Tools and Textiles - Texts and Contexts

Examination of spinning and weaving samples

Susan Möller-Wiering

19.12.2006

1 Introduction and method
2 Diameter of spinning samples
3 Spinning angle of spinning samples
4 Fuzziness of spinning samples
5 Weaving sample
6 Evaluation of the results with reference to the spinners/weavers and tools
7 Further measurements
8 Evaluation of the final results
9 Summary
10 Bibliography

1 Introduction and method

The experimental archaeological project "Tools and Textiles - Texts and Contexts" included analyses of 12 spinning samples and one piece of woven fabric, all made of wool. As with all of the experiments in this project, the samples were produced by two different people. In the first stage of this investigation, no information was given concerning the spinners – *i.e.*, which sample was done by whom - or about the tools with which the experiments had been carried out.

The first aim was to describe the products and in particular possible differences between the samples and within the fabric. Afterwards the results were to be related to the information about spinners, spinning tools and loom.

For documentation, the samples were scanned, which turned out to be a quick way to produce pictures of good quality (see Cooke and Jones 2002). After several trials with different configurations, scanning with 1000 dpi was chosen (fig. 1).

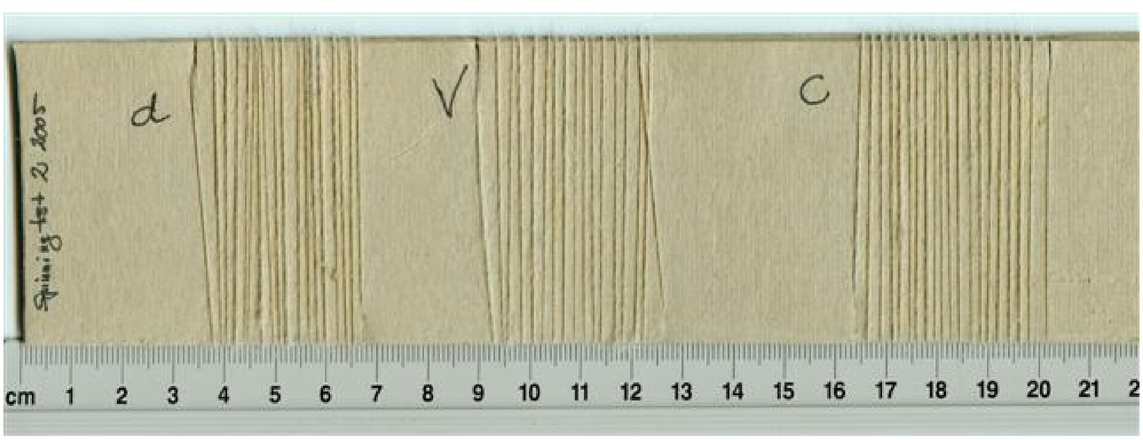


Figure 1: Cardboard with three spinning samples

The criteria that were examined concerning the spinning samples comprised:
1. thread diameter
2. spinning angle
3. fuzziness

Before starting the measurements, general impressions were gathered for all three criteria. For this, the samples were investigated only with the naked eye and with 10x magnification. To examine the diameter and the spinning angle, another three criteria had to be established and followed:
a. a procedure for choosing where to make the measurements
b. enough points to get a suitable sets of data
c. as few points as possible

In the first instance, a set of 30 measurements per spinning sample (= 360 measurements in all) was aspired (fig. 2). Ten measurements should be taken along a line in the middle of each sample, *i.e.*, halfway between both edges and crossing 10 threads (marked in orange). Another 10 measurements should be carried out *c.* 2 cm above and below that medium line (marked green/grey). Thus, unrepresentative data due to untwisting thread ends as well as to possible alterations near the folds should be avoided. However, the measurements taken in the beginning were limited to the middle line, *i.e.*, 120 measurements of diameter and spinning angle respectively on the spinning samples. Since the cardboards are 5.6 - 6.0 cm wide and *c.* 2 mm thick, the distance between every two measured spots of each sample is about 12 cm. The investigation of the weaving sample was based on the same procedures. Further details will be given below.

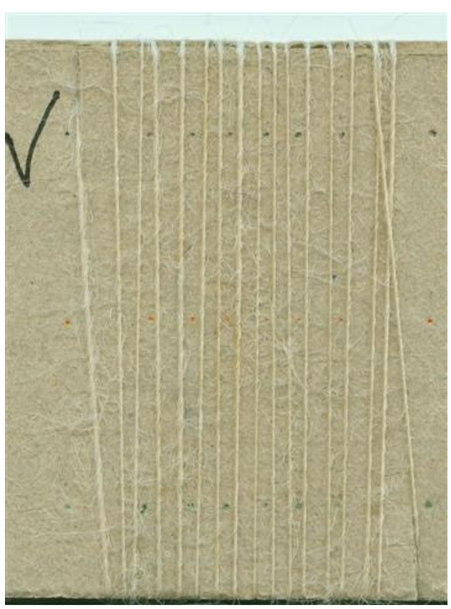


Figure 2: Spinning sample “v” with marked lines for measuring yarn diameter and spinning angle

2 Diameter of spinning samples

Having the structure of many archaeological textiles in mind, the general impression of the diameters is that of fine and mostly evenly spun wool threads with some sections of clearly lesser quality (fig. 2). Such sections appear in all samples. The examination was carried out on the original samples using a magnification of 40x. The results for each sample are compiled in table 1; the table also includes the mean, the median and the range. The upper and lower halves of the table encompass a first and a second set of samples respectively. Within the sets, the samples are sorted according to their numbers and/or letters. Figure 3 presents the diameters in a graph.

sample	**diameter in mm**										**mean**	**median**	**range**
4a	0,45	0,45	0,4	0,3	0,4	0,55	0,3	0,25	0,35	0,35	0,38	0,35 / 0,4	0,3
4b	0,25	0,3	0,3	0,35	0,4	0,3	0,25	0,2	0,4	0,25	0,3	0,3 / 0,3	0,2
8a	0,35	0,35	0,3	0,4	0,3	0,25	0,25	0,25	0,55	0,35	0,335	0,3 / 0,35	0,3
8b	0,6	0,45	0,4	0,65	0,45	0,35	0,4	0,35	0,45	0,4	0,45	0,4 / 0,45	0,3
13a	0,4	0,3	0,5	0,45	0,4	0,45	0,45	0,4	0,35	0,4	0,41	0,4 / 0,4	0,2
13b	0,3	0,3	0,4	0,3	0,3	0,35	0,3	0,2	0,3	0,25	0,3	0,3 / 0,3	0,2
a	0,5	0,4	0,55	0,45	0,5	0,6	0,5	0,5	0,5	0,55	0,505	0,5 / 0,5	0,2
b	0,65	0,45	0,5	0,45	0,45	0,5	0,6	0,35	0,4	0,3	0,465	0,45 / 0,45	0,35
c	0,35	0,45	0,6	0,3	0,3	0,35	0,4	0,25	0,45	0,35	0,38	0,35 / 0,35	0,35
d	0,25	0,3	0,5	0,25	0,4	0,45	0,4	0,35	0,45	0,5	0,385	0,4 / 0,4	0,25
v	0,4	0,55	0,4	0,4	0,5	0,3	0,3	0,35	0,35	0,3	0,385	0,35 / 0,4	0,25
x	0,5	0,75	0,45	0,4	0,45	0,5	0,35	0,4	0,55	0,4	0,475	0,45 / 0,45	0,4

Table 1: Diameters of single threads, their mean, median and ranges (orange line); light yellow = lowest/best value, deep yellow = highest/worst value

24					x							
23												
22												
21			b		b							
20			13b		a							
19					13b							
18				x	8a	x						
17				b	4b							
16				13b		b						
15				8a	v							
14			8a									
13						a	x					
12			4b	4b	d	d						
11		13b		v			b					
10		8a			c	c						
9			v	d	13a		a					
8				c		13a						
7		4b										
6			d					x				
5			c	13a	8b	8b		a				
4		d		8b			v		b			
3			13a				d	8a	a			
2	13b	c	4a	4a	4a	4a		v	c	b		
1	4b	4a					13a	4a	8b	8b		x
▲ number ► diam. in mm	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75

Figure 3: Diameters of single threads (orange line)

Looking at the raw data of 120 measurements, the diameters vary between 0.2 and 0.75 mm, while the mean diameters of the 12 samples differ between 0.3 and 0.505 mm. The diameter depends on several factors such as the tools used (spindle whorls), the fibres (length, smoothness, curliness), the skill of the spinner and perhaps other factors as well. Since information about these variables was not provided at the first stage of the experiment, the interpretation of these figures is very limited at this point. If the diameter is taken as a criterion for quality - meaning the finer the better - the samples “4b” and “13b” are on top of the list, both with mean diameters of 0.3 mm.

