Manufacturing

# The impregnation of the im

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by Luca Melideo

he first generation of hybrid and electric cars used essentially traditional electric motors, in which the magnetic field was generated by an electrical winding of copper, both in the static component (stator) and in the rotary one (rotor).

A car was typically equipped with a single electric motor, powered with a voltage of 400 V. Since then, it has been continuously rethought both the architecture of the cars (Full Electric, Mild Hybrid, Plug-in) the number and the type of motors: for stators, in addition to winding technology it has been the copper bars technology (hairpin motors, U-Pin, I-Pin etc.), and in the case of the rotor the permanent magnets. In the most high-performance cars, we have moved on from 400 to 800 Volt and above.

# The impregnation process

More the technology evolves, more the performance increases and the impregnation process become essential. The process of impregnation consists of covering the copper, wires or bars, with a layer of resin.

The resin, which can be polymeric or epoxy, is dispensed on the ends of the



wire, inside the cavities thanks to capillarity effect, reaching the most inaccessible points (the slots). At the same time, the resin must be applied just on the copper to prevent the contamination of the lamination, a part of the stator where the current does not pass.

The coating obtained with resin, of which there are countless versions, has multiple purposes:

the most important target is the copper bonding, to strengthen the whole stator and avoid frictions between the copper wires or bars that could cause damages.

Another important target is to provide a second insulation of the electrical circuit, to avoid short-circuits between the various phases. In some cases, there is also the purpose of protection from weathering and improving heat dispersion, avoiding any air bubble that can interfere with heat distribution.

The impregnation quality has a strong impact on the motor performance, and it is significant to guarantee its reliability over the time, protecting it from mechanical and electrical stresses.

The capillarity principle, a phenomenon connected to surface tension of liq-





Modular Line loading phase trough a 7-axis Robot on a motorized slide



Lateral view of a Modular Line for hairpin stators impregnation

Trickling process of a hairpin stator under UV light

uids, requires perfect control of temperatures of both, resin and the part to be treated. Viscosity and density are parameters linked to it.

Once applied, the resin should be jellified following by a polymerization process to guaranty a full protection of the surface.

# A development program for the new impregnation lines

With the hairpin motors higher technical requirements and the demand to guarantee high quality levels, Tecnofirma launched a development program for the new impregnation lines.

The first step was to start a research collaboration with the Politecnico University Milano with the focus of developing a theoretical model to define and understand variables that influence the impregnation process.

The theoretical model was subsequently validated with experimental tests, partially carried out at the university and partially at Tecnofirma laboratory on real samples.

The variables taken into consideration include typical parameters of the hairpin stator (dimensions, copper bars position, copper bars coating, insulating materials), of the resin used (viscosity trend as a function of temperature) and of the operating conditions during the impregnation process (speed and di-

# **TECHNICALLY SPEAKING**

Modular machine represented in a single unit. The starting point for the development of a mass production lines

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from the line, rather than dedicating them to different types of products. This feature is very appreciated, especially in this historical period, where volumes are often uncertain due to youth of the product and the consequent inability to predict life cycles and market responses

rection of rotation, temperatures, stator inclination) Thanks to the technical background and the knowledge about market requirements, it was possible to develop a new machine concept capable of adapting to any type of motor and production requirement.

# New process lines developed and patented by Tecnofirma

Process flexibility, investment scalability and modularity were the pillars for the development of new technologies and machines.

Flexibility is guaranteed by the possibility of creating a specific impregnation recipe for each motor model, giving the user the possibility to customize the process by modifying parameters such as: dispensing nozzles positioning, the dispensing flow rate, the speed rotation (during the impregnation and gelling phase the stator must be kept rotating on its axis, in a horizontal or slightly inclined position), the direction and the parts inclination. The recipe is specific to each part and is tested beforehand in the laboratory.

# Flexibility and modularity

Modularity is the basis for line the architecture: impregnation and gelation phases, the most delicate ones, in which the motor must be kept rotating to

avoid resin contamination and dripping, occur at the same time, inside an individual unit - the modules - identical to each other, in a number defined according to the process requirements and expected production outputs.

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Each line is completed with a one or two ovens, always according to production volumes in which are carried over three phases of thermal management of the parts: Preheating (the stators must be brought from room temperature up to the temperature suitable for the impregnation process), Curing (after to gelation: the resin is poured and hardened must complete cross-linking) and Cooling before the parts unloading. The oven is designed to maximize energy efficiency, concentrating the hottest areas at the top of the oven and which prevent the escape of hot air.

# The coverage of the welding joints

Beside the impregnation process can be added the coverage of the welding joints (for hairpins and ipin stators) with epoxy products. The purpose of the treatment, called powder coating, is to restore the electrical insulation against the stripping and the welding of copper bars and to increase the resistance over time to mechanical stress and thermal stress. At the unloading phase, the motor result ready for electrical tests and for the final assembly.

Tecnofirma historical experience has allowed the introduction of a series of measures that guarantee reliability and maintainability of machinery, an essential requirement for production contexts of the automotive industry.