similar for the two members, in this case the top at 3 mm thick and the bassbar, taken at 10 mm by 6 mm, and springing the ends by 1.5 mm followed by a final deflection of 0.75 mm, the maximum fibre stress in the bassbar would be about 4×10^6 Pa and in the top about 1.25×10^6 Pa giving a difference across the glue line of 2.75×10^6 Pa and will be compressive. Loading from the bridge foot would reduce the tension in the top and increase the tension in the free surface of the bassbar.



clamped and glued under load

Figure 1. Possible stress distribution for case 1.

CASE 2.

If the shaped bassbar (approximate at this point to allow tuning) is forced to conform with the top held to the carved arching during glueing, on release, the top will be placed in tension as the bassbar tries to recover. If we assume the same geometry as above and a spring of 1.5 mm at each end of the bassbar, the maximum fibre stress in the surface of the bassbar glued to the plate would be about 8.0×10^6 Pa. If it relaxes to half, the top locally will be in tension to somthing less than this.

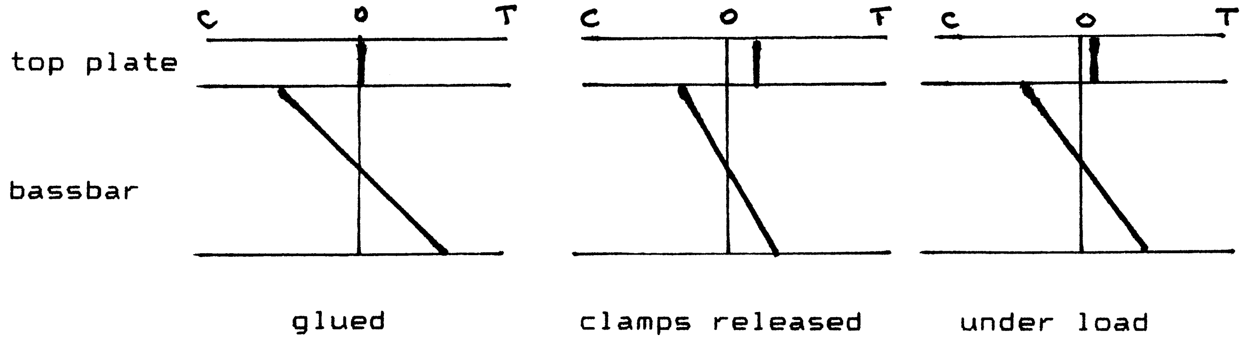


Figure 2. Possible stress distribution for case 2.

CASE 3.

An alternative would be to shape the bassbar blank to the spring required and when gluing, to deform the plate to conform with the bassbar blank. This assumes the blank is rigid enough not to bend. On release the bassbar would be placed in tension and the top would relax slightly. Carving the ends of the bassbar blank would allow further relaxation in the top as the ends of the bar are pulled up. Tension in the bassbar would increase as the top returned further towards its carved shape. Using the above numbers, the stress in the top would be about 2.5 x 10^6 Pa relaxing to about half this.

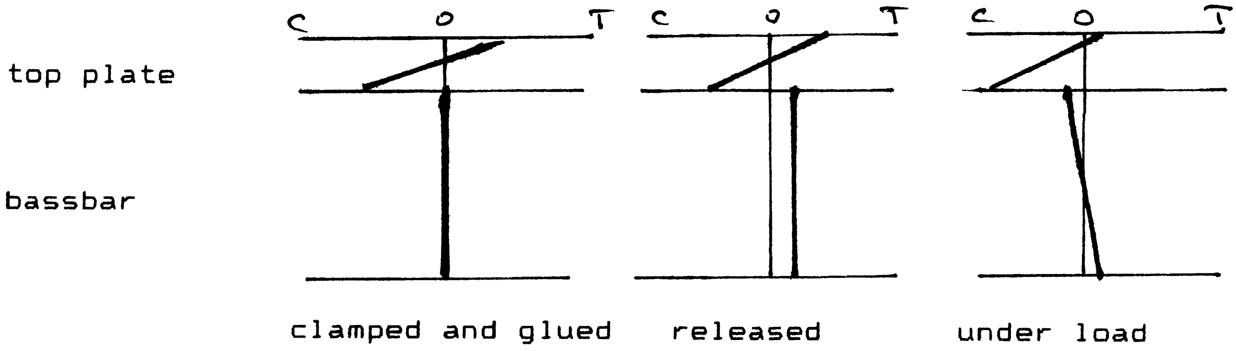


Figure 3. Possible stress distribution for case 3.

CASE 4.

The method proposed by Saunders [5] to prestress the bassbar blank by gluing a strip to the convex edge of the bent blank and then shaping the free edge of the blank to fit the top plate curve, gluing it in place and then planing off the "tensioning strip" has the effect of not deforming the top while fitting a stressed bassbar. Removing the clamps after the initial stressing allows some recovery; a thicker "stressing member" would reduce the amount of recovery. Shaping the bassbar would allow more stress relaxation and following gluing to the top and removal of the "tensioning strip" the final stress state intuitively is the top in tension and the bassbar in tension at the free surface. In this method there would be a varying stress difference across the glue line between the bassbar and the top.