Besides the mean diameter, the median was calculated[1]. Using a median reduces the statistical influence of extreme values on one side of a scale, such as an exceptional spinning fault that makes the thread very thick in one particular spot. Since in this case 10 measurements per sample were taken, two values were registered as medians. Ideally, when the distribution of figures is even, the mean diameter will be the same as the two median values or lie somewhere between these two figures. This is the case for example in samples “4a” and “4b”. Mean values clearly lower or higher than the median would indicate one or more extremely different values. With due cautiousness because of the rather small number of measurements, such samples might be described as less even and therefore of lower quality. Samples “c” and “x” reveal such a tendency.

The quality in terms of evenness is best indicated by the “range”, which is the difference between the highest and the lowest value per sample; the smaller the range, the greater the evenness. The most evenly spun threads are found in the samples “4b”, “13a”, “13b” and “a”, which all have a range of only 0.2 mm. However, “13a” and “a” are relatively thick, having mean diameters of 0.41 mm and 0.505 mm respectively. Including a small diameter as a criterion for quality, these two samples must be disregarded, while “4b” and “13b” remain the best. The greatest range (0.35 - 0.4 mm) is seen in the samples “b”, “c” and especially “x”, which might be considered the worst in quality as far as this parameter is concerned. This corresponds to the evaluation of the median. But the lower the range is, the less relevant is the median. Therefore, the samples “a”, “d” and “13a” in which the median is not ideal, cannot be considered as low quality products since the range is low (0.2 - 0.25 mm).

An important question is whether it might be possible to identify any groups of samples clearly distinguishable from the rest and possibly related to individual spinners or certain tools. Yet, the distribution of all measurements, presented in figure 3, turns out to be quite even, allowing no grouping. The slight depression at 0.35 mm seems to be insignificant, possibly due to some rounding. Only one indication was found: when a ranking for the mean diameter as well as for the range is added to the data of table 1, there is a tendency for the better ranks to be found in the upper half (tab. 2).

sample	mean / rank		range / rank	
4a	0,38	4	0,3	7
4b	0,3	1	0,2	1
8a	0,335	3	0,3	7
8b	0,45	9	0,3	7
13a	0,41	8	0,2	1
13b	0,3	1	0,2	1
a	0,505	12	0,2	1

[1] In a row of, for example, 5 measurements, the 3rd value represents the median, no matter how low or high the other figures are, as long as there are 2 figures lower or equal and another 2 higher or equal compared to this median (e.g., five measurements of a Mouflon coat: 10-12-15-20-80 µm: the median is “15” which appears to represent the quality of that coat better than the mean of “27.4”).

b	0,465	10	0,35	10
c	0,38	4	0,35	10
d	0,385	6	0,25	5
v	0,385	6	0,25	5
x	0,475	11	0,4	12

Table 2: Ranked mean diameters of single threads and their ranges (orange line); light yellow = lowest/best value, deep yellow = highest/worst value

3 Spinning angle of spinning samples

In general, before measurements were taken, the spinning angles of the samples were considered medium. In one case, “8b”, the angle tends towards low or soft, in two others, “a” and “b”, towards high or hard. Regarding the angle, the spinning might be described as even.

For measuring the spinning angle, close-ups of the scans were used. On these, the angles were marked on the screen (fig. 4). The close-ups with the marked angles were then printed and the angles measured on the paper. These data are presented in table 3, while figure 5 presents their distribution. The measured spinning angles give a much more detailed overview than does the plain description. It should be kept in mind, however, that the angle may change within very few mm if not from fibre to fibre. Therefore, the decision concerning where to fix the mark for measuring the angle is always - to some extent - subject to interpretation and therefore the results are not as exact as they pretend to be.

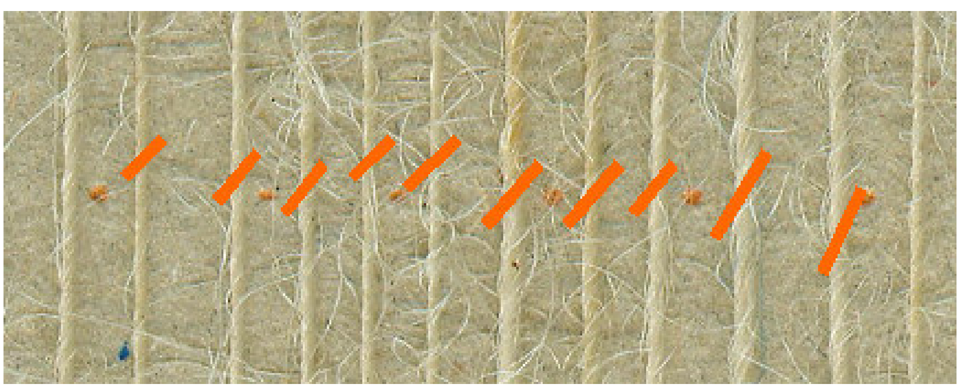


Figure 4: Example for angle measurements, sample “v”, orange line

The possibilities and limitations for interpretation are comparable to what has been discussed before. The mean angle does not bear much information in itself since it was unknown whether, *e. g.*, the aim of the spinning test might have been the production of a very hard spun thread. These data will become more valuable when related to other variables later on.

sample	angles in °										mean	median	range
4a	36	30	31	35	31	26	27	31	32	27	30,6	31 / 31	10
4b	44	26	33	25	36	30	44	45	45	39	36,7	36 / 39	20
8a	38	30	39	32	38	37	37	45	34	26	35,6	37 / 37	19
8b	31	28	28	23	28	37	31	31	22	25	28,4	28 / 28	15

13a	38	46	38	28	32	32	30	31	33	33	34,1	32 / 33	18
13b	34	45	31	37	31	44	45	45	45	39	39,5	39 / 44	14
a	38	46	45	46	31	40	37	32	47	37	41,9	38 / 40	16
b	41	49	48	47	39	39	48	41	40	36	42,8	41 / 41	13
c	36	30	23	36	46	46	34	44	36	35	36,6	36 / 36	23
d	30	45	34	38	40	37	45	38	31	31	36,9	37 / 38	15
v	23	29	35	38	37	44	45	38	37	44	37,0	37 / 38	22
x	32	30	30	27	38	41	47	39	39	45	36,8	38 / 39	20

Table 3: Spinning angles of single threads, their mean, median and ranges (orange line);
light yellow = lowest value/softest spin, deep yellow = highest value/hardest spin

Again it is especially the range which may tell something about the quality, in this case reflected in the evenness of the spinning angle. The lowest range was found in sample "4a", followed by "b"[2]. The highest range is given in sample "c". Sample "x" has a wide range as well as a relatively big difference between mean angle and median. Therefore this sample might be interpreted as the one of lowest quality. Sample "4a" might be considered the best.

