Multi Bifurcation Branch Braided Structures on a Herzog Variation Braiding Machine

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Abstract A project about multi bifurcated branch braided structures for lashing straps and cables was carried out in the Institute for Materials Science at Hof University. For this work three manufacturing processes were used. The braidings were produced on a Herzog variation braider and the woven structures on shuttle and needle looms. The aim was to create bifurcated structures without sewing several woven or braided fabrics together. The woven fabrics had only two branches, but with the Herzog variation braiding machine structures with two and up to six branches have been produced. The two branched fabrics were tested for their tensile strength. The main result is that the structures with less elongation have better tensile strength.

Introduction

The limbs and the roots of a tree are splitting into branched structures to increase its stability and to ensure sufficient nutrition. The natural bifurcation of the roots braces the treÅåe securely in the ground and improves it resistance against external influences like rain, snow and wind. In nature and in technical science, bifurcations are essential. Therefore the Institute for Materials Science at Hof University has been working to transfer the biomimetic properties of natural bifurcations into braided and woven lashing straps, cables and other applications. The target of this project was to produce versatile interlaces of bifurcated branches and to analyze and compare the resulting technical properties, especially their tensile strength. The bifurcated branches should be manufactured in a continuous production process excluding any

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manual sewing processes. Those additional time consuming steps shall be avoided and an increased stability is expected, caused by a higher integrity of the structure.

To realize the project and to compare different production processes, a Herzog variation braiding machine, a Univall-Jacquard loom with shuttle weft insertion and a needle loom have been used. The bifurcation characteristics of the resulting products have been tested and compared to assess their suitability for industry applications. Beside the tie-down segment, a possible application field for branched structures is the medical sector, e.g. as artificial multi-bifurcated vessels and veins.

Implementation

Braiding requires a minimum of three threads, while the maximum number of threads is only limited by the chosen machine. A conventional braiding machine features a circular setup, in which the bobbins are handled by horngears, crossing each other on counter-rotating, pseudo-sinusoidal tracks. The necessary thread stock for the entire braid is pooled on these bobbins. Through the movement of the bobbins, the threads cross each other and produce the braid.

The advanced setup of a variation braiding machine allows producing much more complex braids if the number of threads exceeds the minimum amount of three threads. The setup of the Herzog variation braiding machine for example consists of a 4 × 4 arrangement of horngears. Between the transfer points of the horngears, the traveling tracks for the bobbins are equipped with pneumatically triggered crossings. Instead of just counter-rotating pseudo-sinusoidal tracks, it is possible to change the track plate pattern individually and to allocate each bobbin separately on different tracks. Provoked by intensive research, there is a huge number of possibilities to produce undivided braids using the tracking plate of variation braiding machines [1, 2].

To produce a single braid (basic braid) all tracks need to cross each other. If the tracks are separated correctly, for example if the tracking plate is split in two areas, a bifurcated branch will be produced. Using this technique, it is possible to produce basic braids, splitting up in multi bifurcated braids and consolidating back into a basic braid, using only one braiding machine, just by changing the pattern of the track plate.

For this project, several variations of basic braids have been produced; each one equipped with a different branched braid with two ends. One example is shown in Fig. 1.

The potential of the variation braiding machine in optimizing the bobbin setup is multifarious, the track setup and the crossing setup are widely used for splitting and reuniting the tracking plate. Because of the crossing options, the variation braider is able to produce a huge amount of different basic and bifurcated two end branches.

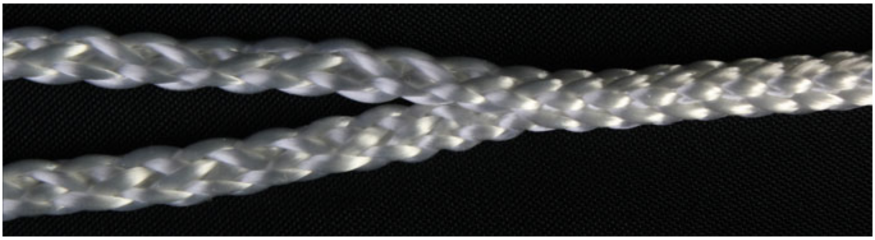

Fig. 1 Picture of a bifurcated braid

A big number of different combined braids have been produced, using this technique, although the total possibilities of the variation braiding machine are not close to exhausted, because of the freely programmable controllers. The combination of basic braid and bifurcated two end braid is realized with changing the crossings and might take some horngear rotations. Depending on the braid, the time for track changing may vary from one to several horngear rotations and might require complex combined setups of crossings and tracks. The changing should be as short as possible, because otherwise unwanted effects such as thread twisting or loosing up of the existing braids might occur. Additionally, existing braids can de-braid because of unfavourable setups. Such behavior should be avoided, because it is equal to destroying the braid. Furthermore an eye should be kept on the lay length and the pulling speed of the takeoff disk, because it varies between the different setups and has to match the situation. The lay length has to be adapted by the control engineering. It could happen that during the setup change, the disk has to stop, to guarantee a clean transition between the different braids.

