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Tortoise brooches, textile impressions and textiles

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This article deals with the identification of fabric used at the production of tortoise/oval brooches and finding out the function of the textile fabric in the casting process. One hundred textile impressions on the reverse side of tortoise/oval brooches from Birka, Björkö parish, Uppland, and Vendel, Vendel parish, Uppland, from the Early and Middle Viking Periods were analysed and "translated" to original fabric. After comparison with contemporary fabric, the quality and way of production of the analysed "translated" fabrics could be established.

Tortoise/oval brooches have been studied from several points of view. They have been used as instruments for chronological seriation and the ornaments on the brooches have gained the interest of art historians (cf. Jansson 1985 and references cited therein).

During the excavations at an Iron Age settlement in Vendel in 1994 (Arrhenius & Isaksson 1995) a pair of tortoise/oval brooches was found. On the reverse side of the brooches there were textile impressions. During the preparation of these (Malmius 1995) I thought about the impressions and wondered what was the function of the textile fabric in the casting process – was it of aesthetic or of practical character? Zachrisson (1960) thought that the fabric was a means to handle the moulds before they were dried, and Arrhenius (1975) suggested that the fabric was a tool to achieve thin castings. Lønborg (1992) elaborated the hypothesis of Arrhenius and suggested that the fabric was used together with warm wax to form the thickness of the castings. To gain more knowledge about the role of the fabric in the mould production, I carried out experiments, making my own moulds.

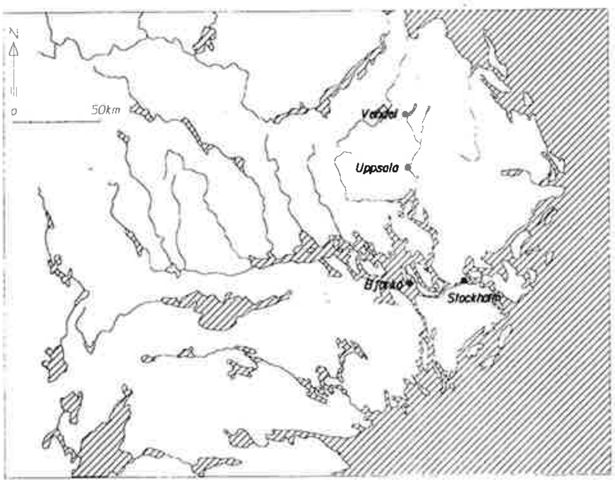


Figure 1. Map showing the geographical location of Birka (Björkö), Adelsö par., Uppland and Vendel, Vendel par., Uppland, Sweden. Drawing Kjell Persson.

I also wanted to know if the fabrics used in the brooch production were specially made; if they were made in a specific quality or if they correspond to other fabrics of a particular quality, or if they belonged to the everyday dress, feather beds, cushions, etc. In order to study this, the impressions have to be "translated" into original textile and defined with respect to binding system, thread count, material, etc. The classification forms the basis for comparison with contemporaneous fabric.

The material used for this study was 98 oval brooches from Birka and two from Vendel (fig. 1).

Methods

Fabric and casting

In order to find out the function and the desired features of the fabric in the casting process, I carried out experiments producing moulds for oval brooches using different kinds of fabric.

To produce a mould, tempered clay was put on the front side of a finished oval brooch. This upper piece of the mould was then dried, shrinking in the process. The fabric was then dipped in warm wax and installed in the shallow mould, the warm wax making it possible to in-

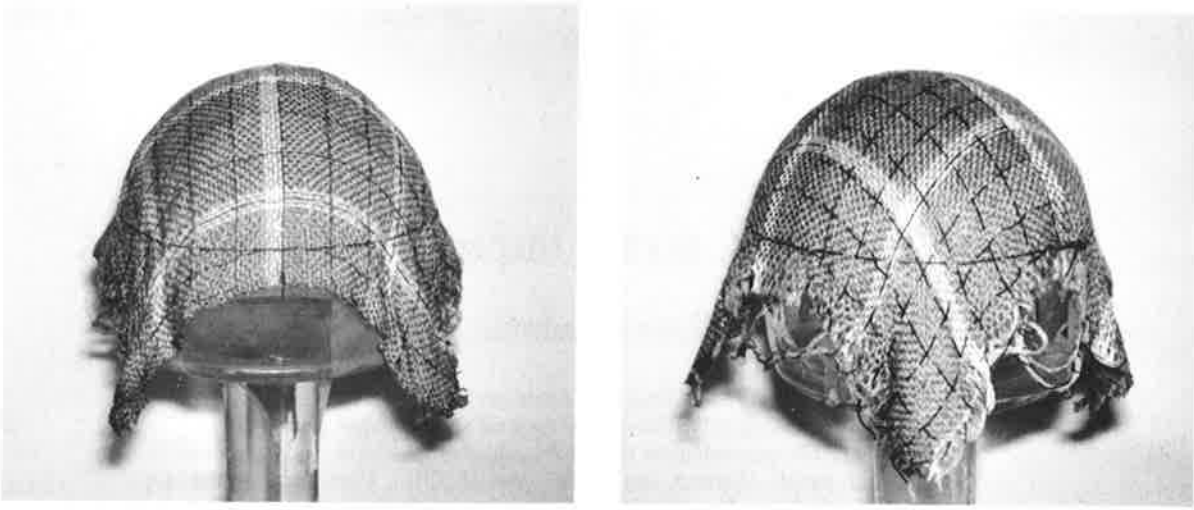


Figure 2. Textile models showing how and where the compression of the fabric takes place when it is installed in a concave form, here on a rounded form.

stall the fabric without any creases. To create the bottom half of the mould a second layer of wet clay was worked into the cavity remaining above the wax-coated fabric. In this process the newly added clay had to be wet, flexible and soft. At this stage the fabric/wax layer acted as a membrane, preventing the water in the clay from reaching the upper piece of the mould and damaging its ornamentation. After drying, the lower piece of the mould was lifted out. It now had textile impressions all over the surface. The waxed fabric was then taken away. (In proper casting, the upper and lower pieces of the mould would now be fixed together, warmed, and the bronze poured into the mould, the fabric/wax layer forming the thickness of the casting. The textile impression is hence transferred to the brooch itself.)

