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Multi-Shed Rotational Formation (Along the Warp) of Woven Structures

Abstract

A new concept and implementation is presented of multi-shedding based on rotational formation of woven structures along the warp. The difference between the hitherto designed rotational constructions and that presented in this article is stressed. In contrast to the aim of previous designers (to achieve more efficient looms), the author emphasises the possibility of weaving woven structures with the use of warp and weft threads of complex surface and cross-section structures which, up to the present, could not be formed by means of modern weaving machines. The basic principles of the disk shed-forming and the assemblies used for them are presented. The new loom has been verified by weaving various woven structures hitherto impossible to obtain, for example such as woven fabrics with roving or selvedges from air-jet looms used as warp threads, woven structures with pile loop and double-woven fabrics. The possibility to manufacture complex woven structures by means of simple constructions and with the use of very cheap raw material is given special emphasis.

Key words: *shedding, multi-shedding, rotational formation, formation along the warp, woven structures, pile loop, double-woven structures, complex linear textile.*

Assumptions of a New Shedding Conception

An up-to-date loom is one of the most modern manufacturing machines regarding its design, construction, material application, automatisation, and application of electronic circuits & computer aided control. However, the formation of the sheds, which is a very critical operation , is performed by means of heald shafts. On one hand this allows us to achieve a significant density of warp, but on the other, the use of heald shafts has some disadvantages. The origin of these disadvantages is the dynamic loading of the warp by cyclic tension, rubbing, bending, and shearing, which also results in material fatigue. All these factors impose high requirements of the threads' mechanical properties. What is more, the small dimensions and the specific geometry of heald mails, together with the edge barriers encountered on them, exclude the possibility of using them for weaving linear products with a developed, complex surface and cross-section.

These factors in turn cause assortment restrictions, especially within the range of technical and decorative woven fabrics; different fibres (the so-called unspinnable fibres) cannot be generally used, and as a final effect the rational management of textile raw materials is disturbed. What is more, traditional shedding requires the use of complex and expensive mechanisms which form the shed (during the phase of machine investment and their exploitation), as well as expensive technical articles for exploitation.

The aspects mentioned above constituted an inducement to commence research aimed at changing the dynamic of shedding. Considering various ways to solve this problem, the designers reached back to the primary weaving techniques applied thousands of years ago which used (among other techniques) triangular and prismatic rods for shedding (Figure 1a).

In the second half of the twentieth century, an attempt was begun to apply such a solution to modern woven techniques. Ripamonti, who together with Gentilini designed the first looms of such a construction in 1955, achieved multi-shedding along the warp. The next was the Orbit loom from the Bentley company which appeared in the seventies. The most fully developed construction was the M8300 Sulzer-Rüti loom demonstrated at the ITMA'95 exhibition.

All the attempts presented above were developed with the aim of replacing the existing looms characterised by a particular assortment which they could weave by a new, technically more efficacious and efficient solution.

In contrast to the undertakings mentioned above, the conception of a new shedding method presented herein emphasises and exposes only these advantages which are, according to the author's conviction, the greatest benefits of the construction described. Firstly, there is the possibility of shed formation without dynamic warp loading and the lack of limitation of the surface or cross-section complexity degree of the linear textile products used as warp. A certain importance is also visible in the ability to achieve complex woven structures by simple technical means.

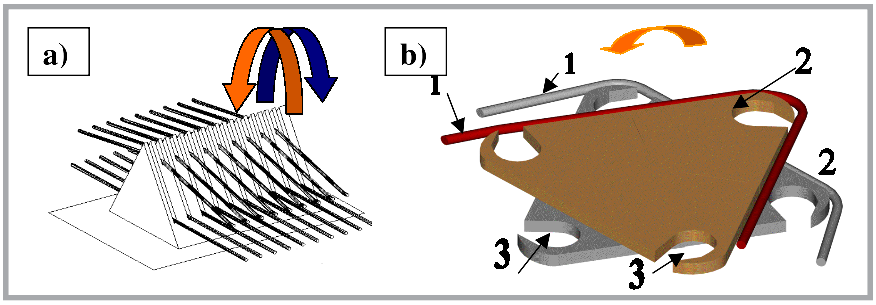

Figure 1. Options of shedding without shafts: a) shedding in primary looms with the use of prismatic rods of partially rotating reversible motion; b) shedding without dynamic loading of warp with the use of polygonal disks: 1 - warp threads, 2 - polygonal disks, 3 - channels for weft passing.