Contrary to braiding, which crosses the threads at an angel of approximately ±45°, for weaving the crossing angle is usually 0/90°. Therefore the threads are separated into vertical warp threads and horizontal weft threads. The weave pattern is developed by rhythmic lifting and lowering of the warp, while the weft secures every change by crossing the warp.

To produce a multilayer weaving structure, it is mandatory to use one weft thread for each layer [3]. A bifurcated structure with two threads is a woven multilayer structure with two layers.

There are different ways to transport the weft through the shed. In this work two possibilities have been used: shuttle weft insertion and needle weft insertion. Only these two have been considered because they are the only systems with a continuous weft thread. Other weft insertion systems include cutting the weft thread, which is not useful for this project.

A needle loom has been used as a reference machine to the Univall-Jacquard loom machine with shuttle weft insertion. The differences between simple bifurcated woven structures produced using the two different machine types should be analyzed.

Fig. 2 Picture of a bifurcated shuttle loom woven product

On the Univall-Jacquard loom with shuttle weft insertion, the whole weft thread stock is traveling through the warp. After the shuttle has reached the end of the warp, the warp changes position and the shuttle returns to its starting point. The Univall-Jacquard loom has four independent shuttles, which allow producing a multilayer structure with four unconnected layers. The Univall-Jacquard loom lifts or lowers every thread independently by an electric powered drive. Advanced control systems allow individual positioning of every thread in the weft, which means that the weft movement of every single thread is individually manageable. Therefore it is possible to configure several sheds, while having low harm and stress for each warp thread. This facilitates a high variability of the warp threads position in z-direction. Furthermore, it provides the possibility to produce 3-dimensional structures, as seen in Fig. 2.

The weft insertion of the needle loom is carried out, as already stated by the name, by a needle. The needle inserts the weft as double layered thread with a loop. At the end of the shed the loop of the weft thread is trapped by a second needle and intermeshed with the loop of the previous weft thread. The needle loom has two independent needles, which are both needed, to create the two layered structures analyzed in this work.

Results

Every produced structure was made from the same material, with the identical thread thickness. The bifurcation structures were tested in terms of their tensile strength and elongation, especially in the bifurcation area. Eleven different bifurcation braids with two ends were compared to fifteen shuttle loom—and six needle loom bifurcation fabrics. The potential of every single bifurcation production process, which affect the maximum strength of load restrain assemblies, could be evaluated. The gathered test data was used to calculate the average tensile strength of every bifurcation production process. The same comparative calculation has been done for the resulting average structural lay length. Both values are shown in Fig. 3.

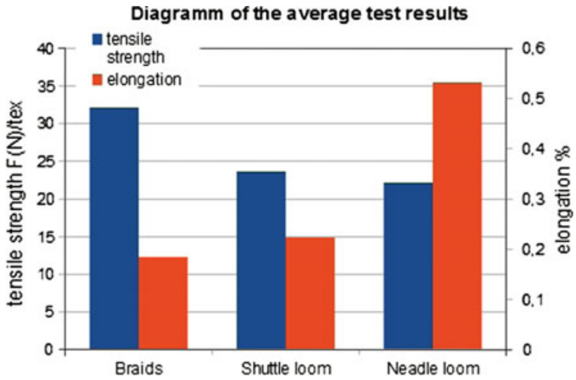

Fig. 3 Diagramm of the average tensile test results

The diagram shows that the bifurcated shuttle loom fabrics have a higher tensile strength than the bifurcated needle loom fabrics. Also it is clearly visible that even the bifurcated shuttle loom fabrics cannot compete with the bifurcated braidings. Furthermore, it shows that the lay length of the bifurcated weavings is in both cases higher than the lay length of the braided bifurcations, with the needle loom fabrics having the highest lay length. This is owed to the different processes of braiding and weaving with different insertion systems. Because of the correlation between tensile strength and lay length, the hypothesis that a high lay length decreases the tensile strength, can be confirmed.

In the course of this study, only pieces of the big picture could be considered. The possibilities are not yet exhausted and with modern machines the limitations of pattern variations are widely conceived, which still leaves much room for innovation.

Conclusion

Summarizing the results, the braided structures with two ends showed better abilities in case of tensile strength as woven structures. Furthermore, the Herzog variation braiding system allows to design different bifurcations fitting the needs for lashing straps, cables and other applications, even if the load is split differently between bifurcations.

As stated above, for this work only bifurcation braids with two ends were developed. The possibility of producing complex bifurcated braided structures, with more than two ends, is also given with variation braiding machines. Mostly a basic braid is only split in bifurcated structures with two branches, but it is also possible to produce braids that are bifurcated in three or four ends from one basic braid.

Beyond this, the Institute for Materials Science at Hof University has developed a basic braid which is split in a bifurcation with six branches. Each one of the six bifurcation braids is an evenly flat braid. The braid shows a structure like a normal

Fig. 4 Picture of a bifurcated braid as net structure

three strained hair braid. In addition it is possible to connect the six bifurcated braids to a net shaped structure. This net shaped structure can be a plane or tubular structure, as seen on Fig. 4.

It is conceivable that the Herzog variation braiding machine allows producing a bifurcated braiding with eight branches, starting in one basic braid. This shows the high potential of the research on multi bifurcated braiding structures and their production. This area of research is very promising.

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