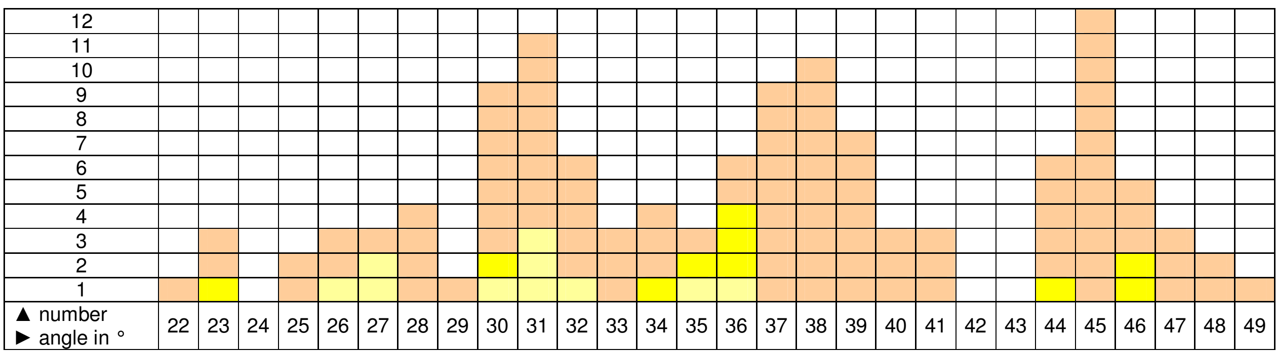


Figure 5: Spinning angles of single threads (orange line)
light yellow = sample "4a" with lowest/best range, deep yellow =: sample "c" with highest/worst range

And again the question arises as to whether the samples can be grouped in any way. Figure 5 shows three peaks. This might be due to the spinning process as such. But these peaks give no information about possible spinners or tools because the range of figures is big and each sample contributes to more than one peak. To demonstrate this, the figures for the most and least even samples are marked in colour. Only when a ranking of the ranges is added to the data of table 3, the better ranks tend to appear in the table's upper part (tab. 4).

sample	range / rank	
4a	10	1
4b	20	9
8a	19	8
8b	15	4
13a	18	7
13b	14	3

[2] In sample "b", the median differs quite a lot from the mean angle, but as the range is low, this figure is irrelevant.

a	16	6
b	13	2
c	23	12
d	15	4
v	22	11
x	20	9

Table 4: Ranked spinning angles of single threads and their ranges (orange line); light yellow = lowest/best value, deep yellow = highest/worst value

According to Cooke and Christiansen, the angle or "twist distribution is highly geared to yarn diameter" (2005: 72). Also apparent from experience, it often seems that the thinner threads within a fabric are spun harder than are the thicker ones. The data presented before offer the opportunity to test this. For this purpose tables 1 and 3 were combined and presented figure 6. If the correlation was really strong, the figures should be clustered around a line running from top left to bottom right. There is a trend toward this, but many thin, but loose threads as well as thick, hard spun yarns spoil the ideal picture.

► diam. in mm ▼ angle in °	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75
49						x						
48							x		x			
47				x		x	x					
46			ox	x	x	x						
45	oo	o	oooxx		oxx			x				
44		oox	xx	o								
43												
42												
41				x			x			x		
40					xx				x			
39		oo	o		x	x	x	x				
38		x	o	oxx	ox	x	ox					
37		oo	o	ox		x	xx	x				
36			xx	x	o	ox						
35			o	x	x							
34			o		x		x	o				
33			o	o	o							
32				o	oo	o	xx					
31		ox	o	o	ooooo	x	xx		o			
30			oo			ooxx						x
29								x				
28					o	ooo						
27			o	o	x							
26			o	o				o				
25				o	o							
24												
23					x				x	o		
22						o						
	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75

Figure 6: Relation between diameter and angle (orange line)
o: 4a **o**: 4b **o**: 8a **o**: 8b **o**: 13a **o**: 13b
x: a **x**: b **x**: c **x**: d **x**: v **x**: x

4 Fuzziness of spinning samples

The examination of the fuzziness is restricted to general impressions because there is no method for quantifying it. All the threads are considerably fuzzy, *i.e.*, many fibres stick out of the threads (fig. 4). This is due to the structure of the fibres (their curliness) and the extent to which they were - or could be - paralleled. As might be expected, the fuzziness is generally higher in thicker and more loosely spun sections than it is in finer, harder spun threads.

5 Weaving sample

The weaving sample is 18 cm long and 27 cm wide. Two areas are outlined in green and red respectively (fig. 7). Some information was given:
- After about 3 cm of weaving, the piece has been glued with wax/flour and water (1-1-2).
- The finished piece was washed twice (58°, 45°). Because the washing caused some crimping, the fabric was needled up and spread flat again.
- In the red and green marked rectangle, respectively, one weaver produced warp and weft and did the weaving as well.
- The bottommost part below the brown thread was woven after changing the loom weights.

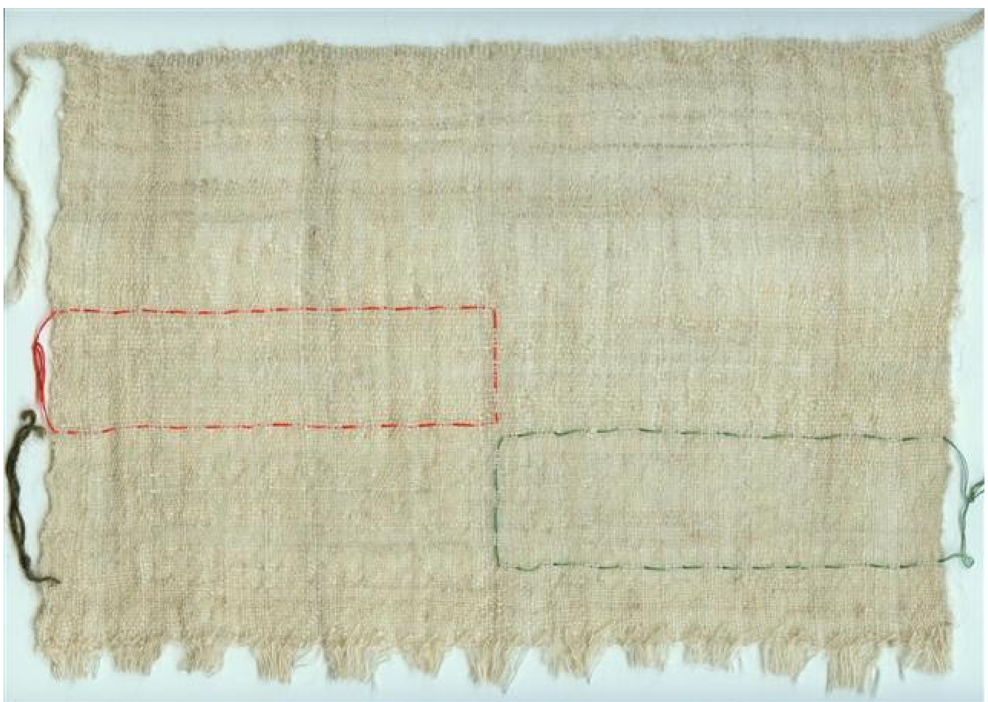


Figure 7: Weaving sample

The general impression is that of a light, open weave. The density of the fabric may be expressed by the 'cover factor' (Hammarlund 2004: 8-9). It is calculated according to the formula: WA + WE - (WA x WE).
WA is the thread count in cm x yarn diameter in cm for the warp, WE is the equivalent for the weft. Theoretically, the maximum cover factor is =1[3]. According to Ham-

[3] In practice, the cover factor can also be >1: "This can occur because the formula is based on the assumption that yarns are compact cylinders in the shape of a circle, but in reality, a yarn may be more or less elliptical." (*ibid.*: 9)

marlund, a factor between 0.75 and 0.94 might be regarded as medium dense while a figure below that represents an open weave. For the present fabric, the figures are 0.62 and 0.64 for the red and the green rectangles respectively. Furthermore, Hammarlund calculates the thickness of a woven woollen textile (*ibid.*: 10) by counting together the mean diameters of warp and weft yarns (in mm). She then establishes seven thickness groups ranging from very thin (less than or equal to 0.6) to very coarse (greater than or equal to 2.4). With figures of 0.84 and 0.825 for the red and green rectangles respectively, the weave discussed here falls into the "thin" category (0.6 - 0.9). Both calculations - for the density as well as for the thickness - confirm the impression described above.

Furthermore, based on an examination of woollen tabbies from Mons Claudianus in Egypt, Hammarlund (2005) has proposed a pentagon - *i.e.* five features - to describe a fabric. Besides the regularly given characteristics of binding, yarn and thread count, she includes "weaving" (*i.e.*, loom type, tools for weaving, weaver's work) and "finishing". Using these five criteria, Hammarlund is able to explain the differences between the seven groups of tabbies into which she had grouped the material in the beginning, based on visually distinguishable qualities. Being a woollen tabby, the present weaving sample can be compared to Hammarlund's results and thus be related to the group called "movable tabby", which

> "has a curving or undulating movement in the yarn in one or both thread systems [...]. Twist in the yarn, combined with sufficient spacing between threads, allows for movement" (*ibid.* 108)[4].

