Knud Vagn Valbjørn

Reconstruction of the Hjortspring Boat

In the year 1922 a plank-built boat was excavated from a bog in the island of Als in the southern part of Denmark. The boat was interpreted as a war canoe, it was 18 m long and 2 m wide, built mainly of limewood. The five wide boards were sewn together with organic materials. At both ends there were remains of horns like the ones well known from boats in the rock-carvings in Scandinavia. Shortly after the excavation, the Norwegian naval architect Fr. Johannessen made a documentation of the boat. The drawing of the boat is in the publication "Hjortspringfundet" (fig. 1).[1]

Reconstructing the boat

In 1991 a group of people on the island of Als decided to investigate the possibility of building a replica on the scale 1:1 of the Hjortspring Boat.

As the task of building such a replica proved to be an enormous one, especially as the result was desired to be of high quality, "The Guild of the Hjortspring Boat" was formed. This gave us a platform from which we could co-ordinate the work, raise funds and obtain support from scientists working in the field of archaeology. The guild attracted a wide variety of people as members with different interests, professions and skills. To exploit these qualifications and interests to the utmost, the guild was organised into various groups, for example design, boat-building, wood-procuring, history, tools, video, organisation, fund raising etc. The groups met once a month to report on their work and findings.

The training and introductory period

As we had no members with a formal training as shipwrights, carpenters or cabinetmakers, we decided to start with a training period. During this period the tool group studied likely tools from the Celtic Iron Age and eventually forged samples of these (fig. 2). The samples were then taken into use, commented on and refined by the boatbuilding group. This group started by producing copies of shields and other wooden artefacts from the find. Next they produced a few thwarts. Then followed a 1.4 m-long

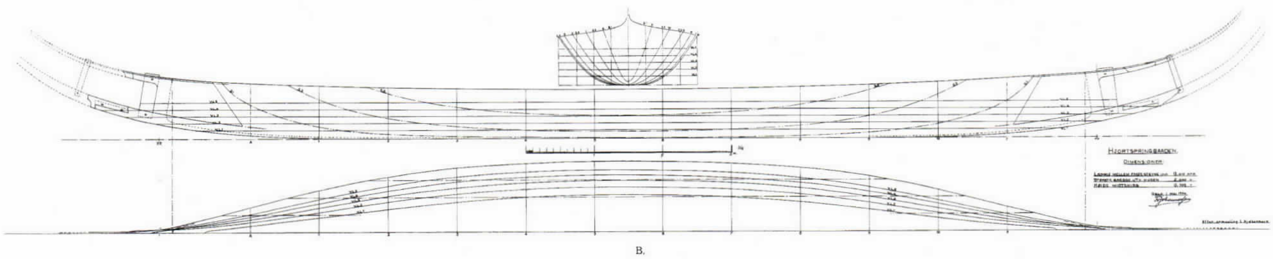


Fig. 1. Lines drawing of the Hjortspring Boat. After Rosenberg 1937.

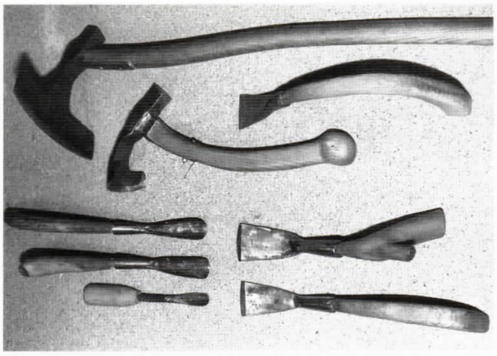


Fig. 2. *Tools used for reconstructing the Hjortspring replica. Photo: K.V. Valbjørn.*

Fig. 3. *Sample of middle section. Photo: K.V. Valbjørn.*

middle section of the boat on the scale 1:1, containing two frame-systems (fig. 3), and finally the first 5 metres of the prow, containing one frame. For these samples they used local lime-trees (*Tilia grandifolia*). The training period for the boat-building group was two years and, 1,650 man-hours were logged.