Consequently, the development of the new multi-shedding was not aimed at replacing the high efficient looms which had hitherto been used by a new solution; however, an assessment was made to make possible the formation of woven structures, in the majority technical and decorative, which cannot otherwise be obtained with the use of currently used modern looms , and to achieve a significant improvement in fibre utilisation, raw material management, exploitation conditions, and energy demand.

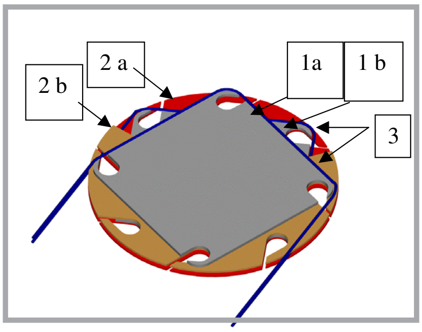

***Figure 2.** Schematic view of a technological modulus of the weaving rotator: 1a, 1b - disks for shedding; 2a, 2b - disks for increasing the weft density; 3 - warp threads.*

The accomplishment of this conception was possible thanks to the sponsorship of the research project 'Woven fabric formation without dynamic warp loading' granted by the Polish State Committee for Scientific Research (KBN). The investigations were carried out at the Department of Woven Fabric Structure and Technology, Textile Faculty, Technical University of Łódź, and next at the Department of Textile Architecture, Faculty for Engineering and Marketing of Textiles.

Implementing the Concept of Disk Shedding

To resolve the accepted assumptions, a solution was selected for shedding with the use of polygonal disks. By means of this design, the warp threads **lie only** on the surface of the disks when the shed is formed, as shown in Figure 2.

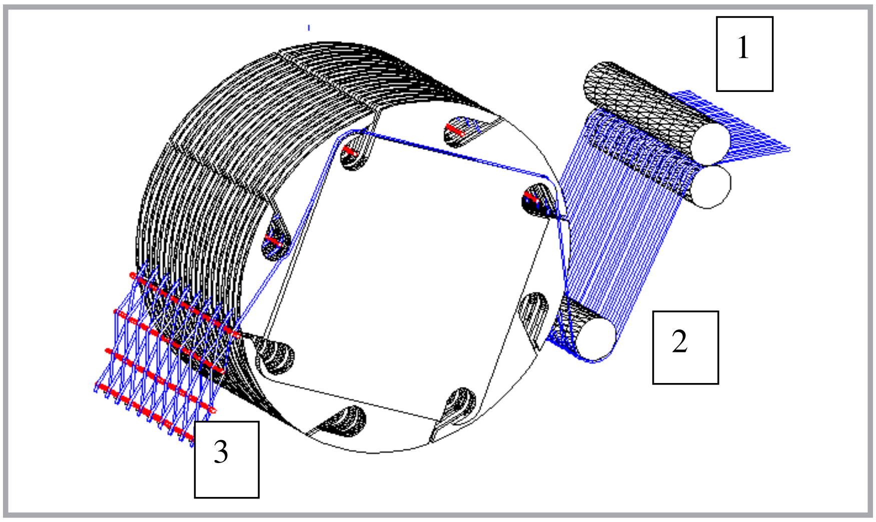

***Figure 3.** A part of the weaving rotator: 1 - warp feeding, 2 - tensioner if necessary, 3 - woven fabric.*

Construction of a Test Model for Weaving with the Use of Polygonal Disks for Shedding

The construction of a rotational multi-shed weaving machine was based on the use of four-sided disks for shedding, and of eighth-segment disks for increasing the weft density. An assembly of two identical shedding disks which are displaced against each other at 45°, followed by two identical disks for increasing the weft density, forms a technological modulus of the weaving rotator (Figure 2).

A part of the weaving rotator is shown in Figure 3. The kind of warp feeding presented in this figure is one of several feeding methods which can be applied. At the preliminary stage of this research work, an air nozzle for weft feeding has been used. A cam assembly drove this nozzle, and an electronic device controlled the opening and closing of the valves for the air stream.

By using only one kind of disk, it is possible to achieve various weaves by means of changing their mutual angle displacements alone. An example of such a possibility is demonstrated in Figure 5.