Binding system and thread count

The textile impression left in the cast brooch reflects but does not reproduce the original fabric. In order to map the original thread count and fabric character, one must take account of several variables: the techniques used in weaving, the distortions to the imprint caused by shrinkage in the clay mould and others due to cooling in the copper alloy as it sets/hardens.

To determine the thread count it was necessary first to find out how the compression of the flat fabric distorted the material when it was installed in a concave form (fig. 2). The textile model shows that the thread count is unchanged along the middle of the fabric in both warp and weft direction and that the fabric is compressed in between, at most in the four corners. But – also here the thread count is unchanged! What happens is that the fabric is turned in the points of binding, whereby the form of the fabric is changed (fig. 3). This is valid provided that the number of threads is counted along the warp and weft – as normally is done when working with textiles. This means that it is possible to count the threads, wherever they are seen in the oval brooch, and the thread count does not have to be corrected for the compression of the fabric.

In oval brooches one seldom can count the threads over a distance longer than half a centimetre. If the distance is short, the number of counted threads becomes uncertain and the following method has therefore been used. When 6 threads/0.4 cm are measured, the number of threads should perhaps instead be 5.5 or 6.5 threads/0.4 cm, something that is hard to decide when the distance is so short. The obtained thread count in the oval brooches will therefore be written as ranges in both warp- and weft-direction, in this case 13.75–16.25 threads/cm.

To transform the thread count obtained from the impression to that of the used fabric, the thread count has then to be corrected for the shrinkage of the clay and the copper alloy. The dry shrinkage of the raw clay is usually between 5 and 6% depending on the tempering and the quantity of water, and the shrinkage of the copper alloy is less than 1%. In the experiment I assumed a standard 6% for the dry shrinkage of the clay and the copper alloy, which gives a correction factor of 0.94 (100%–6%=94%). (To transform impressions in *moulds*, one only has to correct for the dry shrinkage of the clay, i.e. a correction factor of c. 0.95)

Example. A fabric with the thread count 19 thr/cm, gives an impression in the oval brooch of $19/0.94=20.21$ thr/cm. To get back to the fabric the tread count of the impression is multiplied by 0.94, for instance $13.75\times0.94–16.25\times0.94=12.92–15.28$ thr/cm. The figures are then rounded to the nearest whole- and half-thread, in this case 13–15.5 thr/cm.

Rib factor and thread count sum

To identify a fabric, two parameters, besides thread count, were used: *thread count sum, T* and *rib factor, R*. These two parameters have been constructed to get an ob-

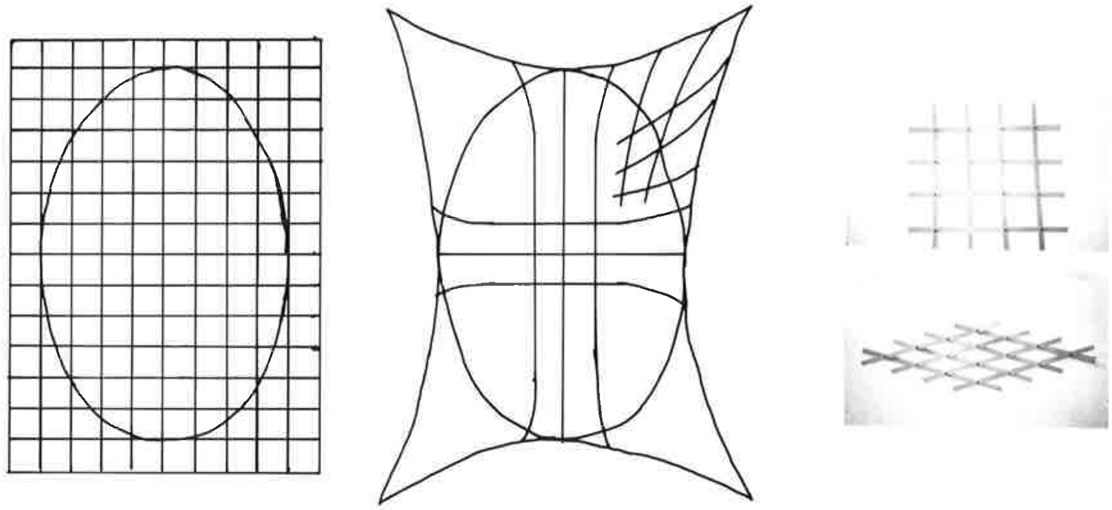


Figure 3. Figures showing how a flat fabric acts when installed in a concave rounded form. a) The directions of the threads in warp and weft in the flat fabric. b) The fabric installed in the concave rounded form; the directions of the treads in warp and weft along the middle of the fabric is unchanged, but in between – and at most in the four corners – the fabric is compressed.; c) Paper models showing how the compression of the fabric take place in the corners. The fabric is turned in the points of binding, whereby the form of fabric is changed/compressed, but the thread count is unchanged.

jective picture of the fabric and to add objective facts, useful in the comparison with other fabrics.

