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# Preserved in clay: Ornamentation of Late Neolithic ceramic funerary vessels

## Abstract

Knowledge about textile production in the Neolithic period is relatively poor throughout Europe. Due to the rarity of organic remains, textile imprints preserved on pottery or other fired clay artefacts are valuable sources. This paper presents the results of technical analyses and experimental research into textile impressions identified on funerary ceramics. The materials are 19 pots from archaeological sites from the Polish lowlands. Fragments are dated to the Late Neolithic period. The set of vessels analysed feature impressions of decorative textiles. These included impressions possibly made with textile constructions, but also the so-called “free-hand” cord impressions. Ornaments made using the latter method are in the majority.

**Keywords:** Textile impression, Polish lowlands, the Late Neolithic period, cord ornament, pottery

## Introduction

Textiles have been used by humans since the Middle Palaeolithic (Hardy et al. 2020). The history of processing organic fibres into various types of plaited fabric, mats, baskets, and textiles is extremely rich and diverse in terms of the raw materials and techniques used. The invention of a cord or thread twisted from plant fibre can be considered revolutionary, as this skill rapidly accelerated people’s ability to adapt to environmental conditions (Łaszczyńska 1966, 21; Good 2001, 209; Rast-Eicher 2005, 117; Hardy 2007, 9). Although textile production was an important part of early human activity, archaeological finds of pieces of cord, mats, or fabrics are quite rare. In the case of the area of the Polish lowlands in the Neolithic era, researchers have to work with indirect evidence such as spinning and weaving tools, and marks left by pressing textiles into the surface of clay vessels or other fired clay artefacts (Chmielewski 2009, 226–223; Grömer 2016, 30; Kaczmarek 2023). These types of artefacts, despite their limited information value, are the only source on natural fibre processing in the area in question during the Neolithic period.

The aim of this paper is to present and discuss the results of technical analyses and experimental research into textile impressions on ceramic funerary vessels. It also attempts to determine what items and methods were used to make the ornamentation on the collection of clay vessels analysed. The source material presented here dates mainly to the Late Neolithic

period (2970 BCE to 2200 BCE) and covers nearly 1,000 years (Szmyt 2013, 36–42; Włodarczak 2017, 17). The evidence discussed comes mostly from the western part of the Polish lowlands (fig. 1).

Textiles is the generic term used for all products of processing plant and animal-based fibres, both woven and non-woven (Good 2001, 209–226; Gleba and Mannering 2012, 1–24). The use of cord in pottery decoration appears in the Polish lowlands in the Middle Neolithic period (Wierzbicki 2013, 108–148; Szmyt 2017, 220–221). Ornamental motifs made using cord decorate ceramics from settlements and graves, but in the latter, they are more ornate and frequently almost entirely preserved.

## Funerary pottery from the Polish lowlands and selection of ceramic vessels for further analysis

A literature review led to investigations in museums and research institutions in Poland. These established that, in the western part of the Polish lowlands, approximately 180 burial sites (including presumed ones) were discovered, associated with the cultural units functioning in the relevant area in the Middle, Late, and Final Neolithic period (3600 BCE to 2000 BCE). These are the Funnel Beaker culture, Globular Amphora culture, Corded Ware culture, and Bell Beaker culture (Szmyt 2013, 36–42; Włodarczak 2017, 17). Ceramic vessels were found in 149 burial sites. Unfortunately, many of them, discovered before 1945, were lost as a result of the



Second World War or immediately afterwards. Only 87 vessels preserved in their entirety or to a significant degree, and several hundred fragments of vessels were found.

All the vessels and pottery fragments, including those without a cord ornament, were subjected to detailed macroscopic analysis. Particular attention was paid to the bottoms of the vessels, the area around the handles and the areas with ornaments (if present), in order to verify whether there were marks associated with the use of technical textiles during the shaping and drying of vessels before they were fired (Rast-Eicher 2005, 118–119; Marian

2009, 119–120; Grömer and Kern 2010, 3144; Harris 2013, 113; Kaczmarek 2023, 29–32).

No traces of the use of technical textiles were observed on any of the examined vessels, both with or without textile decoration. Only on 23 vessels (preserved in their entirety or reconstructed) and four fragments from two different vessels, was the ornament made using textiles (table 1). It should be noted that five of these have already been analysed previously (Kaczmarek 2015) and therefore they are not discussed further (table 1: 20–24). A total of 19 vessels and their fragments were selected for further analysis.

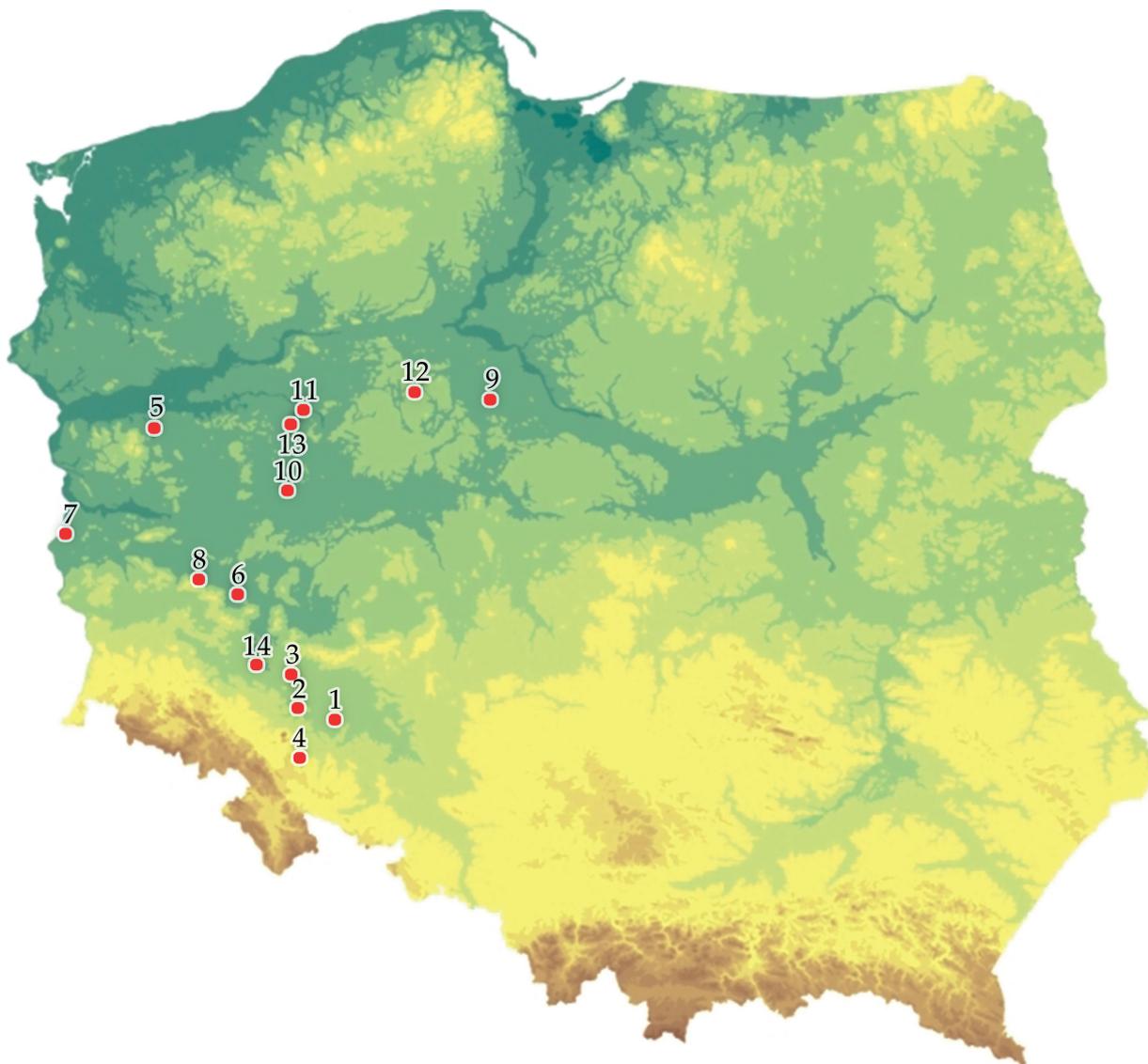
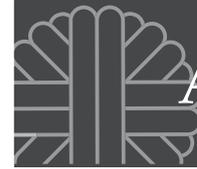


Fig. 1: Sites location: 1 – Marszowice; 2 – Pietrzykowice; 3 – Brodno; 4 – Łagiewniki; 5 – Międzyrzecz, site 106; 6 – Głogów-Nosocice; 7 – Gubin, site 32; 8 – Dobrzejowice, site 2; 9 – Giżewo; 10 – Głuchowo, site 1; 11 – Obrniki; 12 – Żnin; 13 – Kowalewko, site 12; 14 – Janowice Małe (Image: Monika Kaczmarek)



Fig. 2: Funeral vessels with cord decoration: a and h – Głogów-Nosocice; b – Oborniki; c – Giżewo; d and m – Żnin; e – Kowalewko; f – Pietrzykowice; g – Brodno; i and r – Łagiewniki; j and n – Międzyrzecz; k – Gubin; l – Marszowice; o – Głuchowo; p – Janowice Małe; s and t – Dobrzejowice (Images: a-k, m, n and r-t – Monika Kaczmarek; l – Tomasz Gąsior; o – from Czebreszuk and Szmyt 2019; p – Tomasz Stolarczyk)