Verification of the General Assumptions

Shedding without warp tension (without dynamic loading of warp)

It was accepted that the best verification of the new shedding conception would be the manufacture of woven fabrics from textile linear products of very low tenacity, which would have been impossible to process on any conventional loom. The two most significant warp features, which are a drawback in weaving, are:

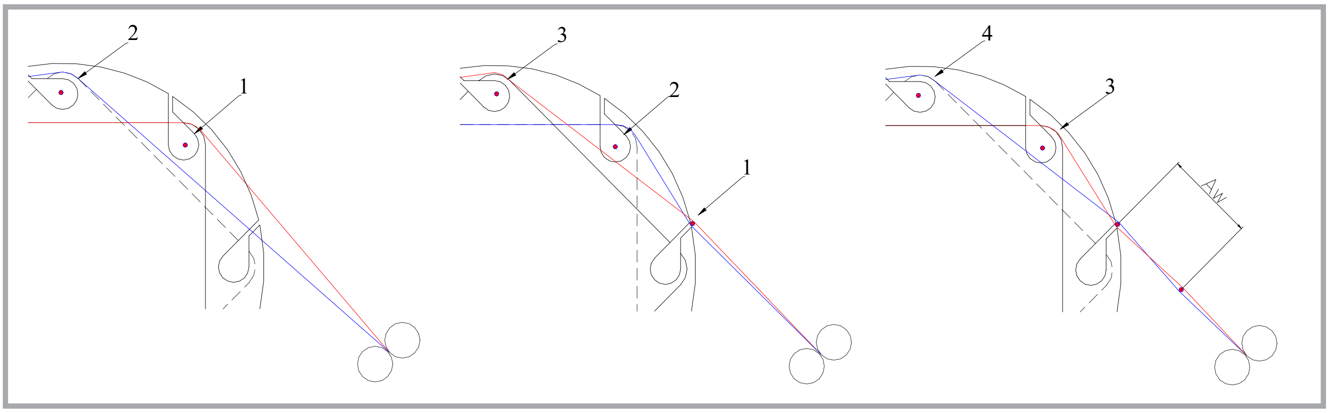

***Figure 4.** Forming of 3 elements of the woven structure - rotation angle of the weaving rotator relating to 45°; 1, 2, 3, and 4 - numeration of the successive wefts.*

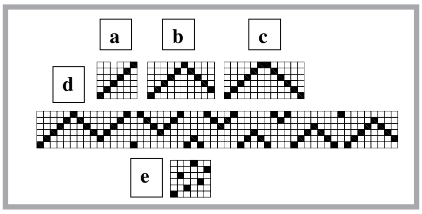

Figure 5. Twill weaves (a, b, c, d, and e) and sateen weaves can be achieved by means of a hexagonal disk.

- extremely low tenacity (breaking strength) of warp threads; and
- loose thread structure and strong developed thread surface.

For this reason, raw materials with such properties were chosen for tests. One of the first tests carried out with an extremely unprofitable raw material was a test with cotton roving of 125 tex linear density and breaking force below 15 cN (Figure 6). The weaving process ran excellently. To stress the undoubted achievements of the disk shedding application, it should be emphasised that the only difficulties which arose in the weaving process resulted not from the use of the new shedding, but from feeding the warp consisting of roving into the weaving machine.

The technology presented allows us to manufacture completely new assortments of woven fabrics, and this with great success. First of all, the manufacturing of cheap woven fabrics which could be used for thermal and acoustic insulation is possible. Such fabrics can be produced from waste raw materials which are manufactured only in the form of bands, without spinning, e.g. from rovings. A quite different application of the new loom construction is weaving fibres with very valuable selected properties, e.g. bio-fibres and carbon fibres, some kinds of which are not spinnable in normal conditions.

The unrestricted structure of the thread surface and unlimited dimension change of the warp thickness

The lack of shearing barriers and thickness limitations along the way the warp threads move creates a new opportunity to manufacture a new kind of woven fabric with warp from yarn of any dimensional structure (Figure 7).

One example of this is terry thread, which could not be used as warp in conventional looms. Using the model of the multi-phase rotational loom constructed according to the instruction of the author, a terry fabric with loop pile was manufactured without any difficulty. For warp, as well as for weft, a terry thread was used and the weft pneumatically introduced.

Further evidence for new possibilities to create new kinds of woven fabrics is the example of selvedge utilisation, constituting a great problem for woven fabric manufacturers who use hydraulic, pneumatic and rapier looms. The garnetting of such materials as selvedges is possible but expensive, whereas the multi-phase rotational weaving machine has the capability directly to process selvedges when using them as 'warp threads' (Figure 8). By such technology, woven fabrics are formed which can be applied in many different fields, e.g. in geotextiles, textiles for insulation and in the building industry as inserts and reinforcements for concrete.

