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Fortepiano kapsels old and new

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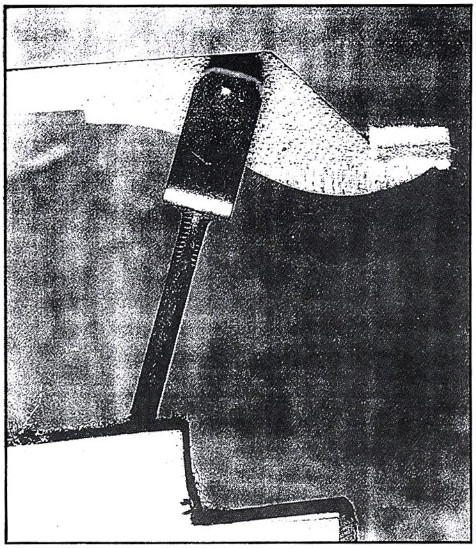
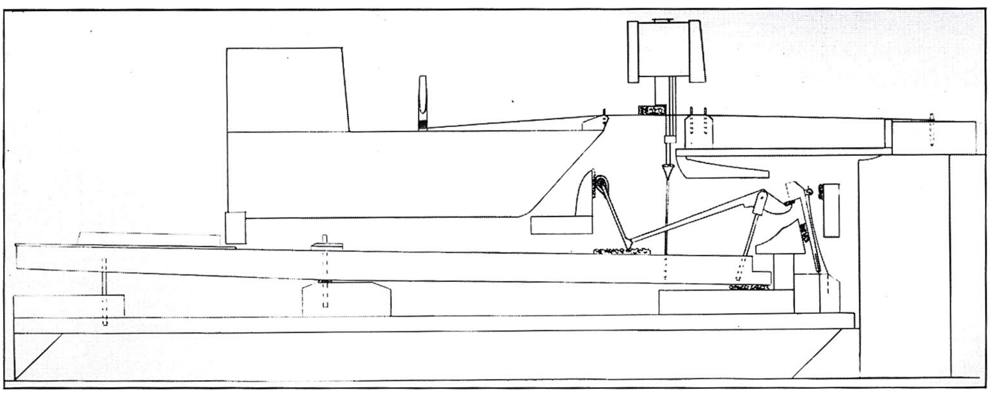
Martha Goodway's investigations into the metallic content of 19th-century fortepiano kapsels have clear implications for modern makers and restorers.

ONE OF THE FEATURES that distinguish the late 18th- and early 19th-century fortepiano from the modern, cast-iron framed piano is the lighter action of the fortepiano (see diagram, illus. 2). The kapsel — or capsule — is the part of the fortepiano mechanism that links the key lever to the rest of the action. It has two parts: the stem, and the stirrup or yoke. Both are made of brass. One end of the stem is shallowly threaded so that it can be screwed into the end of the key lever, which is of wood (illus. 1 and 3). The other end is joined to the stirrup.

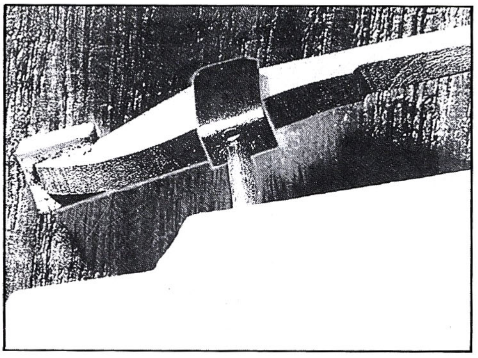
Traditionally the stem was mechanically joined to the stirrup through a square hole in its base. The end of the stem was prepared by being broached to a cross section that was nearly square that at the same time produced four burrs bent at right angles to the axis of the stem, arranged symmetrically to form a flange (illus. 4). The stem was then pushed through the square hole in the stirrup until the stirrup was firmly seated on the burrs, and the end of the stem hammered down to form a secure rivet. Illustrations 5 and 6 show such a joint in a kapsel from a fortepiano dated by R.J. Regier to about 1810.



