 Ton Pel

Report on the construction of a nyckelharpa

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2. Introduction

This report provides information on how I built a nyckelharpa, using the instructions found in "*Chromatic nyckelharpa - A construction manual* (ISBN 91-7910-416-9)' written by Sören Åhker. This report reflects my personal experiences and approaches and it shows my diversions from the directions of Sören Åhker.

This report does not replace the above construction manual. On the contrary. It is, I think, better understandable by those who know the content of the construction manual.

During the building process I recorded each day what I did and how much time I've spent on it. Information about the time spent can be found in Appendix. The time spent is the net time = time at the workbench. I also have included pictures of the work made.

I hope future nyckelharpa builders will benefit from my experience and tips, and especially from the mistakes I made.

Questions or comments about this report are welcome at my e-mail address.

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Hilversum, The Netherlands, November 2011

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2. Tools, equipment and experience

It will be clear that my approach was partly determined by the workshop and the tools I had. I'm usually using micro tools, such as from Proxxon or Dremel. My workshop is about 15 square meters. It has three workbenches, which allows one to leave unfinished work for a while, and to carry on with something else.

My approach was also determined by my experience with woodworking. It is limited to the use of the common DIY hand tools such as saws, files, planes, chisels and power tools such as drill presses and belt sanders (I had no band saw). I had never made such a complex device as the nyckelharpa. After making it, I am convinced that anyone who masters the basic techniques of woodworking, can build a nyckelharpa, according to the construction manual mentioned earlier.

Tip: Work with the original drawings and not with a copy

Because I was concerned that the drawings attached to the construction manual would be damaged during the building process, I made copies of them. I started working with the copies. When I compared the key guides I had created from the copy, with the original drawing there were unacceptable differences. The measures on the copy were not exactly equal to those of the original.

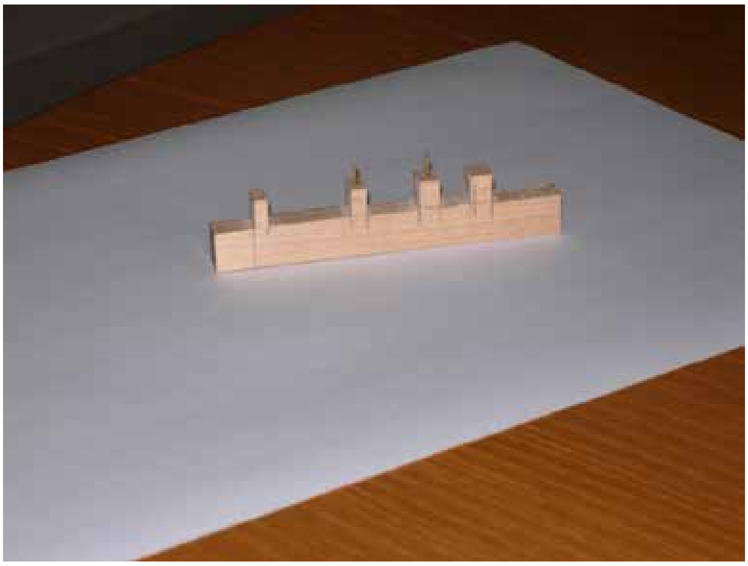
The construction manual suggests making templates for all parts of the nyckelharpa and using these to create shapes on the wood. I have not done so: I have measured all shapes from the original drawing and have drawn these directly on the wood. I could work that way, I think, because I can draw well.

3. Key box

In the construction manual making the body is the first step. Because the key box seemed to me the hardest part of the knucklehead, I started with it. My idea was that, if I could make the key box I could make the other parts too.

Key Guides

Because I wondered if the teeth of the key guides were strong enough to withstand lateral forces, I made a test piece. I reinforced a few teeth with copper wire. The others were not reinforced. By exerting pressure on both types of teeth, I could conclude that the non-fortified teeth were strong enough.



I then drew the four key guides on wood, cut them with an electric jigsaw and finished them with key files.

Finally, I covered the inside of the teeth of the key guides with supple leather of 1 mm thickness. (This means that where the keys slide through the key guides; the keys should be 1 mm less thick than is indicated in the construction manual).

Keys

I started by drawing the sizes of the keys, and the place of the long holes on the wood.