Further Advantages of Weaving with the Use of Disks for Shedding

Manufacturing woven grid structures

Taking into consideration the small thread density in warp and weft directions, the weaving loom is especially suitable for manufacturing all kinds of woven grids.

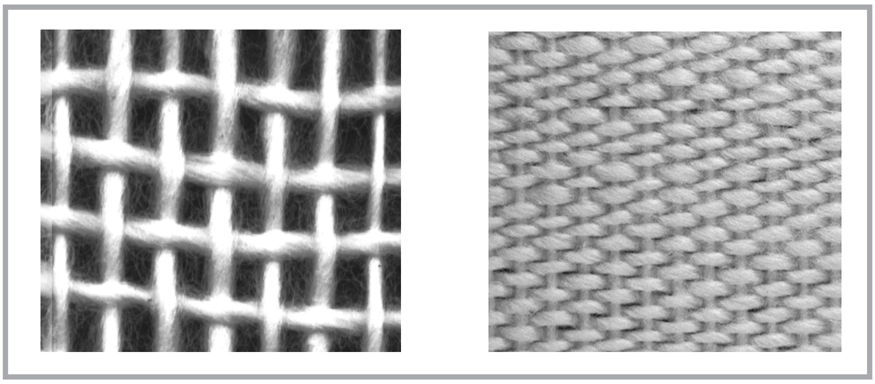

Figure 6. An impossibility proved possible: photos of woven fabrics with warp and weft from roving of 125 tex, breaking force below 15 cN, great irregularity of linear density and loose structure.

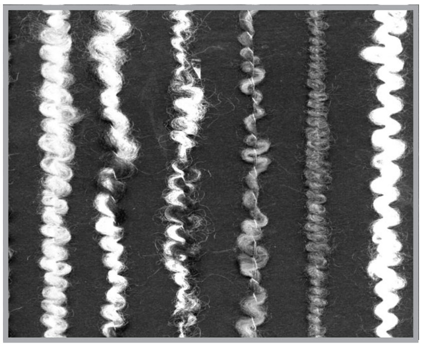

Figure 7. The impossibility made possible yarn used for warp.

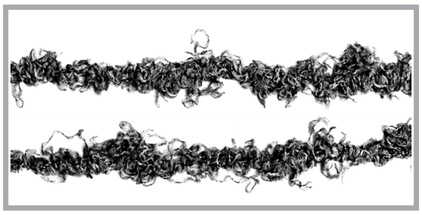

Figure 8. Selvedges from air-jet looms used as warp threads.

When manufacturing special woven grids, the possibility to insert the weaving operation in the technological process of the particular product is one considerable advantage of the multi-phase rotational weaving machines. Two examples of products for which the application of the new loom in the technological line is advantageous are listed below:

- Tyre cords, whose loose structure makes them very difficult to transport. Instead of this, the multi-phase rotational weaving machine inserted in the technological line can easily serve as an elastic link of the tyre cord formation band.
- Armouring with woven grids as a sequence of composite manufacturing. The above-mentioned advantages of the multi-phase rotational weaving machine are also of great importance here.

Woven structures with pile loop

The classical looms are used for manufacturing pile loop woven fabrics such as terry fabrics, sponge-cloths and bouclé fabrics. Terry threads are used to make the first kind of fabrics, but almost exclusively for the weft. The other two structural realisations of woven fabrics with loop pile require special arrangements when using standard weaving machines.

In a further stage of this research work, a successful trial to manufacture terry fabric in which loops are created was carried out. A model of such woven fabric structure is presented in Figure 9. For the manufacturing of this woven structure, we used only 2 kinds of shedding disks.

Forming of double-woven fabrics

One of the tests carried out was intended to prove:

- the possibility of doubling the working capacity of the multi-phase rotational weaving machine by manufacturing two woven fabrics in tandem on two planes (Figures 10, 11);
- the possibility of forming double woven fabrics (Figures 12, 13, 14).

Figure 10 presents the first case: the manufacturing of two layers not bound together, which means two woven fabrics independent in raw material and thickness woven simultaneously. Only two kinds of shedding disks were used for manufacturing such two fabrics which were not bound together. For manufacturing of a self-stitching double woven structure, in which all lower warp threads are interlaced with upper wefts, also two kinds of shedding disks only were used (Figure 13).

