Innovative automated factory starts to produce composite CNG solutions for one of the most-progressive auto-brands

Automated Filament Winding Production Cell will produce competitive composite CNG tanks

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World known composite machine manufacturer, Mikrosam, deliver a fully automated Filament Winding Line for Type IV premium quality CNG vessels. Developed for a leading global automotive supplier Magna, and installed at its plant in Austria, this production cell was designed to manufacture a cost-effective lightweight CNG tank module. Using filament winding technology and application of composite materials, the produced alternative propulsion system would result in reduction of weight of up to 50% compared to equivalent steel cylinders and 40% lower fuel expenses. The CNG vehicle is environment-friendly. This kind of powertrain system will shrink the CO\textsubscript{2} emission by 20% to 29%. The CNG module of tanks is predicted to hold a total of 19 kg of gas, allowing the range of over 500 kilometers.

Global challenge

Road transport contributes about one-fifth of the EU’s total emission of carbon dioxide (CO\textsubscript{2}), the main greenhouse gas (similar to the situation in the U.S.). The 2009 regulation sets a 2015 target of 130 g/km of CO\textsubscript{2} and the standard for 2021 is 95 g/km of CO\textsubscript{2}. The 95 g/km target corresponds to about 3.8 liters per 100 km (l/100 km) of fuel consumption. As mentioned, CNG fueled vehicle emits 20% to 29% fewer GHG emissions than a comparable gasoline or diesel fueled vehicle on a well-to-wheel basis (for natural gas vehicles that run on biomethane, the GHG emissions reduction approaches about 90%).

Mikrosam develops solutions to make changes happen. It aims to solve big challenges. Cut vehicle weight to meet carbon emissions reduction targets:

“For every 100 kg of vehicle’s weight, reduced fuel consumption falls by 0.25l/100 km, delivering a reduction in carbon emissions approximately 6–7 g CO\textsubscript{2}/km”.

Weight reduction offers a potentially cost-effective means to reduce fuel consumption and greenhouse gases from the transportation sector. Alternative fuel vehicles using gaseous material require strong, safe, lightweight tanks to maintain “normal” vehicle size, weight and driving ranges. Traditional alternative fuel tanks are made of common grade steel and, over time, the gas can migrate into the metal. This makes the metal brittle, wearing it to the point that gas can leak from the tank. The benefit of using a composite material (a combination of glass, carbon fibers and resin) for alternative fuel tanks is that they keep weight to a minimum, while offering high shock resistance and a long life. The CNG fuel module combines the technology of reducing the weight of the vehicle and using cleaner fuel. The composite CNG vessels propulsion system will result in consumption of less than 4 kg CNG (compressed natural gas) per 100 km corresponding to fuel costs of roughly four euros. CO\textsubscript{2} emissions are 100 grams per km.

Mikrosam’s solution – smart factory automation

The new era of automation makes factories smarter and optimizes the manufacturing process! Complete turnkey solutions for end customers meet requirements for high-level automation of the manufacturing process.

Over the past few years, Mikrosam has specialized in the manufacturing of top-to-bottom automated factory systems for
production of LPG, CNG, hydrogen and other types of high pressure vessels. The capacity of such lines is sized according to customer requirements and can be in the range of 30,000 up to 1,000,000 per year. With clear vision and long-term strategic approach for innovations, Mikrosam is making permanent efforts to deliver customers the highest level value in composite production by continually developing not just in the field of composite manufacturing, but also in motion control and process automation as well as software developing.

The automated cell for Magna is first of its kind in the world based on many special features. One is the patented cut & restart mechanism for cutting and placement of fibers impregnated with a resin. . . A fully integrated solution by Mikrosam, is first of its kind in consisting of multi spindle filament winding machines with Mikrosam’s sophisticated cut & restart patented solution for automated cut and restart of the fibers tape during the winding process; a handling system with a robot that performs loading and unloading operations of the liners, winded tanks and cured tanks between numerous equipment units; and a high-tech curing oven that matches curing requirements of different resin systems. An automated multi-component resin mixing device is also part of the production cell. After obtaining the required resin system, the device is capable of delivering it to the impregnation bath where composite reinforcements (glass or carbon fibers are impregnated).

