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Development of full carbon wheels for sport cars with high-volume technology

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Abstract
Aim of the paper is to present the methodology used to develop a new process, based on high-pressure resin transfer molding (HP-RTM), to produce full carbon reinforced plastic rims for sports car. These components are nowadays made by pre-preg autoclave processing, which is expensive and time-consuming, so that they are basically sold as aftermarket option. The proposed technology allows a manufacturing volume high enough to be suitable for series production. In this paper, the resin and fiber selection criteria and tests are shown, as regards the mechanical properties, durability and injection strategies.

1. Introduction
Weight of cars increased continuously through the years up to 2010, in relation to improvements in comfort, driving aid systems and the more challenging homologation passive safety requirements. Since 2000 an increasing attention towards weight reduction in all car segments was adopted by all OEM (Original Equipment Manufacturer) as consequence of increasing requirements on pollution emissions reduction. Indeed, despite the development of more efficient engines, the higher fuel consumption, and consequently higher CO\textsubscript{2} emissions, due to weight have required the intervention from the governments (in particular US and EU) to set a path for emission reduction through the years \cite{1}.

Research into lightweight components, materials and the related processes, has therefore become one of the main challenges in the automotive industry and has led to the substitution of standard steel with alternative materials in many components and systems. Typically, steel was first substituted by aluminium, but OEM are now looking at carbon fibre-reinforced plastics (CFRP) technologies for their premium models, since they offer further weight reduction together with higher specific stiffness. This trend will also be particularly important for next-generation hybrid or electric vehicles. Indeed, CFRP are not only lightweight and high-strength but they can also be tailored in order to improve structural, functional or cosmetic properties. The market size for CFRP composites accounted for $20.3 billion in 2014, and is projected to register a compound annual growth rate (CAGR) of 9.9\% between 2015 and 2020, to reach $35.8 billion \cite{2}. CFRPs were traditionally used in the aerospace, defence industry or in racing applications but today they are finding new uses in automotive, marine, energy (e.g. for wind blades), industrial components and other sectors \cite{3}. Automotive is the most promising application field for composites, and offers the highest growth potential. Many leading automotive manufacturers, such as BMW and Mercedes, are planning or have already started to scale-up their production of fuel-efficient cars through weight reduction by using carbon fibres. These efforts are projected to drive the CFRP market in the automotive industry, making it the leading industry by 2020 \cite{2}.

Several factors are driving the automotive market but the costs are, still today, a major barrier. If the cost of raw carbon fibre is following a decreasing trend, the manufacturing costs are instead almost constant if conventional high-performance technologies are used (i.e. autoclave processing). Moreover several composite technologies cannot provide a component cost reduction by increasing the production volume (series production). To achieve a reliable component-cost reduction, new out-of-autoclave technologies (like infusion technologies, prepreg compression technologies or short fibre

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