Using Saunders' dimensions and the simple model described above, an approximate estimate of the stresses induced can be made. For a curvature similar to the one illustrated in reference [4] with spruce for both members, the maximum fibre stress in the bassbar blank would be about 14 x 10^{6} Pa and in the "tensioning strip" 6 x 10^{6} Pa. This would give a stress difference of about 20 x 10^{6} Pa across the glue line. On removal of the clamps, a "tensioning strip" of the dimensions given is unlikely to hold the bassbar in the clamped shape. Some relaxation will take place but the stress difference at the glue line is assumed to remain unchanged. It is possible that the "tensioning strip" would be placed more in compression with a reduction in the residual stess in the bassbar blank. To estimate the possible residual stress level after the clamps have been removed, we might relate the change to the respective depths of the two bars glued together. A tension strip equal in depth to the bassbar blank is assumed to result in no relaxation while no tension strip would result in complete relaxation. In the present example, the amount of relaxation would be (17-7)/17 of, say, the largest single stress, keeping in mind that the stress difference across the glueline is preserved. This leads to a compressive stress of about 11.75×10^6 Pa in the "tensioning strip" and a tensile stress of 9.25×10^6 Pa on the other side of the glue line in the bassbar blank. The stress profiles might be similar to that shown in figure 4. It would be interesting to know what the shear resistance of animal glue is, although for a properly glued joint it is the shear resistance of the wood that is important. The edge of the bassbar blank when shaped to fit the top plate will be in residual compression of about 8.25×10^6 Pa and after glueing and removal of the so called "tensioning strip" the readjustment of stresses would most likely lower this compressive stress in the bassbar and put the top plate in local tension. On further shaping the bassbar these stresses will be further reduced. The level of stress induced in the blank will be proportional to the depth of the "tensioning strip". If no relaxation occurred, a maximum fibre stress of about 1.6×10^6 Pa would be needed in a bassbar, when sprung, to support a load of 5 Kg.

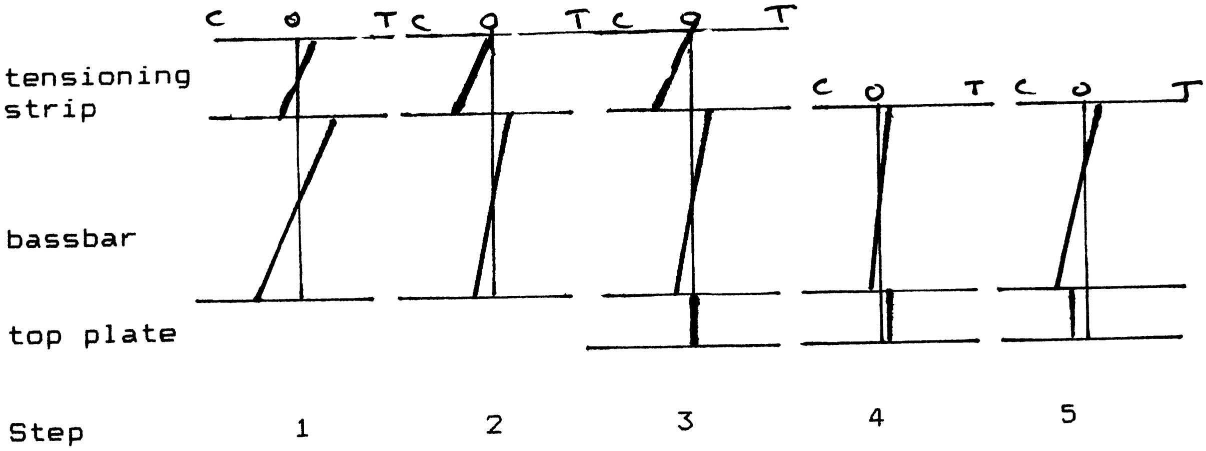


Figure 4. Possible stress distribution for case 4.

1. tension strip/bassbar bent and glued
2. clamps removed
3. bassbar shaped and glued to top
4. tension strip removed
5. under load

If the intuitive reasoning above is correct, cases one and three give rise to compressive stresses in the top plate, in the region of the bassbar, while cases two and four induce tensile stresses. Case two would be difficult to achieve easily.

After the violin has been assembled the combined string tension of about 23 kgf puts the top plate in compression and a downbearing at each bridge foot of about 5 kgf. If one makes an over simplified assumption that the string force is borne by the top over the section between the upper eyes of the ff-holes, measureing about 42 mm x 3 mm, the compressive stress in this region would be about 2×10^6 Pa. Any stress of this kind will modify the stress distributions described above.

The uncertainties associated with springing the bassbar have led to a mixed reaction to the idea and probably most makers do not spring the bassbar. It would be interesting to know if, when bassbars are removed by means that would preserve the internal stresses remaining in the wood, whether there is any evidence of "springing", either in older violins or, more specifically, in violins that are known to have had the bassbar "sprung" at some earlier date. The thoughts expressed above are offered in the hope that they may stimulate further discussion.

Springing the bybar may have been used to give extra support to the bridge when the top was thought to be too thin. This may also limit the depression of the top plate on the bass side as indicated by the [illegible] near the f hole corner at the top [illegible] note.

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