Mikrosam’s cut & restart patented mechanism is used to automatically cut fibers after a tank (or other kind of mandrels) has been wound using a filament winding production process, and the mechanism automatically places those previously cut fibers over the surface of a new tank which then allows the winding to restart again. In the current state of winding, placing the fibers on the surface of the tank which has to be wound using a “Filament Winding” production process is performed manually. Once the tool is wound, it has to be removed from the filament winding machine in order for the resin to be cured, typically in an oven. To remove the wound tank from the machine, the operator first needs to manually cut the fibers and then hold them, while the wound tool is removed, and another new, unwound tool, is installed on the machine. Then the operator places the fibers manually over the surface of the new tank just like the first step described. This process is quite time consuming, prone to error and unsafe due to a human factor involved, which can result in serious accidents where the operator cuts himself by accident. Also the quality of the part can be compromised if the fibers are not placed with enough pressure, and thus slip during the winding process. Using the cut & restart mechanism, the process is completely automated and thereby operator intervention time and skill, before and after winding, is reduced drastically which increases the safety of operating a filament winding machine and increases the productivity in cases where wounded parts are produced one after another in large volumes.

The multi-axis winding machine is equipped with two winding carriages, upgrading the automatic cut & restart system to work with both, primary carriage for winding of the main composite layer and secondary carriage for winding of the outer protective layer, so that full continuous production of CNG tanks is realized on the same machine in a single winding cycle.

Before the finished tanks are loaded in the curing oven, visual inspection is performed with a size-adaptable buffer inspection unit. The filament winding machine is adjustable for different dimensions of the liners with diameter from 150 mm up to 500 mm and length up to 2 meters. In total, there are 24 servomotor controlled axes integrated in the filament winding machine itself, which makes it one of the most advanced winding machines in the world built so far (Fig. 1).

What makes this production line unique is the flexibility to change production cycle from one tank size to another. When this is required, all programs, mechanical and electrical parts, are automatically adjusted to the different CNG tank sizes that are necessary to be produced. The possibility to make these changes and adjust the capacity of each single equipment station very fast increases the productivity of the overall production line.

Control and monitoring of the work cell and the whole manufacturing process is carried out from one place, TCON – Top level automation control system. This system manages all modules in the integrated production line from one location while it records all important parameters, such as raw material consumption, complete set of production parameters, product tracking at every station and data for the multiple quality check points.

Experts bring expertise

Being an expert means you’re competent to deliver value to your clients, teach others in a simple and understandable manner, use your expertise to create something, be willing and flexible to improve your developing work, always aim for premium satisfaction. Among the large number of professional engineering experts that have been working on the automated production cell for CNG tanks, Mikrosam proudly presents a different kind of expert, responsible for collaborating with software engineers in order to create, edit and simulate winding programs. Its name is Winding, its title is Expert – Winding Expert™.

The Winding Expert has a very user-friendly interface, multilingual support, and is specialized in featuring hoop, helical, transitional and other customized winding layers and programs (Fig. 2). This expert allows the creation of winding programs for all type of axis-symmetric geometries such as: pressure vessels (for storing CNG, LPG, Air, water) pipes, cones etc. In order to assist the work cell to deliver composite parts, filament wound CNG tanks, with
great mechanical properties; the Winding Expert™ uses its module to export all necessary data to a program that makes the necessary calculations and analysis - the Finite Element Analysis program (FEA). The Winding Expert is great cooperative tool because it can always, and with very precise accuracy, predicts the need of raw materials (resin, glass, carbon, aramid etc.), thickness of the composite parts produced, duration of the winding cycle etc.

