Self-optimisation of the Radial Braiding Process
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Introduction

Thomas Walford, a Briton from Manchester, claimed the first patent for a braiding machine in 1748. On this machine, as well as on the subsequent machines, it was possible to manufacture two-dimensional structures, such as laces and straps.

According to DIN 60000 braids are described as fabrics with closed selvedges. Braids consist of at least two thread systems that intersect alternately and have a defined angle at the selvedges, the so-called braiding angle.

At least two thread systems are needed to manufacture a braided structure.

With braids it is possible to produce 2-dimensional as well as 3-dimensional structures. The most commonly known methods for braiding are flat braiding, packing braiding, rotary braiding and overbraiding. A special method of braiding is the radial braiding. The bobbins face radially towards the centre of the machine. Threads from the bobbins pass to the centre of the ring body, where the...
braiding ring collects them. Due to the radial arrangement of the bobbins, thread deflections are minimised. This ensures lower thread damage during braiding and thus enables braiding of delicate materials. The braided structure is created in a radial braiding process by intersecting of two thread systems on two paths by moving in opposite directions (clockwise and anticlockwise). Consequently, the threads of the one thread system cross the threads of the other one. Braided structures can be divided into biaxial and triaxial braids. Biaxial braids consist only of the two thread systems which form the braid. Triaxial braids are created by adding 0°-threads, the so-called stationary threads, to the biaxial structure.

Practical Issues

A consistent quality over the entire overbraided core, through the length as well as diameter, is desired. For example, the deviation of the braiding angle from the local target value and the damage of the fibres are example quality criteria. The braiding angle varies with the geometry of the braiding core and the take-off speed of the core moved by a robot through the braiding ring. The tension of each thread is another factor which affects the braiding angle. Furthermore, the thread placement is affected by the friction of the filaments with each other. The more stationary threads (0°-threads) and braiding threads are used, the greater the friction of the threads with each other. If the radial braiding machine is for example only half-fitted with stationary threads, the friction of each thread changes consequently at an angle of 180 degree. In addition, the combination of materials has an influence on the friction. The braiding angle is influenced by varying the speed of the core that is pulled through the braiding ring. Furthermore, the complexity of the core affects the braiding angle.
Currently, the thread tension is controlled mechanically via a spring. Thereby, the thread passes from the coil over the guiding plate and then through an eyelet. The eyelet moves upwards against a spring when the thread is pulled. When the maximum suspension travel of the spring is reached, the bobbin releases more material. Thus, the thread tension is about the tension that results by the spring during the pull process of the thread from the bobbin. However, the spring can only compensate the difference in take-off speed from the bobbin, but not the fitting of stationary threads and other factors, such as unequal thread tension. The unequal tension can result in damages of the thread.

In case of unequal yarn tension is the possibility of the thread to be damaged by too much tension. In case of low thread tension, there is a risk that a braid may deflect by overbraiding of the core.

**Approach**

The approach here is to monitor and control the braiding angle and thread tension by the interaction of a sensor system in a bobbin developed at ITA and an Active Carrier system designed by ITA for regulation of the thread tension.

The Active Carrier System includes an electric motor, a tension sensor at the pedestal of each of the 144 bobbins of the braiding machine and a data processing unit. The tension sensor measures the thread tension, which is than processed and the electric motor releases the thread or holds it back. In this way, the thread tension of each bobbin can be individually detected and controlled.
Technical Challenges

A standard for quality evaluation of braids needs to be developed. This measurement basis is required for benchmarking of measurements and results.

Another challenge is the online process monitoring. A concept for an active default of bobbin tension is already available. However, the implementation is taking some time due to its complexity.

Furthermore, the exact interrelations between machine, material parameters and resulting parameters of other components are still unknown. ITA has a large amount of experimental data available. A solution containing the linking of all the parameters and thus methodically defining a fast realisation of a desired component configuration is still missing. Particularly, the automated determination of a trajectory of the robot, which guides the braiding core through the braiding ring is relevant. A module based on a knowledge database and the component geometry will be adding great value. The module should write and simulate a program for the robot and dictates necessary machine configuration. The knowledge database is intended to learn continuously. Furthermore, there is a lack of solutions for monitoring the winding process as well as the integration in the monitoring and braiding process. Furthermore, a solution for detection and influences to changes in thread tension between the bobbins and the braiding ring, which is dependent on the stationary threads and the material pairing has to be found.
Technical Equipment

- Radial Braiding Machine Herzog RF1/144-100
- Industrial Robot Kuka KR 150 for the core handling
- Kuka Sim Pro
- Thread Tension Sensor (self-development)
- Bobbin Winding Machine
- 3D-Rotary Braiding Machine 12x12 of company Herzog
- 3D-Rotary Braiding Machine 5x5 of company Herzog
- 3D-Hexagonal Braiding Machine
- APODIUS Vision System (AVS) for quality management
- Minitab 16 Statistical Software

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