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Meaning of spindle whorls

Log in Spinning with a whorl (c) on a spindle (b) and distaff (above) A spindle whorl is a disc or spherical object fitted onto the spindle to increase and maintain the speed of the spin. For ages the whorls have been made of many different materials: amber, antler, bone, ceramic, coral, glass, metal (iron, lead, lead alloy), and wood (oak). Some types of local materials have been also used, such as chalk, limestone, mudstone, sandstone, slate, and soapstone. One of the most famous spindle whorl artists is Susan Point. Gallery Spindle Whorl (Sulsultin), Chemainus, Coast Salish (Native American), 19th century, Brooklyn Museum Whorl (12th or 13th century) found in Poland Ancient Greek spindle whorls, 10th century BC, Kerameikos Archaeological Museum, Athens Muisca spindle whorl (500AD – 1500AD). Archaeology Museum, Sogamoso, Colombia Whorl made of antler, Viking Age (793–1066 AD), Björkö, Sweden Retrieved from " Spindle-whorls are tools used for transforming the mass of fibres into yarn. These tools can be made of a large variety of materials as ceramic, bone, wood, or glass. They can vary largely in shapes (conical, biconical, lenticular, etc…), size, and weight according to archaeological contexts and chronological period of human history. The recurring association of spindle-whorls with different measurements in the same archaeological site lead scholars to address this issue investigating the relationship between size/weight of the tool used and the quality of the final product or the spinning technique employed (Andersson Strand, 2012a, 2012b, pp.208-210 and references therein; Grömer, 2016 and references therein). Experimental archaeology is currently playing a key role in answering this research question and improving our knowledge regarding the actual use of textile tools in ancient social and economic contexts. Reconstructing use activities, in which spindle-whorls were involved, means to investigate human behaviours behind the steps of textile processes. Indeed, connecting material culture to specific stages of the fibre's processing provides a complete framework to improve our comprehension of the archaeological contexts. For example, spindle-whorls are commonly found in settlements or houses where they have a specific location which usually suggests the areas of the living space likely dedicated to the textile activity. Nevertheless spindle-whorls and other textile tools (according to the chronological period) are frequently unearthed from burials which were left as grave goods and deposited close to inhumations, or in urns within cremated remains; in these cases, small-sized spindle-whorls raised doubts regarding their use as textile tools or beads or even as ornaments in general (e.g. clothes clips). This requires a scientific approach favouring empirical data for interpreting material culture. Although experimental archaeology can provide insights into their functionality in spinning specific kind of fibres and or using specific techniques, the point relies on the connection between the results from experimental tests of use and the actual use of the archaeological items. For this reason, we suggest that integrating residue investigation and use-wear analysis on textile tools can represent the necessary step in this methodological framework. Indeed, such an approach allows us to identify wear or residues on tools, distinguish them from post-depositional alterations and interpret the actual use activities they were employed in. This can contribute to a better interpretation of the material culture and a wider comprehension of the archaeological contexts. This article provides an analytical protocol based on a dedicated experimental collection of residues deposited in and on spindle-whorls after repeated use in spinning activities. The experiments discussed here suggest that integrating residue analysis with a use-wear investigation (Forte and Lemorini, 2017) can provide a novel approach of research in the textile field and contribute to improving the methodology used so far to address the interpretation of textile tools. With this aim, the article discusses the results of the experimental research and define an analytical protocol to address the study of use traces on archaeological textile tools combining experimental archaeology with OLM and SEM. Materials and Methods The methodology applied in this study consists of a combination of experimental archaeology and use traces analysis at low and high magnification (low and high-power approach) in order to address the identification and investigation of spinning residues on spindle-whorls. The method presented here develops on the basis of an approach recently applied to investigate use wear on experimental and archaeological textile objects (see Forte and Lemorini, 2017 and references therein). The study of spinning residues in spindle-whorls for interpreting their actual use is a novel approach in textile research; the exception being for an article on organic remains found within the sediments extracted from the central hole of spindle-whorls from late prehistoric layers of Pyrgos (Cyprus) (Belgiorno and Lentini, 2011). These results show that it is possible to find mineralised or well-preserved fibres within or on tools and define their origin, but their extraction by floatation does not allow for distinguishing fibres from spinning or deposits due to contamination. Conversely, the results discussed here show how experimental archaeology can lead to exploring a series of important aspects: the process through which residue deposition on textile tools occurs, if it is possible to identify other kinds of residues associated with spinning (fibres, wood etc.), the relationship between residues and use wear affecting spindle-whorls, and the timing of residue formation. In this scenario, the application of an integrated low and high-power approach allows for a better characterisation of spinning residues