The thread count sum is calculated as the [thread count in warp] + [the thread count in weft].

The rib factor shows the thread relationship between warp and weft. It is calculated as [thread count in warp]/[thread count in weft]–1 ($R \geq 0$). Working with textile impressions, it is impossible to determine which is warp and which is weft, and therefore warp is here defined as having the greatest thread count. A low rib factor makes the fabric more or less equally elastic in both directions, which makes it easier to install the fabric in the brooch. $R=0.0$ is defined as *balanced,* $R=0.1$–0.9 as *ribbous,* and $R \geq 1.0$ as *ribbed* (see *Definitions* below).

Classification

Fabrics are traditionally identified by, for instance, thread count and binding system. Additionally any fabric can be classified with rib factor and thread count sum. Fully classified a fabric could then be written: tabby, 26×20 thr/cm, $R=0.3$, $T=46$.

Any fabric can be objectively characterized by these means in figures, and figures are possible to arrange in diagrams. Fabrics can then be classified as coarse, less fine, fine and very fine. The T-ranges that I have used for the Viking Age textiles are based on the publications of Geijer and Hägg, see *Definitions* below.

When the number of threads counted in the oval brooches is used to classify the "original fabric", great intervals of uncertainty is received, for instance 15–19×25–27 thr/cm. The measure method involves that the uncertainty within these intervals is not normally distributed but has a rectangular distribution, that is, all values within each interval have the same probability to constitute the correct thread count of the fabric.

To be able to specify the thread distribution of the complete fabric, in lack of an adequate formula, a *rib factor diagram* must be constructed. In this diagram the uncertainty rectangle of a fabric can be marked and all points in this rectangle/area have the same probability to constitute the thread count of the fabric.

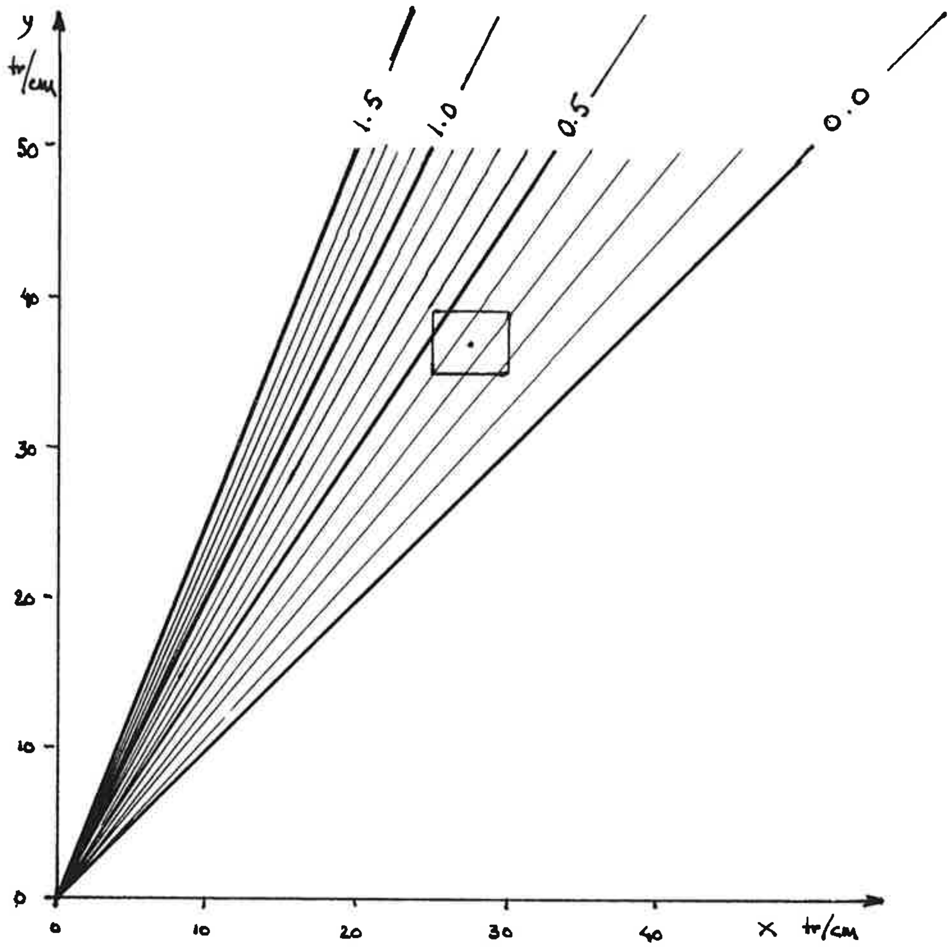
Construction of a rib factor diagram and calculation of the rib factor

A rib factor diagram is constructed with the lowest thread count on the x-axis and the highest thread count on the y-axis, according to the formula: $y=(R+1)x$.

The diagram is subdivided with lines between *balanced* ($y=x$) and *ribbed* ($y=2x$). The diagram is also provided with lines $y>2x$. For instance, at the thread count 33×22 thr/cm, the rib factor will be 0.5 ($R=33/22-1$). This diagram should be drawn as big as possible for correct reading (fig. 4).

When the rib factor of a fabric is to be defined, its uncertainty rectangle is marked in the R-factor diagram. The biggest thread count is always to be drawn along the y-axis. Also the T-value could be elucidated from the diagram, making lines perpendicular to the $y=x$ line (fig. 4). Here the mean of the thread count sum, T, is used.