Tip: Do not use an electric jigsaw without guides

I tried to cut out the long holes with an electric jigsaw. That did not work properly because it was a very difficult to saw straight without guidance. The result was a key with a hole whose edges are not straight and taut.

I thought it would be better to cutter the keys. To do that and I have turned a micro drill into a router table below. That was pretty simple: 1) by turning the micro drill holder upside down and 2) by fitting a custom-made small plateau which the cutter sticking up.

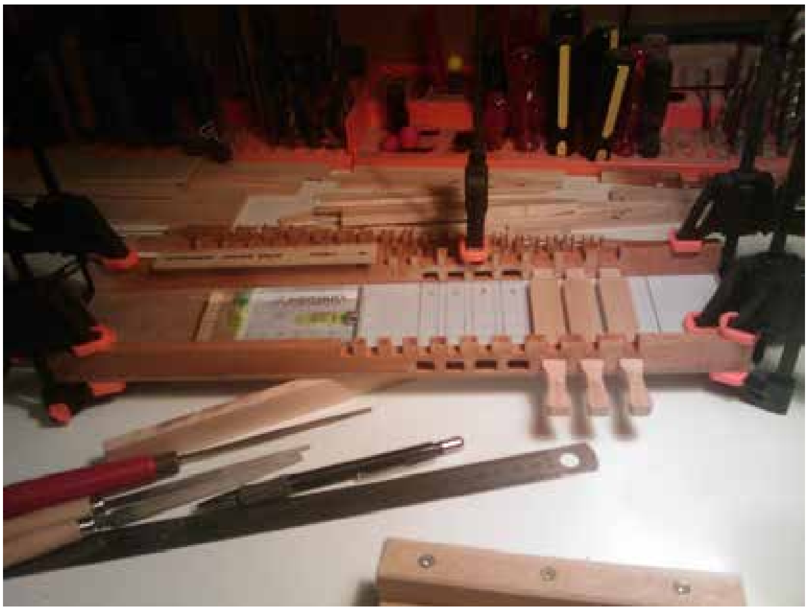
That worked perfectly. So, I could accurately cutter out the holes.

With this tool, I could also cutter the outside of the keys in the desired form.

Please note: the picture shows a hole for a tangent. These holes and tangents, however, should be made later in the process.

Placing the keys in the key guides

Because I did not make the harpa body first I had no neck to mount the key box on. Instead of the neck, I used a piece of MDF 10 cm wide, with a length of the neck. I glued graph paper on it, as a guide for parallel and perpendicular placement of the keys in the key guides.



I glued thin leather on the MDF piece under the lower the key guides. The key guides were clamped to the MDF piece. That made little adjustments possible.

Then I precisely fitted each key in the key guides using knife and file. The graph paper was very helpful.

After the bottom row of keys was mounted in position, I fixed the guides with screws instead of clamps. Then the middle and top row keys were fitted and placed in the key guides.

Thus, the key box was built step by step.

The vertical block at the left side of the key box is a temporary replacement for the nut over which the strings will run. It is an easy tool to place on the keys exact marks for placement of the tangent (holes). The holes in the keys at each layer have a different diameter. I drilled them with a drill press.

Tangents

The tangents have a different thickness for each key row: 8 mm for the bottom, 8 mm for the middle and 6.5 mm for the top row. For tangents with a certain thickness, I started with a square bar with that thickness. Then I drew the tangent at the top of the bar, the pen of the tangent pointing up. The rest of the bar serves as a handle for holding the workpiece. At the place where the pen stops, I sawed the bar so far in that a pen could be rough cut with aknife and be rounded to the diameter of the pin with a file.

To cut the sloping sides that form the angle which touch the string, I used a sharp knife. After that the tangent is ready and can be cut from the bar. On the bar, the following tangent can be drawn, etc.

Key box finishing

After placing all the tangents, I have finished the key box.

Because key guides remained not exactly vertical, I made cross connections between the left and right key guides. They consist of threaded rod that runs through the key guides. For show, I caught the rod in a brass tube.

When I was ready, I adjusted the key box to form a self-contained unit, which could later be mounted on the neck. To that end I replaced the MDF piece by a wooden plate of 5 mm thick, 10 cm width, length of the neck. To ensure that this plate is not going to bend due to temperature or humidity, I made it of plywood. For decoration I finished the short edges with hardwood.