through identifying fibres morphology and consequently establishing their nature (keratine- or cellulose-based fibres) and preferably their species. We present here a research protocol addressing these questions through a combination of experimental archaeology with OLM and SEM in order to identify and interpret residues deposited on textile tools during their use activities (See Figure 1). Experimental spinning and reference collection To analyse spinning residues, a dedicated experimental collection of ceramic spindle-whorls was made. Tools were produced using working clays of diverse compositions and granulometry, modelled by hand with the support of small wooden, bone or stone tools for piercing and refining the object's surfaces by smoothing or polishing. A framework of traces left by manufacture was also collected to characterise the topography of tools' surfaces before their use in experimental spinning activity and in order to avoid misinterpretations (see Forte and Lemorini, 2017). The experimental whorl items were fired reaching a range of temperatures within 800-900°C. Subsequently a program of experimental spinning was carried out by two expert spinners1 that used 9 ceramic replicas for spinning plant and animal fibres including flax, cotton, and wool through two main techniques: spinning with a low whorl drop spindle (See Figure 2), and spinning in a bowl with spindle-whorl at the bottom of a wooden spindle (Barber, 1991; Forte and Lemorini, 2017, p.18). The choice of two diverse spinning techniques aimed to ensure different controlled conditions of tool use. During the spinning on a drop spindle the external surfaces of the spindle-whorl did not any kind of contact with hard surfaces but only with the spinner's fingers or with the floor in case of accidental drops; the internal surface of the central hole interacts mechanically with the wooden spindle sliding over one another at the moment of assembly. Conversely, spinning in a bowl consists of performing the activity within a wooden bowl; in this case the spindle-whorl was located at the bottom of the wooden spindle and worked interacting continually with the wooden surface of the bowl. Also, in this case, the internal surface of the central hole interacts mechanically with the wooden spindle sliding over one another at the moment of assembly. On a total of nine experimental items involved in a spinning session of a duration of no more than 15 hours each, all showed spinning residues associated with use wear caused by performing the specific spinning techniques (See Table 1). Experimental spindle-whorls use wear and residues ID high (cm) width (cm) weight (g) fibre spinning technique top hole bottom hole top external surfaces bottom external surface 1 2,5 4 30,1 mixed low whorl drop spindle fibres+wood fibres+wood associated to polish detachment hole's edge+ detachment protruding parts detachment along the edge 2 2 2,5 14,3 mixed low whorl drop spindle fibres+wood fibres+wood associated to polish detachment along protruding part (with exposure of ceramic paste) detachment along the edge 3 1,5 1,5 3,3 mixed wooden bowl fibres+wood fibres+wood associated to polish rounding of the edge rounding of protruding parts 4 2,5 3 58,4 mixed low whorl drop spindle fibre fibres   5 2 4,3 33,3 mixed low whorl drop spindle fibres fibres   6 2 2,6 12,2 mixed low whorl drop spindle white residue fibres impairment protruding parts   7 1,7 2,2 7,9 flax low whorl drop spindle fibres+white residue   detachments along edge   8 1,5 1,8 4,5 cotton wooden bowl fibres+white residue   spall detachments along edge and extended rounding 9 2 2,2 4,7 wool low whorl drop spindle fibres+white residue   detachments along edge Table 1. Measurements of samples with use wear and residues caused by a controlled spinning activity. Low and high-power approach to investigate use traces The traces analysis on the ceramic replicas was carried out through a stereomicroscope and a reflected light system (low-power approach, Tringham et al., 1974; Van Gijn, 2010). integrated with analyses using SEM (high-power apparoach, Knutsson, 1988; Van Gijn, 2010) to identify and characterise the spinning residues. Each item, independently of the magnification, was observed dividing the tool into the following areas: internal hole (top and bottom) and external surfaces (top and bottom). Splitting the manufact in two areas ensures a precise localisation of use traces and understand stratigraphic relationships between use wear and residues deposition. The first step of analysis on each sample was carried out through a stereomicroscope2 Nikon SMZ-U with a 1X objective, 10X oculars and a magnification range of 0.75X - 75X. At this stage, a preliminary observation to ascertain presence and eventually localisation of use wear and residues was completed (See Table 1). Use wear was described to collect data regarding the precise position along the tool's surfaces, followed by shape and morphometric features of traces according to the parameters used in Forte and Lemorini (2017). The preliminary observation even allowed for the selection of samples with residues in order to characterise their morphology during the second step of the analysis. Indeed, by establishing morphology and nature of residues, it is possible to distinguish organic residues from contaminations (e.g. modern fibres and roots) and to recognize which fibre residues constitute the actual remains of a spinning activity. The samples with residues were analysed with a high-power approach using a scanning electron microscope – SEM2 Hitachi TM 3000, magnification 50x – 2000x, in a low vacuum and "analy" observation condition mode, in order to investigate the process leading to characterise a residue's provenance and the kind of alteration affecting the fibres during the spinning activity. Only two samples (IDs 2 and 4) have been currently excluded by the SEM investigation. These spindle-whorls were revealed to be incompatible with the SEM chamber capability due to their size even if