The design group entered the data from Johannessen's lines drawing into a computer and was subsequently able to print out profiles that were used for the building of the boat. The data in the computer was also used to analyse the boat from a hydrostatic, hydrodynamic and stress/strain point of view.[2]

The wood-procuring group looked all over Western Europe for lime-trees with trunks rising more than 18 m, before the first branch appeared (*Tilia parvifolia (cordata)*). Eventually the group was recommended to search in Poland and Russia. In Poland, 100 km south of Gdansk, they identified a forest of lime-trees of the type we needed. Four trunks were acquired.

The boat building

The boat was built as a shell, with five planks fixed to each other and to the stem parts to form the hull, followed by the insertion of the frame-systems.[3] This reflects the typical building methods of later Scandinavian boats, for example the Nydam Boats and the Viking ships (fig. 4).

Each of the planks (the bottom plank, the two side planks and the two gunwale planks) required half a trunk because of their width. Fig. 5 shows a side plank in position in a split trunk. A loose core in two of the trunks caused much trouble and eventually we had to glue an addition to two of the planks to obtain the necessary width. Tests showed, however, that glued planks had the same elasticity and strength as whole planks.

The prow and stern were carved out from short trunks with a diameter of one metre. While the lower horn, the keel horn, was connected to the bottom plank in a manner well illustrated in the find by means of a groove and feather assembly,

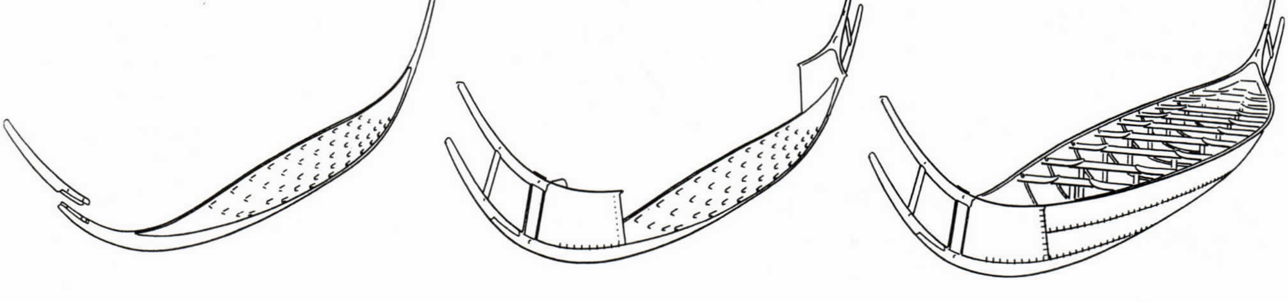


Fig. 4. Schematic drawing of the construction. After Kaul 1988.

Fig. 5. Plank production. Photo: K.V. Valbjørn.

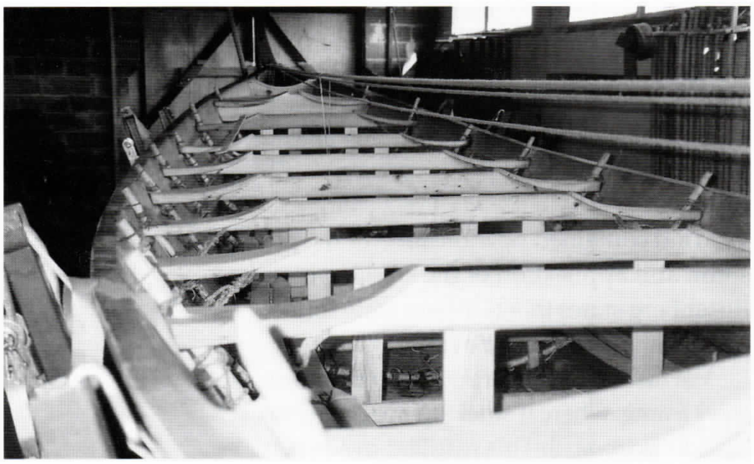
the connections between the gunwale-horn and the prow and stern were unknown to us. We decided to use a loose branch for the gunwale horn as well and connect it to the stem with a groove and tongue joint.

The material employed for sewing or lashing the parts together was strings made from lime-bast with a mass density of 11 g per metre. The strings could alternatively have been thin roots of spruce or fir.

The caulking material chosen was sheep's wool, saturated in ox tallow and rapeseed oil. The two latter materials were identified in the find.