4. Body

Having taken all measures and shapes from the original drawing I drew them on the wood. I checked everything thoroughly. Because I had no band saw, I used the band saw from a shipyard. The width of the blade of the saw did not allow to saw certain curves in one movement.

To solve this some curves were cut out from two sides. It proved difficult to match cuts made from two sides. Then there is a lot of finishing with chisels, files and sandpaper needed to get everything in order.

Tip: Work with a band saw with a blade width that can saw all curves in one move

The neck

With a drill press, I drilled left and right a series of holes adjacent to each other. I cut them out with a chisel and file so that elongated holes for the guitar strings were created. The edges of these holes were not nice and tight. That was solved by gluing mahogany strips with an oblong hole. Drilling the holes for the guitar string tuner was simple.

This work was done when the neck was not attached to the harp.

The reinforcement plate and the tuning pegs of the cello strings were made of two types of wood. That is a matter of taste.

I used a peg reamer and peg shaver to fit the pegs in the neck.

The assembly of the harpa

The assembly of the harpa is quite simple.

Here you can see how the parts are glued together and clamped. After this was done, I glued and clamped the back to the harpa.

Bending the top plate

I bought the top plate. It consisted of two parts glued together, 5 mm thick. From the construction manual one can (mathematically) deduce that the top plate should have the shape of a circle segment with a radius of 29 cm.

I have therefore made a mould on which the top plate could be bent and clamped.

The make the top plate easier to bend, I put it one hour in hot tap water. It was held under water with a weight of iron.

Then I clamped the top plate on the mould.

As you can see the glued seam parted in the middle. So, this was not the way to bend the top plate!

To reconstruct the top plate, I let the wood dry, sawed both halves apart, and glued them back together using a specially made mould.

With the template I could exercise horizontal and vertical pressure. I attached adhesive tape to the edges of the top plate to protect the wood against glue. The mould had a notch below the bond line which gave room for the expansion of the glue.

After the top plate was reconstructed, I decided to bend the plate with steam. Therefore I have a steam box made of MDF. The box interior was coated with aluminium foil.

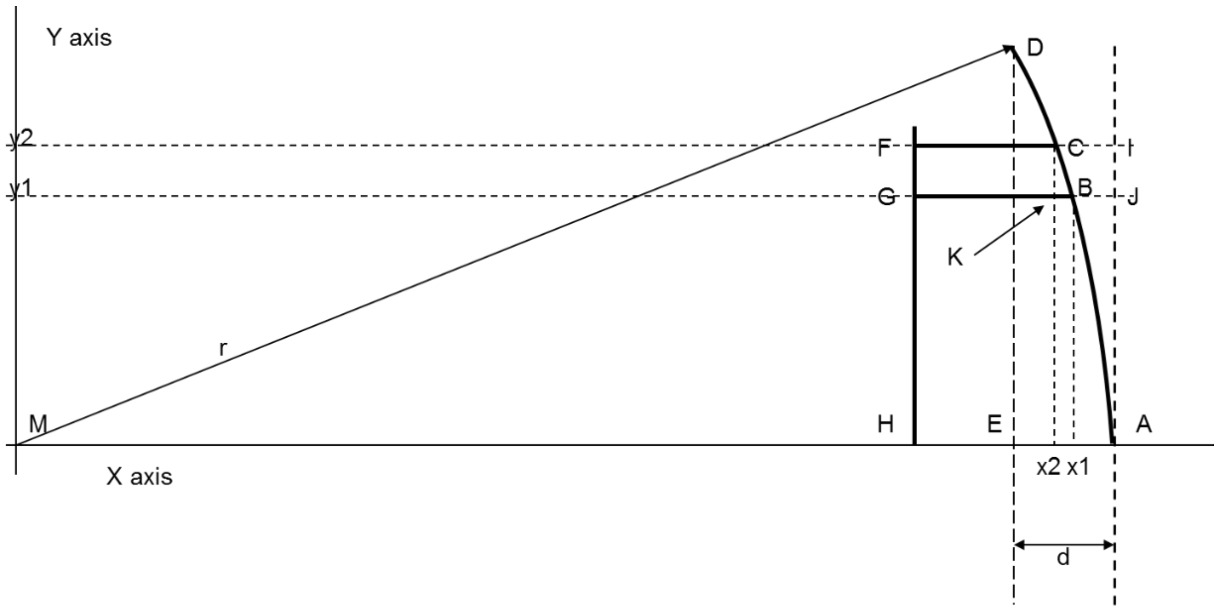
After 15 minutes steaming the top plate could be bent and clamped to the mould that I created earlier.