they were characterised by residues as ascertained during the low-power approach analysis. At this stage of the analytical work no samples of residues were physically extracted by the spindle-whorls's; conversely, any use traces identified were observed and analysed in their original localisation in favour of a more conservative and non-destructive approach. The fibres analysis and the use traces reference collection was carried out at the Laboratory of Technological and Functional Analysis of Prehistoric Artefacts (LTFAPA) of Sapienza University of Rome (Italy). Results Use wear on experimental spindle-whorls According to these experiments, the morphology and the localisation of use-wear can reflect the spinning technique performed (Forte and Lemorini, 2017). Observing spindle whorls used in drop-spindle technique, use-wear patterns are localised along the hole's edge and the hole's internal surfaces as roundings, spall detachments, and polishing (See Table 1, Figure 3). The external protruding parts appear free from alterations, with the exceptions made by casual spall detachments due to unintentional drops of the spindle-whorls on the floor during spinning (See Figure 3a). Experimental tools involved in spinning with a bowl show recurring extended rounding localised along the most protruding parts on the external tool surface corresponding to the body or the area around the bottom hole as the one in repeated contact with the surface of the wooden bowl (See Figure 3b-c). A localised abrasive wear as rounding or levelling of the tool's edge was identified in the experiments in which the yarn touches the spindle-whorls. Conversely, the edge appears more preserved. Fibres and other organic residues on experimental spindle-whorls The analysis of the experimental items with a high-power approach allowed us to identify recurring residues deposited during spinning activities. Residues found on experimental tools include traces of organic materials as fibres (See Figure 4a-b) and amorphous deposits likely corresponding to wood, respectively left at the contact with yarn and wooden spindles (See Figure 4c). The most common residues deposited on experimental spindle-whorls consisted of small fragments of yarn, but it was not always possible to identify the kind of fibre worked due to their conservation and reduced size (IDs 3, 6, 9; Table 1, 2). The fibre identification depends on the preservation of diagnostic elements, called "guide elements" (Houck, 2009), allowing us to characterise the material and distinguish, for example, flax from wool. The fibre residues found within the central holes of the experimental spindle-whorls consisted of flat fragments pressed onto the ceramic, usually fixed on the rough surface and often embedded in wood or greasy residues (See Figures 4, 5). The spindle-whorls investigated with the high-power approach provided fibre residues in the form of fibre splits (max 3 µm_thikness) or short fragments. These residues were localised along the internal hole's surface where they can also be preserved as longer fragments. Within a limited sampling, like the one discussed in this article, each spindle-whorl provided evidence of several fragments of fibres visible at a low and high-power but few of them show the original surface morphology allowing for fibre determination (See Figure 5, Table 2). Features of fibre residues ID type size shape guide elements preserved 1 Bast fibres Flattened areas: 18-19 µm Well preserved areas: 10-14 µm Ovoidal/polygonal Nodes, polygonal shape 3 Unrecognizable Fibre split - - - 5 Wool 31-36 µm Round/ovoidal Scales and medulla (badly preserved) 6 Unrecognizable Fibre split - - - 7 Bast fibres 10 µm Polygonal Nodes, polygonal shape 8 Cotton 9-12 µm Spiral ribbon-shaped Helix structure 9 Unrecognizable Fibre split - - - Table 2. Samples with residues analysed through OM and SEM. According to the morphometric analysis with a high-power approach, cotton (ID 8) was revealed to be better preserved and the mainly identifiable fragment within the fibres processed; This material was identified according to the characteristic helix structure (See Figure 6 c). Although many fibres fragments were in a poor state of preservation, two samples (IDs 1, 7) were still recognizable according to the characteristic elements of the bast fibre morphology, such as nodes or kinkbands perpendicular to the fibre axis and the oval or polygonal shape (Bergfjord et al., 2010). The original fibre shape can be documented, including cases when the fibres are generally flattened by the sliding of the spindle (See Figure 6a, 6b-c). More problematic was the case of the wool fibres (ID 5). The experimental wool resulting was extremely damaged by the friction after the spinning process, probably caused by the loosening of the external cuticle with its characteristic "scales" feature (See Figure 8b) (Rast-Eicher 2016, p.32, fig. 30). The analysis highlighted the presence of other organic residues identified along the central hole of the experimental spindle-whorls. Among them, additional traces observed with a low-power approach (See Figure 4c) revealed at least two cases of residue deposition not corresponding to fibre fragments (See Figure 7c). The lack of fibre guide elements, their morphology, the deposition process, and localisation could lead us to hypothesise a correspondence of these traces with residues of wood left at the contact with the wooden spindles on which experimental spindle-whorls were assembled. Future research will allow us to improve the characterisation of these residues. Discussion The investigation of spindle-whorls at a low and high magnification suggests that spinning residues can develop along specific areas of the textile tools and their morphology can change according to the spinning technique performed. The recent application of use-wear analysis on textile tools suggested new potentials for interpreting and improving the study of these kinds of objects based on the alteration of surfaces caused by repeated