The second step in our investigation was the manufacturing of a double fabric with centre-stitching, in which a special warp interlaced alternately with upper and lower wefts (Figures 12, 14). Figure 12 shows a part of the weaving rotator of a multi-phase rotational weaving machine (larger than presented in previous figures but simplified) destined for manufacturing of double woven fabrics, which layers are connected by additional warp. To simplify the view for better clarity of presentation of the loom construction, the disks for increasing the weft density, the weft vents and the flat springs which have been pressing the binding warp to the grooves of the particular disks are not presented in this picture.

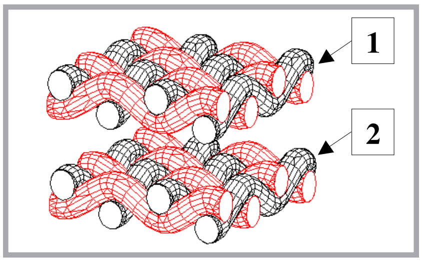

Figure 10. The schematic shape of two independent fabrics woven together: 1 - upper woven fabric. 2 - lower woven fabric.

Summary

The following manufacturing possibilities were achieved by applying the new loom construction:

- The creation of woven fabric structures, with the use of textile linear products of very low breaking force and large developed surface, which until

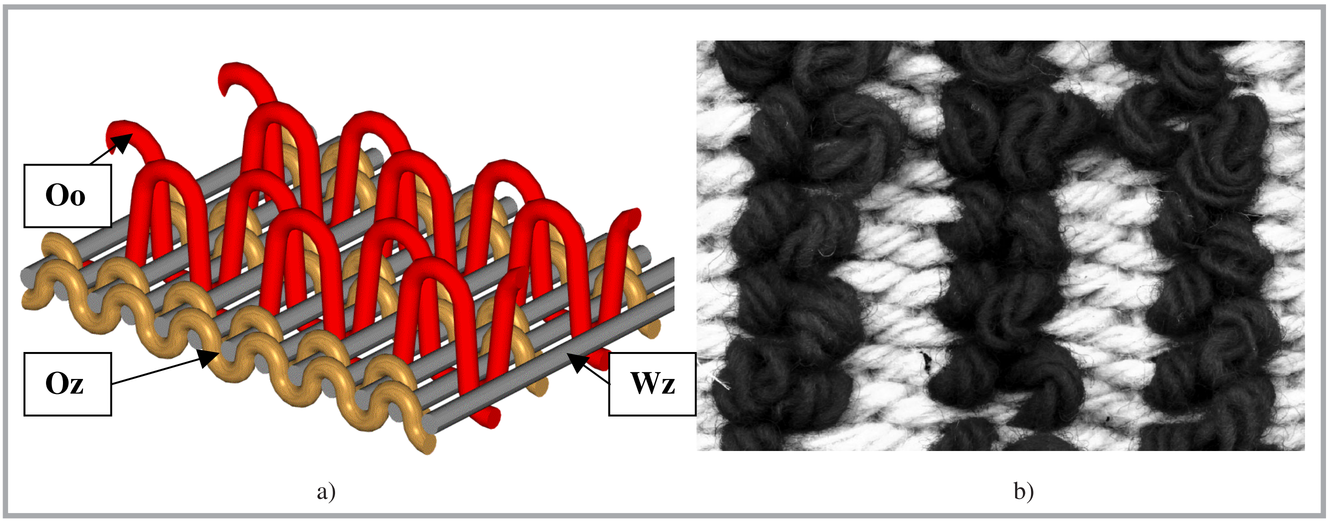

***Figure 9.** Woven structure with loop pile: a) Model: Oo - warp pile thread, Oz - ground warp thread, Wz -ground ends, b) manufactured terry fabric.*

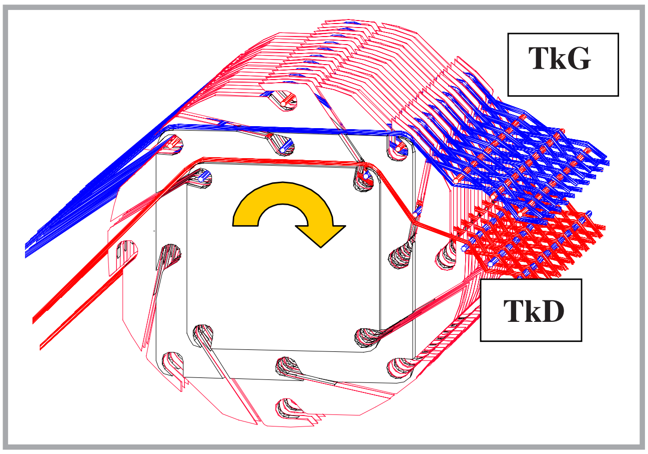

***Figure 11.** Manufacturing of two independent fabrics, woven together: TkG - upper woven fabric, TkD - lower woven fabric.*