Placing the top plate on the body

The side edges should follow the profile of the now-bent top plate. Where the side edge moves towards the centre line of the harpa, it should be higher. Where it moves outwards it should be lower. It seemed hard to make a perfect fit between edges and top plate, just by hand only.

Note: apply the Pythagorean theorem to calculate the height of the sides edges

Then I noticed that the edges should connect to of the circular segment which is formed by the top plate. With the Pythagorean theorem this easily can be resolved, as shown in the figure below. MA is the axis of the harpa. FH is the top of the bottom plate. CF and BG are the outer and the inner edge of the harpa. DCBA is the bottom of the curved top plate with radius r = 29 cm. If the outer edge of the side is y2 cm from the centre line of the harpa, it is easy to calculate x2. At that spot the height of the edge should be reduced by (r-x2) cm be. In this way all points on the inside and the outside of the edge can be calculated. With a spread sheet with the only variable 'y' are all points can be calculated (the spread sheet formulas and other nyckelharpa mathematics are given in Appendix B).



With the spread sheet calculations in the hand it is simple to mark all points on the inside and the outside edge by pencil.

I checked the formulas, measurements and the pencilled points a few times. I then cuttered away unwanted wood - that was exciting.

I then lightly worked on the edges with a file and sandpaper and verified that the profile fits the top plate everywhere. The next picture shows how I did it.

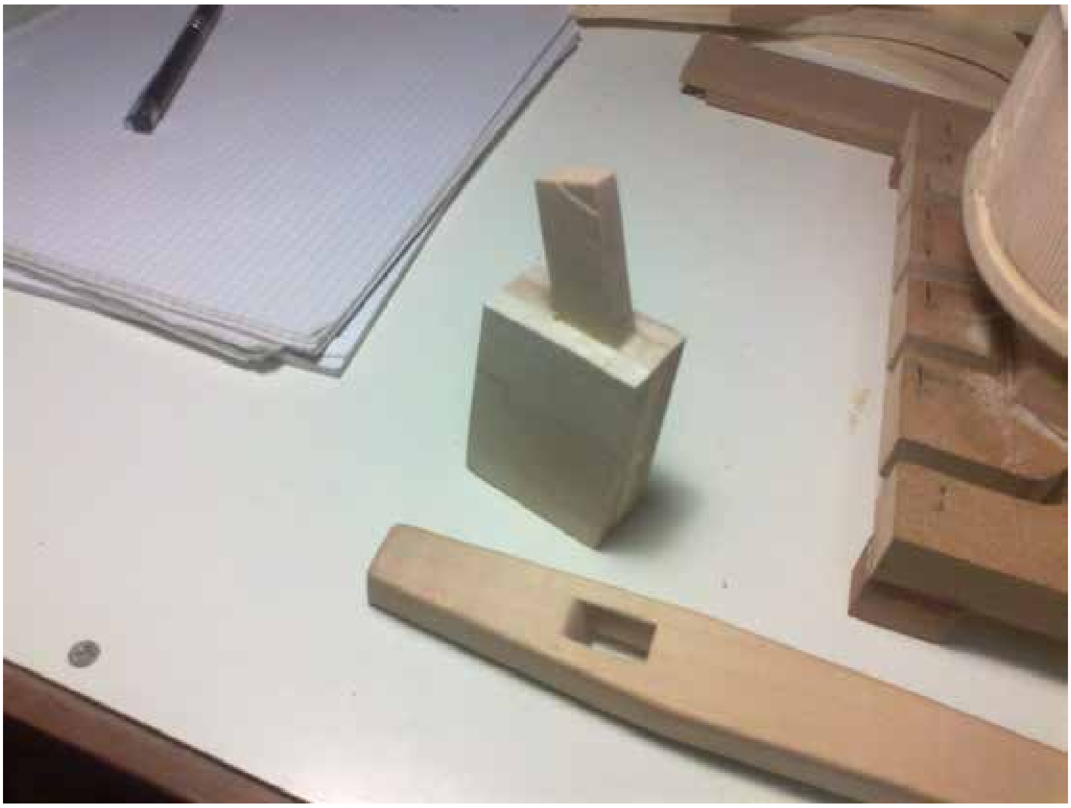
The result was perfect. We were now ready for the next step: gluing the top plate.