The frame-systems are of a highly refined design. The frame itself is a hazel branch with a diameter of 30 mm. The frame projects through the thwarts, the deck beams and the columns. The elements are not fixed to each other with keys (fig. 6). The stability of the frame system is obtained when the whole assembly is inserted down into the boat shell and the frames are lashed to cleats that are carved out as a part of the planks. The choice of materials and the shape of the different parts show refined thinking with regard to strength versus weight.

Fig. 6. Frame-system. Photo: K.V. Valbjørn.



A major difference between the boat, as documented by F. Johannessen and our choice is the sheer. According to Johannessen's interpretation the boat had a very moderate sheer. Calculations show that the gunwale-plank (before mounting) describes a high curve. This required a width of plank far exceeding what was available to us. The work involved in building the boat was basically that of chipping away wood. The original trunks weighed 12 tons, while the end result, the boat, has a weight of 530 kg. 800 m of lime-bast string was used for sewing the planks together and for lashing the frames to the planks. A total of 10,000 man-hours were logged.

During the process of building the boat more than 2,000 photos and more than 20 hours of video film were taken. The process of documenting the work, analysing the

Fig. 7. Launching. Photo: K.V. Valbjørn.

produced hypothesis and confronting the calculated characteristics with those established during handling and sailing, have started. Extensive plans for the publication of results have been outlined.

Testing the hypothesis

The boat was launched on 29th May 1999 and named *Tilia Alsie* (fig. 7). During the summer of 1999 the boat sailed on six separate occasions. Between sailings it was wheeled up to the building, where it was built.

The object of the sailings the first year was to get acquainted with the boat and to test the many choices that had been made when building the boat in order to verify or refute their usefulness.

When the boat was lying in the water, there was no heeling and the draft of the empty boat was, as calculated, 10 cm. The water line was 9 metres, showing the high sheer. There were several leaks, mainly through sewing holes that had been inadequately caulked. The seams themselves were not very leaky. A crack in the portside board aft let in considerable amounts of water. The leaks were easily caulked by pressing ox tallow into holes and cracks from the inside.

Manning the boat produced an immediate feeling of instability. Sitting in the boat, before sailing commenced, gave the same impression (fig. 8). Once paddling began, it was felt that the boat functioned well with respect to stability. No doubt the crew counteracted any heeling by moving of their bodies. The velocity probably helped as well. The boat felt safe.

Some sailing was done with 600 kg of ballast placed between frames 3-5 and 6-8. This increased the stability considerably when the boat was lying at the pier but not when sailing. On the contrary, should the boat capsize, it would sink. The nominal load was selected to be 2 tons. We actually performed sailing trials with loads ranging from 1.4 ton up to 2.5 tons. The latter load gave a total displacement of 3 tons. There was ample freeboard even with this heavy load, so the war canoe would have been able to bring some loot back home after a successful raid.

The find contained no indication of the position and application of the steering oars. Rosenberg states that two oars were found, one at each end of the boat.

We lashed one steering oar to the aftermost frame, where it stuck up over the gunwale to starboard. This resulted in a rather

Fig. 8. Sailing. Photo: K.V. Valbjørn.

horizontal position for the oar and this did not have a convincing effect. Depending on the direction of the wind the steering was inadequate. A test with both steering oars, one at port and the other at starboard, did not help much. Eventually the steering oar was lashed to the keel horn at its root and operated by twisting it in an almost vertical position, just like the steering oars of the Nydam- and Viking-ships (fig. 9). In this position the steering was convincingly good. A test with the other oar mounted similarly but at the prow and letting that do the steering alone also gave good results. Using both steering oars, one at each end of the boat, gave excellent results.

Speed measurements

Of major importance in the sailing trials were of course speed measurements. A group of people from The Viking Ship Museum in Roskilde helped the Guild for three days of trials in Dyvig Vig in September 1999 with Max Vinner captaining the boat.

A test range of 1,160 m and a shorter one of 320 m were used, and the velocity was calculated by measuring the time taken to cover the range. Waves were insignificant and the wind had a velocity of 5-8 m/s with a direction 30 degrees off the direction of the range.