Example. A fabric, 35–39×25–30 threads/cm; mean value 37×27.5 threads/cm is clearly defined by this method when written: T 64.5; R 0.2–0.6. Thus, by reading off the diagram, one gets a "picture" of the fabric, in this case a very fine, dense and weakly to medium-ribbous fabric. The comparison between fabrics with uncertainty factors can also be done in a quick and simple way. In areas where the uncertainty rectangles of the fabrics overlap, they have a similar thread count (fig. 4).



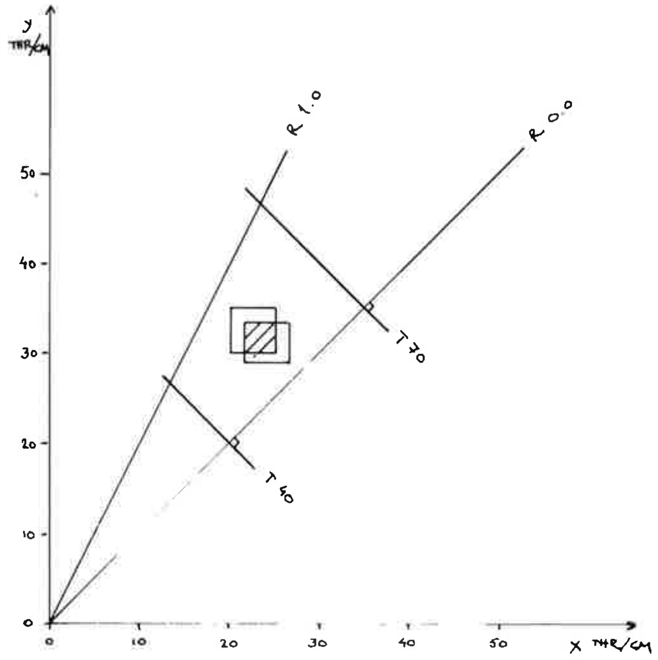


Figure 4. (Above) Rib factor diagram where lines are marked for every tenth R-factor and a fabric of 35–39×25–30 threads/cm is marked. (Left) two fabrics are compared. In the areas where the uncertainty rectangles overlap, they are of the similar thread count.

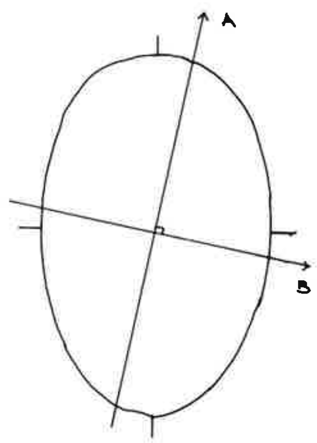


Figure 5. The fabric, with marked A- and B-axis, placed in the mould.

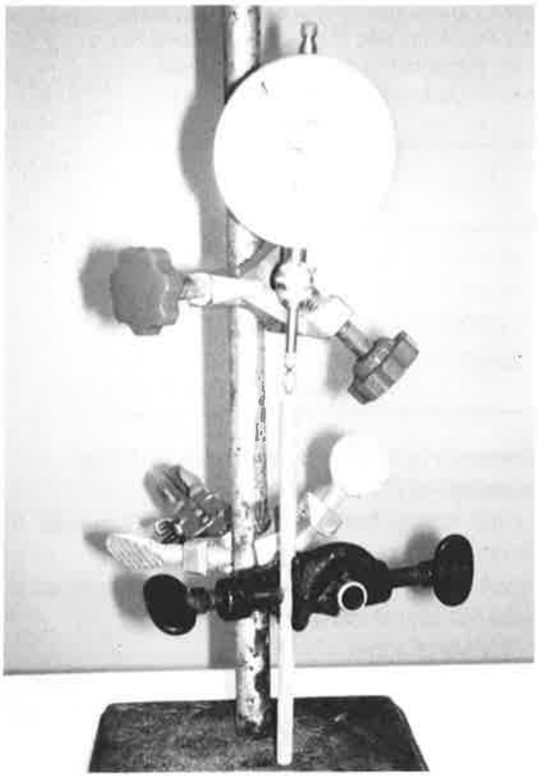


Figure 6. Instrument for measuring. The instrument is made of a stand, where a measuring instrument with a clock is fastened. The measuring instrument has, in the vertical direction, a movable arm that is ended with a ball of 2 mm diameter. This ball meets another ball of the same diameter, fastened in a counter hold. To measure the thickness of an object the movable arm is lifted and the object is placed perpendicular to the counter hold. Then the sensitive measuring arm is carefully let down and the distance is read off the measure clock. Distances can be measured with a precision of 0.01 mm. For this investigation the diameter of the balls is of great importance. The ball must not be too big, then the ball cannot reach the bottom between the ornaments, on the other hand it may not be so small that it like a point can damage the metal.

Comparable textile impressions

To find out if the fabrics used at the production of Birka's and Vendel's oval brooches correspond to those fabrics that were used for the oval brooches from Denmark (Bender Jørgensen 1986) and other sites in Uppland, Sweden (Rosborg 1991), these textile impressions were "translated" into "brooch fabrics" and supplemented with thread count sum and rib factor. The "brooch fabrics" were then compiled and compared. The textile impressions could of course have been compared without translation into "brooch fabrics", but my goal here was to compare the used "brooch fabrics" with found comtemporary fabrics.