1. Kapsel in c′ position on a c. 1826 Conrad Graf fortepiano, number 988, in the collection of Richard Burnett. Photograph courtesy of R.J. Regier.



2. Diagram of a fortepiano action, courtesy of R.J. Regier.



3. Closer view of the joint in illus.3. The diameter of the stem is 0.103".

Contemporary makers of fortepianos have found it difficult and occasionally impossible to reproduce kapsels in their historically correct form when using brass rod of the appropriate diameter that is commercially stocked. Though this rod is easily threaded, on broaching the other end the burrs tended to break and fall off. In an attempt to avoid this the stem was heated to a dull red colour before broaching. The results of this annealing were mixed.

Although it often permitted successful broaching, after three to five years' use stems failed at the threaded end at the point where they entered the key lever. One recent (1985) lot of rod stock, however, was an exception to this behaviour. It gave consistently good results with no treatment.

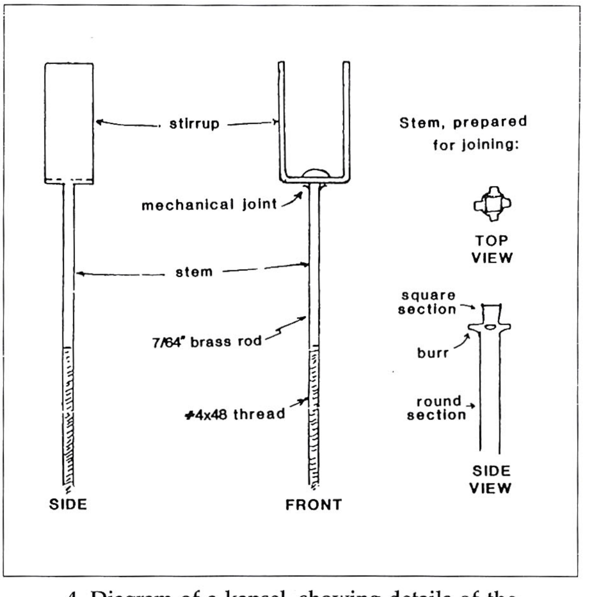
There are only a few brass alloys routinely stocked as rod of the appropriate diameter (7/64" or about 2.78mm) for stems, and one of these, ASTM (American Society for Testing Materials) alloy B16, had been specified. This is a yellow brass containing 3% lead; it will be discussed further below.

Metallurgical observations

The Smithsonian Institution has a large collection of musical instruments, some in playing condition. These include fortepianos that require the occasional replacement kapsel, so the problem in fabricating them was brought to the Institution's Conservation Analytical Laboratory for solution. In order to identify the cause, samples of reproduction stems were compared metallurgically with three intact stems from early 19th-century fortepianos. In addition to the 1810 kapsel shown in illustrations 5 and 6, small samples were taken from the threaded end of two more 19th-century stems. One of these came from a Walter fortepiano, courtesy of Thomas and Barbara Wolf, and the other from the Viennese fortepiano of about 1815 by Ferdinand Hofmann at the Metropolitan Museum of Art (1984.396), courtesy of Stewart Pollens.

The samples were prepared by sectioning and the chemical composition of both old and modern stems was estimated by energy dispersive spectroscopy (EDS) on the freshly prepared surfaces. No lead was detected in the 1810 stem, nor in the successful 1985 stem. (The limit of detection of lead by this method was estimated to be about 0.1% or less.) The only elements that were detected in the 1985 stem were copper (65%) and zinc (35%). There was little, if any, lead in the old samples. Analyses done by Mark Wypynski at the Metropolitan Museum of Art in New York City comparing a replacement kapsel with an original one from their 1815 Hofmann fortepiano yielded similar results: both were high-zinc brass, but no lead was detected in the 1815 kapsel, 1.4% lead in the modern one.