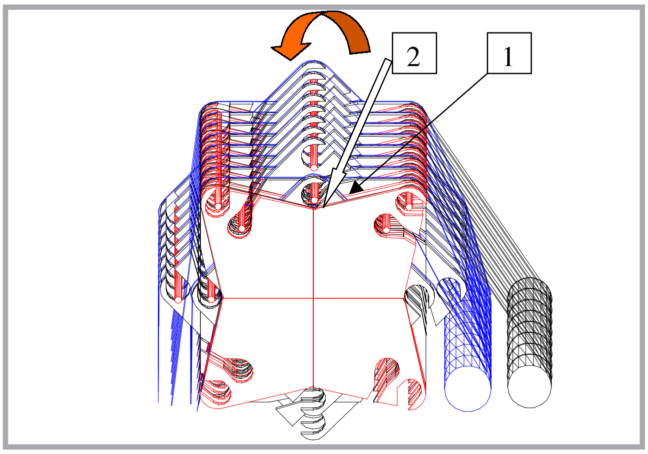

***Figure 12.** Simplified view of a part of the weaving rotator for manufacturing double woven fabrics with centre-stitching: 1 - disk for the binding warp, 2 - pressing of the binding warp.*

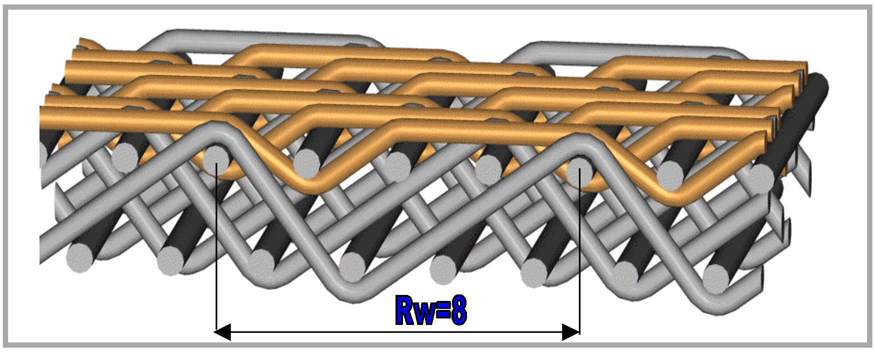

Figure 13. Manufacturing a self-stitching double woven structure, in which all lower warp threads are interlaced with upper wefts.

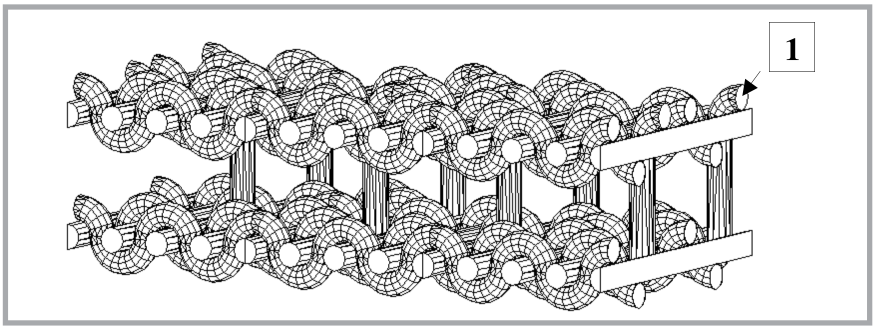

Figure 14. Model of a double woven structure with centre-stitching: 1 - binding warp.

now could not be manufactured with conventional looms.

- The improvement of the economy of secondary raw materials and the utilisation of unspinnable raw materials.
- The manufacture of woven grids with the use of very simple arrangements, and with the possibility for insert the new weaving machine as a full elastic link into the technological production lines of the particular product, e.g. a composite.
- The design and construction of the new weaving machine can be carried out without major problems, and it should only be remembered that any amount of disk assemblies consisting of two or three disks must be multiplied to form an appropriate shedding. Thanks to the continuous rotational movement, the dynamic of the rotational weaving machine is advantageous for the weaving process as well as for the conditions during usage.

As of now, further research work is being carried out. Further investigation is planned, with the aim of obtaining differentiated woven fabric forms and structures with the use of different raw materials.

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