Quality

The quality of the fabrics is dependent on raw material, spinning/twisting, yarn thickness, binding system, thread count, etc. Out of the textile impressions from the oval brooches it is above all facts about binding system and thread count that can be gathered. These two parameters provide a certain picture of the quality. To be able to produce a certain type of fabric, all the above mentioned components must be in harmony, and by examining binding system and thread count the rest of the components can – to a certain degree – be estimated. Two fabrics with the same thread count can look quite different, however. It is therefore most important that as many parameters as possible are elucidated for a correct description of the original quality.

To determine these parameters, the calculated "brooch fabrics" from textile impressions in oval brooches from Birka and Vendel have been compared with contemporary textiles from graves at Birka (Geijer 1938; Hägg 1984; 1986) and Thumby-Bienebek (Tidow 1976:63ff; Hägg 1984:table 6), with settlement finds from Hedeby harbour (Hägg 1984) and with those at Hessens II (Hägg 1984:table 5). To be able to make this comparison these fabrics have been compiled and supplemented with thread count sum and rib factor.

Results

The fabric was placed in the oval brooch so that the A-axis of the fabric (i.e. the warp direction), in only 12 of the brooches, was parallel to the length axis of the brooch (fig. 5). The reason for this is that a small piece of fabric is easier to install if the fabric is placed somewhat diagonally. If the A-axis is placed about 10–40° from the length axis of the brooch, the fabric will be sufficient – and in this way the fabric also forms itself easier.

The fabrics used in the casting process were thin, a point established by measuring the oval brooches between the ornaments and the inner surface with an instrument constructed for this purpose by Henry Freij, at the Archaeological Research Laboratory (fig. 6). Of all the measured castings (n=37), 28% varied between 0.35–0.57 mm, 62% varied between 0.60–0.80 mm, and 10% varied between 0.88–1.07 mm. The remaining brooches were double-shelled, and could therefore not be measured.

It appeared that the fabric together with wax had more than one function: to form the thickness of the casting and to act as a membrane. The wax also prevented the fabric from getting frayed or crinkled.

The fabrics used at the production of the oval brooches at Birka and Vendel are shown in tables 1–2. The fabrics were woven in 2/2 diamond twill, 2/2 diagonal twill, 2/2 broken chevron twill and tabby. Fabrics in the binding system tabby could be established in 81 oval brooches from Birka and in the two oval brooches from Vendel. Twill could be established in 17 oval brooches from Birka.

Table 1. The 30 used fabrics in the production of the Early Birka Period types of oval brooches at Birka (28) and Vendel (2), c. AD *775–875. The type description of the oval brooches, P+number, refers to the figures in* Vikingetidens smykker *(Petersen 1928), and types not registered by Petersen are defined according to older research named after finding place, Bj=Björkö (Birka)(Jansson 1985:13).*

Binding system	Brooch type	number of brooches	T	R (based on mean value)
2/2 diamond twill	Bj 485, P27, P37	4	34–43.5	0.1–0.27 (3); 0.69 (1)
2/2 diagonal twill	P37	1	31.25	0.45 (1)
2/2 broken chevron twill	Bj 464, P37	4	31.5–55	0.27–0.35 (2); 0.41–0.48 (2)
1/1 tabby	P11, P15, P27, P37, Birka-type	19 + 2	20–37	0.02–0.3 (2); 0.1–0.38 (10); 0.45–0.64 (6); 0.72–0.9 (3)

Generally it can be said about the fabrics that were used in the oval brooches:

- that the *tabby fabrics* from Birka and Vendel, with few exceptions, were of fine (T 20–30) and very fine T-quality (T > 30) and that they were mostly balanced and weakly to medium-ribbous, R 0.0–0.6
- that the *twill fabrics,* all four-binded, in the bindings diagonal twill, broken chevron twill and diamond twill, were of very fine T-quality (T > 30) and were mostly balanced and weakly to medium-ribbous, R 0.0–0.6
- that all sorts of combinations of thread count and rib factor exist, both in *tabby* and *twill* fabrics. A certain T-quality cannot be tied together with a certain type of brooch. Nor can it be said that the fabrics are getting more and more balanced during the Viking Age.

Tabby woven fabrics dominate also in the material from Denmark and Uppland. The same twill bindings that exist in the impressions of Birka's oval brooches exist here. In the Danish material one oval brooch was found with an impression of a settled net pattern or sprang, dated to the ninth century. Unique for the Upplandic material are three impressions of fabrics in 2/1 twill, one from the tenth century and two undated. (for definitions of tabby, different twills, and spin direction, see Geijer 1979).

The comparison shows clearly that the fabrics used in the production of Birka's and Vendel's oval brooches are obviously representative of the fabrics that were used during the Viking Age. This is valid, except for the noted exceptions, both for binding system, rib factor and thread count sum.

The time in which these fabrics were used was however somewhat different:

- Impressions of *2/2 diamond twill*
  - exist during Early Viking Age in Denmark, in Birka and in the rest of Uppland
  - do not exist during Middle Viking Age
- Impressions of *2/2 diagonal twill*
  - exist during Early Viking Age in Denmark and at Birka
  - exist also during Middle Viking Age at Birka but commence to exist in Uppland outside Birka
- Impressions of *2/2 broken chevron twill*
  - exist during Early Viking Age in Denmark, in Birka and in the rest of Uppland
  - exist during Middle Viking Age in Denmark and at Birka but not otherwise from Uppland
- Impressions of *tabby*
  - dominate during Early Viking Age in Denmark
  - dominate during Middle Viking Age at Birka and in the rest of Uppland
- Impressions of *2/1 twill* exist during Middle Viking Age only in Uppland outside Birka

Early Viking Age is here defined as the ninth century in Denmark and Early Birka Period in Birka, Vendel and Uppland; Middle Viking Age is defined as the tenth century in Denmark and Late Birka Period in Birka and Uppland (Bender Jørgensen 1986; Jansson 1985).

