The Hydra among Diode Lasers

Multiple Processing Heads in a Row Optimize Processing Speed

Diode lasers are often used for the production of lightweight components by means of thermoplastic tape laying. However, common tape laying systems are noticeably limited in their production capacity, as they only work with one processing head. With a flexible multi-head system, Laserline GmbH promises a cost-efficient system that should also pay off in large-scale production.

In automotive engineering, aerospace technology as well as onshore and offshore pipeline construction, steel as a conventional construction material is increasingly replaced by lightweight components. Besides aluminum, fiber-reinforced plastics are becoming more and more important: they are 60 to 70% lighter than steel and 25% lighter than aluminum while offering high stability, corrosion resistance and good material fatigue properties. The established processing method for such fiber-plastic composites was hitherto based on the use of thermoset matrix systems and epoxy resins.

With the so-called thermoset tape-laying process, components are produced flexibly by gradually laying down unidirectional pre-impregnated fibers in the form of tapes or rovings. But the processing of thermosets has significant disadvantages, namely, the adhesive is classified as harmful to health and requires a daily, intensive cleaning of the production equipment with environmentally hazardous solvents. This clearly limits any possible automation. Furthermore, the tapes must be consolidated in a time-consuming and cost-intensive autoclaving process. Even afterwards, the components cannot be reheated and formed again, while the possibility of a later recycling remains unclear.

However, thermoplastic matrix systems with continuous unidirectional (UD) tapes made of e.g. carbon, basalt, aramid or glass) do not have any of these disadvantages. Similar to thermoset processing, thermoplastic materials are typically processed in the form of rolled tapes.

The direct diode laser LDMdirect from Laserline facilitates installation in assembly lines thanks to its small housing width of only 50 mm. Another plus point: Several processing heads can be integrated into one mounting © AZL Aachen GmbH

What the Thermoplastic Matrix Systems Score with

The tapes are pulled off a roll by a feed unit parallel to the working surface and deposited in the desired position on the work platform or the partially finished component. In this way, organic sheets can be produced or local reinforcements of large plastic components can be realized. Tape winding, on the other hand, which is used to produce rotationally symmetrical components such as pipes, shafts or pressure vessels, involves placing the tapes in a kind of cross-winding pattern on a rotating container or pipe (**Fig. 1**). In contrast to the use of thermosets, the thermoplastic tapes are directly consolidated during placement. For this purpose, the tapes are melted by a heat source and then pressed onto the existing top layer for fixation by means of a pressure roller, so that they are attached to each other with a material bond. The heating can be done through different sources; for example, you can choose between infrared or halogen emitters, hot gas or laser. Lasers enable a controllable, locally concentrated, and very fast heat input into the tape matrix. Connected with a high degree of automation, the laser-supported thermoplastic tape placement process offers therefore from a technological standpoint the highest economical potential.

The laser-based process has been successfully used in series production since 2009, including the manufacturing of components made of carbon »

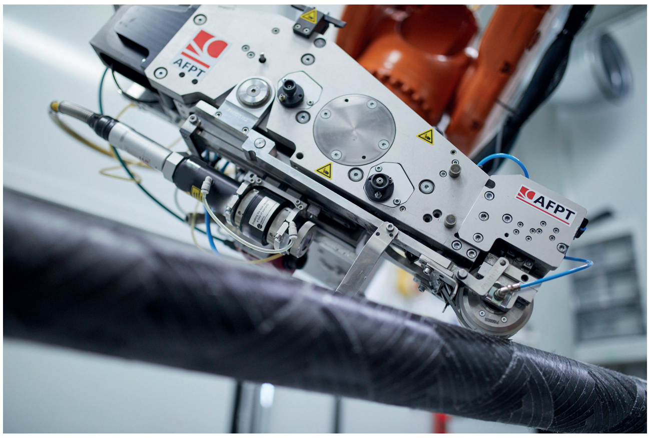

Fig. 1. In the case of rotationally symmetrical components such as pipes, shafts or pressure vessels, the tapes are placed in a kind of cross-winding on the rotating component © AFPT GmbH

fiber-reinforced plastics (CFRP). Here, lasers achieve tape laying speeds of around 5 m per minute with outputs of up to 3 kW. The beam sources were step-by-step adapted to the application requirements while the size and investment costs were continually reduced. Despite this, conventional tape placement systems with only one processing head are noticeably limited in their production capacity. The growing demand for lightweight components – whether in the offshore sector (e.g. for the construction of kilometer-long pipelines), in the onshore sector for the manufacturing of water pipes, in the production of pressure vessels, or for large-scale lamination of organic sheets for automotive or aircraft parts – requires a new technological approach that allows for a higher tape deposition rate at an economical price.

In the Multi-Head System, Several Processing Heads Work in a Row

With those increased industry requirements in mind, Laserline has developed the LDMdirect, a modular direct diode laser with a housing width of less than 50 mm that offers the possibility of integrating several processing heads into one mounting device for the parallel processing of commercially available tape widths (**Title figure**).

