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Review Article

Structure-Winding Components Made of Paper Yarn for Construction Applications

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Abstract

Structure-winding technology makes it possible to produce structural components economically. By using paper yarns, recyclable, sustainable components can be produced for building applications, which, for example, can also be used as wall systems to enable a new and flexible use of living space. The modules are manufactured in a dry structure winding process. Subsequent consolidation can be carried out using various techniques, depending on the application.

Keywords: Structure-winding; Paper yarns; Consolidation; Conceptual living; Sustainability; Recycling

Introduction

The world's population is growing, and at the same time more and more people are moving from the countryside to the cities. New concepts are needed to create enough living space - because free space in cities is limited. Sustainable materials and utilization concepts are also needed to meet the huge demand for living space in a way that conserves resources. To ensure that the available space can be used efficiently, it makes sense not to prescribe fixed usage scenarios. In line with the Conceptual Living trend, furniture and rooms are assigned more than one function. A subdivision into different functional areas is achieved by means of modular living elements, e.g., wall elements and variable furniture pieces.

Solutions to these problems are being developed at the DITF Denkendorf. Paper yarns have been identified as a sustainable and locally available basic material. Paper yarns can be processed into structural components and also surfaces using known textile processes. These are characterized by great cost-effectiveness and energy efficiency, as they are usually well established and have great potential for automation. After use, components made from paper yarns can be fed into the familiar recycling routes for paper. With a recycling rate of almost 80%, these are very well developed and established in Germany [1].

Paper Yarns: Production and Properties

Paper yarns are produced by twisting previously cut strips of paper. A typical paper for this purpose is Hanji, a traditional Korean paper made from mulberry fibers [2]. Cable spun papers, which belong to the kraft papers, are used especially for technical applications. In addition, however, paper yarns based on the established recycling cycle can also be used for technical applications.

Paper yarns have comparatively high tensile strengths and low elongations. In addition, textiles made from paper yarns show excellent color fastness during washing and drying and high resistance to soiling. Even after repeated washing, no pilling could be observed in fabrics made of paper yarn. Paper yarns can be woven and knitted, but these two technologies also show disadvantages.

In weaving, one disadvantage is the reduced processing speed, and in knitting, only larger stitches can be knitted due to the low elongation [3,4].

Processing into Structure Winding Bodies

One possibility for producing textile structural components is the structure-winding technique. In this process, the yarn is placed on a rotating mandrel or tube, while at the same time the yarn guide oscillates back and forth. In this way, a wide range of structural patterns can be produced, such as ribs and openings, but also precisely closed surfaces. The high efficiency of the process results on the one hand from the high winding speeds of up to 2,000 m/min and on the other hand from the very high automation potential. It has also been possible to process paper yarns into lampshades and other bodies [5]. One strength of the structure winding process is the ability to position the yarns very precisely. In this process, higher-function yarns can be intrinsically integrated. In this case, intrinsic means that these yarns are themselves part of the actual structure. This eliminates the need for separate applications of attached components, for example.

Recycling-Friendly Consolidation into Structural Components

In order for the shaping tube or mandrel to be removed from the structural component, the deposited yarns must be consolidated to form the finished component. Either a component contained in the yarn, or a separately supplied component can be used for this purpose. In the sense of a structural component which, after use, is fed into the recycling path typical of paper, an adhesive system must be used here which does not interfere with this recycling path. Biodegradable starch- or dextrin-based adhesive systems are well suited. Four concepts can be used for the application of the adhesive:

1. application of the adhesive after the structure winding process, for example, as a spray application,

2. coating of the paper yarn in advance with the adhesive (with subsequent drying before winding) and subsequent processing to the structure package, (with subsequent application of water

3. impregnation of the paper yarn during winding just before it is positioned on the core or mandrel.

4. impregnation of the structure during winding.

The choice of the adhesive impregnation concept depends on the yarn diameter, the structure pattern to be wound and the other process control and must be evaluated individually. As an example, two tubular bodies A and B (inner diameter: 20 mm) were produced with different paper yarns (diameter A: 0.4 mm, diameter B: 1.6 mm) and different structure patterns (A: closed face, B: open rib). Body A can be produced well using insertion concept 3, but here the process speed is reduced. Body B was produced in variants by means of concepts 1 and 2, whereby the high process speeds can be well represented by the “dry spooling” (Figure 1).

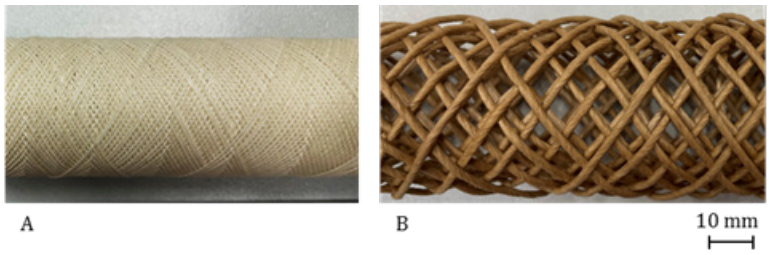

Figure 1: two representations of structure winding components made of paper yarn. A - Yarn diameter: 0.4 mm, closed face. B - Yarn diameter: 1.6 mm, open rib structure.

Structure-winding technology can be used to produce not only round, rotationally symmetrical components, but also flat structures. Multi-layer structures with gradients can also be implemented.

Use of the Structural Components in Building Applications

The aim is now to use the mechanical strength and properties of these structures in building applications and to combine them in such a way that typical building areas are created. Based on the experimental experience gained so far, a modular wall system for interior use appears to be a particularly interesting application. Here, the mechanical possibilities, the physical properties, the optical qualities and possibilities, the high manufacturing flexibility as well as the economic potential can be used. Lighting solutions and cable connections for bus systems can also be integrated. In terms of building physics, new possibilities are opened up, particularly in acoustics and in the possibility of moisture buffering. These modular and paper-recyclable wall systems offer new possibilities for the flexible use of existing rooms. If the individual modules are connected, for example, by means of plug-in connections, the wall can be assembled, converted, and dismantled on site. Likewise, elements can be reprocessed after use and reused elsewhere. This saves high logistics costs and, due to the low weight, also CO2 equivalents that are generated during transport.

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Conflict of Interest

No conflict of interest.

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