According to Anne Batzer, the curliness of the warp in the present sample is mainly due to too little weight per thread in the warp weighted loom[5]. The curliness seems to lessen towards the bottom of the sample, but this is not proven yet. The warp is less evenly spaced than the weft. There are weaving faults such as doubled or floating warp ends (fig. 8).

Figure 8: Weaving faults: doubled (left) and floating warp ends (right)

[4] Confirmation of this grouping by Lena Hammarlund, 06/2006.
[5] Personal communication, 03/2006.

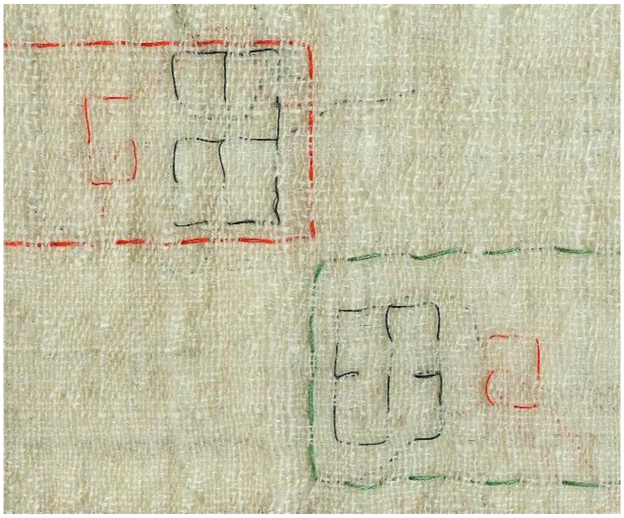


Figure 9: Marked off squares of 10 x 10 threads

To compare the work of the two weavers, the threads were investigated as before and additionally the thread count was stated. For this purpose, five areas of 10 x 10 threads were outlined in both rectangles (fig. 9). Four of these areas in the red as well as in the green areas build up a rectangle of their own. They are marked in black and used to measure the thread count. The fifth area of each is separate, marked in red and used for examining the threads. The areas are arranged symmetrically in the red and the green rectangle. The criteria for interpreting the figures are already discussed above. The measurements were taken from left to right and from top to bottom respectively; the diameters are given in table 5 and figure 10, and the spinning angles in table 6. As a plan for the future, it might be useful to mark off further areas closer to the edges of the weave and take measurements there as well.

sample	diameter in mm										mean	median	range
red warp	0,4	0,6	0,2	0,5	0,55	0,5	0,45	0,4	0,3	0,3	0,42	0,4 / 0,45	0,4
green warp	0,2	0,5	0,35	0,4	0,9	0,3	0,4	0,4	0,3	0,5	0,425	0,4 / 0,4	0,7
red weft	0,45	0,6	0,45	0,3	0,4	0,4	0,35	0,25	0,3	0,7	0,42	0,4 / 0,4	0,45
green weft	0,3	0,35	0,4	0,35	0,45	0,35	0,5	0,6	0,3	0,3	0,39	0,35 / 0,35	0,3

Table 5: Diameters of the threads in the weave, their mean, median and ranges; light yellow = lowest/best value, deep yellow = highest/worst value

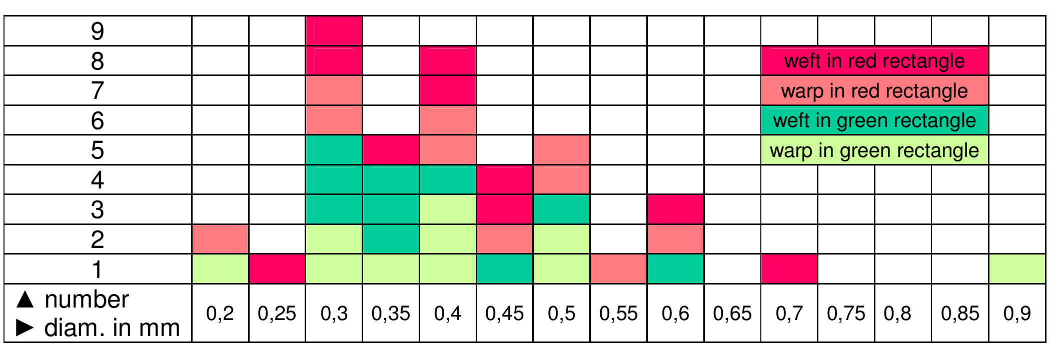


Figure 10: Diameters of the threads in the weave

sample	angles in °										mean	median	range
red warp	48	40	52	42	34	44	38	41	45	33	41,7	41 / 42	19
green warp	52	35	39	37	40	27	38	32	45	31	37,6	37 / 38	25
red weft	32	38	45	37	22	31	40	38	30	34	34,7	34 / 37	23
green weft	33	38	31	37	35	45	35	30	32	33	34,9	33 / 35	15

Table 6: Spinning angles of the threads in the weave, their mean, median and ranges;
light yellow = lowest value/softest spin, deep yellow = highest value/hardest spin

The finest and most even set of threads is the weft in the green rectangle. The thickest and most uneven set is the warp in the same rectangle. So the best as well as the worst threads come from the same spinner/weaver. The spinning angles are even less precisely to measure here than in the spinning samples because the threads are less straight in the fabric. The lowest and the highest ranges as the best information about the evenness of the spinning angle are again to be found in the weft and warp of the green rectangle. So these results correspond with the evaluation of the diameter.

When compared to the threads of the spinning tests, the mean diameters of the threads in the woven fabric lie within about the same spectrum. However, while the lowest absolute figures (0.2 mm) are identical, the thickest thread of all (0.9 mm) was found in the weave in the "green warp". And in three out of four cases ("red" warp and weft, "green" warp), the range of diameters in the fabric is higher than in all spinning samples. This indicates a lower quality in the woven piece. Similarly, the range of spinning angles is higher in the tissue than in the single threads. At least three explanations seem possible:
- other threads were used for the weaving than in the spinning test sets
- the threads lost quality during weaving and/or washing afterwards
- the threads of the spinning samples were stretched significantly while being wound around the cardboards, thus giving incorrect figures; in this case the mean of the mean diameters as well as of the mean spinning angles should be lower in the single threads than in the woven fabric, which is indeed the case: the values are 0.399 mm compared to 0.414 mm and 36.4° compared to 37.2°.

The thread count of a weave is usually examined by counting the number of threads per cm. Here, it is measured - as a first step - in terms of how wide a row of ten threads is. Differences in the shape of the small rectangles of 10 x 10 threads can be seen with the naked eye (fig. 9). The corresponding figures are given in table 7. The data are then transformed to the usual version of threads per cm (see tab. 8).

		top left square	top right square	bottom left square	bottom right square
warp	red rectangular	0,89	0,95	0,85	0,90
	green rectangular	0,92	0,83	0,97	0,94
weft	red rectangular	1,55	1,55	1,46	1,45
	green rectangular	1,20	1,25	1,20	1,15

Table 7: Width of rows of 10 threads (in cm) in marked off squares;
light yellow = lowest value/highest thread count, deep yellow = highest value/lowest thread count

		top left square	top right square	bottom left square	bottom right square	mean	range
warp	red rectangular	11,2	10,5	11,8	11,1	11,15	1,3
	green rectangular	10,9	12,0	10,3	10,6	10,95	1,7
weft	red rectangular	6,5	6,5	6,8	6,9	6,675	0,4
	green rectangular	8,3	8,0	8,3	8,7	8,325	0,7

Table 8: Threads per cm in marked off squares;
light yellow = highest value/highest thread count, deep yellow = lowest value/lowest thread count

The mean thread counts for the warp is 11.15 and 10.95 respectively, *i.e.*, almost exactly 11 threads per cm overall. For the weft, the figures are 6.675 in the red and 8.325 in the green rectangle or 7.5 threads per cm on average. This shows clearly that generally the warp is closer than the weft, which can already be seen with the naked eye since the marked off areas of 10 x 10 threads are not square but are rectangular.

Comparing the measurements of the work of the two weavers, it can be stated that the variation within the red rectangle is smaller than it is within the green one. This is expressed in the figures for the range. Another point is that the mean values for the thread count in the warp are very similar (11.15 and 10.95 respectively), while those for the weft (6.675 and 8.325 respectively) differ considerably. While the smaller variation in the warp is predicted by the arrangement of the loom, the bigger differences in the weft depend on the weavers. This result is true despite the fact that the measurements presented so far may not be representative.