No.	Storage location/ inventory number	Site, County	Type of object (number)	Culture and chronology	Literature
1	MAW/ 613:03	Marszowice, Oława	grave (14)	CWC, 2800-2600 BCE	Seger 1904
2	MAW/ I/60	Pietrzykowice, Wrocław	grave	CWC, 2500-2200 BCE	Machnik 1979
3	MAW/ N/D	Brodno, Środa Śląska	undefined	CWC, 2500-2200 BCE	Seger 1919
4	MAW/ 334/14/8	Łągiewniki, Dzierżoniów	grave? (8)	GAC, 2850-2520 BCE	Wojciechowski 1967
5	MAW/ 385:14	Łągiewniki, Dzierżoniów	grave? (8)	GAC, 2850-2520 BCE	Wojciechowski 1967
6	MZM/ 4/00?	Międzyrzecz site 106, loco	grave (1)	CWC, 2300-2000 BCE	Łaskiewicz 2016
7	MZM/ 4/00?	Międzyrzecz site 106, loco	grave (1)	CWC, 2300-2000 BCE	Łaskiewicz 2016
8	MASN/ 1136:14	Głogów - Nosocice, Głogów	grave (12)	CWC, 2800-2600 BCE	Seger 1919
9	MASN/ 1140:14	Głogów - Nosocice, Głogów	grave (1)	CWC, 2800-2600 BCE	Seger 1919
10	MASN/ N/D	Gubin site 32, loco	grave (37)	GAC, 2970-2850 BCE	Przechrzta 1996
11	MH/ A/5135/25	Dobrzejowice site 2, Głogów	grave (245)	CWC, 2600-2300 BCE	Museum Inventory
12	MH/ A/5135/25	Dobrzejowice site 2, Głogów	grave (245)	CWC, 2600-2300 BCE	Museum Inventory
13	MAP/ LfV 1940: 77	Gizewo, Inowrocław	grave? - gift	CWC, 2500-2200 BCE	Machnik 1979
14	MAP/ 45D115	Głuchowo site 1 (A1 - 145), Kościan	grave (D129)	CWC, 2300-2200 cal. BCE	Czebreszuk and Szymt 2019
15	MAP/ LfV 1940: 129	Obrniki, loco	grave? - gift	CWC, 2850-2250 BCE	Pospieszny 2009
16	MAP/ KFM 1909: 272	Żnin, loco	undefined - gift	CWC, 2500-2200 BCE	Machnik 1979
17	MAP/ KFM 1909: 271	Żnin, loco	undefined - gift	CWC, 2500-2200 BCE	Museum Inventory
18	MAP/ N/D	Kowalewko site 12, Oborniki	grave (384)	CWC, 2850-2250 BCE	Pospieszny 2009
19	ML/ A 1024	Janowice Małe, Legnica	undefined - gift	CWC, 2800-2600 BCE	Museum Inventory
20	MAP/ 1974: 398	Chodzież site 3, loco	grave	GAC, 2920-2885 cal. BCE	Prinke and Wiślański 1977
21	MAP/ 1974: 398	Chodzież site 3, loco	grave	GAC, 2920-2885 cal. BCE	Prinke and Wiślański 1977
22	MAP/ 1974: 374	Łęki Małe site 3, Grodzisk Wielkopolski	grave (3)	CWC, 2500-2200 BCE	Lipińska 1962
23	IAiE PAN	Lutol Mokry site 36, Międzyrzecz	grave (A382)	CWC, 2300-2000 BCE	Czebreszuk and Szymt 2012
24	IAiE PAN	Lutol Mokry site 36, Międzyrzecz	grave (A382)	CWC, 2300-2000 BCE	Czebreszuk and Szymt 2012

Table 1: Catalogue of the set of vessels analysed. Abbreviations: MAW Museum of Archaeology, Wrocław; MAP Archaeological Museum, Poznań; MZM Museum of the Międzyrzecz Region; MH Museum of Archaeology and History, Głogów; MASN Archaeological Museum of the Middle Odra River Area; ML Copper Museum, Legnica; IAiE PAN Institut of Archaeology and Ethnology PAN, Poznań; CWC Corded Ware culture; GAC Globular Amphora culture; FBC Funnel Beaker culture; N/D = no data



No.	Site	Ornament description	Photo
1	Marszowice	All-round(?) ornament of 16 horizontal rows of cord impressions on the neck of the vessel.	fig. 2l
2	Pietrzykowice	All-round ornament of 17 horizontal rows of cord impressions on the top of the vessel.	fig. 2f
3	Brodno	Ornament of diagonal cord lines surrounded by two horizontal lines below and two more above. The diagonal lines are arranged in groups (four-five line each) and slope alternately from right to left and from left to right.	fig. 2g
4	Łagiewniki	Ornament of diagonal hatched festoons. Below it is a motive of multiples downbend arches and then impressed single cord line.	fig. 2i
5	Łagiewniki	Two horizontal rows of vertical stanchions on the neck of the vessel. Between them is a motive of multiple diagonal hatched triangles. On the top of the belly zone is a single horizontal cord impression. Below, on the belly zone and handles zone, are diagonal short cord lines arranged in groups (four-five lines each).	fig. 2r
6	Międzyrzecz, site 106	Two horizontal rows of cord impressions, five below and five above. Between them are multiple rows of horizontal cord zigzags. The ornament appears on the vessel neck and the belly zone.	fig. 2n
7	Międzyrzecz, site 106	Two horizontal rows of cord impressions, five below and five(?) above. Between them are multiple rows of horizontal cord zigzags. The ornament appears on the top of the vessel.	fig. 2j
8	Głogów - Nosocice	Four-five horizontal rows of cord impressions on the neck of the vessel. Below it is a diagonal row of nail impressions.	fig. 2a
9	Głogów - Nosocice	Ornament of vertical cord lines arranged in groups (four lines each) on the belly zone. Two vertical cord lines are also on the handle zone.	fig. 2h
10	Gubin, site 32	The vessel is decorate with two rows of vertical stanchions and double horizontal zigzags below. The four handles feature an elongated triangle motif in the upper part of the handle, which turns into four vertical lines of string in the lower part. The decoration is located in the upper part of the belly zone and in the handle zone.	fig. 2k
11	Dobrzejowice, site 2	Ten horizontal rows of the cord impressions on the neck of the vessel. Below, on the top of the belly zone, is a motive of diagonals hatched festoons and triangles(?).	fig. 2t
12	Dobrzejowice, site 2	12 (?) horizontal rows of the cord impressions on the neck of the vessel. Below, on the top of the belly zone, is a motive of diagonals hatched triangles.	fig. 2s
13	Gizewo	Ornament of diagonal cord lines surrounded by three horizontal lines below and three more above. The diagonal lines are arranged in groups (four line each) and slope alternately from right to left and from left to right.	fig. 2c
14	Głuchowo, site 1	14 (?) horizontal rows of cord impressions on the neck of the vessel.	fig. 2o
15	Oborniki	All-round ornament of 14-15 horizontal rows of cord impressions on the top of the vessel.	fig. 2b
16	Żnin	Ornament of diagonal cord lines surrounded by four horizontal lines below and three more above. The diagonal lines are arranged in groups (six-seven lines each) and slope alternately from right to left and from left to right. Below are two rows of tiny side-bend arche and finished of two diagonal cord lines. The ornament is on the neck of the vessel and on the belly zone.	fig. 2d
17	Żnin	Five horizontal bands of three-four rows of cord impressions on the neck of the vessels.	fig. 2m
18	Kowalewko, site 12	All-round ornament of 25 horizontal rows of cord impressions on the top of the vessel. Below is a row of vertical stanchions. Single cord impression is also on the rim zone of the vessel.	fig. 2e
19	Janowice Małe	Ornament of horizontal and multiple rows of the cord lines, below which is a row of horizontal chevrons. These two motives are duplicated and located in the neck and belly zone of the vessel.	fig. 2p

Table 2: Description of the decoration of ceramic vessels



No.	Site	Firing atmosphere	Kind of temper	Wall thickness	Type of pot	State of preservation
1	Marszowice	oxidising	coarse crushed white stone and mica	up to 6 mm	hendleless (?) amphora	reconstructed
2	Pietrzykowice	oxidising	medium crushed white stone and mica	up to 6 mm	mortar-shaped beaker	completely preserved
3	Brodno	oxidising	coarse crushed white stone and fine sand	up to 6 mm	cup	reconstructed
4	Łagiewniki	oxidising	coarse crushed pink stone	up to 6 mm	bowl	completely preserved
5	Łagiewniki	reducing	coarse crushed white stone	7-9 mm	amphora	3 large fragments
6	Międzyrzecz, site 106	oxidising	fine sand and crushed white stone	up to 6 mm	amphora	reconstructed
7	Międzyrzecz, site 106	oxidising	coarse crushed white stone	up to 6 mm	amphora	partially preserved
8	Głogów - Nosocice	oxidising	medium crushed white stone and crushed shells	up to 6 mm	small bowl	completely preserved
9	Głogów - Nosocice	oxidising	medium crushed white stone	up to 6 mm	cup	reconstructed
10	Gubin, site 32	oxidising	medium crushed white stone, fine sand and crushed shells	up to 6 mm	amphora	reconstructed
11	Dobrzejowice, site 2	oxidising	coarse crushed pink stone and mica	7-9 mm	amphora	reconstructed
12	Dobrzejowice, site 2	oxidising	coarse crushed pink and white stone	up to 6 mm	amphora	reconstructed
13	Gizewo	oxidising	medium crushed pink stone	7-9 mm	beaker	completely preserved
14	Głuchowo, site 1	oxidising	medium ceramic grog and sand	up to 6 mm	beaker	reconstructed
15	Obrniki	oxidising	fine sand	up to 6 mm	small beaker	completely preserved
16	Żnin	reducing	medium crushed pink stone	up to 6 mm	cup	completely preserved
17	Żnin	reducing	medium crushed pink stone	up to 6 mm	cup	completely preserved
18	Kowalewko, site 12	oxidising	medium crushed white stone and fine sand	up to 6 mm	small beaker	completely preserved
19	Janowice Małe	oxidising	coarse crushed white stone	7-9 mm	beaker	reconstructed

Table 3: Taxonomic analysis of pottery



Ceramic materials intended for technical analyses of textile impressions feature various decorative motifs, made using cord impressions and other techniques, as shown in table 2. A total of 19 vessels and their fragments were discovered at 14 sites in the western and central part of the Polish lowlands (fig. 2). Ten of them were found in burial sites, five in presumed burial sites, while four were in undetermined sites. However, it seems that the last can be classified as funerary vessels too, given their state of preservation and the absence of traces of use. The analysed collection of vessels was discovered during research, rescue works, and as accidental discoveries (table 1). From a cultural point of view,

the vessels were likely to have been produced by the people of the Globular Amphora and Corded Ware cultures. They lived in the Polish lowlands in the period between 3500 BCE and 2200 BCE (Kadrow 2001, 49–65; Szmyt 2017, 218–219; Włodarczak 2017, 284–286).

