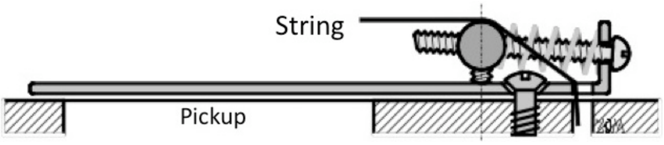
7.10.2.2 Leo Fender's Telecaster

The Telecaster was Leo Fender's first "true" electric guitar. To start with, it was designated Esquire, then Broadcaster, and finally Telecaster [Duchossoir]. According to Fender's patent application US 2,573,254, the string length was to be individually adjustable – but that is only possible in pairs of two: two strings have to share a cylindrical bridge saddle (**Fig. 7.112**). Compared to the non-adjustable bridges customary until then, that definitely represented an improvement although it still was a compromise. Fender however already points to a further development: the bridge saddles are drilled through at an angle. Each of the three bridge saddles may be adjusted in height using two setscrews, and a long tensioning screw takes care of the intonation adjustment. A thick steel plate anchored with 4 large bolts in the guitar body serves as a base for the setscrews and the tensioning screws. The strings run across the bridge saddles through the guitar body to fastening bushings mounted from the rear of the body.



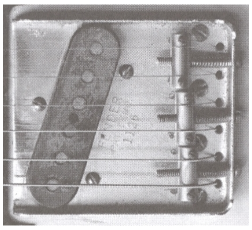


Fig. 7.112: The Telecaster bridge. [Duchossoir]

What has been said in Chapter 7.10.1 holds for the setscrews and tensioning screws – their transmission stiffness depends on contact surfaces and forces. In principle, this bridge does work. It may, however, develop an idiosyncrasy that helps this guitar to achieve a special status: the steel plate rests in an undefined manner on the guitar body, and its resonances (Eigen-modes) may re-act on the strings – not necessarily, but possibly. Using a hard nonmagnetic item to knock on the upward-bent flanks of the plate, we hear a clicking noise coming out of the amp/speaker. The **sheet metal** is not comprehensively damped by the body wood below it, but can resonate with its **natural frequencies** at a high Q-factor. Mechanical reactions from sheet metal to bridge saddles are possible, and – given steel as material – also inductive coupling to the bridge pickup. Generally, the sheet metal is electrically conductive and thus a place where **eddy currents** circling the pickup may roam (Chapter 9.5).

The necessity to make the string action **adjustable** was not only connected to the drive of all guitar players to make each new guitar "playable" according to one's own ideas. It was also unavoidable in view of the separation of guitar body and (bolt-on) neck into two individual production entities each subject to manufacturing tolerances. From Duchossior's close-up pictures it can be seen that these adjustment possibilities were indeed put to use, and that the bend-angles that the strings form as they run across the bridge saddles are specific for each individual guitar (they are string-specific in any case). However, this means that the vibration characteristics of the bridge are specific to each individual guitar, too.

Fig. 7.113 shows the decomposition of forces at the bridge saddle. The string-tension force Ψ is almost the same on both sides of the bearing cylinder (bridge saddle), and the frictional force may be neglected in a first approximation. The force F acting towards the lower left has two components. The setscrew just resting on the surface below can only take on the vertical component F_y; the horizontal component F_x is taken care of by the tension screw. Nevertheless, Fender's patent application shows a set screw mounted at an angle (Fig. 7.113)

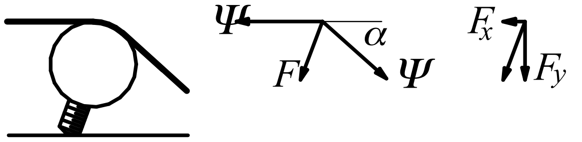


Fig. 7.113: String with bearing cylinder (left), force resulting from the string forces (center), decomposition of the resulting force in horizontal and vertical component (right).

We shouldn't expect too much here: *"Leo Fender was an ingenious, resourceful technician, but – as it is frequently reported – he had not even had formal training as an engineer, and he certainly was not a guitarist – couldn't even tune the instrument" [G&B Fender special edition]*. Duchossoir's citation is even more merciless: *"Leo had a knack of thinking slowly and consecutively – no flashes of genius – a merciless unstoppable slow degree of thinking [Tavares]."* At some point, the angled screws raised some eyebrows, and one day they stood upright (Fig. 7.112). More specifically: in the patent application [USPTO.gov], the angle between setscrew and tension screw amounts to 70°, in later bridges it is 90°. What is better?