Furthermore, it can be perceived with the naked eye that the warp threads are spaced unevenly. Even only within the two small areas marked off in red, three warp threads may take as little as 1.5 mm or as much as 3.8 mm (both in the green rectangle), which is a difference of 2.3 mm. The figures for three weft threads vary between 3.8 - 5.1 mm in the red and 2.9 - 4.4 mm in the green rectangle, which are differences of 1.3 mm and 1.5 mm respectively. In other words, the weft is clearly more evenly spaced than is the warp and this is true for both weavers despite their somewhat different weave.

6 Evaluation of the results with reference to the spinners/weavers and tools

After the investigation had been completed to this point, some information about the spinners/weavers and the tools were given to evaluate the results from additional perspectives.

All the spinning samples of the first set were done with whorls of 8 g while those of the second set were produced with whorls weighing 18 g. Thus, tables 1 - 4 give the 8 g figures on top and the 18 g figures below. It was noted earlier that the ranking of the mean values and ranges of diameters revealed a tendency for thinner threads to be placed in the upper part of the list, thus corresponding with the light whorls. A relation between weight of whorl and thickness of thread might be expected and has been demonstrated in earlier experiments (Andersson and Nosch 2003: 198). However, the distribution of all measurements, as shown in figure 3, did not allow any grouping. Only when the information about the whorls is included and the earlier figure divided (fig. 11), a difference between both tools becomes visible. It becomes also apparent when the overall mean diameters for both whorls are compared: 0.363 mm for the lighter and 0.434 mm for the heavier ones. But still, the difference is not more than 0.071 mm. The slight depression at 0.35 mm, which was mentioned before, is only visible in the 8 g group.

12							x					
11					x					18 g		
10						x	v					
9							d					
8				x	v	d						
7			v	v			b					
6						c						
5				d	d		a					
4			d	c		b		x				
3		d	c		c			v	c			
2					b			a	b			
1		c	b	b	a	a			a	b		x
14			13b									
13					13b					8 g		
12					13a							
11												
10				13b								
9				13a								
8		13b	13a	8b	8b	13a						
7		8a	8a									
6				8a								
5			4b		8a	8b						
4		4b			4b							
3				4b								
2	13b		4a	4a	4a	4a		8a				
1	4b	4a					13a	4a	8b	8b		
▲ number ► diam. in mm	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75

Figure 11: Thread diameters according to weight of whorls (orange line)

At this point, it is also clear that in figure 6 all samples represented by “o” belong to the 8 g group, while those marked by an “x” encompass the 18 g group. Thus, figure 6 shows that the yarns worked with 8 g tend to be softer spun than are those produced with 18 g. While the range of angles in the 8 g group (22° - 45°) is almost identical with the one in the other (23° - 49°), most of the hardest spun yarns derive from the heavier whorls.

The next question is whether the experience gained within the experiment had any influence on the results, *i.e.*, whether the spinners got used to the specific tools and produced better threads in the end than they did in the beginning. The samples were spun in this succession: “4a”/”4b”, “8a”/”8b”, “13a”/”13b” and “b”/”d”, “v”/”x”, “a”/”c”. It is then clear that no development towards better quality is discernable. The samples “4a” and “4b” were mentioned several times before for their good quality in different aspects, while “x” and “c” are situated on the low end of different scales.

Additional information provided about the tools was that one of the light spindle whorls was slightly unbalanced. Both spinners stated that this whorl did work, but that it took more time to spin with it and that it was very uncomfortable to handle. The samples “4a”, “8a” and “13a” were produced with this tool. When the figures for these samples are compared to those of the other 8 g whorl, from which samples “4b”, “8b” and “13b” derive (tab. 1), the threads spun with the better whorl are slightly thinner (0.35 mm compared to 0.375 mm), in two cases with a range of only 0.2 mm. On the other hand, not only the lowest mean diameters of 0.3 mm belong to this well made tool, but the highest within this group as well: 0.45 mm. Thus, the difference in the mean diameters may be regarded as insignificant. In other words, though it was harder to work with the slightly unbalanced whorl, the quality of the threads is as good as if they were done with a perfect whorl.

The data were then related to the spinners: spinner 1, Anne Batzer, made the samples “4a”, “8b”, “13a”, “c”, “d” and “v”. Spinner 2, Linda Mårtensson, created the samples “4b”, “8a”, “13b”, “a”, “b” and “x”. When this information is related to table 1, it turns out that spinner 2 has spun the best threads with the lowest mean diameter combined with the lowest range in diameter (samples “4b” and “13b”). But she also produced the thickest thread (sample “a”) and the one with the highest range in diameter (sample “x”). Expressed the other way round, the spinning results of spinner 1 are a little closer to each other, her work is slightly more even all in all, as can also be seen in figure 12, where all 120 measurements of diameter are related to the individual spinners. And it is most obvious in figure 13, where the measurements are plotted according to weight of whorls plus spinner. Spinner 2 spun clearly different threads depending on the whorl, with mean diameters of 0.31 mm and 0.48 mm respectively. The depression at 0.35 mm is solely due to her work, where it indeed provides the clue for differentiating the figures for both categories of spindle whorls. But unexpectedly, the figures for spinner 1 are not only quite similar for both weights of whorls, but the mean yarn diameter for the 8 g whorl is even slightly bigger than that for the 18 g whorl, the figures being 0.41 mm and 0.38 mm respectively.

24					x							
23										spinner 2		
22										spinner 1		
21			b		b							
20			13b		a							
19					13b							
18				x	8a	x						
17				b	4b							
16				13b		b						
15				8a	v							
14			8a									
13						a	x					
12			4b	4b	d	d						
11		13b		v			b					
10		8a			c	c						
9			v	d	13a		a					
8				c		13a						
7		4b										
6			d					x				
5			c	13a	8b	8b		a				
4		d		8b			v		b			
3			13a				d	8a	a			
2	13b	c	4a	4a	4a	4a		v	c	b		
1	4b	4a					13a	4a	8b	8b		x
▲ number ► diam. in mm	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75

Figure 12: Thread diameter according to spinners (orange line)

12							x					
11					x				18 g, spinner 2			
10						x	b		18 g, spinner 1			
9												
8				x	b	b	a					
7			b	b	a							
6			v	v	v							
5						a						
4				d		d		x				
3		d	d	c	d		v	a	b			
2			c			c	d		a			
1		c			c			v	c	b		x
14			13b									
13					13b				8 g, spnner 2			
12					8a				8 g, spinner 1			
11					4b							
10				13b								
9				8a	13a							
8		13b	8a			13a						
7		8a										
6			4b	4b								
5				13a	8b	8b						
4		4b		8b								
3			13a									
2	13b		4a	4a	4a	4a		8a				
1	4b	4a					13a	4a	8b	8b		
▲ number ▶ diam. in mm	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75

Figure 13: Thread diameters according to weight of whorls and spinners (orange line)

Next, the data of figure 6 were related to spinners as well as weight of whorls (fig. 14). Here it can be determined that the spinning angles in the threads of spinner 2 (marked in red) are somewhat larger, *i.e.*, the yarns are spun a little harder on average. She produced 23 relatively hard spun threads of over 40°, but only 4 soft ones of less than 30°. Her colleague produced 9 hard and 13 soft spun threads. However, the differences are small and not discernable without the background information.

▶ diam. in mm ▼ angle in °	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75
49						x						
48							x		x			
47				x		x	x					
46			ox	x	x	x						
45	oo	o	oooxx		oxx			x				
44		oox	xx	o								
43												
42												
41				x			x			x		
40					xx				x			
39		oo	o		x	x	x	x				
38		x	o	oxx	ox	x	ox					
37		oo	o	ox		x	xx	x				
36			xx	x	o	ox						
35			o	x	x							
34			o		x		x	o				
33			o	o	o							
32				o	oo	o	xx					
31		ox	o	o	ooooo	x	xx		o			
30			oo			ooxx						x

29								x				
28					o	ooo						
27			o	o	x							
26			o	o				o				
25				o	o							
24												
23					x				x	o		
22						o						
	0,2	**0,25**	**0,3**	**0,35**	**0,4**	**0,45**	**0,5**	**0,55**	**0,6**	**0,65**	**0,7**	**0,75**

Figure 14: Diameters and angles in relation to spinner and weight of whorl (orange line)
o: spinner 1; 8 g **x**: spinner 1; 18 g
o: spinner 2; 8 g **x**: spinner 2; 18 g

Similarly, only small differences are characteristic for the threads in the woven fabric. Yet, here spinner/weaver 1 (Anne), whose spinning samples are more similar to each other than are those of spinner 2 (Linda), reveals a slightly wider range in thread count than does spinner/weaver 2, given the fact that the green rectangle was woven by spinner/weaver 1 and the red one by her colleague (see tab. 8). Furthermore, weaver 1 has beaten in the weft a little harder, resulting in a higher thread count.