With a laser power of over 2 kW per processing head, this flexible multi-head tape placement system ensures a significant increase in process speed and a correspondingly higher production capacity. Thanks to their compact design, these direct emitters can easily be integrated into robots or machines, thus enabling economical series production on a large scale.

For the processing of endless pipes for offshore pipelines or onshore water pipes, it was also necessary to adapt the laser systems. For this purpose, Laserline has developed world's first rotating multi-kW diode laser systems for endless pipe winding machines (**Fig. 2**). In this process, several lasers rotate simultaneously and continuously on a rotary device around the pipe's longitudinal axis. The pipe is guided through the rotating device solely by back and forth movements until the desired number of layers has been applied. Each of the lasers deposits one tape, such that several tapes can be placed in parallel. The entire component production process is thus significantly accelerated, while large-scale production of several kilometers of pipes can be implemented economically for the first time.

Flexible Adjustment of the Laser Beam

Laserline has also developed special homogenizing optics with zoom function especially for tape processing, which can tailor the laser beam to the tape width. For this purpose, special optical lenses generate a variable rectangular and almost ideally homogenized laser beam that plasticizes tapes with typical dimensions of up to a width of 2" with extremely uniform energy input in a continuous, stable and reliable process. Thus, the already uniform intensity distribution of Laserline's diode lasers can be further optimized with the help of homogenization optics. At the same time, such optics allow for a flexible adjustment of the laser beam to the placement speed. Depending on the application, parameters can be defined before the process starts and maintained throughout the entire process or dynamically adjusted during the process. The total energy input is always precisely limited to the joining zone. Both the periphery and component itself are not exposed to excessive heating. Due to the possibility of precise process adaptation, the diode laser with a zoomable homogenizing optic achieves high and therefore economical depositional speeds, especially in comparison to other heat sources such as halogen lamps. With this new approach, a fast production of lightweight component based on tape laying is currently possible.

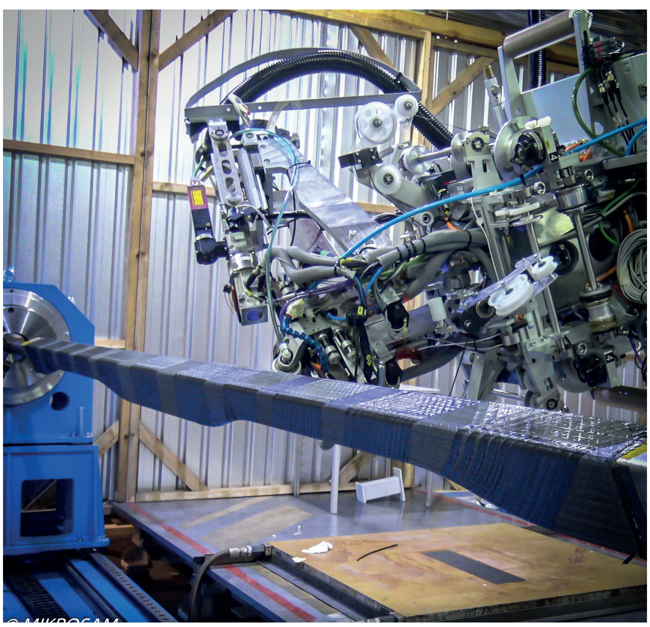

Fig. 2. Laserline has developed the world's first rotating multi-kW diode laser that enables the production of endless pipes for short pipes or construction components by tape winding © Mikrosam 2020

Technical and Economic Advantages of the Diode Laser

Even beyond these technological advancements, the diode laser further offers a number of economic and technical advantages for use in tape processing. For example, the tape's temperature input can be precisely regulated at any time thanks to the precise power scaling and almost optimal homogeneity of the diode laser. This allows the plastic matrix to be melted without local decomposition, thus ensuring optimal welding results. An on- or off-axis temperature measurement permanently controls the laser power and ensures that the material is heated below the critical decomposition temperature. A further advantage is that the diode laser is power-stable and almost wear-free. This means that hardly any maintenance is required, which thus has quite a positive effect on the total cost of ownership (TCO). In addition, with a wall plug efficiency of up to 50%, the diode laser offers the highest energy efficiency in the industrial laser environment. The somewhat higher investment costs of the diode laser compared to conventional heating sources are therefore fully justifiable in view of the accelerated production of CFRP components and the low operating costs.

With laser-based tape winding and laying of thermoplastic fiber composites, continuous fiber-reinforced plastic components can be produced at a fully-automated, energy-efficient manner and at high speed. Using technical adaptations such as zoomable homogenization optics, rotating multi-kW diode lasers and direct emitters, the tape deposition rate is further augmented, which allows for the serial production of FVK components. In the future, this will pave the way for the large-scale production of tanks, kilometers of pipelines for the offshore sector, and organic sheets or local reinforcements such as molded components. The manufactured components can then be further processed depending on the area of application, for example being equipped with connecting flanges, being hot deep-drawn or cut to size and then assembled. ■

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Service

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