The microhardness of the 1810, 1985 and 1988 stems was measured along the axes of the longitudinal section using a square pyramid (Vickers) indentor and a 100g load. (The two

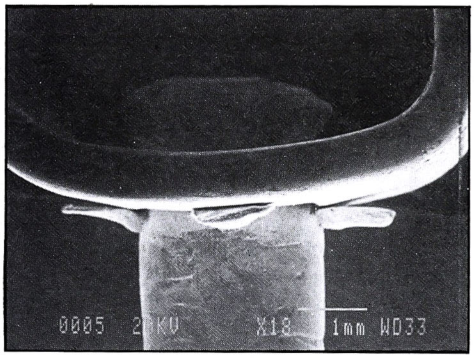


4. Diagram of a kapsel, showing details of the mechanical joint.

other 19th-century samples came from the threaded end, which after mounting presented surface areas, reduced by the threads, that were too small for reliable hardness determinations.) The sections measured were approximately parallel to, but not on, the axis of the stems. At the hardnesses obtained the results in Diamond Pyramid Hardness (DPH) are also equivalent to Brinell hardness. The 1810 stem had a DPH of 98.5kg/mm^2. The 1985 stem was as soft as this in some areas; its average DPH was 135kg/mm^2. The 1988 stem had a DPH of 173kg/mm^2, nearly twice as hard as the 1810 stem, whose softness is visible in the clamp marks (illus. 6).

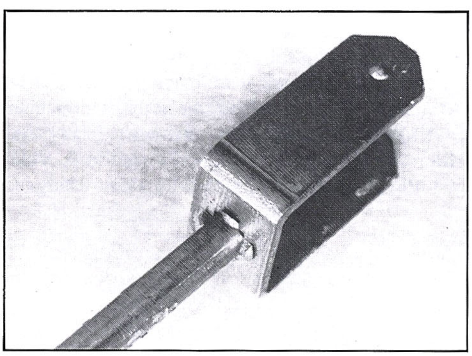
The microstructure of the 1810 stem (illus. 7) is consistent with its measured softness. The grains of the α phase are equiaxed, indicating that after the metal was drawn into rod, which greatly extended the grain structure and hardened the metal, the rod was completely annealed. These α grains are more or less surrounded by a higher zinc, β phase whose structure allows the annealing temperature to be estimated at above 750°C, perhaps about 800°C, followed by a quench to ambient temperature. Temperatures of 750 or 800 degrees are unnecessarily high temperatures for annealing brass, and are unlikely to have been reached if the heating had been under some sort of modern automatic temperature control. Annealing of this alloy should not have been required at all unless perhaps the rod had been drawn too hard. However, the softness of this stem does suggest that modern rod need not be drawn even so much as half-hard to be successful in this application.

In examining the microstructures generally, the most obvious difference between the stems that failed and those that did not was in the amount of lead present. Lead, like oil in water, does not



6. Scanning electron micrograph of the mechanical joint in the 1810 kapsel. Note also the clamp marks on the stem.

dissolve in brass. Instead the lead is distributed as separate globules between the brass grains, in the grain boundaries, where microscopically it is easily visible. No globules of lead were visible in any of the 19th-century samples, nor in the successful, 1985, stem. The amounts visible in the 1988 brass (illus. 7) represent an intentional addition rather than a 'tramp element' accumulated as a result of repeated recycling of the metal. Lead is routinely added to copper alloys, in casting alloys to make them more free-flowing, and, as a soft metal that tends to smear on cutting, as a lubricant in machined ones.



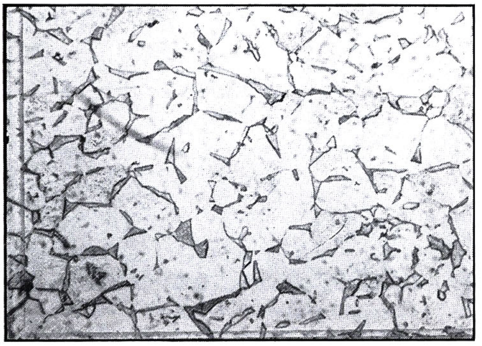
5. Oblique view of the 1810 kapsel, showing the mechanical joint

