ADDITIVE MANUFACTURING OF COMPOSITES USING CONTINUOUS ROVINGS IMPREGNATED WITH THERMOSET RESIN

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Abstract:

Wet Fiber Placement (WFP) is a process, that was recently developed to manufacture fiber-reinforced polymer composites (FRPC) out of in-line thermoset impregnated filament bundles (rovings). So far, the impregnation and conveying unit has been put into operation. In this paper, a method to automate the laying process is presented.

Automated wet fiber placement

One of the most researched topics of the 21st century is additive manufacturing. The advancements in additive manufacturing of plastics, metals, and composites have been tremendous, especially in the fields of 3D printing and automated fiber placement. Recently, a new process - called wet fiber placement (WFP) - has been developed [1]. Figure 1 shows a schematic of the basic process. WFP is an additive process, in which filament bundles are impregnated in-line with a thermoset resin and then placed into a mold without tension to form the final product. During impregnation, the filament bundles require high pulling forces, because they are subject to high surface pressure, which drives the resin in between the fibers of the roving. At the end of the process chain, two feeding rollers employ the pulling force. The strength of the pulling force depends on the motor, which is driving the feeding rollers, and the distance between the rollers. The distance between the feeding rollers needs to be small enough to generate a significant pulling force and large enough to prevent the feeding rollers from squeezing out all the resin inside the roving or from damaging the fibers. The roving is guided through an arrangement of driven rollers to exploit belt friction effects and to significantly reduce the required pulling force. In this manner, the feeding rollers only have to generate a minimal force of less than 1 N.

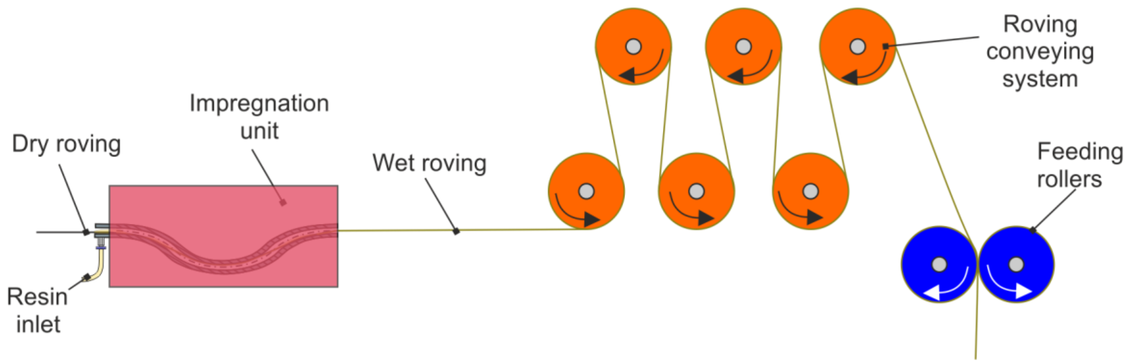

Figure 1 – Schematic of a basic WFP setup

For the placement of conveyed rovings, a system is required, that allows for relative movement between the placement tool and the feeding rollers. Hence, in order to automate the process, it is essential to be able to move either the roving or the tool in X/Y/Z direction, while simultaneously rotating the roving to maintain the intended fiber orientation – spreading effects in the conveying system can even form the roving into a tape-like shape. The system also provides a roving cutting unit to allow discontinuous placement and dancer units for measuring the roving tension, to balance the power of the different motors in the system. Figure 2 depicts the current solution for the automation challenge. An end-effector unit, that combines the functions of the feeding rollers, a pneumatic cutting

unit and a spring-loaded compaction lip, forms the heart of the new setup. The end-effector unit is mounted to a rotational axis and a Z-axis, while the mold is placed on an X/Y-axis table.
The entire set-up is connected to a control system, which synchronizes all the units and allows the user to program the placement path for the rovings. The rotational axis and the X/Y-axis table are synchronized to maintain unidirectional fiber orientation during laying the rovings on a curved path. A dancer unit measures the tension of the roving to synchronize the rotational speed of the motors, that are used for the conveying system and the end-effector. An additional dancer unit is placed inside the end-effector to coordinate between the cutting unit, the feeding rollers and the X/Y-axis table.

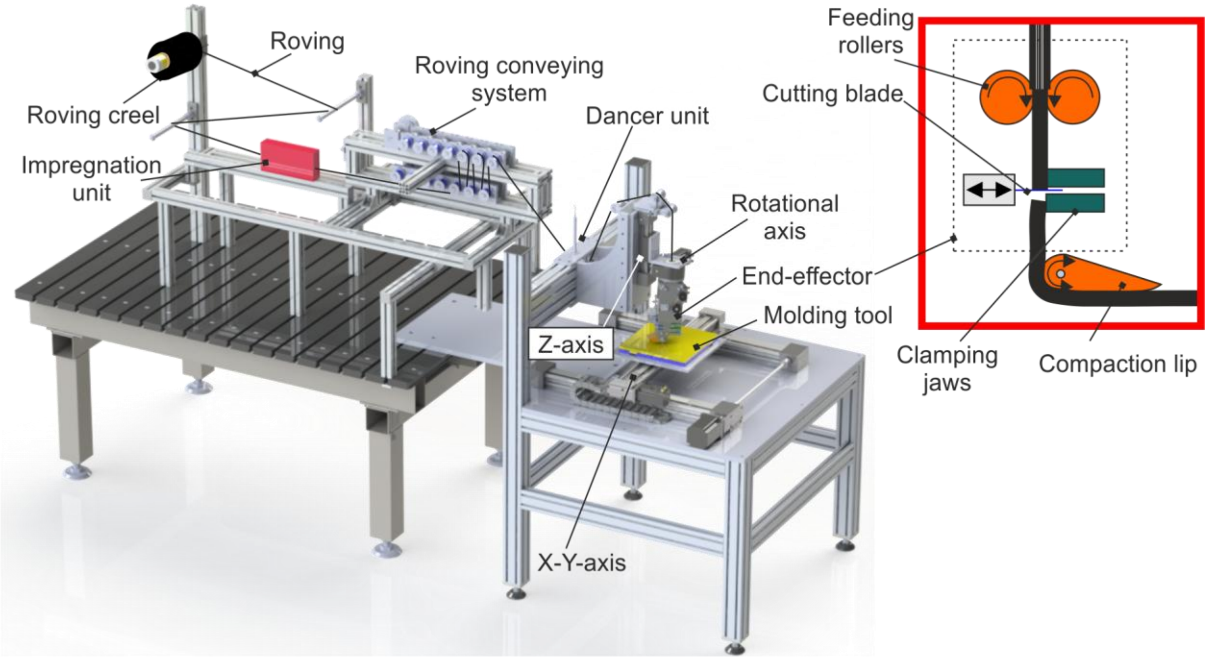

Figure 2 – Model of an automated WFP setup with a schematic of the end-effector unit

Summary and Outlook

An automatized process for a new additive manufacturing process, in which rovings are impregnated with thermoset resins, is presented. With the current state of the art, the impregnation process and the roving conveying methods were automated, but cutting and laying of the rovings were still executed manually. A 4-axis computer numerically controlled (CNC) system was designed, that contains a cutting unit and a compaction lip, which helps to stick the cut rovings to the surface of a mold. The automated placement system is currently being built-up and commissioned. Future works will demonstrate the novel and extended capabilities of the manufacturing system.

Acknowledgement

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References

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