Control of the quality at every point of the production cycle is inevitably imperative in Mikrosam’s work

Hand in hand with delivering premium quality solutions to customers comes a control software – the Winding Commander™. Its major task is to features the most advanced and rich control application for Filament Winding machines. It commands every single move of the machine and knows everything for a fast and accurate winding process. At every moment the status display shows the most important information about the current machine status and the status of the numerical control unit, as well as alarms for some changes needed or warnings.

Quality Control System – QCS

The QCS ensures premium quality of the composite wound tanks. This special software is designed to work in the background while the production line produces tanks. It monitors all the given parameters such as temperature from various places, fiber tension, winding program information, starts/stop and many other data points necessary for quality control.

The expertise of this software lies in securely storing all data in a database and the ability to retrieve data at any time. If you think that only reporters have the ability to report, you should definitely see the reports that QCS creates. They are amazingly comprehensive.

After setting up the complete automated line to produce parts with the exact fibers and resins to be used, the customer can see its line in operation. When customer approval is received, the line is disassembled and transported to the customer’s site for re-assembly and commissioning. Continued support via remote maintenance system is guaranteed from the moment the automated factory is installed in the customer facility. The customer connects the production line to us via the Internet and our personnel then do maintenance on the production line software and control systems, providing any updates available.

All software solutions are updated for the lifetime of the automated production line.

Process automation at Mikrosam is at the highest level. Experience has shown that there are lots of reasons to automate the composite manufacturing process. Automated manufacturing systems perform operations such as processing, assembly, inspection, material handling, and in some cases accomplishing more than one operation in the same system. Automation of such a production cell is justified considering the following advantages: increase in the overall quality and uniform consistency of products, increase in the production rate, reduction of the human labor costs and improvement in worker’s safety, avoid the high cost of not automating, significantly decrease the cycle time, operation time and work handling time.

Automation conserves manpower and reallocates labor to other more value added roles such as design, development, deployment, supervise, maintenance and running of the automated processes.

Designed to fit the required high volume production capacity, a FW Production Cell combines: full automation; optimum production rate by avoiding bottle necks; flexible equipment stations; well-timed process between each component in the cell; lower material waste; energy efficiency; real control of the quality at every point of the production cycle, monitoring of the complete manufacturing process and integration of safety functions in all modes of operation. All of this is included in one package with full support, training and assistance from engineering experts.

More than 26 years “eyes wide open” for trends in the composites market. Considering that Europe is the largest growing market for NGV, and the increasing demand for NGV in the rest of the world, Mikrosam’s engineering bureau has, in the last few years, developed and enhanced the world’s most advanced fully automated high-volume production lines for filament-wound CNG, LPG, Hydrogen tanks, water vessels. In addition to this, Mikrosam’s engineering bureau has developed some of the most advanced Filament Winding machines with up to 6-axes for complex parts, AFP/ATL machines, prepreg making and slitting equipment, as well as software products. Customers from more than 40 countries around the globe, including European Union, Japan, China, Russia and India, are more than satisfied with what Mikrosam has delivered, as Mikrosam’s solutions have enabled them to exceed their production objectives. Moreover, customers have positive reactions about the capabilities and influence of Mikrosam, as a Macedonian company, in the field of composites and robotics. The management of the company explains that they have a strong relationship with their customers that are based on high-loyal environment and bilateral trust. “We convert our customers to ambassadors”.

The future is based on a steady development in composites and factory automation. Fully or semi-automated multi-component systems. Mikrosam is aiming toward this.

Mikrosam believes that sustainable growth in their company will leverage on clients’ major business growth. Their vision is clear: to continue to develop and improve innovations in the composite industry, which has a high and healthy potential to grow in all sectors, and keep a balance between expertise of labor and automation/semi-automation in the manufacturing processes.

FIGURE 2

In-house developed software – Winding Expert™. Part of the Winding program for vessels.