To the glue and clamp the top plate to the harpa, I made a clamping device.

The harpa body can be placed in it and the top plate can be glued and clamped with 25 clamps. Before applying glue I the attached adhesive tape on places where glue might damage the wood.

The tail

The tail and the tail holder must resist forces of the stretched strings. I decided for a different solution than is shown in construction manual. In the photo below a prototype of a tail holder is shown. It should be attached to the underside of the harpa. An oblique hole was carved in the tail. The hole fits exactly over the pen of the tail holder.



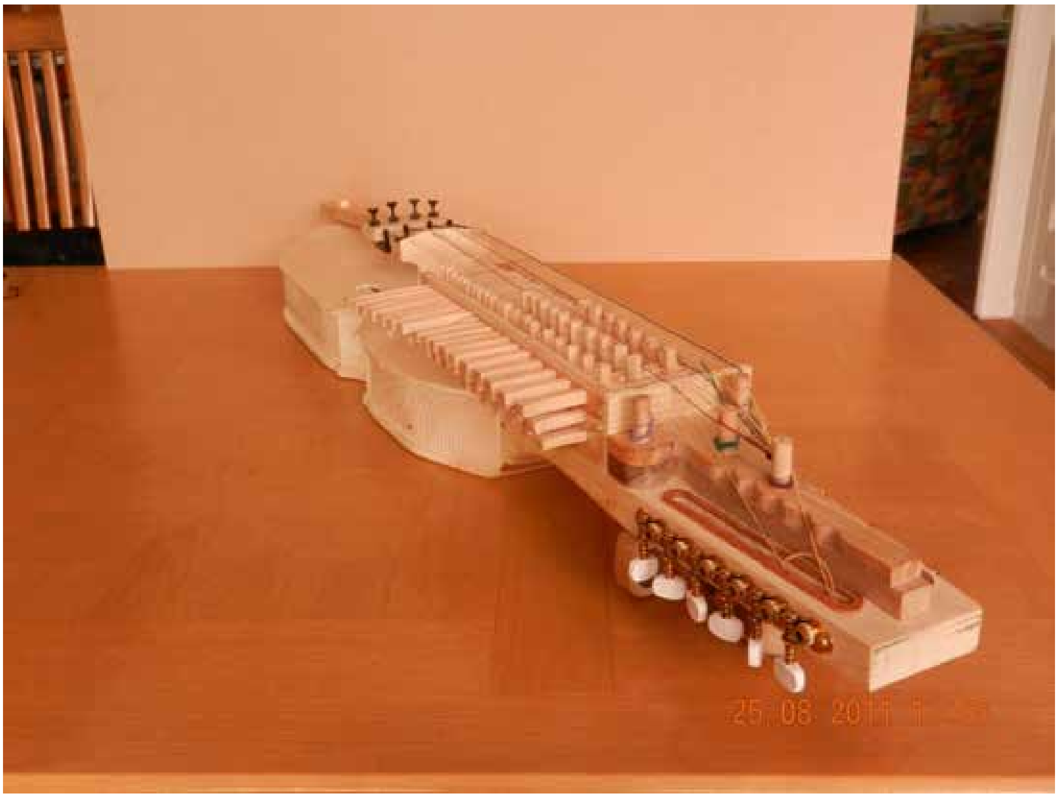
The holes for the sympathetic strings should run through the middle of the front of the tailpiece to the bottom of the cut that is made for the ends of the strings - a slight angle so. I have solved this by tilting and clamping the tailpiece to the workbench and drilling vertically.

5. Harpa

Subsequently I mounted the tailpiece, the key box and a makeshift bridge. I stringed the harpa with nylon strings (cello strings only) to make sure everything is fitting.

Then I made a permanent bridge, 5 mm higher than described in the construction manual (because of a wood plate of 5 mm under the key box. Placing all the strings is a process of trial and error, partly because the bridge can slide a little under the pressure of the strings.

The picture below gives an impression of the stringed, not stained harpa.



Tightening the cello strings was really heavy going and it was therefore difficult to tune them precisely Therefore I made a few accessories to tighten the bolts more easily.