Choice of alloy

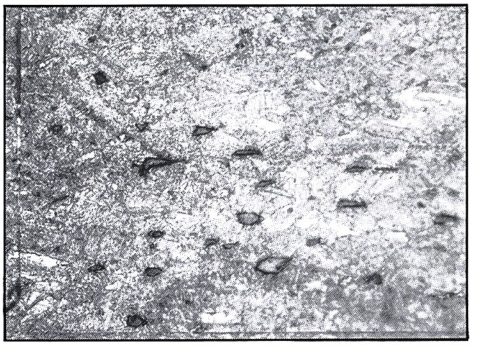
Except for the successful 1985 stock, a very high level of lead was found in the modern stems, as was to be expected from the specification. Alloy B16 has a nominal composition of 61.5% copper, 35.5% zinc, and 3% lead, and allowable limits of 60.0–63.0% copper, 2.5–3.7 % lead, less than 0.35% iron, less than 0.5% other elements, and the remainder zinc. It is described as 'free-cutting brass' and in half-hard rod is supplied in suitably small diameters for use in automatic high-speed screw-making machines. B16 has a machinability index of 100. That is, it is used as the standard of comparison for ease of machining.

Although alloy B16 is an excellent choice for making the threads on the stem (and in practice there has been no problem whatever in machining them) it is entirely unsuitable for making the joint with the stirrup in the traditional way. The *Metals Handbook* (8th Edition, Volume 1, Metals Park, Ohio 1961) advises (p.964) that "...free-cutting alloys *do not bend well* and should be avoided.... Lead does not dissolve in copper alloys but is finely dispersed throughout the alloy matrix.

7. Microstructures at 650X of longitudinal sections of:



a) the 1810 stem, showing the effect of annealing in the form of equiaxed grains, and



b) the 1988 stem with globules of lead visible in the grain boundaries; the heavily worked grains indicate that the stem was not annealed in this area. Both sections have been etched by standard reagents (potassium dichromate followed by ferric chloride.)

Consequently, it provides a lubricant for the cutting tool and results in relatively low tool wear. It *breaks the chips* so they are easily flushed away by lubricants" (my italics).

This breaking of the machining chips describes exactly the problem encountered in fabricating reproduction kapsels from B16 (and demonstrates the skill that was required to make any successful joints at all with this material). The root of the problem lies in the presence of a substantial amount of lead, more than might have occurred as an impurity in the 19th-century. A change in the specification of the brass was clearly indicated, to one that has little or no lead. According to the *Metals Handbook* (p.963) "Best results in cold forming operations are obtained with the non-leaded... brasses over 63% copper...". These brasses include standard commercial alloys such as yellow brass (nominally 65% copper, 35% zinc) or cartridge brass (70% copper, 30% zinc). This explains why the stock used for the 1985 stem did not fail. It contains no globules of lead to act as points of weakness. It is yellow brass, not B16, and so proved workable. In composition it is very much nearer the brasses of the old capsules.

Successfully cold-forming the mechanical joint requires no obsolete or arcane alloy. The solution is simply to change the specification for the stem to an unleaded high-zinc alloy such as yellow brass. There is a widespread but false presumption that for threading only a free-machining brass will do. This, along with its availability in small rod stock, may have led to the original specification of a leaded alloy. It is true that unleaded brasses must be threaded at lower machining speeds. Cartridge brass, for example, has a machinability index of 30. However, fortepiano stems are not threaded very deeply nor at great speed so that in practice the decrease in machinability presents no difficulty.

Yellow brass is a commonly available alloy but in a diameter small enough for stems usually cannot be ordered off-the-shelf from a supply house. However, it is possible to obtain brass rod of the appropriate composition, diameter and hardness by special order from a redraw house. One of these is Little Falls Alloys (201–278–1666) in Patterson, New Jersey. Rod of yellow brass supplied by them has proved entirely satisfactory in fabrication and in use.

Acknowledgements

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