Among the 30 pairs of brooches examined, 22 pairs, including that from Vendel, have impressions of tabby fabrics, four pairs have impressions of twill fabrics and four pairs have impressions of different bindings – tabby and twill.

The textile impressions investigated in this study are mostly faint, but exceptions occur. When studying these well-preserved brooches under a microscope it was seen that the threads were uneven and single-plyed. The twist of the yarn could not be determined.

Discussion and conclusion

The fabrics that were used in the production of oval brooches were mostly weakly or medium-ribbous, sometimes balanced, which gives a fabric with almost uniform elasticity, easy to install into the concave mould. A strongly ribbous or ribbed fabric, on the contrary, is not equally elastic in both directions and is therefore not suitable in the production.

The investigation of the textile impressions in the oval brooches showed that the fabric reached the edge but was never uneven or frayed due to the fact that the fabric was fixed by wax to the mould. The overflow of the fabric was cut away, before the under-mould was produced. This suggests that the used piece of fabric would be too

Table 2. The 70 used fabrics in the production of the Late Birka Period types of oval brooches at Birka, c. AD 875–975. The type description of the oval brooches, P+number, refers to the figures in Vikingetidens smykker *(Petersen 1928), and types not registered by Petersen are defined according to older research named after finding place, Bj=Björkö (Birka)(Jansson 1985:13).*

Binding system	Brooch type	number of brooches	T	R (based on mean value)
2/2 diagonal twill	P51	2	33.75–37.5	0.0 (1); 0.15 (1)
2/2 broken chevron twill	P42, P51	6	37.5–60	0.0–0.18 (3); 0.42–0.49 (2); 0.79 (1)
1/1 tabby	P42, P51, Bj 845, P47, P52	62	15.5–36.75	0.0–0.09 (12); 0.1–0.38 (32); 0.4–0.68 (13); 0.77–0.92 (5)

small when removed to be installed in a new mould. This fact, together with the presence of wax adhering to the material, indicates that the piece of fabric wasn't used over and over again but was consumed after the casting of a single brooch. Consequently the bronze founder had to find new pieces of fabric when a new oval brooch was to be produced.

On the textile impressions the origin of the raw material cannot be established. However it was established that the fabric was elastic, for in no brooch, neither from Birka, nor from Vendel, were any crinkles seen. The elasticity is partly seen in the oval brooches where the fabric is denser near the edge in the corners of the fabric and partly in some brooches where the fabric completely follows the heterogeneous surface, due to the piercing ornaments (fig. 7). Out of my own experiments I would stress that it is not possible to install a fabric into the mould without the help of wax if the result is supposed to be a completely plain fabric. The experiments made it also clear that it is much easier to install a fabric made of wool than of flax. The linen fabrics I used were not possible to install without crinkles. From this it seems most probable that the impressions in the oval brooches comes from fabric that was most often made of wool.

Of the real fabrics, the 2/2 diamond twill, 2/2 diagonal twill and 2/2 broken chevron twill are all made of *wool*. Fabrics in tabby could be made of both wool and flax/hemp/nettle. The "brooch fabrics", inferred from the impressions of the oval brooches, from Birka and Vendel were therefore compared with woollen fabric from graves and settlements.

The comparison of the fabrics in *2/2 diamond twill* showed that Birka's W10 and W11 (see Geijer 1938) are strongly ribbed, $R > 1.2$, and have a higher thread count sum, T, and that real fabrics from Hedeby mostly have a lower T than the "brooch fabrics" from Birka's oval brooches. The fabrics are totally different. Diamond twill that was weakly ribbous was used during the Migration/Vendel Periods, but during the Viking Age the strongly ribbed imported fabrics W10 and W11, increased.

The Birka "brooch fabrics" from oval brooches in *2/2 diagonal twill* have a higher T than the real fabrics from Birka and Hedeby. They are also *balanced* to *medium-ribbous*, while some of the Hedeby and Birka fabrics are ribbed. However, one rather close relationship was found from Birka, W36, which had z/z spun even yarn.

The Birka "brooch fabrics" from oval brooches in *2/2 broken chevron twill* are mostly *balanced* to *medium-ribbous*, while the real fabrics from Birka and Hedeby often are ribbed. Here the T value corresponds to some extent, both to the Birka and Hedeby real fabrics. One rather close relationship was found, a Hedeby fabric, 49B, which had z/s spun yarn, and was used for puttees, worn by the upper class.

The Birka and Vendel "brooch fabrics" from oval brooches in *tabby,* made of wool, correspond with most real fabrics from Hedeby, Hessens II and Birka. But also here real fabrics from Birka and Hedeby exist that are ribbed. The fabrics are mostly of fine and very fine T-quality and *balanced* to *medium-ribbous*.

In Hedeby the under-tunic was made of woollen tabby fabric, and the skirt, as in Birka (besides the exclusive ones in diamond twill) were of woollen ribbous fabric (Hägg 1984:215).

Birka's and Vendel's "brooch fabrics" from oval brooches were mostly balanced to medium-ribbous in contrast to the imported real fabrics from Birka, which were strongly ribbed and of even and high quality. Most of Birka's and all of Vendel's "brooch fabrics" from oval brooches were woven in tabby. The thread count varied.

During the Vendel and Viking Periods in the Scandinavian countries ordinary people used wollen fabrics predominantly. Fabrics of linen became more common first during the Viking Age and were then used above all within the highest social groups. Such fabrics were also used in burial costume (Hägg 1984:218).