The last variables that can now be taken into account are the consumption of wool and the weight of the final product. As expected, both spinners needed much more wool for the work with the heavier whorl than with the lighter one (see Mårtensson's report; Andersson and Nosch 2003: 200). And theoretically, the wool consumption should be related to the yarn diameter as well as to the spinning angle. Given a certain diameter, the thread should contain more wool the harder it is spun. The relevant mean figures for diameter, spinning angle, weight of whorl and weight of yarn are shown in table 9.

	8 g			18 g		
	spinner 1	spinner 2	mean	spinner 1	spinner 2	mean
diameter in mm	0,413	0,312	0,3625	0,383	0,482	0,4325
spinning angle in °	31,03	37,26	34,15	36,86	40,50	38,68
weight in g/m	0,0898	0,1054	0,0976	0,1489	0,1722	0,1606

Table 9: Mean thread diameter and spinning angle (orange line) plus weight of yarn according to spinning whorl and spinner

Regarding the diameter, the threads worked by spinner 2 meet these expectations, since clearly thinner yarns derive from the lighter whorl. Her threads are spun harder compared to spinner 1 but also harder on average when using the heavier whorl; especially her thick, hard spun sections may require a lot of material. So it is an expected result that:
1) her threads are generally heavier than are those of spinner 1 because of her harder spin,
2) her threads worked with 18 g whorls are heavier than are those produced with 8 g whorls due to higher diameter and harder spin,
3) the consumption of wool - which is not shown in the table - is much higher when working with 18 g whorls.

The measurements for spinner 1 on the other hand are difficult to evaluate:
1) her threads are generally lighter, which seems logical because of the lower spinning angles,
2) unexpectedly, there is hardly any difference in the diameter for both categories of whorls, which should then result in rather similar figures for weight of yarn per m and consumption of wool,
3) yet, in accordance with spinner 1, her yarns from the 18 g whorls weigh considerably more than do those from the 8 g whorls and the consumption of wool is much higher.

7 Further measurements

One of the results deriving from the microscopic analyses turned out to be unexpected, as such, and inconsistent with the measurements taken during the experimental work. The crucial question is why spinner 1, Anne Batzer, like her colleague used much more wool for the work with the heavier whorl compared to the 8 g whorl although her threads produced with the 18 g whorl are relatively thin (even a little thinner on average than those of the 8 g whorl), loosely spun and therefore light. Possible explanations are that:
1) spinner 1 discarded an extreme amount of wool while spinning with 18 g whorls though not with 8 g whorls. This seems unlikely and could furthermore not explain why her threads from the 18 g whorls weigh much more than those from the 8 g whorls,
2) the analysed yarn sections belong to threads ("spindle full") that are not representative. However, this does not seem to be the case as is indicated by the figures for yarn weight and yarn length (see Mårtensson's report),
3) the measurements taken so far are not representative of the samples,
4) the analysed yarn sections are not representative of the whole threads ("spindle full") from which they were taken.

To test whether the analysed spots are representative of the samples, another set of measurements was established. In order to get figures from spots as far away from the first ones as possible, a blue line was marked in the middle of each sample on the back of the cardboards[6]. Thus, the distance between old and new measurements is *c.* 6 cm each. The figures for the diameters are presented in table 10.

sample	diameter in mm										mean	median	range
4a	0,25	0,3	0,25	0,3	0,5	0,35	0,35	0,4	0,4	0,3	0,34	0,3 / 0,35	0,25
4b	0,25	0,35	0,3	0,25	0,25	0,3	0,2	0,4	0,3	0,3	0,29	0,3 / 0,3	0,2
8a	0,3	0,5	0,2	0,3	0,25	0,2	0,3	0,4	0,4	0,3	0,315	0,3 / 0,3	0,3
8b	0,45	0,55	0,45	0,35	0,55	0,4	0,6	0,4	0,6	0,3	0,465	0,45 / 0,45	0,3
13a	0,25	0,25	0,6	0,35	0,35	0,6	0,35	0,6	0,3	0,4	0,405	0,35 / 0,35	0,35
13b	0,25	0,35	0,4	0,25	0,2	0,3	0,35	0,3	0,3	0,3	0,3	0,3 / 0,3	0,2
a	0,45	0,5	0,55	0,5	0,45	0,45	0,7	0,55	0,4	0,6	0,515	0,5 / 0,5	0,3
b	0,55	0,35	0,5	0,45	0,45	0,75	0,4	0,5	0,4	0,4	0,475	0,45 / 0,45	0,4
c	0,4	0,3	0,3	0,45	0,4	0,35	0,45	0,5	0,6	0,4	0,415	0,4 / 0,4	0,3
d	0,4	0,45	0,35	0,4	0,55	0,4	0,35	0,3	0,35	0,4	0,395	0,4 / 0,4	0,25
v	0,35	0,3	0,3	0,4	0,4	0,35	0,5	0,3	0,4	0,45	0,385	0,35 / 0,4	0,2
x	0,5	0,45	0,4	0,4	0,65	0,4	0,45	0,6	0,5	0,5	0,485	0,45 / 0,5	0,25

[6] Those lines (green/grey) 2 cm away from the orange middle lines, which were prepared and planned to be examined in the first instance, were not used because the spots are much closer to the already inspected ones.

Table 10: Diameters of single threads, their mean, median and ranges (blue line); light yellow = lowest/best value, deep yellow = highest/worst value

The interpretation of these figures compared to table 1 (orange line) are as follows:

- The absolute figures range from 0.2 mm to 0.75 mm, which is identical with the orange line.
- Correspondingly the means vary between 0.29 mm and 0.515 mm, which is very close to the figures discussed before (0.3 mm / 0.505 mm).
- Here again, the mean of the yarns spun by spinner 1 with 18 g whorls is slightly lower than that belonging to the 8 g whorls, the figures being 0.398 mm and 0.403 mm respectively.
- The mean diameters of the individual threads are usually similar, in two cases even identical (“13b”, “v”). The biggest difference (“4a”) is only 0.04 mm. Again, “4b” and “13b” are thinnest as “a” is thickest. All three last mentioned yarns are from spinner 2.
- “4b” and “13b” reveal also the lowest ranges of diameters and are therefore again considered the best. A high range (0.4 mm) combined with a big mean diameter (0.515 mm) is found in “a”, which may therefore be regarded as the worst thread. Within the orange line, it was sample “x”. Both were spun by spinner 2.
- “13a” is the most prominent example of differences in quality between the two sets of measurements. The deviation of 0.055 mm between the mean and the median of the blue line indicates a less even yarn. Among the first measurements for this sample, the mean was not identical with the median either, but the gap was smaller. And while the range was very low in the first instance (all figures within the span from 0.3 to 0.5 mm), it is rather high here (0.25 to 0.6 mm). Yet, these figures should not be overestimated.

26					x							
25									18 g, spinner 2			
24									18 g, spinner 1			
23			13b		b				8 g, spinner 2			
22									8 g, spinner 1			
21												
20					a							
19			8a		13b							
18					8a							
17												
16				b	4b							
15			4b	13b	v							
14												
13				4b		x						
12				v	d							
11			v			b	x					
10		13b		d								
9						a						
8		8a	d		c		b		x			
7		4b	c	c					a			
6				13a		v	a	b	c			
5			13a		13a	d		a	13a			
4	13b	13a	8b		8b	c	8a					
3	8a		4a	8b			v	d				
2		4a		4a	4a	8b	c	8b	8b			
1	4b						4a			x	a	b
▲ number ► diam. in mm	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75

Figure 15: Diameters of the single threads in mm (blue line)

- The overall distribution presented in figure 15 is very similar as well: it is almost even, only the depression at 0.35 mm is a bit more emphasized here.
- The distribution according to the spinning whorls is also included in figure 15, but to some extent more obvious in figure 16. Again, the depression at 0.35 mm marks the difference between the two weights, but only in the work of spinner 2. For spinner 1, the figures for both whorls build just one clear peak at 0.4 mm (fig. 15).
- So again, all measures for spinner 1 are closer to each other than are those of spinner 2. Her overall range is smaller (0.35 mm compared to 0.55 mm of spinner 2) and no difference between the two categories of whorls was found.
- To conclude, the additional measurements confirm the first ones completely.