#### Technical analyses of textile impressions

Cord ornamentation pressed into ceramic vessels dating to the Middle and Late Neolithic has been the subject of numerous typological studies. This distinctive ornament is also considered to be one of the determinants of conventional dating (Nowak 2009, 489–490; Wierzbicki 2013, 108–109). Far less attention

No.	Site	Impression depth (mm)	Twist direction	Twist angle	Width of cord (mm) / single yarn or fibre	Number of twists per 1 cm	More detailed measurements in different parts of the ornament	
							Twist angle (contact points of the cords / other parts)	Number of twists per 1 cm (contact points of the cords / other parts)
1	Marszowice	0.4-0.5	S	30	0.99	4-6	N/R	N/R
2	Pietrzykowice	0.7-1.2	S	30	1.8	2-3.5	N/R	N/R
3	Brodno	0.1-0.5	S	33	1.24	4	22 / 37	2.5 / 3-4
4	Łagiewniki	0.2-1.1	S	32	1.57 / 0.38*	4-5	N/A	N/A
5	Łagiewniki	0.1-0.5	S	38	1.84 / 0.87*	4	N/A	N/A
6	Międzyrzecz, site 106	0.3-0.4	S	31	0.52	5-6	N/A	N/A
7	Międzyrzecz, site 106	0.2-0.4	S	24	0.71	5-7	N/A	N/A
8	Głogów - Nosocice	0.2-1.2	S	22	1.58	2-3	N/A	N/A
9	Głogów - Nosocice	0.4-1.3	S	32	1.79	2-3	N/A	N/A
10	Gubin, site 32	0.5-0.8	Z?	37?	0.89	4-5?	N/A	N/A
11	Dobrzejowice, site 2	0.6-1.0	S	38	1.18	5-5.5	32 / 41	4-4.5 / 5
12	Dobrzejowice, site 2	0.3-0.9	S	25	1.12 / 0.31*	4	22 / 28	3 / 3.5-4
13	Gizewo	0.3-0.5	S	20	1	2-3	30 / 22	2-3 / 2-3
14	Głuchowo, site 1	0.4-1.50	S	31	1.71	2-4	N/A	N/A
15	Obrniki	0.9-1.3	S	30	1.56	2.5-4.5	N/A	N/A
16	Żnin	0.1-0.6	S	38	1.54 / 0.43*	5	26 / 34	3-4 / 4-5
17	Żnin	0.1-0.5	S	29	1.21	4	N/A	N/A
18	Kowalewko, site 12	0.4-0.7	S	31	1.31 / 0.63*	3-4	N/A	N/A
19	Janowice Małe	0.6-0.9	S	27	1.81	2.5-3	N/A	N/A

Table 4: Technological analysis of textile impressions in pottery (N/A = not applicable). \* Single spun yarn/fibre between the main cords (average thickness)

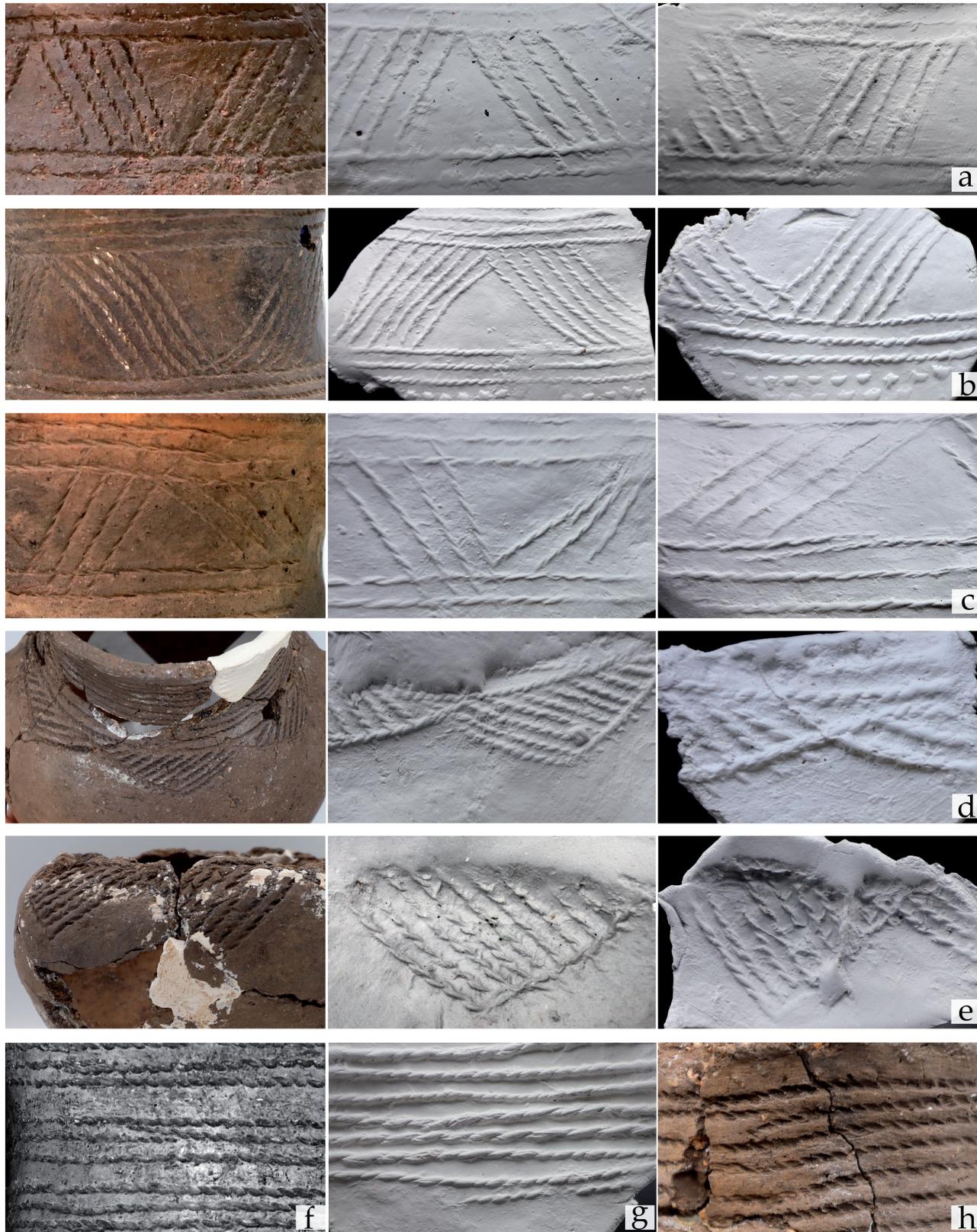


Fig. 3: Textile impression on archaeological evidence – close-up for ornamentation area: a – Brodno (vessel and positive casts); b – Żnin (vessel and positive casts); c – Gizewo (vessel and positive casts); d and e – Dobrzejowice (vessels and positive casts); f – Żnin (vessel); g – Oborniki (positive cast); h – Dobrzejowice (vessel) (Image: Monika Kaczmarek)



No.	Textile						Textile impression					Photo
	Number of strand	Kind of raw material	Twist direction	Twist angle	Width of cord (mm)	Number of twists per 1 cm	Impression depth (mm)	Twist direction	Twist angle	Width of cord (mm)	Number of twists per 1 cm	
1	2-strand	lime bast	Z2s	18	1.21	3.5-4	0.4-0.6	Z	19	1.08	3.5-4	fig. 7a
2	2-strand	lime bast	Z2s	26	3.34	1.5	0.8-1.5	Z	27	2.65	1.5-2	fig. 9a
3	2-strand	flax (w)	Z2s	22	1.84	3.5-4	0.4-0.5	Z	26	1.34	3.5	fig. 8a
4	2-strand	lime bast	S2z	18	1.5	3	0.2-0.4	S	22	1.6	2-2.5	fig. 8c
5	2-strand	flax (f)	S2z	18	1.12	4	0.2-0.3	S	24	1.1	3-5	fig. 7b
6	3-strand	flax (w)	Z3s	32	4.3	1.5	0.9-1.4	Z	29	3.6	2	fig. 9b
7	3-strand	lime bast	Z3s	23	3.18	1.5-2	0.6-0.9	Z	30	2.82	2-2.5	fig. 9f
8	3-strand	lime bast	S3z	23	1.5	3-4	0.3-0.6	S	23	1.48	4	fig. 8d
9	3-strand	flax (w)	S3z	26	0.83	6-8	0.4-0.6	S	24	0.77	7	fig. 7c
10	3-strand	flax (f)	S3z	28	1.1	6-8	0.4-0.7	S	30	1.06	5	fig. 7d
11	4-strand	flax (f)	Z4s	32	1.64	7-7.5	0.9	Z	31	1.44	8	fig. 8b
12	4-strand	lime bast	Z4s	23	2.46	3.5	0.7-1.0	Z	30	2.43	3-4	fig. 9e
13	4-strand*	lime bast	S2z/4s	?	3.65	?	0.8-1.4	both	?	2.97	?	fig. 9c
14	4-strand*	flax (w)	S2z/4s	24	2.64	2.5	1.1-1.6	S	26	2.26	2	fig. 9d
15	4-strand	flax (w)	S4z	25	1.1	6-8	0.4-0.7	S	25	1.1	5-6	fig. 7e
16	2-strand	lime bast	Z2s	24	2.32	2-2.5	1	Z	28	2.24	2.5	fig. 9g
17	2-strand	lime bast	S2z	28	1.29	4-6	0.5	S	34	1.4	4-5	fig. 7f
18	2-strand	flax (w)	S2z	26	0.87	6-7	0.2	S	25	0.99	6-7	fig. 7g
19	2-strand	flax (w)	Z2s	23	1.66	3-3.5	0.7-1.2	Z	31	1.7	3-4	fig. 8e
20	2-strand	flax (f)	S2z	29	1.37	4-5	0.7	S	30	1.27	4-5	fig. 8f
21	2-strand	flax (f)	Z2s	28	0.8	6-7	0.3	Z	30	0.91	7	fig. 7h