The mechanical engineer would probably prefer the setscrew perpendicularly positioned on the base plate, because it can transmit only vertical forces in any case (horizontally, only small frictional forces remain). With the screw positioned at an angle, a bending moment results that loads cylinder and tension screw flexurally, while with a perpendicular setscrew there is merely a tensile force acting on the tension screw. What in fact prohibits sideways motion of the latter? This would be a motion within a borehole in which – according to the patent publication – the screw should be borne *"sufficiently loosely"*! An additional brace could make for more stability but the effect would probably not be very dramatic. Also, an axial force applied to a setscrew could possibly readjust the screw over time – therefore the perpendicularly oriented screw may offer slight advantages. These are, however, untried speculations for which no additional experiments were done. With

$$F = 2\Psi \cdot \sin(\alpha/2), \qquad F_x = \Psi \cdot (1 - \cos\alpha), \qquad F_y = \Psi \cdot \sin\alpha,$$

we can see the angle dependency of the forces; the bend-angle of the strings α amounts to about 25° to 50°. The tension screw has the sizeable length of 32 mm – apparently indeed necessary to allow for a sufficient adjustment range. With $\Psi = 50$ N (certainly possible for thin strings), F_x amounts to a minimum of 4.7 N, and F_y amounts to a minimum of 21 N[♣]. For heavy strings, $F_x = 50$ N and $F_y = 100$ N are possible, as well. That is quite a respectable degree of variability in the compression force, and correspondingly large will be the **differences** in the contact-stiffnesses and –impedances. Which tilting, rotating or wobbling motions the bridge saddle will be subjected to under real deployment conditions cannot be anticipated with a general consideration – the conditions vary too much. The offset-force acting on the setscrew presumably is so strong that this screw can a priori not be suspected as a "vibration killer". A longitudinal force of merely 4.7 N is scant, but then there are 2 strings pulling at one screw. Within the string, however, also longitudinal vibrations appear (dilatational waves) that could excite the bridge saddle to rotational vibrations. In that case, too, much slack between the screw and the bridge saddle would be counterproductive.

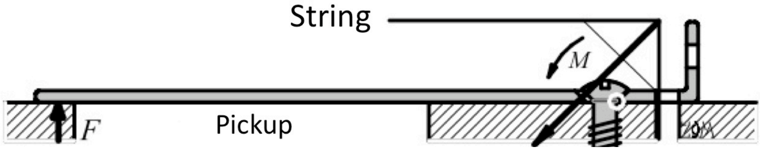


Fig. 7.114: Forces on the guitar body

The interface from the base plate to the guitar body is shown in **Fig. 7.114**. The sum of the two string forces generates a resulting force pointing towards the lower left, just missing the wood screw and thus resulting in a torque around the bearing point (circle). The main share of the retention force occurs at the screw; in order to compensate for the torque, a supplementary force F is necessary (here sketched in arbitrarily).

[♣] A mass of 1 kg generates a weight force of 9.8 N (1 N = 1 Newton → 102 Gramm).

Where exactly which forces act cannot be specified, because how the bridge rests on the body wood remains undefined: this depends i.a. on the curvature of both components and materials. The torque designated with M rises with increasing string diameter and increasing string height (distance between string and base plate). If there is (at F in Fig. 7.114) a tiny gap left of the pickup, half of the base plate is suspended in mid-air … opening un-dreamt of possibilities of vibration.

Also undefined is which of the four wood screws bears the main load – they just somehow share the retention forces. If the guitar body as a vibrating system were to be coupled in a defined manner to the bridge (or the bridge to the body), a completely different design would be required. No, this ain't no sound-design – it was simply a matter of bolting a base plate to a wooden board – over and done! As **Fig. 7.115** shows, the arrangement can in fact work pretty decently: here we see the decay times of the partials compared to the situation with a Stratocaster. Both guitars were measured with brand-new strings, although the diameters were not completely the same (Tele: 009 – 046, Strat 010 – 046). For the Tele, the decay is slightly faster, and it depends a bit more on the frequency. Before anyone starts to derive the general verdict that a Tele would have a shorter sustain than a Strat, let's be reminded that what we have here are individual results, measured merely with one single representative of its species[♣].

Note: in Fig. 7.116, the grey area indicates the theoretical maximum T_{30}-decay due to internal & radiation damping (Chapter 7.7.2).

If we would want to extract **Telecaster-typical characteristics**, we would first have to define what a typical Telecaster in fact is: over the decades, Fender changed the headstock, the neck, the body, the pickups, the bridge – it was only the body shape that approximately remained the same: consequently, there is not "the" Telecaster. For most variants, the bridge does have the base plate of about 85x74 mm^2, but differences start already with the bearing-cylinders: thick, thin, made from brass, or from steel, with/without groove, with/without thread. From the 1970s on there is also a version with small or large Strat-like individual bridge saddles, or even a pure-bred Stratocaster bridge. Telecaster-typical remains apparently merely the body shape but that has next to no influence on the sound. Even if we limit ourselves to the single-coil-fitted original type, we find a multitude of different variants: 250-kΩ- or 1-MΩ-pot, bridge pickup impedances between 5.5 – 11 kΩ, (complete) solid body or (half the weight) Thinline body, bolt-on neck, tilt-neck, set neck [more info in Duchossoir]. If the pickup cover is the secret of the neck pickup, why then does Fender include a different pickup in the Thinline-Telecaster (2nd version), the Tele Plus, the Elite Telecaster, the Telecaster Deluxe and the Custom-II? Why are there also Lace and Seymour Duncan variants on top of the Fender version? Presumably, that is so that each guitarist can realize his/her personal idea of the Telecaster sound.