It is therefore most likely that the raw material used in the production of oval brooches was wool, a common material when the production of the oval brooches started.

Pieces of the exclusive linen could be used as lining and as loops, which joined the edge of the woollen skirt to the needle of the oval brooch and the needle and the strap.

The analysis of the pairs of brooches, found in the same graves at Birka, suggests that the bronze founder

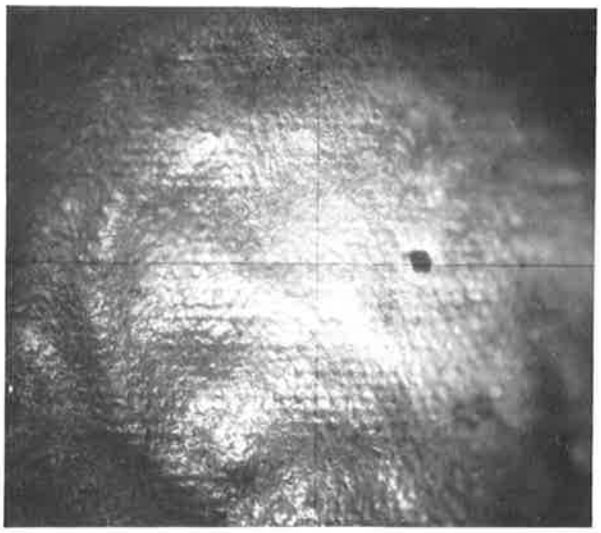


Figure 7. The plasticity of the fabric shown in the textile impression in the oval brooch Ve 134:2b. Photo Lars Sundkvist.

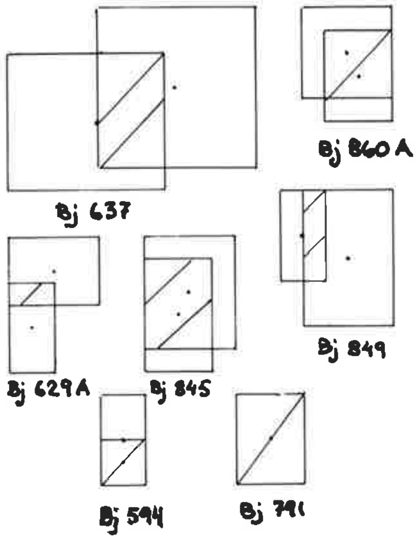


Figure 8. The seven pair of brooches with impressions of the same binding system and with overlapping thread count.

consistently placed pieces of the same fabric in the same orientation with respect to the brooch. The fabrics, tabby as well as twill, have – if possible – been placed with the greatest thread count somewhat diagonally to the length axis of the brooch. This indicates that the fabric was longer in the warp direction. Hägg suggests from the material from Hedeby, that warp and weft can seldom be determined with certainty when the selvages are missing. She infers, however, that the denser thread system with firmer spun threads usually have formed the warp and that the fabrics were so-called warp fabrics (Hägg 1984:230). This is also valid for the Danish material (Bender Jørgensen 1986:13) and the Birka material that Geijer published in 1938. Nockert states that woollen fabric in 2/2 broken lozenge twill, i.e. diamond twill, found in graves at Birka were weft fabrics (Nockert 1988:99ff).

The oval brooches were worn in pairs, and belonged to the woman's skirt. As shown in fig. 8 the thread count only overlaps to any great extent in at most four pairs of the brooches with the same binding system (Bj 791, 845, 860A, and 594). These examples have impressions of pieces that might have come from the same original fabric. But overall the evidence suggests that different fabrics have been used at the production of the oval brooches.

Usually the pairs of brooches were of the same type or variant. Three exceptions existed: Bj 585 and Bj 1012 are C1- and C2-variants of P51; Bj 605A are D- and C3-variants of P51. There is consequently a possibility that the brooches were produced on different occasions, sometimes close in time, sometimes with a longer interval. The material in the pair of brooches is sometimes also of different bronze texture, clear to the eye. This might explain why the fabric in the pairs of brooches mostly is of different kinds.

The investigation showed that the bronze founder's selection of fabric above all is based on fabrics of a certain T-quality to be suited for the production of the oval brooches. But the fabrics are not of a uniform T-quality. The selection was also due to the fabrics that were available at the time of production. The pieces that were used could have been:

- the ends of the newly produced fabrics that the bronze founder had bought or exchanged (Bender Jörgensen 1991:64);
- waste pieces that were left after cutting out pieces of the costume. In Hedeby harbour a lot of such off-cuts were found. Hägg has showed that in Hedeby professional tailors cut out and sewed garments of different fabrics designed for various functions (Hägg 1984:214);
- pieces of old worn-out garments (Geijer 1965:124). In the material from Hedeby harbour there is no evidence at all of repairs having been made to costumes, although there are examples of worn-out garment being reused as a lining fabric. A lot of pieces of only slightly worn-out garments have been found in the harbour, however being degraded to rags. Several of the fragments were so big that they would have been possible to reuse as fabric for children's clothes or as repairing pieces (Hägg 1984:218f) or in the casting of brooches.

Of the investigated oval brooches from Birka and Vendel only one brooch, Bj 513 (2) had an impression of a short thread left "sewn" through the fabric, maybe from a former garment.

Most of the "brooch fabrics" were woven in tabby, and the thread count varied. This indicates that the fabrics were not produced in a unique quality especially for the production of the oval brooches.