26					x							
25									18 g, spinner 2			
24									18 g, spinner 1			
23			13b		b				8 g, spinner 2			
22									8 g, spinner 1			
21												
20					a							
19			8a		13b							
18					8a							
17												
16				b	4b							
15			4b	13b	v							
14												
13				4b		x						
12				v	d							
11			v			b	x					
10		13b		d								
9						a						
8		8a	d		c		b		x			
7		4b	c	c					a			
6				13a		v	a	b	c			
5			13a		13a	d		a	13a			
4	13b	13a	8b		8b	c	8a					
3	8a		4a	8b			v	d				
2		4a		4a	4a	8b	c	8b	8b			
1	4b						4a			x	a	b
▲ number ► diam. in mm	0,2	0,25	0,3	0,35	0,4	0,45	0,5	0,55	0,6	0,65	0,7	0,75

Figure 16: Thread diameters according to weight of whorls and spinners (blue line)

Since it has turned out that the measurements taken so far indeed reflect the character of the samples, the premise that the investigated yarn sections are representative for the whole yarn balls ("spindle full") should be checked. For this reason, another four samples were analysed (yellow line), one of each spinner with each spindle weight. In general, the procedure was the same as before. But as the cardboards on which the threads are wound are broader and only every third thread along the middle line is examined, the investigated yarn sections are much longer and the distance between every two measurements is *c*. 64 cm compared to *c*. 12 cm before. The results are given in table 11, figure 17 and figure 18.

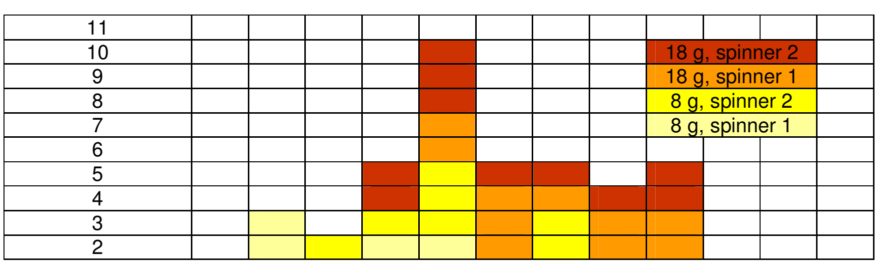
sample	diameter in mm										mean	median	range
sp. 1, 8 g	0,35	0,25	0,2	0,35	0,4	0,4	0,5	0,25	0,25	0,3	0,325	0,3 / 0,35	0,3
sp. 2, 8 g	0,45	0,4	0,55	0,3	0,4	0,35	0,6	0,5	0,5	0,4	0,445	0,4 / 0,45	0,3
sp. 1, 18 g	0,6	0,6	0,4	0,55	0,4	0,55	0,45	0,5	0,45	0,45	0,495	0,45 / 0,5	0,2
sp. 2, 18 g	0,45	0,4	0,55	0,6	0,6	0,5	0,35	0,35	0,4	0,4	0,46	0,4 / 0,45	0,25

Table 11: Diameters of single threads, their mean, median and ranges (yellow line); light yellow = lowest/best value, deep yellow = highest/worst value

Compared to the measurements of the diameters along the orange and the blue lines, the following can be stated:
- The absolute measurements lie between 0.2 mm and 0.6 mm, which is a smaller range than before, where the thickest threads measured 0.75 mm.
- The mean diameters are shown in table 12. For the 8 g group as well as for the 18 g group, the mean diameters are bigger in the new set of measurements. This might be due to some kind of different treatment, for example the broader cardboard and less tension while winding the yarns onto the cards. It might be suspected that the threads are thus allowed to open up a little bit. However, the thickest threads are 0.6 mm in diameter in the new set compared to up to 0.75 mm before.
- In contrast to the previous measurements, it appears now that the measures of spinner 2 are closer to each other: 0.445 mm with 8 g whorls and 0.46 mm with 18 g whorls compared to 0.325 mm and 0.495 mm spun by spinner 1.
- Before, there was a steady difference of *c*. 0.1 mm between the mean yarn diameters produced by spinners 1 and 2, in the 8 g group as well as in the 18 g group and along the orange line as well as along the blue line. Within the new set, the difference is a little bit bigger for the 8 g whorls (0.12 mm), but only 0.035 mm for the 18 g whorls.
- The last measurement in particular confirms the statement that the results are closer together all in all. To some extent this might be due to the fact that the new set of measurements (yellow line) consists of a total of 40 figures whereas a total of 240 measurements were taken from the original samples (orange and blue lines).

thread group	mean diameter in mm		thread group	mean diameter in mm	
8 g orange line (60 spots)	overall	0,3625	**18 g orange line** (60 spots)	overall	0,4325
	spinner 1	0,4133		spinner 1	0,3833
	spinner 2	0,3117		spinner 2	0,4817
8 g blue line (60 spots)	overall	0,3525	**18 g blue line** (60 spots)	overall	0,4450
	spinner 1	0,4033		spinner 1	0,3950
	spinner 2	0,3017		spinner 2	0,4917
8 g orange + blue line (120 spots)	overall	0,3575	**18 g orange + blue line** (120 spots)	overall	0,4388
	spinner 1	0,4083		spinner 1	0,3892
	spinner 2	0,3067		spinner 2	0,4867
8 g yellow line (20 spots)	overall	0,3850	**18 g yellow line** (20 spots)	overall	0,4775
	spinner 1	0,3250		spinner 1	0,4950
	spinner 2	0,4450		spinner 2	0,4600
8 g all (mean of 120 / 20 spots)	overall	0,3713	**18 g all** (mean of 120 / 20 spots)	overall	0,4582
	spinner 1	0,3667		spinner 1	0,4421
	spinner 2	0,3759		spinner 2	0,4734

Table 12: Mean diameters of yarn produced with 8 g and 18 g whorls by the two spinners, grouped according to lines of measurement



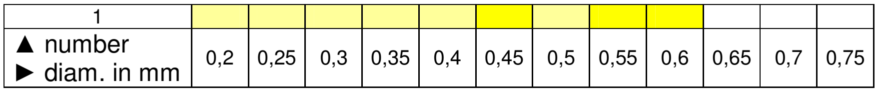


Figure 17: Diameters of the single threads in mm (yellow line)

All measurements of the new set are combined in figure 17. The results are as follows:
- The curve is more or less regular, only the 0.6 mm value is overrepresented.
- There is one clear peak at 0.4 mm, no depression at 0.35 mm is visible.
- If these diameters were to be found in archaeological material, the suggestion of different spinners and/or different spindle whorls would be highly speculative.
- In figure 18, the measurements are split up again according to the weight of the whorls. The values for the bigger whorls are to be found within the rather small range between 0.35 mm and 0.6 mm with a slight peak at 0.4 mm.
- The peak within the 8 g group lies again at 0.4 mm. The measurements for one of these threads are practically identical with those for the other group. Only the yarn of spinner 1 is distinguishable based on the given background information.
- Interestingly enough, it is now spinner 1 whose figures for the 8 g and the 18 g whorl are very much alike, whereas spinner 2 produced yarns with a discernable difference.

To conclude, the results of the third set of measurements are principally the same as those of the previous sets. Generally the yarns are a little bit thicker but the expected clear difference between the products deriving from different whorls is not visible. Again, the yarns spun by one of the spinners are very much alike despite the use of differently weighing whorls while the other spinner's threads - given the appropriate background information - can be related to the various whorls.