Table 5: Technological analysis of different types of cords made during an archaeological experiment. \* Twist from 2-strand cord; fibre treatment process: w – water retting, f – field retting



No.	Type of pot	Typ of decorative motive (typ of textile product)	Impression depth (mm)	Twist direction	Twist angle	Width of cord (mm)	Number of twists per 1 cm	More detailed measurements in different parts of the ornament	
								Twist angle (contact points of the cords / other parts)	Number of twists per 1 cm (contact points of the cords / other parts)
1	mortar-shaped beaker (P)	no.1 (M1/A)	0.8-1.3	Z	22	2.22	1.5-2	N/A	N/A
2	mortar-shaped beaker (P)	no. 1 (cord*)	0.6-1.3	Z	27	1.94	3-4.5	N/A	N/A
3	hendless (?) amphora (M)	no. 1 (M1/B)	0.3-0.7	Z	18	1.66	2.5-3	N/A	N/A
4	hendless (?) amphora (M)	no. 1 (cord*)	0.5-0.7	Z	20	0.95	3	N/A	N/A
5	small beaker (K)	no. 1 (M1/B)	0.3-0.5	Z	19	1.44	2.5-3	N/A	N/A
6	small beaker (K)	no. 1 (cord*)	0.5-0.8	Z	20	1.28	2.5-3	N/A	N/A
7	amphora (D)	no. 2 (M2/A)	0.4-1.1	Z	14	1.44	2-3	13 / 16	2-3 / 3
8	amphora (D)	no 2 (M2/B)	0.5-1.0	Z	21	1.3	3-3.5	15 / 23	2.5-3 / 3-4
9	amphora (D)	no. 2 (cord)	0.4-0.9	Z	21	1	3-4	19 / 20	4-5 / 3-5
10	amphora (D)	no. 2 (M2/C)	0.3-0.5	Z	28	1.31	2.5-4	21 / 25	2.5-3 / 3.5-4
11	amphora (D)	no. 2 (cord)	0.3-0.9	Z	17	1.06	3-4	15 / 18	3-4 / 3-4
12	cup (B)	no. 3 (M3/B)	0.6-0.8	Z	22	1.26	3-5	14 / 24	2.5-3 / 3-5
13	cup (B)	no. 2 (cord)	0.5-0.8	Z	22	1.19	4	20 / 19	3.5-4 / 3.5-4
14	cup (B)	no. 3 (M3/B)	0.4-0.9	Z	20	1.17	3-3.5	18 / 22	3 / 3-3.5

Table 6: Technological analysis of textile impressions on vessels made during an archaeological experiment. Abbreviations: P Pietrzykowo; M Marszowice; K Kowalewko; D Dobrzejowice; B Brodno; N/A not applicable. \* cord wound on a stick



has been devoted to the technical analysis of the cord ornament. It is only in the past decade that it has become an important source material for the study of textile production in the Neolithic period (Grömer and Kern 2010; Sikorski 2010; Kaczmarek 2015; Skrzyniecka 2020).

### *Methods*

The study was carried out using commonly accepted research methods for the analysis of textile impressions (Drooker 2000, 59–68; Marian 2009, 120–121; Grömer and Kern 2010, 3136–3137; Skrzyniecka 2020, 235–238; Kaczmarek 2023, 23). Positive casts were analysed using a Dino-Lite Premier AM4113ZT(R4) digital microscope. Impressions collected from the surface of the ceramic vessels using self-hardening sculpting clay (FIMO Air Basic®) were subjected to microscopic observation (Drooker 2000, 59; Skrzyniecka 2020, 235; Kaczmarek 2023, 23).

The categories of data on structural features included: twist direction (Z or S-twisted); width (mm) of the yarn imprints; twist angle (in degrees) indicating the intensity of the cord twist (loose, medium, or tight); and density measured by number of twists per centimetre (table 4). The results of the measurements were used to identify the technical parameters of the textiles and the techniques for making an impression (Hurley 1979, 5–13; Emery 1980, 8–14; Grömer and Kern 2010, 314).

Taxonomic analyses were also carried out to determine the depth and location of the impression, as well as the type of temper added to ceramic mass (recognised macroscopically only), wall thickness, firing technique, the vessel type, and state of preservation (table 3) (Czebreszuk et al. 2006).

The results of the measurements obtained during the analyses do not fully reflect the dimensions of the impressed textile products. The ceramic mass shrinks during the drying and firing process, similar to casts made with various modelling clays (Drooker 2000, 61–62; Grömer and Kern 2010, 3141; Harris 2013, 112; Ulanowska 2021, 116). Another limitation results from the deformation occurring when textile materials are applied to the soft clay (Podkańska 2012, 207; Ulanowska 2021, 116).

The measurements were taken on impressions and, therefore, accurately reflect the original structure of the product. Three terms based on the diameter of the element are identified in the literature: thread – up to 2 mm, cord – between 2 mm and 8 mm, and rope – more than 8 mm (Rast-Eicher 1997, 305; Grömer and Kern 2010, 3136–3138; Harris 2014, 6; Andersson Strand 2015, 48). The impressions identified in the

analysed set are less than 2 mm in diameter. Despite this, for the sake of consistency, it was decided to use the traditional nomenclature of “cord ornaments”.

The textile materials were all made of plant fibres, as indicated by the sharp edges of the fibres in the negatives (Rast-Eicher 2005, 118–119; Grömer and Kern 2010, 3144; Harris 2013, 113; Skrzyniecka 2020, 238). No attempt was made to identify the raw material more precisely because of the relatively high lack of certainty of such assessments solely based on the impressions (Kordysh 1951, 104; Marian 2009, 84–87; Chmielewski 2009, 226; Rammo 2018, 117; Lukesova and Holst 2021, 217).

### *Results*

The elements that dominate in the analysed set are vessels of small size preserved in their entirety (between about 10 cm and 20 cm in height) (fig. 2). Most of them were formed from lean clay with a temper of coarse to medium-grained crushed stone. Some vessels also have a temper of sand and grog. Thin-walled vessels (up to 6 mm) fired in an oxidising atmosphere dominate. The following vessel forms can be identified based on morphological features: amphora (7), beaker (6), cup (4), and bowl (2) (table 3). The identified textile impressions are located on the outer surface of the vessel, on the neck and on the upper part of the body. They can be classified as decorative textiles, used for the ornamentation of ceramic vessels just after their forming but before firing.

A total of 18 vessels were made of S-twisted cords. Only one was possibly made of a Z-twisted cord (table 4.10). Tightly twisted cords dominated (with a twist angle between 25 and 45 degrees). Only in the case of four samples, were medium-sized twist angles (between 10 and 25 degrees) identified (table 4.7, 8, 12, and 13). The average width of a single impression on the samples ranged from 0.52 mm to 1.84 mm, with the dominant value being 1.0 mm or thicker. In four cases, the average thickness of the cord was between 0.52 mm and 0.99 mm (table 4.1, 6, 7, and 10). The number of cord twists per centimetre was from two to seven.

In the case of five vessels, additional single yarns or fibres were observed between the main cords forming the ornament. The width of a single impression of yarns or fibres ranged from 0.38 mm to 0.87 mm (table 4.4, 5, 12, 16 and 18).

It was concluded that on eight of the 19 vessels the ornaments were achieved by applying individual fragments of cords or threads by hand. The features indicating the use of “free-hand” cords to decorate



the vessels were the visible starting and ending points where the cord was twisted around the neck of the vessel (fig. 2a, b, o, and p; fig. 3g) or the meeting point of the two ends of one of the all-round horizontal cords (fig. 2c and m; fig. 3c, f, and h). Another feature is a simple decorative motif, which is easy to obtain using a “free-hand” cord impression (fig. 2h and r). Textile constructions could have been used to decorate six vessels (fig. 2d–g, s, and t). On this set, it was possible to observe the repetitive nature of the ornamentation, its even distribution on the vessel, or the connections between the different areas of the ornamentation (fig. 3a, b, d, and e). In the case of five vessels, it was not possible to corroborate whether a textile construction or “free-hand” cord were used due to the significant degradation of the surfaces in the area where the ornamentation is placed (fig. 2i–l, and n).

All identified textile impressions might be considered to have been made by non-woven products. Visible negatives of twisted fibrous structures suggest that the products used were made of twisted cords (Reichert 2020; 2021, 74). In the case of textile constructions, these are composite products, the base unit of which was also a twisted cord.

### Experimental research

The experimental research was designed to verify whether the ornaments on the selected set of vessels could have been made with the use of textile constructions. The technical parameters of cords made from different numbers of strands were also tested. For this purpose, previously prepared textiles were impressed on clay plates and/or freshly made pots. Subsequently, the results from the experimental tests were compared with the impressions from the original vessels. The analyses were carried out using a digital microscope (Dino-Lite Premier AM4113ZT(R4)).

Only plant fibres (lime bast and flax fibres) were used for the tests. As the results of the research carried out on material from Swiss and German pile dwellings showed, both flax and bast were known and used in textile production during the Neolithic period (Gleba and Mannering 2012, 5; Grömer 2016, 42; Harris et al. 2016, 3–4; Siennicka et al. 2018, 4; Karg 2020; Banck-Burgess and Rosch 2021). Previous experiments did not confirm the use of wool textiles during ornamentation of clay vessels therefore they were not used in this experiment (Grömer and Kern 2010, 3142; Ferrero 2014). Furthermore, technological analyses of the textile impressions of the archaeological material likewise did not confirm the use of wool

products. Horse and human hair were not used in this experiment. However, it should be noted that it has already been recognised as a potential raw textile material used in the decoration of Neolithic ceramic vessels (Grömer and Kern 2010).