Several test runs were performed. The results were somewhat disappointing compared with our expectations. Based upon the water line we expected a velocity of close to 8 knots. The maximum velocity was measured to be 5.1 knots with the wind from astern and 4.5 knots with the wind from ahead, both measurements made when using the long range.

The following parameters that influenced the speed negatively may be divided into two groups, namely too little power produced by the paddling and a too high skin-friction of the boat. Wave resistance is insignificant with such a long, slim boat.

Firstly, the tests were performed with 16 paddlers only, although there is room for 20. Secondly, it was obvious that the crew was not experienced in the paddling technique. Many different ways of paddling were observed. Thirdly, the strokes were not in synchrony. And lastly, half the crew was not sufficiently strong to represent sturdy, trained warriors from our past. To counteract these drawbacks we have plans to learn the correct technique. We shall have to adopt some measures to make it possible to paddle synchronously, either with the aid of paddling songs like those used by the Maori people or with the use of a drum, as in the Chinese Dragon boats. Finally, we must man the boat with strong people when repeating the velocity tests. It is not unreasonable to expect that the propulsion power could be raised three times if we adopt the above-mentioned measures with success. Should that be the case the velocity will be increased 50%.

As to skin friction, a major difference between the original boat and our replica is that while the original boat had all its sewing seams covered on the outside with a smooth layer, probably of resin, our boat had the sewing strings exposed to the water. This creates streams of vortices, which increase the resistance where the seams are by a factor of ten. Calculations show that the friction resistance of the boat caused by these vortices is 10% higher than with covered seams. Should we decide to cover our seams, we would expect a 10% increase in velocity. Should the above improvements be implemented and should the resulting effects be as estimated, the velocity would be increased from 5.1 to 8.4 knots!

Manoeuvrability

Owing to the horns the boat was not easy to manoeuvre close to a pier. It was, however, possible to move the boat sideways to and from the pier by paddling at right angles to the direction of the boat. Carrying the boat into the water or landing on a flat beach, seem natural ways of avoiding the problem.

The boat could be rotated around a vertical axis on the spot by paddling on one side and doing reverse paddling on the other. The boat could be brought from a velocity of 5 knots to a full stop in less than a boat length by reverse paddling.

Future tests

The objective for the continuation of the tests will be to clarify the potential of the velocity and, at the expected higher velocity, to carry out manoeuvrability tests. The stability measurements must be repeated and the water resistance measured.

Fig. 9. New position of steering oar. Photo: K.V. Valbjørn.

We shall have to investigate the position of the steering oar more closely. The one that we adopted has not been proved to be the right one, although it did give better results than the position first chosen.

We shall investigate whether we can measure the twisting and bending of the boat when it is sailing in waves.

We want to establish the long-range sailing speed, for instance by letting half the crew paddle while the other half takes a rest.

Finally we should like to study the kinematics of the paddles in order to investigate the reason for their very narrow design.

The objectives for building a replica of an antique boat may vary. Regardless of the objective, however, the following parameters should always be considered when planning to build a replica of a boat.

- *Authenticity*. The boat should reflect the most up-to-date knowledge about the materials, design and manufacture of the boat.
- *Seriousness*. Each choice to be made should be discussed in depth before a decision is taken and then only be considered as a working hypothesis.

- *Quality* in all details and processes.
- *Documentation*. All aspects of the process should be documented, even if it is only possible to do this sketchily.
- *Time* in man hours.

One of the five parameters should be kept open to absorb deviations from the plan, while the others should be put into an order of priority that is to be followed when conflicts occur.

In the case of building the replica of the Hjortspring Boat, the main objective was to illustrate the functional value of the boat as a contribution to our understanding of the society that built and used the original boat. Another objective was to increase our evergrowing understanding of the development of boat designs in antiquity. Of major interest here was the understanding of Bronze-Age ship designs. Thus it was time (man hours) that was considered to be the open parameter, while the other four parameters were placed on the priority list as stated above.

Finally the produced data must be processed, i.e. interpreted and published. This should be considered a separate project with its own priority list.

Notes

1. Rosenberg 1937.
2. Fenger *et al.* 2000.
3. Valbjørn *et al.* 2000.

References

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