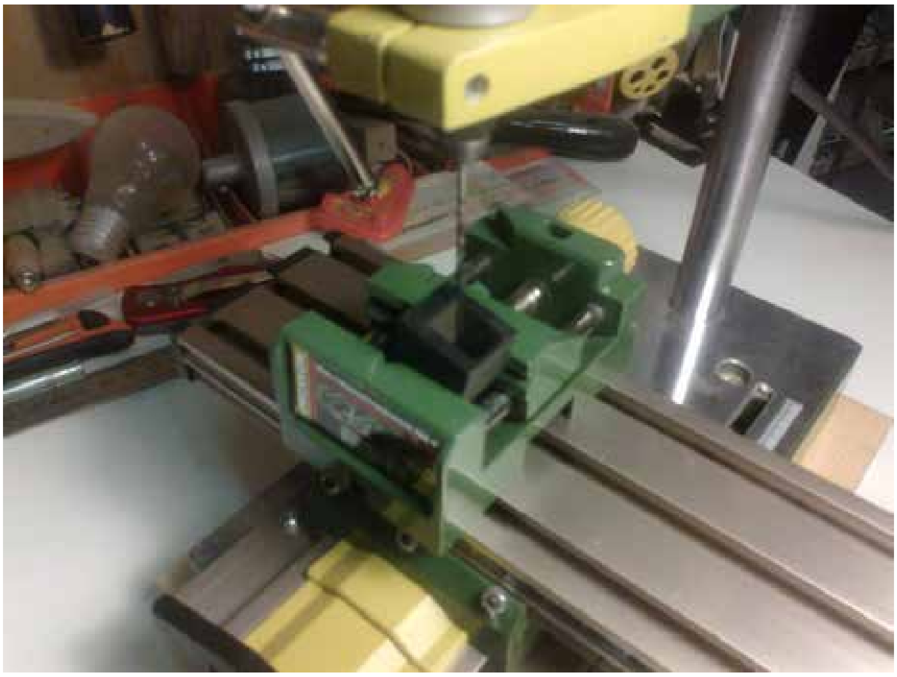
I made these before I discovered the existence of a lubricant for pegs which ceased to run smoothly.

6. <u>Bow</u>

I have built the bow by gluing a number of layers of two different types of veneer and bending and clamping it with a mould. The result was a rectangular stack of glued veneer with a curve. I planed and sanded it into the proper shape.

For the frog I have made an oblong hole in the bow, by moving a cutter with a mechanical stage over the fixed bow.

At the tip of the bow, I have glued an ebony block with square hole in it. This hole is for fastening the bow hair. The next picture shows how I have drilled a square hole by drilling away the edges of the hole and by filing.



The picture below shows how the ebony block is glued and clamped to the tip.

The picture below the shows the ready bow. The bow hair was fastened by a professional violin maker.

7. Standard

It seemed useful to have a stand on which the harpa could stand stable if not played. There are standas for violin and cello for sale but I did not like them and they did not fit. I decided to make one myself. Any design will do as long as the harpa stands stable.

The picture above shows what I've made. The standard consists of five parts which click together without screws: two round legs that click together, a vertical support for the harpa that clicks around the legs, a back support which is attached to the vertical support with a wedge, and a safety bracket which is clicked on the vertical support. All parts coming into contact with the harpa have been covered with felt (not in this photo) to prevent damage to the harpa.

8. Case

The case was made from plywood. I covered the outside with vinyl. On the case bottom I placed a mould fitting the bottom of the harpa. This prevents forwards or sideways movements of the harpa. For the end of the neck, I made a recess. I made clips covered with felt in the lid. They press the harpa tight against the bottom as the lid is closed. The bottom of the box has enough room for the bow and other accessories.

The box is strong but also very heavy. For someone who is small or not strong, this is a disadvantage.

Tip: Try to build a strong case with lighter materials

The round legs of the stand I have attached with Velcro to the inside of the box. I have clamped the long supports using a swivel clip.

9. Testing the harpa

I started to play the unstained harpa a few weeks tried (I had never played on a violin or harpa). This gave the opportunity for small corrections to the harpa. On my request an experienced harpa player tested the quality of the instrument. Her judgement was that I made an instrument that is acoustically and mechanically completely satisfactory.

The instrument is still unstained.