The textiles used for the experiment were made by hand, from raw plant materials processed using traditional techniques.

Flax fibres were obtained from the stalks of the modern variety of fibre flax, Modran (*Linum usitatissimum* L.), sown and harvested in 2021. Subsequently, the stalks were divided into two parts and subjected to field retting or water retting. Bast was derived from two stems of the small-leaved lime tree (*Tilia cordata*). The trees were felled in mid-June 2020 and the bark strips were immersed in water.

A light-coloured clay with an admixture of approximately 25% of fine-grained grog was the ceramic material used for the experiments (Goerg & Schneider GS 254). The research questions posed did not concern the correlation between the quality of the impression and the type of ceramic material, so no special method of preparation was used. The vessels were dried but not fired due to the risk of cracking during the process.

### Research questions and experimental procedure

There are a number of publications discussing the basic principles and methodology of conducting experimental research (Coles 1977; Reynolds 1999; Paardekoooper 2019). According to all researchers, the most important element of a well-designed experiment is the formulation of a clear hypothesis in relation to the specific research problem, precise definition of the research procedure and comparison of the results obtained with archaeological data. Prior to the experiments, six research questions were formulated:

- 1) Was the ornamentation on the vessels made using textile constructions?
- 2) What technique was used to make them?
- 3) What features could indicate the use of a textile constructions?
- 4) Is it possible to make such a decoration using a “free-hand” cord?
- 5) How were they impressed?
- 6) Based on the impressions of the cord, is it possible to determine how many strands were used to make it?

To address the questions from the first to fifth, several versions of textile constructions were prepared, mimicking the ornamental motifs observed on the vessels. Only lime bast was used to prepare them.

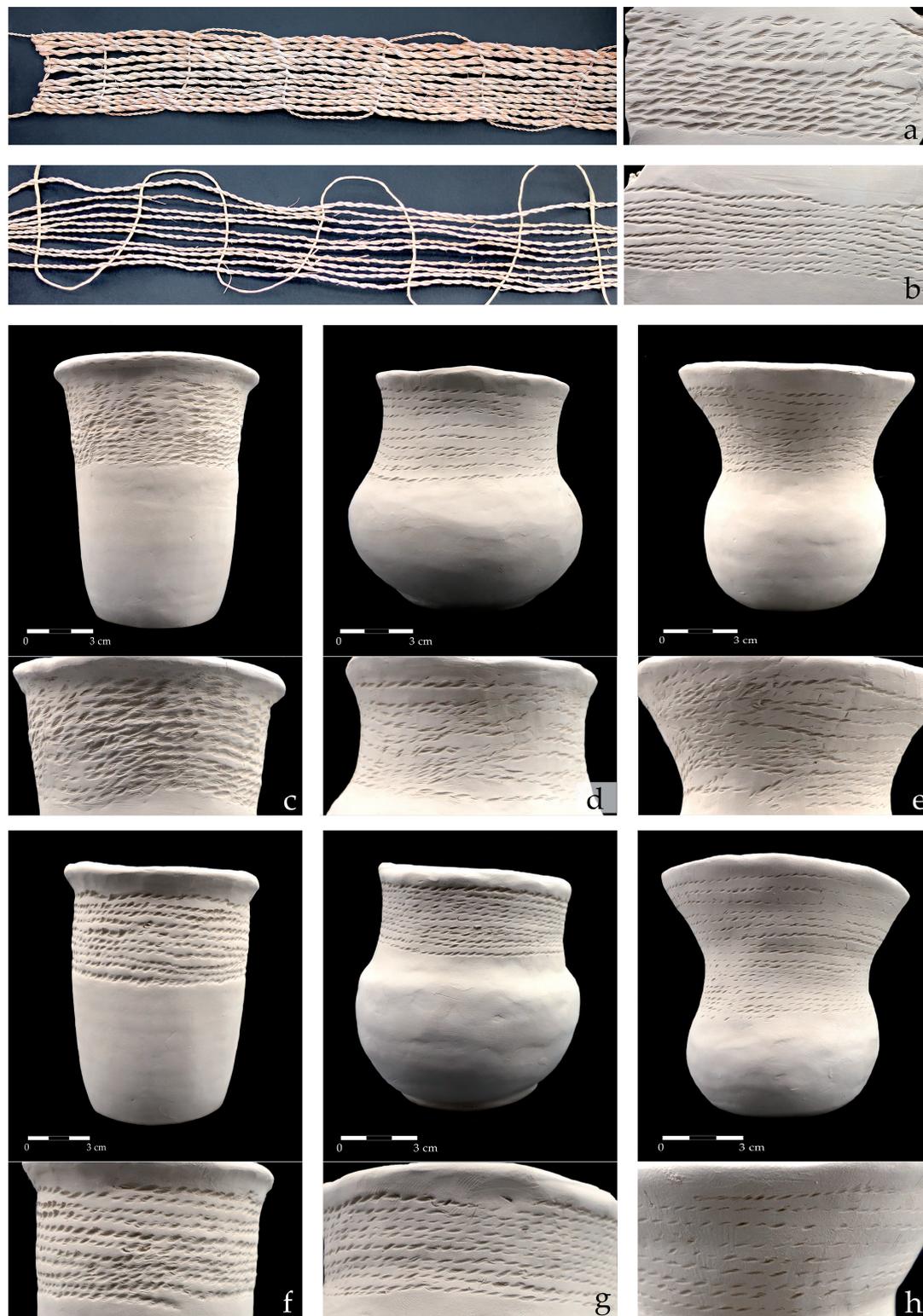


Fig. 4: Archaeological experiment. Decorative motive no. 1: a – textile construction M1/A and its impression on flat clay plate; b – textile construction M1/B and its impression on flat clay plate; c – impression of the textile construction M1/A on mortar shaped beaker and close-up of the place where the two ends of the textile construction meet; d – impression of the textile construction M1/B on handleless amphora and close-up of the place where the two ends of the textile construction meet; e – impression of the textile construction M1/B on small beaker and close-up of the place where the two ends of the textile construction meet; f-h – impression of a cord wound on a stick and close-up of the starting and ending cord points (Image: Monika Kaczmarek)



Its rigid structure made it easier to interlace the different parts of the textile constructions by hand (without using an additional frame). The experiment was preceded by previous tests on the process of producing textile constructions.

The fibre products were imprinted on flat clay plates in order to verify whether the impressions obtained were similar to those observed on the archaeological material (fig. 4a–b; fig. 5a–c; fig. 6a–b). Then, five vessel forms (a mortar-shaped beaker, an amphora, a cup, a handle amphora, and a small amphora), on which the potential use of the textile constructions was identified, were prepared. The textile constructions were imprinted on the soft walls of the clay vessels (fig. 4c–e; fig. 5d–f; fig. 6c–d). Additional markings not observed on the archaeological material were carefully removed. The next stage of the experiment was to check the possibility and difficulty of making the analysed ornamental motifs with the so-called “free hand” cord impression (fig. 4f–h; fig. 5g–h; fig. 6e).

Neither the textile constructions nor the vessels were faithful copies of the archaeological material but rather approximations thereof, taking into account the curves and lines of the shapes. The same applies to the textile products. The fibres were twisted in the opposite direction. All the textile constructions were made of cords twisted counter-clockwise (Z-twist), while the textiles impressed on the archaeological material were twisted clockwise (S-twist). The research presented here should, therefore, be considered an experimental study of technological processes and the use of tools; in this case, the use of textile constructions in the process of decorating ceramic vessels (Outram 2008, 3).

An impression on wet clay does not fully reflect all the characteristics and technical parameters of the textile used to make it. The distortions resulting from the very process of making an impression on a soft material or preservation of only part of the textile (if it is three-dimensional) must be taken into account. Despite these limitations, an attempt was made to verify whether it is possible to capture differences in the structure of cords twisted from different numbers of strands and with different parameters. Similar experiments making impressions with cords made from a variety of fibres in clay have been carried out in the past (Grömer and Kern 2010). Their purpose, however, was to verify whether the quality and legibility of the impression was affected by the type of leaning temper added to the clay, the humidity level of the vessel during the process of ornamentation, and the type of fibre from which the cord was made.

All the textile constructions created during the experiment were made from two-strand cords. It was noted that the twist angle of the cord on most of the textiles created for the purpose of the experiments ranged between 15 degrees and 22 degrees (although in one case it was 28 degrees) and was looser than that recorded on the archaeological material (22 degrees to 38 degrees). For this reason, it was decided to check for a correlation between the parameters of the cord impression and the number of strands from which it was made. It was also decided to include coarse cords, even though they were not identified in the archaeological sources. In addition, it was possible to observe differences in imprints depending on the different cord thicknesses.

A total of 21 cords were prepared using the twining technique (both the S and Z-twists). The plant fibre cords were twisted by hand from two, three, or four strands. Subsequently, the textiles were pressed onto freshly formed clay plates and left to dry (without firing) (fig. 7–9). Impressions were then taken from the surface of the clay plates using a self-hardening sculpting clay and analyses of the textiles and their impressions were carried out (table 5).

### *Results of experiments*

The possibility of using textile constructions for ornamentation was identified for six ceramic vessels, in the case of which the ornaments displayed similar motifs and could be classified into three types. This suggests that these ornamental motifs could have been made using a similar textile construction. However, this does not mean that the decoration on the vessels were made using the same textile product. This possibility only exists in the case of vessels from the same grave, which were created and deposited at the same time.

The method of making three types of textile constructions and the features indicative of their use to decorate vessels are presented separately for each of the ornaments. The technique used to prepare all the textile constructions closely corresponded to plaiting techniques. They were made from several twisted cords, interlaced together and creating specific textile products.