Fabrics of wool were woven during the Vendel and Vi-

Table 3. Comparison between the "brooch fabrics" (italics) from the impressions in the oval brooches and contemporaneous, real fabrics, in wool. The rib factor is here shown within ranges, where b=balanced, we=weakly ribbous, me=medium-ribbous, st=strongly ribbous and ri=ribbed, see Definitions. Bj=Birka, Ve=Vendel. EBP and LBP=Early/Late Birka Period. Birka, Hedeby and Hessens II refer to real fabric. W=wool; W10 etc., see Geijer 1938.

Place/Period	Sp.	T 14–19.75 b/we/me/st/ri	T 20–29.75 b/we/me/st/ri	T 30–39.75 b/we/me/st/ri	T 40–49.75 b/we/me/st/ri	T 50–59.75 b/we/me/st/ri	T 60–69.75 b/we/me/st/ri	Tot
2/2 diamond twill								
Bj+Ve/EBP	–		---1---1-------					2
Bj/EBP	–		---1-----------	---1-----------				2
Birka (W10)	z/z				-------------×	-------------×	-------------×	–
Birka (W11)	z/z					-------------×		–
Hedeby	z/s		---3---1-------	-------------1				5
2/2 diagonal twill								
Bj/EBP	–			-------1-------				1
Bj/LBP	–			1--1----------				2
Birka (W36, 39)	z/z		-------×-------					–
Hedeby	z/s	--------1--2----	---------------6					9
Birka (W34, 35, 38)	z/s	-------×-------	-------×-----×					–
2/2 broken chevron twill								
Bj/EBP	–			-------1-------	---2---1-------			4
Bj/LBP	–			1----------1--	---1---1-------	-------1-------	---1----------	6
Birka (W12, 13)	z/z				-------------×	-------------×		–
Hedeby	z/s	-------1------1	---------------1	-----------1--1				5
1/1 tabby								
Bj+Ve/EBP	–		1---9---------	1--1---6--3---				21
Bj/LBP	–	--1----1--2----	8--22--7------	4--9---5--3---				62
Hedeby	z/z		-------2------1	---------------1	--------3--------			7
Hessens II	z/z		2-------------					2
Birka (W22–24, 26, 28–30, 33)	z/z		---×--------×	------×-----×				–
Hedeby	z/s	-----------1----	---2---1---1---					5
Hessens II	z/s	1--2-----------	1------1---1---	---2-----------				8
Birka (W25, 27)	z/s		-------×--×---					–

king Periods preferably at the warp-weighted loom. Here it is required that the warp is dense and that the warp yarns are either made of long fibres or plyed. It was essential that the single-plyed yarns were spun to be strong enough to hold the loom-weights. Z-spun yarns are often spun of long-fibered wool at an under-weighted spindle to produce "worsted" yarn. The soft yarn, used for weft, was spun of wool that was short-fibered, often on an over-weighted spindle, producing "card" yarn (Grenander Nyberg 1984:287f; 1994:58).

The horizontal loom was introduced at the end of the Viking Age and this can be related to the introduction of three-end twill, which became common during the Middle Ages (Hoffmann 1974:172, 263; Grenander Nyberg 1994:59). In the material from Uppland three oval brooches had impressions of three-end twill. There is consequently a possibility that some of the fabrics were produced on a horizontal loom or were imported.

The evidence gathered (table 3) about the real fabrics from Birka, Hedeby harbour and Hessens II suggests that the woollen warp yarns were always z-spun. The finest fabrics have z-spun weft, and the everyday fabric have s-spun weft.

The synthesis also shows that the fabrics during the Early and Middle Viking Age varied a lot with reference to thread count and rib factor. The T-quality of Birka's and Vendel's "brooch fabrics" from the oval brooches are, with few exceptions, fine (T=20–29.75) or very fine (T>30). This indicates that these fabrics were woven for garments or came from used garments. The fabrics that were used in the grave equipment at Birka and some garments at Hedeby were of coarse and less fine T-quality (T < 20).

The very fine T-quality of the textiles used in the moulds for oval brooches is impressive. The woollen warp fabrics used in the production of the oval brooches in Birka and Vendel could not have been made in a unique T-quality especially for this purpose. The very fine T-quality indicates that these fabrics belonged to the upper-class dress and the used pieces came from fabrics intended for garments or used garments. The fabrics used in the production of the oval brooches are most certainly left-over pieces from a special production. The used fabrics were mostly thin, of fine or very fine T-quality. The fabrics were mostly woven in tabby, but also in four-ended twill: diamond twill, diagonal twill and broken chevron twill. These fabrics were all balanced or weakly to medium-ribbous, which gives a fabric with almost uniform elasticity, easy to install into the concave mould. The woollen warp yarns were always z-spun, the finest fabrics had also z-spun weft yarn, the everyday fabrics s-spun yarn. The fabrics were woven preferably at the warp-weighted loom.

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Definitions

Rib factor

Balanced – woven fabric that has equal thread count in both warp and weft, R = 0.0–0.09

Ribbous – woven fabric where the thread count in the warp more or less dominates the weft (or vice versa), subdivided into

- *weakly ribbous*, R = 0.1–0.39
- *medium-ribbous*, R = 0.4–0.69
- *stongly ribbous*, R = 0.7–0.99

Ribbed – woven fabric where the thread count in one thread system is at least twice the other, R ≥ 1

The thread count in tabby weaves can be summarized balanced > ribbous < ribbed

T-quality ranges for Viking Age fabrics

Very fine	T > 30 thr/cm
Fine	T = 20–29.75 thr/cm
Less fine	T = 14–19.75 thr/cm
Coarse	T < 13.75 thr/cm

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