Appendix A. Time used

Part	Hours at the workbench
Key box	130
Body	130
Harpa	40
Bow	15
Standard	20
Case	25
Finishing the harpa	
TOTAL	

In this time several moulds were made, as described in the report. The time does not include time for shopping and pick up wood and tools.

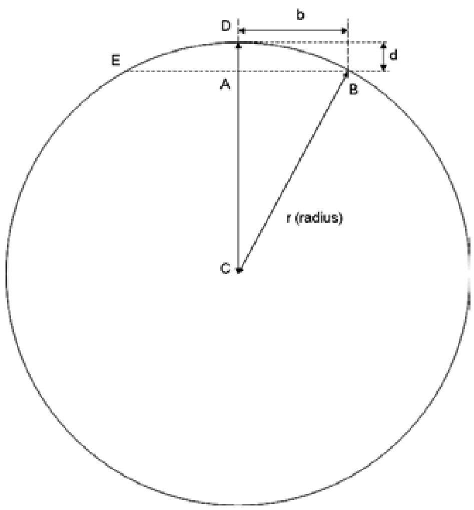
Appendix B. Nyckelharpa mathematics

Fitting the top

Deflection curve or the top

Drawing 1.3 [1] shows a peak deflection of 15.5 mm over a total breadth of 185 mm (90 mm 95 mm). Assuming the form of a deflection is a circle segment, the centre point and radius of the circle can be easily calculated. See figure 1 below.

Figure 1



Curve EDB is the underside of the deflected top. Half of the breadth b is (it is assumed for calculation purposes that both half breadths are equal). The deflection is d. The radius of the circle is r. Now the radius can be calculated using the right triangle ABC the Pythagorean theorem and applying: $BC^2 = AB^2 + AC^2$. AC = r-d and AB = b. Therefore $r^2 = b^2 + (r-d)^2$. From this follows: $r^2 = b^2 + r^2 + d^2 - 2rd$, and thus $2rd = b^2 + d^2$. Finally we conclude the $r = (b^2 + d^2) / 2d$. By filling in the values of b (= 90 mm) and d (= 15.5 mm), we calculate r = 295.5 mm.