All textile constructions and cords were imprinted on the freshly formed and moist vessel walls. Thanks to this, the textiles adhered better to the fresh wall of the clay vessel. This made the imprint more visible (Grömer and Kern 2010, 3142; Ferrero 2014). Wetting the fibres also made it easier to apply the product



evenly on the wall of the vessel. It also prevented fibrous products from coming unstuck when they were applied.

The textile products were pressed tightly against the entire width of the vessel, with each element carefully pushed with the fingers. Textile constructions constituting decorative motifs were pressed onto the vessel as a single action. Applying a textile construction in this way does not exclude the use of other techniques to create subsequent motifs on the same vessel.

In the case of all-round ornaments made without textile constructions, the cord was wound on a stick and then wrapped around the vessel neck. In this way, it was possible to obtain even and proportional impressions. The remaining decorative motifs were

made by pressing individual pieces of cord onto vessel walls without using any tools.

#### *Decorative motif number one – multiple cord impressions*

A feature indicative of the use of a textile construction was the absence of a visible start and end point where the cord was twisted around the neck of the vessel. The meeting points of the cord ends imprinted all around the vessel were not visible either. The number of cord imprints around the entire surface of the pots was even.

The possible use of this type of textile construction was recognised on two vessels: a mortar-shaped beaker from Pierzykowice (fig. 2f) and a small beaker from Kowalewko (fig. 2e). Despite the damage, experimental copies of the amphora without handles from



Fig. 5: Archaeological experiment. Decorative motive no. 2: a – textile construction M2/A and its impression on flat clay plate; b – textile construction M2/B and its impression on flat clay plate; c – textile construction M2/C and its impression on flat clay plate; d – impression of the textile construction M2/A on the vessel and close-up of the decoration; e – impression of the textile construction M2/B on the vessel and close-up of the decoration; f – impression of the textile construction M2/C on the vessel and close-up of the decoration; g and h – “free-hand” cord impression on the vessels and close-up of the decoration; i – positive cast from experimental vessel (textile construction M2/C); j – positive cast from experimental vessel (textile construction M2/B); k – positive cast from experimental vessel (“free-hand” cord) (Image: Monika Kaczmarek)



Marszowice (fig. 2l) were made to verify whether the shape of the vessel could be ornamented using textile constructions. It should be noted that the vessel from Pierzykowice also has minor damage in the decoration zone. Therefore, observing any diagnostic features that indicate textile construction use is complicated.

The textile constructions were made from several twisted two-strand cords, joined together by another, thinner cord. The cord connecting the structure was interlaced into the interior of the cords forming the stem of the textile constructions. A characteristic feature of such a textile construction is the ability to modify the spacing between the horizontally distributed elements by changing the position of the stabilising cord.

Two textile constructions were prepared – from fine (fig. 4b) and medium cords (fig. 4a). During the experiment, three vessels were made and decorated using textile constructions (table 6.1, 3 and 5) and three by “free-hand” cord impressions (table 6.2, 4, and 6). The impression on the vessel from Pierzykowice made by a textile construction in the experiments is proportional and looks similar to the one observed on the original vessel. The distribution of each line is relatively even.

It is difficult to verify whether their number is equal over the entire surface of the vessel because the cords are placed very close to each other. This close spacing also hid the connecting cord. If the spacing between the horizontal cords was wider, the markings left by the connecting element could still be covered easily. It was also possible to connect both ends of the textile construction in such a way as not to disturb the uniform pattern of the decoration and avoid leave the meeting points visible (fig. 4c).

It was impossible to confirm the use of a textile construction to make the motif of distant horizontal lines. The shape of the small beaker from Kowalewko made it complicated to apply the textile product evenly and thus achieve a proportional decoration. It was also not possible to connect the two ends of the textile construction in such a way as to obtain the same number of cord lines covering the entire surface of the vessel (fig. 4e). Creating a decoration by using a textile construction on an amphora from Marszowice, it was possible to obtain a proportional impression on almost all of vessel. The only problem was in an area where the two ends of the textile met. In this case, it was also not possible to connect them evenly and invisibly (fig. 4d). The “free-hand” cord impression was made by imprinting horizontal lines using a cord wound on a stick. The decoration created in this way was even and well distributed over the entire surface of all the vessels. However, it was impossible to hide the starting and ending points where the cord was wrapped

around the neck of the vessel (fig. 4f–h). Additionally, when trying to recreate the decoration from a mortar-shaped beaker from Pierzykowice, it was not possible to imprint the cords as close to each other as in the case of the model vessel (fig. 4f).

#### *Decorative motif number two – hatched triangles or festoons*

A feature indicative of the use of a textile construction for this type of ornament is overlapping parts of individual festoons. It was also observed that one of the end cords, which fills festoon number one, is also the bottom edge of festoon number two (fig. 3d). Another feature indicative of the use of textile products is that successive fragments of cords arranged vertically are woven into the horizontal cord. The individual strands making the ornament were consistently placed in between each other (in almost every segment) (fig. 3d–e). The twist angle of the cord is looser in the area where the individual ornamental motifs are adjacent to each other compared to other areas of the ornament. The same correlation was also observed for the twist density of the cord (numbers of twists per cm). This was lower for the areas where the different parts of the ornament intertwined with one another than elsewhere (table 4.11–12).

The possibility of using this type of textile construction was recognised on two amphorae from Dobrzejowice. The first vessel, only partially preserved, shows hatched triangles (fig. 2s). The decoration on the second vessel is made of hatched festoons (fig. 2t). It should be emphasised that the analysis of the ornaments was difficult because of the fragmentation of the vessels, mainly in the area covered with ornamentation. The decoration on the neck of both amphorae was made by using a “free-hand” impression of the cord, as indicated by the visible meeting point of the cord ends (fig. 3h).

Three textile constructions were prepared – two composed of hatched festoons (fig. 5a–b) and one of triangles (fig. 5c). They were made by interlacing short pieces of cord. The base was a longer horizontal cord, to which shorter cords were attached vertically. These were successively woven into the cord forming the edge of the festoon or the first side of the triangle. Finally, the cord being the festoon edge was woven into the main cord or, in the case of the triangle, the second side was woven into first one. Three vessels were made and decorated using this type of textile construction (fig. 5d–f) and another two by “free-hand” cord impressions (fig. 5g–h).

Attempts to recreate the ornamentation using textile construction number two were quite successful. In this case, the characteristic features identified on the



Fig. 6: Archaeological experiment. Decorative motive no. 3: a – textile construction M3/A and its impression on flat clay plate; b – textile construction M3/B and its impression on flat clay plate; c – impression of the textile construction M3/A on the vessel, close-up of the decoration and positive cast; d – impression of the textile construction M3/B on the vessel, close-up of the decoration and positive cast; e – “free-hand” cord impression on the vessel, close-up of the decoration and positive cast (Image: Monika Kaczmarek)

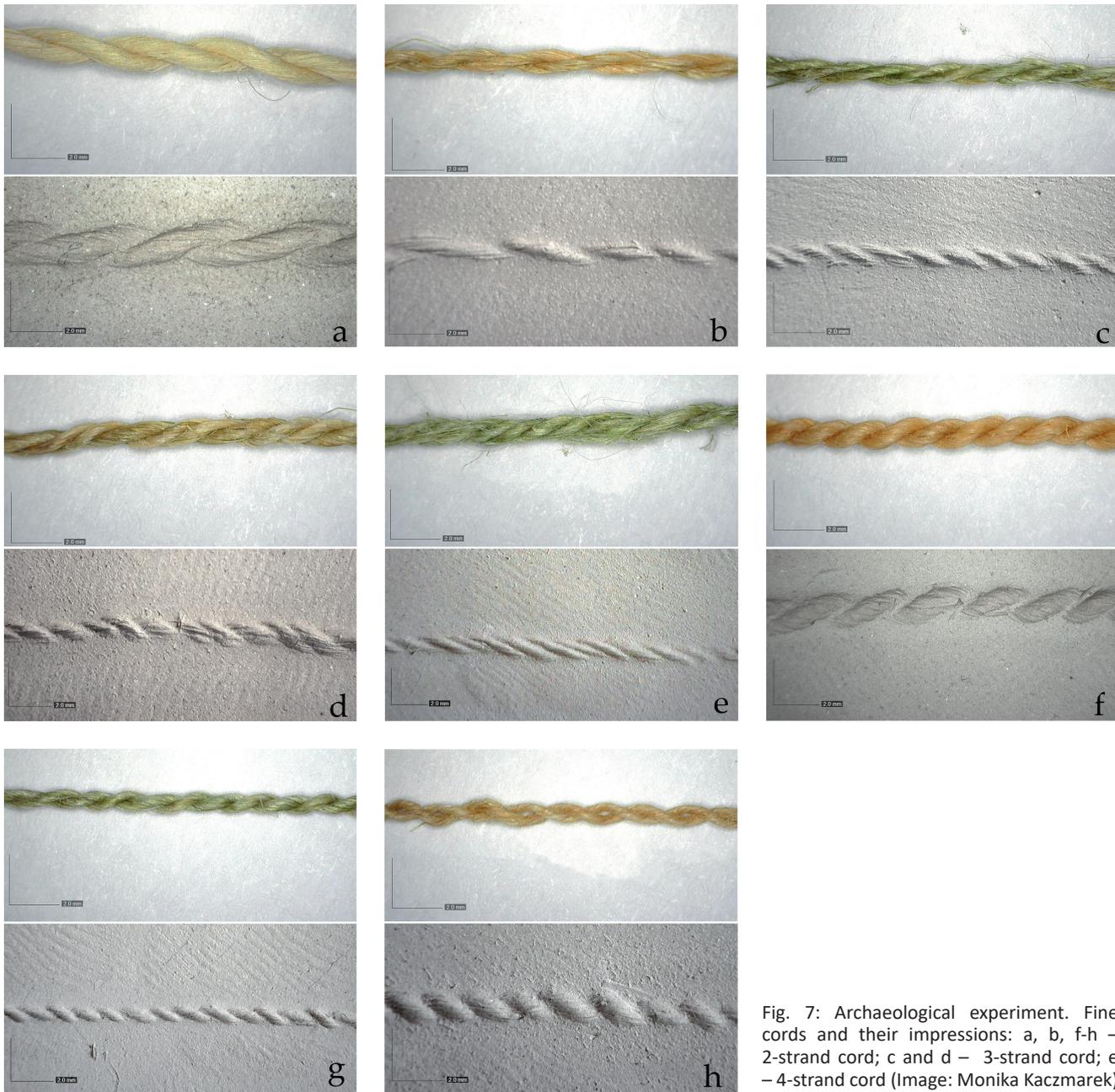


Fig. 7: Archaeological experiment. Fine cords and their impressions: a, b, f-h – 2-strand cord; c and d – 3-strand cord; e – 4-strand cord (Image: Monika Kaczmarek)

archaeological material coincided with the results of the experiment conducted on the three-dimensional form of the vessel (table 6.7, 8, and 10). The impression of the triangle is even and looks similar to the one observed on the original vessel (fig. 5f and j). The motif of festoons obtained using a textile construction is slightly less uniform over the entire surface of the vessel. Although not as precise as that of the archaeological material, it is clearly well proportioned (fig. 5d, e, and i).