use. This contribution proposed a combination of use-wear analysis and residue investigation on experimental spindle-whorls with the aim to identify preliminary criteria in order to distinguish use traces of spinning and develop a reliable research protocol to apply on archaeological items. The analysis of the experimental items has a pivotal role for understanding how these residues were deposited, the interaction with use wear, and how we can identify a yarn residue on an archaeological tool in order to distinguish it from contamination of ancient and modern fibres or roots during the post-depositional processes. A morphometrical analysis was applied to the experimental fibre fragments to identify features suggesting the reliability of organic deposits. Results show that the most common residues consisted of variably sized fragments of fibres along the internal surface of the central whorl hole. The experiment results show that patterns that include the distribution along the area immediately close to the hole edges or inside the hole (middle area), decreased as the depth increased, and the characteristic morphology of fibre fragments and wood correspond to residues deposited respectively by the yarn and spindle during the spinning performance. The analysis of residues at low and high magnification, based on morphometric parameters, with particular attention to the guide elements that are useful to identify the fibre material, revealed that fibres and wood residues remained embedded in the hole's surface over time. The fragments preserved on experimental surfaces suggest that during spinning, fibres were detached from the yarn and dispersed into the surrounding environment. A percentage of these fragments, especially the ones in correspondence to the spindle whorl, were deposited along the central hole, and the assembly of the spindle-whorl on the spindle lead to the development of residues within the central hole. The sliding movement between the ceramic surface and the wooden spindle thus modified the fibre structures. Indeed, the experimental results show that fibre fragments identified on tools usually have a flat shape and this is likely due to an alteration of their morphology caused by the sliding of the spindle on the hole's surface; this can happens each time spindle whorls are removed or assembled on a spindle or even when the spindle is slightly loose and the whorl twists during use. Friction between the spindle and the hole surface caused further alteration and damage of the fibres leading to surface abrasions and a typical mechanical tearing. The residues of these modern experimental fibres show damage features compatible with those found on the archaeological one, leading us to consider the spinning process as the first cause/phenomenon of the fibre degradation (Rast-Eicher, 2016). The experimental replicas also showed that ceramic items used for spinning develop a use alteration consisting of a combination of wear and residues distributed along the spindle-whorl depending on the spinning technique performed. For example, identifying use-wear on external surfaces and along the hole's edge can be associated with use-wear along the central hole with fibres or wood fragments. This combination, according to the experimental framework, can be considered as a trial suggesting the actual use of a spindle-whorl in spinning activity, excluding its use as a bead or clothes clip. Moreover, recurring and extended abrasive wear along eternal surfaces can be compatible with the adoption of specific spinning techniques such as using a bowl support. This preliminary research provides new evidence for interpreting use-wear activities or to identify the lifecycle of archaeological objects and to suggest how necessary it is to improve the reference collection with new experiments. Conclusions The data presented here are the preliminary results of an investigation that combines use-wear and residue analysis on objects such as spindle-whorls that are commonly studied through a typological and morphometric approach. The combination of use-wear and residue analyses supported by controlled experimental trials allowed us to develop a methodological framework to address the actual use investigation of textile tools. Indeed, according to the lifecycle of a spindle-whorl, each tool can demonstrate overlapping traces developed during different use activities. The traceological investigations applied so far on textile tools provided a use-wear reference collection that could be worked as a solid base to carry on the research. This contribution improved the methodological approach by applying the identification and characterisation of organic residues caused by spinning activity. The experimental framework presented in this article suggests that fibres and wood residues can be found on specific parts of a textile tool and can be identified through a non-destructive analysis at high magnification. The next step of research is to complete the collection of experimental residues and to apply this method to archaeological textile tools, including also other kinds of items such as loom weights, and to provide a standardised protocol for extraction and interpretation of such fragile residues. Aknowledgements This work was supported by the project Archaeology and Archaeometry of Textiles funded by Sapienza University of Rome Research Awards 2018. The authors would like to thank Assunta Perilli for taking part to the experimental protocol and the reviewers who provided useful comments and suggestions to improve and strength the article. Authors Contribution: Use wear analysis: Vanessa Forte and Cristina Lemorini Residues analysis: Vanessa Forte and Francesca Coletti Fibre interpretation: Francesca Coletti Experimental Archaeology: Vanessa Forte (spindle whorls reproduction) and Elena Ciccarelli (spinning) Discussion of the results and writing: Vanessa Forte, Francesca Coletti, Elena Ceccarelli, Cristina Lemorini

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