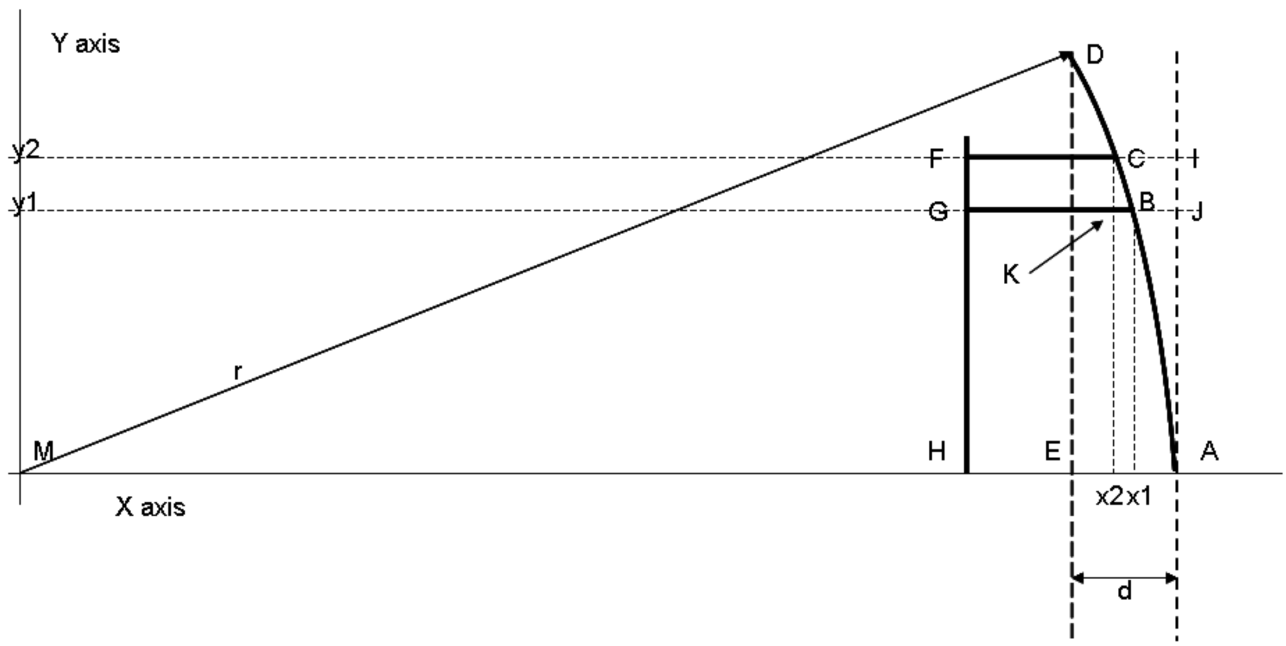
Breadth of the top

The circumference of the circle with centre point C and radius r equals to 2 * pi * r. This length corresponds with 360 degrees. To calculate the length or curve EDB (= net breadth of the top) we are determine angle ECB. ECB = 2 * angle ACB. Tg (ACB) = b / (r-d). Therefore angle ACB = arctg (b / (r-d)) radians. Thus the length of curve EDB = 2 * arctg (b / (r-d) / 2 * pi * r * Add extra millimetres to the breadth to make sure the top sticks out from the sideboard.

Calculating the height and angle at peak each position of the sideboards

In the figure 2 below a cross section of the harpa is shown.

Figure 2



The harpa is standing on its side (this picture shows one half of the harpa). FGH is one half of the bottom plate. FGBC is a cross section of the sideboard. FC is the outside of the sideboard, GB is the inside. FG is the thickness of the sideboard at a certain cross section. HA is the maximum height of the sideboard. ABCD is the deflected top of the harpa. MD is the radius of the deflected top. ABCD is the underside of top half of the deflected top. HEA is the middle line of the harpa. The upper side of the (unbowed) sideboard lies in the plane AJI. At a certain vertical cross section of the sideboard, points C and B and curve CB should be positioned to fit exactly the top. This can be done by filing away at a particular cross section, IC at the outside, and JB at the inside of the sideboard. For practical purposes BC is considered to be a straight line.

Calculating the height

That cross section at the outside of the sideboard, FC, the inside is GB. Easily we can measure the distances of these sides to the centre line of the harpa (which corresponds with a line perpendicular to the plane or figure, through point H). Coordinates of point B and point C are (x1, y1) and (x2, y2). Coordinates y1 and y2 are known by measuring the distance of the outside and inside of the sideboard to the bottom centre line of the harpa. Coordinates x1 and x2 now can be calculated.

We apply the Pythagorean theorem we to the triangles BMx1and CMx2 . In general $r^2 = x^2 - y^2$ applies for triangles , and therefore x =square root ($r^2 - y^2$). For triangle BMx1 applies $x1^2 + y1^2 = r^2$. For triangle CMx2 applies $x2^2 + y2^2 = r^2$. Therefore point B lies (r - square root ($r^2 - y1^2$)) below to the top edge of the sideboard, point C lies (r - square root ($r^2 - y2^2$)) below the edge. These points can be calculated and marked at the inside and outside of the sideboard. By connecting the marked points at the inside and outside, we shall see the curves of the board that side will fit the top exactly.

Calculating the top angle

The top angle of the sideboard is KCB angle in Figure 2. It is equal to arctg (KCB). Tg (KCB) equals to (KB / KC). KB = x2-x1 = (r-sqrt (r^2 $y2^2$) - (r-sqrt (r^2 $y1^2$)). KC is the thickness of the sideboard = y2-y1. From this arctg (KCB) can be calculated.

Spread sheet to perform calculations

		item	symbol	formula
breadth and bend through of top board				
	DA	maximum deflection	d	input data
	AB	half breadth	b	input data
	CB=CD=CE	radius	r	r=(b*b+d*d)/2*d
bend through at distance y1				
	GH	measured distance from bottom centre line	y1	input data
	BX1	horizontal projection		
	JB	bend thru at y1 distance		r - square root (r*r-y1*y1)
bend through at distance y2				
	FH	measured distance from bottom centre line	y2	input data
	GX2	horizontal projection		
	IC	bend thru at y2 distance		r - square root (r*r-y2*y2)
angle from (x2,y2 to (x1,y1)				
	KCB	angle of the upper edge of the sideboard		arctg (KCB)
	tg(KCB)			KB/KC
	KB	x1-x2		(r-sqrt(r*r-y2*y2)-(r-sqrt(r*r-Y1*y1)
	KC			y2-y1