The “free-hand” cord impression was made by

printing a horizontal line at the bottom of the neck, then making the outline of a festoon or triangle and filling it with diagonal lines. Finally, all-round cord impressions were made on the neck of the amphora by winding it on a stick and then pressing it on the amphora (fig. 5g–h).

It is possible to make this type of decorative motif by pressing the “free-hand” cord. The ornament made in this way is proportional and looks similar to the one observed on archaeological material. However,



the individual strands making the ornament were not consistently placed in between each other. It was also not observed that the lines filling the triangles and festoons were woven into the edge lines. The line forming the edge of the festoon or triangle appears sometimes above the hatched cord lines and sometimes below them (fig. 5k). In this case, the characteristic features identified on the archaeological material do not coincide with the results of the experiment conducted on the three-dimensional form of the vessel (table 6.9 and 11). The decoration made in this way is also not evenly pressed onto the entire surface of the vessel as in the case of an impression using a textile construction (fig 5g-h).

*Decorative motif number three – diagonal and slope lines surrounded by horizontal lines below and above*

A feature indicative of the possible use of textile constructions in this type of decorative motif is the even distribution and proportional placement of the impression. Overlapping of cords in horizontal and vertical arrangements is also observed, which may be indicative of their interlacing (fig. 3a-b). It was also

possible to identify characteristic metrical features, that is a looser twist of the cord in the part where the horizontal and vertical impressions meet compared to other parts of the ornament (table 4.3, and 16). The possible use of this type of textile constructions was recognised on two cups: from Žnin (fig. 2d) and from Brodno (fig. 2g).

The textile constructions prepared as part of the experiment were modelled on the decoration on a vessel found in Brodno. It was made by intertwining different lengths of cord fragments. Four horizontal, longer fibre fragments were woven into a short vertical cord. This established fixed spacing between the horizontal parts of the cords from the start, which made it much easier to maintain the correct proportions when creating the textile products. The horizontal fibres were then twisted into cords and short vertical cords were woven in between them at specific points. Shorter cord fragments were woven in diagonally. Two textile constructions were prepared – with two and one horizontal lines above and below the diagonal lines (fig. 6a-b).

Two vessels were made and decorated using this type of textile construction (fig. 6c-d) and one by

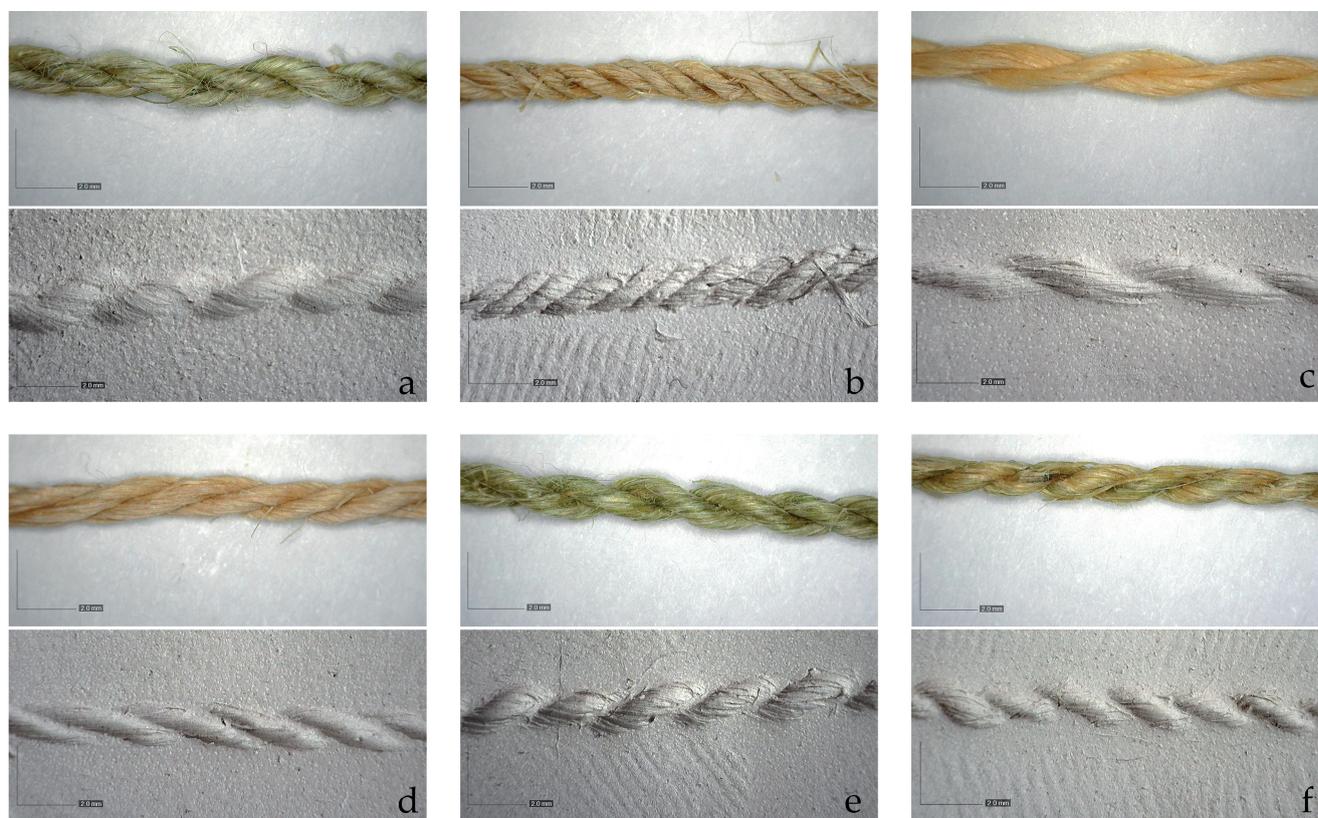


Fig. 8: Archaeological experiment. Medium cords and their impressions: a, c, e and f – 2-strand cord; b – 4-strand cord; d – 3-strand cord (Image: Monika Kaczmarek)

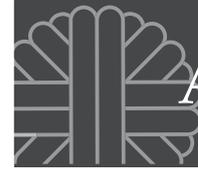


Fig. 9: Archaeological experiment. Coarse cords and their impressions: a and g – 2-strand cord; b and f – 3-strand cord; c-e – 4-strand cord (Image: Monika Kaczmarek)

“free-hand” cord impressions (fig. 6e). Attempts to recreate the ornamentation using textile constructions was problematic. Although similar metric values (twist angles) were obtained (table 6.12 and 14), the uniformity of the resulting impression was not satisfactory. The experiment did not produce an ornament as uniform and well-proportioned as on the vessel from Brodno. The impressions obtained during the experiment are similar to the ornament identified on the cup found in Žnin, which has vertical cord impressions arranged at an angle in a less uniform, wavy manner (fig. 3b). The area of the all-round horizontal cords was the most

problematic. It was not possible to obtain impressions parallel to the edge of the vessel as observed on the archaeological material (fig. 6c–d).

The “free-hand” cord impression was made by imprinting horizontal lines using a cord wound on a stick and then making diagonal lines by pressing individual pieces of cord. The resulting decoration is even and well distributed over the entire surface of the vessel. The print resembles the one on the cup from Brodno (fig. 3a). The only difference is that the lines of the diagonal systems do not interlace into horizontal lines but overlap irregularly. Additionally, an attempt



to remove traces of vertical lines resulted in minor blurring of all-round cords (fig. 6e). The experimental results (table 6.13) do not coincide with the characteristic features identified in the archaeological material.

*Comparison of impressions made with the use of cords twisted from different numbers of strands*

For the purpose of the experiment, cords in three thicknesses were prepared: fine (up to 1.3 mm diameter) (fig. 7), medium (up to 2 mm) (fig. 8), and coarse (more than 2 mm) (fig. 9). When twisting cords numbers 16 to 21, care was taken to separate the strands slightly after crossing them, so as to ensure a more compact structure for the cord and a tighter twist (Reichert 2021, 71).

Among cords made from two strands, those with a medium twist angle (average angle in the range of 19 degrees to 27 degrees) dominated. The number of cord twists per cm was from 1.5 to 4 (table 5.1–5). The situation was different in the case of cords twisted in such a way as to increase the distance between the strands (table 5.16–21). The twist angle in this case varied between 25 degrees and 34 degrees (tightly twisted). The number of twists per cm also increased. In the case of the experimental samples analysed, it was from 2.5 to 7 twists (table 5.16–21).

For the three-strand cords, the tightly twisted angle dominated, with an average value ranging from 23 degrees to 30 degrees. The number of cord twists per cm was from 2 to 7 (table 5.6–10).