In http://www.tdpri.com/forum/telecaster-discussion-forum/77808-new-body-material-build-w-sound-clip.html, Terry Downs presents his new guitar, and lets the congregations of fans guess which material the body is made from. Everybody enthuses about the sound, and conjecture includes: oak, masonite, teak, cork, semi-hollow-body, synthetic counter top material, soy, hedge apple tree, and others – most guesses meant seriously. In fact, it was three medium density fiberboards that were bolted on top of each other – that's it. Result: *Sounds like a Tele* – what else.

[♣] The multitude of limitations in the framework of university operations unfortunately does not make more comprehensive investigations possible.

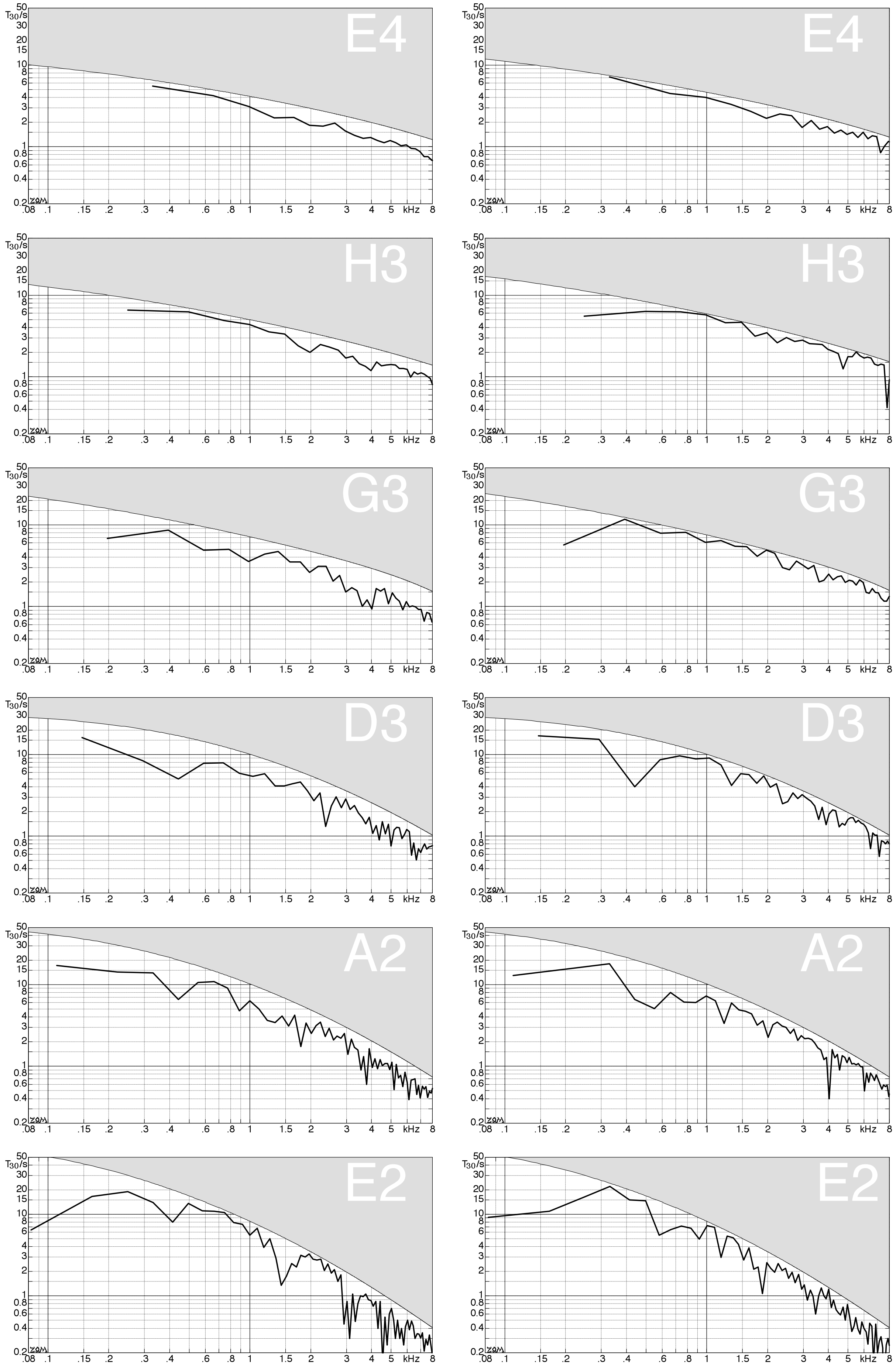


Fig. 7.115: Decay times of partials, Tele (009/046 set, left), Strat (010/046 set, right). “H3” = B(-string).