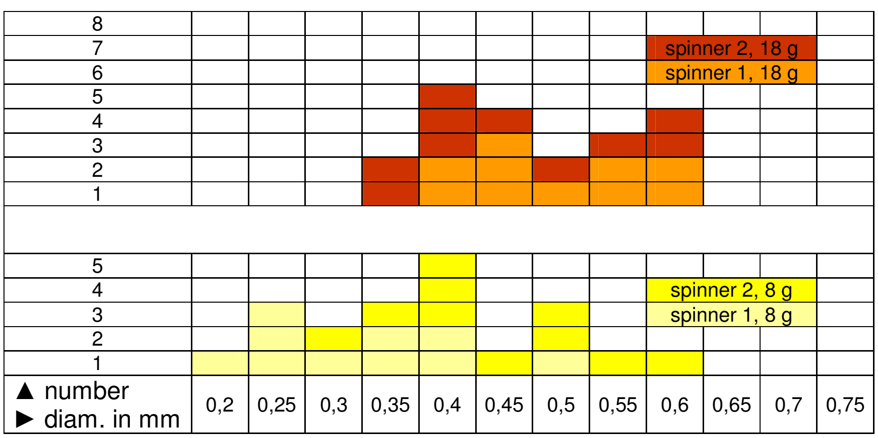


Figure 18: Thread diameters according to weight of whorls and spinners (yellow line)

Finally the question has to be addressed again as to why the spinners needed very different amounts of wool for spinning with the different whorls, although it seemed from the first two sets that the threads of spinner 1 were so much alike that the wool consumption for both whorls should have been comparable as well. The results of the new set of yarns paint a similar picture, but now it is spinner 2 whose threads are very much alike while those of spinner 1 are distinguishable. Thus, the previously registered difference in the work of the two spinners must be related to the fact that the number and/or selection of the first set of samples was not representative for their whole work - it disappears when more samples are investigated. At this point the results of this analysis are now in accordance with the spinners' documentation indicating that there are no major differences in their work.

Yet, this does not explain the degree of wool consumption in relation to the documented fibre diameters. The fact that much more wool was needed while spinning with the 18 g whorls should be visible in the results of this analysis. The range of diameters related to the 8 g whorls and to the 18 g whorls respectively overlap to such a great extent that no separation was possible without the information regarding which thread derived from which type of whorl. But taking this information into account, the mean figures can be calculated (tab. 12): 0.3713 mm for the 8 g group and 0.4582 mm for the 18 g whorls, the first figure being 4/5 of the second one. The difference is clear but does not seem big. Yet, these figures reflect only one dimension, the diameter. When they are used for calculating the second dimension (πr^2) - taking the yarn as an approximately cylindrical feature - the results are 0.1083 mm^2 and 0.1649 mm^2 respectively. So the cross section of the average yarn spun with an 8 g whorl is only 2/3 compared to that produced with an 18 g whorl. And this relation is practically the same in the yarn weight (tab. 9) and wool consumption.

8 Evaluation of the final results

Finally, the significance of these results shall be discussed briefly. What do they mean in terms of prehistoric textile production, experimental archaeology and the interpretation of archaeological textiles? The main factors predicting the quality of a cloth are the preparation of the raw fibre, the thickness and quality of the yarn, the chosen type of weave and the skill of the weaver. The experiments have confirmed the experience that lighter spindle whorls are suitable for spinning thinner threads. The finer and thinner the final cloth shall be, the lighter the spinning whorls should be. And for weaving standard cloth, the use of whorls of similar weight appears to be logical. Furthermore, the influence of their weight on wool consumption is immense. Certainly, these correlations were known and made use of in prehistoric times.

The microscopic analyses of the material have shown, however, that the range of yarn diameter and quality produced with a specific weight can be considerable. Many threads were alike, no matter whether they had been spun with an 8 g or an 18 g whorl. The use of different tools could be traced only when a lot of material was taken into account and - at this stage of knowledge - some background information was given. The consequence for future experiments should be to plan them - as was done in this case - with dimensions big enough to avoid wrong conclusions because the sample size is too small. In other words, the results have confirmed how misleading far-reaching calculations for reconstructing the past may be when they are based on very limited material. The same applies to the interpretation of archaeological textile finds. Quite often there are only a few threads that are suitable for detailed measurements. The results are very valuable but one should be aware that they represent only a very small section of the whole product.

9 Summary

The material analysed consisted initially of 12 spinning samples and one piece of woven fabric. The analyses were carried out and the results - at first - were interpreted without any knowledge about the tools or the two spinners, *i.e.*, which sample was done by whom. On the spinning samples, 120 spots were chosen in accordance with a certain system. The fuzziness was described as a general impression.

The overall impression was that of fine, rather evenly spun threads. The data for the diameters as well as for the spinning angles consisted of a continuous row of figures, proving a certain variety in quality but not allowing any grouping. In other words, it was impossible to separate any sets of data pointing to individual spinners or tools.

A similar result applies to the weaving sample where differences between the two sections produced by the two spinners/weavers could be stated, but only within a small range, which - if found in an archaeological textile - would not suffice to propose that the piece was produced by more than one weaver. All in all the weave might be called open and thin.

When the data were related to the individual spinners and tools, it turned out that both of them worked practically within the same range. Still, one of them tended to spin a little bit more evenly, producing less “extreme” figures. But it must be emphasized that these were details which only became evident after the information concerning which sample belonged to which spinner was uncovered. There were differences, but they were small.

Half of the samples were spun with 8 g whorls, the others with 18 g whorls, so one might expect threads of clearly different diameters. Yet, the overall distribution of the data was almost continuous and no line between any groups of figures could be drawn. Only when the information about the whorls was included, a slight difference of 0.071 mm in the mean diameters could be calculated and it turned out that the absolutely thickest thread was spun with an 18 g whorl while the two thinnest ones belonged to 8 g whorls. The yarns of spinner 2 could then be correlated with the two categories of whorls, but not those for spinner 1, who in fact had spun slightly thinner threads with the heavier whorls. And finally, although one of the light whorls was slightly unbalanced and uncomfortable to work with, the resulting threads were of the same quality as the ones produced with the better whorl.

When these results were compared to the weight of yarn that had been examined by the spinners themselves, a clear difference between the figures for the lighter and heavier whorls should have been visible. Since this was only the case for spinner 2, another set of measurements was taken on the same samples. These results, however, confirmed the first ones totally. Therefore, another set of samples was analysed, consisting of one thread per spinner and spindle whorl category. The measurements on each sample were distributed over a much longer length of thread, *i.e.*, over *c*. 5.75 m compared to *c*. 1.1 m before. The general picture gained from these measurements is the same as before, only that it is now spinner 1 from whom distinguishable threads derive while those of spinner 2 are very much alike. This indicates that the first set of samples alone was not representative of the whole material.

Next, the mean yarn diameters for both categories of whorls were calculated and an overall difference of 0.087 mm stated (compared to 0.071 mm within the first set of measurements). From these mean figures, the area of the corresponding cross sections were calculated. It turned out that it is *c.* 50% larger in the average thread of the 18 g group. Thus, the volume is similarly larger and this figure, 50%, is comparable with what has been found in yarn weight and wool consumption.

The results of the experiments in combination with the microscopic analysis have emphasised the importance of an adequate number of measurements. Too few data will easily lead to wrong interpretations. Consequently, the usually few data gained from archaeological material should be handled even more carefully than before when using them for any further reaching calculations. Furthermore, the investigation confirms that archaeological experiments should be planned on a broad scale as it was done in this case.

10 Bibliography

Andersson, Eva and Marie-Louise Nosch (2003): With a little help from my friends: Investigating Mycenaean textiles with help from Scandinavian experimental archaeology. - K. P. Foster and R. Laffineur (eds.), Metron, Measuring the Aegean Bronze Age, Proceedings of the 9th International Aegean Conference, New Haven, Yale University, 18-21 April 2002, Aegaeum 24, 2003, 197-203.

Cooke, W. D. and T. J. Jones (2002): Low cost digital 'microscopy' for archaeological textiles research. - ATN 34, 2002, 16-20.

Cooke, Bill and Carol Christiansen (2005): What makes a Viking sail? - F. Pritchard and J. P. Wild (eds.), Northern Archaeological Textiles, NESAT VII, Textile Symposium in Edinburgh, 5th-7th May 1999, Oxford 2005, 70-74.

Hammarlund, Lena (2004): Handicraft knowledge applied to archaeological textiles - Fabric thickness and density: A method of grouping textiles. - ATN 39, 2004, 7-11.

Hammarlund, Lena (2005): Handicraft knowledge applied to archaeological textiles. - The Nordic Textile Journal 2005, 87-119.