All four-strand cords had a tight twist angle, the average value of which ranged from 25 degrees to 31 degrees. The number of cord twists per cm was from 2 to 7 (table 5.11–15). Based on the observations made during the experiments, it was not possible to determine whether the cord was made of two or three strands based on the textile impression alone. Both types of cords seemed to have a two-strand structure. The twist angle of two-strand cords can be either medium or tight, depending on how the strands are twisted together.

The difference in negatives of the impressions is apparent only for four-strand cords, the structure of which is much more compact (fig. 7e; fig. 8b; fig. 9e). In these cases, both the twist angle and the number of twists per cm is higher than elsewhere. The structure is fairly even, although there are variations in the widths of the individual cord segments. This is probably due to errors made during the twining process. It was this type of cord that was the most difficult to create. Considerable concentration was

required when twining, in order to twist the strands in the right order.

The impression obtained with the four-strand cord, twisted from two-strand ones, differs considerably from others in the set (fig. 9c–d). The structure of the original twist is visible and clearly shows that the textile is made from a larger number of strands than other examples. The negatives look more like braided cords than twisted ones. Cord number 14 is also highly decorative, but both cords had a considerable diameter. In the case of thinner cords, these features were not as pronounced.

The diameter of the textile increases with the number of strands, as a result of using more fibres or strips of bast. The structure of the lime bast textiles is slightly stiffer than those made from flax fibres. However, this does not affect the visibility of the impression made in clay on the vessels. The most pronounced are the negatives of cords that are larger in diameter and more tightly twisted. They also leave a deeper impression (table 5).

Differences were also noted in the measurement results for the textiles and their impressions in clay. This is probably due to shrinkage of the drying clay and deformation caused by pressing the cord against the wet clay. In the case of manual processing of natural fibres, the resulting product is not uniform along the entire surface, and the thickness and angle of twist may vary slightly.

## Discussion

The set of vessels analysed featured impressions of decorative textiles only. These included impressions possibly made with textile constructions from fine or coarse plant fibres but also from so-called “free-hand” cord impressions. However, ornaments made using the latter method dominate.

No traces of technical textile impressions have been identified. It looks as though all the impressions that were not decorative were carefully removed. The small size of the vessels make them easy to lift, and any undesirable marks could be smoothed out. Negative impressions of Neolithic technical textiles have been identified on ceramic material from settlement sites within the Polish lowlands. Nevertheless, such impressions are rare and associated almost exclusively with one type of vessels – flat plates (Słomska 2018; Kaczmarek 2023). This may indicate a marginal use of technical textiles in the making of clay vessels in the Middle and Late Neolithic period.

Numerous documented experiments and tests



related to the use of textiles at various stages of prehistoric pottery production have been conducted (Hurley 1979; Dumpe 2006; Hurcombe 2008; Grömer and Kern 2010, 2015; Ferrero 2014; Dubovtseva 2016; Rammo 2018; Ankusheva 2020). However, only one of these was an attempt to recreate an ornament on a three-dimensional vessel (Wiedermann 2012), which tested the possibility of reproducing an ornament in the form of a cord impression using a circular knurl. Impressions of a textile, be it a textile construction or a “free hand” cord impression, are much more complicated to reproduce on a three-dimensional vessel than on a clay plate (fig. 4–6). In addition, when making impressions of a textile on a flat surface, it is not possible to observe the meeting points of the textile constructions. It is the even distribution of the textile constructions and their precise arrangement on the vessel that poses the greatest challenges.

In the case of nearly all the textiles prepared in these experiments, the twist angle of the cords making up the textile constructions was much looser than that on the archaeological material (table 4 and 6). This indicates that the textiles used to decorate the original vessels were very carefully made. The compactness of the twist angle of the cord can be achieved in two ways: the first is to carefully separate the two strands of the cord when twisting them; the second is to make the cords from more than one strand (for example, a three-strand cord). Both methods are quite simple but achieve greater compactness and uniformity in the resulting product.

Not all the impressions of the textile constructions obtained during the experiment, were as uniform and accurate despite resembling the negatives observed on the archaeological material. This may be due to the type of the raw material used to make them, a different fibre treatment process, or the looser twist of the fibres. In addition, prehistoric craftsmen were much more manually dexterous than contemporary people (Nørgaard 2008, 45; Outram 2008, 4). Another important factor was the experience and years of practice of the ancient potters and natural fibre processors. It can also be assumed that there may have been other, more sophisticated methods of creating textile products used to decorate clay containers in the past.

The vast majority of the impressions identified on the set of vessels analysed were made from cords twisted clockwise (S-twist). One exception was the impression on the amphora found in Gubin. In this case, however, it is questionable whether the impression was made with a fibrous textile. The heavily damaged fragments of the vessel make it difficult to discern the twist

angle of a potential cord impression (fig. 2k). The use of a knurl or other non-textile tool seems more likely (Wiedermann 2012).

A preference for twisting cords clockwise (S-twist) during the Neolithic period has also been observed in organic material from Swiss pile dwellings and pottery from other regions of Europe (Rast-Eicher 1997; Grömer and Kern 2010; Skrzyniecka 2020). However, in these experiments, the cords making up the textile constructions were twisted in the opposite direction. The counter-clockwise twist (Z-twist), although different from the archaeological findings, was selected for the convenience of a right-handed person brought up in a western European culture. In these circumstances, it is more ergonomic to twist from left to right when making advanced textiles. However, changing the direction of the fibre twist is not too problematic when making simple textile products such as a two-strand cord, as corroborated by experimentation (Reichert 2021, 72). Problems did, however, arise when twisting cords made of more than two strands, with four-strand cords requiring close attention and being the most difficult to produce. The most time consuming and error-prone method was twisting four strands clockwise. The order of the subsequent fibres was mixed much more frequently compared to other methods. It was also observed that twisting the strands in the clockwise direction caused pain in the left hand, which was not experienced when the fibres were twisted counter-clockwise. This observation is in contrast to previous conclusions (Rast-Eicher 1997), which suggested that the S-twist is more ergonomic for right-handed people. However, as mentioned earlier, prehistoric craftsmen were much more dexterous than modern humans and changing the direction of fibre twist may not have been a problem for them. Twisting cords clockwise may also result from traditions at the time or the use of a different fibre twisting technique. There may have been a number of different techniques and methods for making cords as well as threads in the past (Tiedemann and Jakes 2006; Hardy 2007; Andersson Strand 2015, 46; Gleba and Harris 2019, 2342; Reichert 2021).

Another interesting observation made during the analysis of the archaeological material was the presence of single threads or fibres between the main elements of the ornament. It is possible that these are traces of fine fibres that have been separated from the cord that makes up the ornament, as a result of repeated use of the same textile construction several times. Such fibres are clearly visible in the textile construction used in the experiments (fig. 4a–b; fig.



5a–c; fig. 6a–b). However, they could not be observed on impressions made during the tests. This requires further research.

### Conclusion

It can be assumed that vessels with textile decoration were unique products. Making a complicated ornament required time and precision. It was therefore a carefully thought-out and planned process. The advantage of using textile constructions was that they could be reused for decorating subsequent vessels. Nevertheless, the number of funerary vessels decorated with cord ornaments discovered in the area of the western part of the Polish lowlands is not large. Out of 148 burial sites where ceramic vessels were found, only 23 contained vessels decorated with an ornament produced with the use of a textile (cord or potential textile construction). As a rule, each burial contained one decorated vessel of this type ornament. However, these data are incomplete. Some of the vessels, which were lost during the Second World War, were not accompanied by descriptive documentation or drawings which could be used to determine whether the vessels were decorated or what technique was used to make the ornaments. Out of this small set, only a few vessels feature an ornament that can be made using textile construction. The answer to this problem should come from analyses of the pottery from settlements, where more vessels with cord ornament and perhaps decorated with textile constructions may be discovered.

Textile constructions were not necessarily used for the entire ornament. They could be used to impress the more complicated and challenging parts of the ornament. Other motifs could be made with “free-hand” cord impressions. Both impressions on the source material and those obtained in the experiments confirm that some parts of the textile construction impressions can be successfully removed without damaging the ornament and the body of the vessel.

There may be many more ways of creating the textile constructions as well as decorative patterns with cords. The results of previous studies confirm the use of a cord stamp (Kaczmarek 2015), a cord wound on a stick (Dubovtseva 2016, 84) and cords twisted from multiple strands (Hurley 1979; Dumpe 2006). Such tools could be imprinted, rolled over the surface of the vessel, as well as alternately pressed against the surface and lifted.

The results of analyses and experiments confirmed the possible use of textile constructions to produce ornaments on five ceramic vessels. In the case of the set of vessels analysed, the textile constructions were

made by interlacing fragments of cords of different lengths. No traces of the use of technical textiles were observed on any of the examined vessels. This may be because of the careful removal of any undesirable impressions by the craftspeople and/or the infrequent use of this type of textile in making vessels during the era.

The number of funerary vessels found decorated with cord ornaments, especially with more complex motifs, is not large. It can therefore be presumed that these were considered exclusive goods. Making an ornament with a cord takes considerably more time than other decorative techniques known to have been used at the time. This applies both to the time needed for the preparation of cords or the textile constructions and the processing of the natural raw material, careful design of the form of the vessel, and precise planning of the placement of the textile constructions. Taking into account how many factors came into play to achieve a precise and uniform cord impression, the craftsmanship of Neolithic potters and natural fibre processors must be appreciated.

The evidence discussed here covers a period of approximately 1,000 years, so the observed practices cannot be considered contemporary. The research, although constrained by certain limitations, is an important source of information on the methods of pottery decoration and textile production in the Neolithic period. The vessels decorated with cord ornamentation from other archaeological contexts should also be considered as valuable evidence. However, analysis is more difficult in the case of fragmented ceramic material. It is recommended that subsequent studies expand the base of raw materials tested with, for example, horse hair and hemp.

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