BY INÈS A. MELAMIES

Here comes the sun

Atmospheric pressure plasma makes CFRP solar race car lighter

ON 24 September, the starting shot for the international 2016 Sasol Solar Car Challenge running from Pretoria to Stellenbosch will be fired. To speed up the bonding process, optimize adhesion and save several kilos in weight, a participating team of students from KU Leuven University in Belgium pretreated the CFRP components of their solar racing car with atmospheric pressure plasma prior to bonding.

Production manager Dokus Soetemans and his 15 fellow students who make up the Punch Powertrain Solar Team are budding electronic and mechatronic engineers with an average age of 21 years. For over ten years Leuven University has worked closely with industry partners to offer its masters students a special postgraduate course: Those taking part in the biennial Solar Car Project have to build a single-seater racing car powered entirely by the sun and enter it in contests for the world's most efficient electric cars. The first aim was to compete successfully in the longest and toughest solar car rally in the world, the World Solar Challenge in Australia. That goal was achieved in autumn 2015. This year the South African sun beckons and the team is heading for the Western Cape.

The young team – who were entirely responsible for every detail of this €1.5 million euro car project – had just 15 months to make their dream of competing in international solar car races a reality. But before they could even think of the trip, the solar car had to be designed and built from scratch.

Every gram counts

Less mass means less energy consumption and with a maximum overall weight of 165kg, Punch One should be 10kg lighter than its predecessor and a good 25kg lighter than most of its rivals. Six square meters of the vehicle's surface are covered with 391 ultra-thin silicon solar cells. Yet despite their light weight, they still amount to a total weight of 8kg. The heaviest part of the car is the solar battery with a specified maximum weight of 21kg. Here, nothing could be shaved off. So to achieve the desired weight reduction the first job was to replace the two previous motors with a single 5 kW electric motor. The suspension and steering system were also replaced; they are now made mainly from carbon. But the car was still too heavy and the only area left to save weight was the vehicle body itself.

The body

The self-supporting body made by the students is a 1.72m wide x 4.5m long monocoque construction comprising a top and a bottom shell made from CFRP (carbon-fibre-reinforced plastic). Using a vacuum infusion process, the students manufactured the shells from different prepregs; a 0.08mm Textreme, a UD fabric and a 0.23mm twill. The core material is Rohacell. Once cured and demoulded, plastic shells of this size are strong as far as the material is concerned, but still very unstable due to their light weight, curved shape and large surface area. Therefore the top and the bottom shell needed a framework of stiffening ribs with an extra stiffening construction, the torsion box, for the bottom shell to prevent bending and twisting of the substructure. After assembly the two shells will give the solar car its final aerodynamic shape.

Bonding instead of lamination

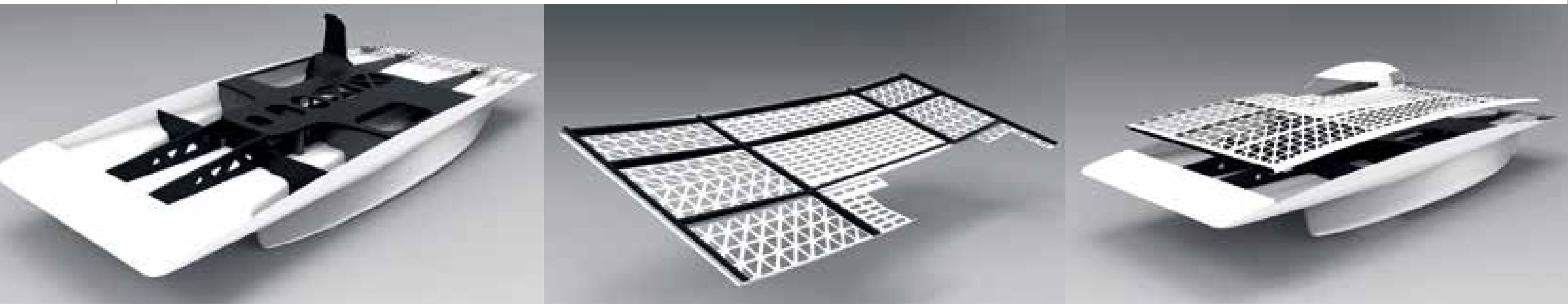
The joining force between the rigid foam ribs encased in Textreme and the bodywork must be strong enough to produce a back pull and counteract any tensile or compressive stresses in the shells in any direction. In view of the challenges the car body has to face during races, previous student teams had always chosen to laminate these static elements. Multiple layers and lengths of prepreg strips were applied at each attachment point of the ribs. But this joining method was not only extremely labour-intensive and time-consuming; all the extra prepreg strips also increased the weight. So the question was whether it would be possible after all to achieve a high-strength bond using adhesives instead of a lamination process.

Various adhesives manufactured by Henkel were tested to find an alternative. Due to the car's strong vibrations, an adhesive was required which had both high elasticity and a short open time for fast bonding operations. Loctite EA 466 was ultimately chosen, a fast curing, 2-component epoxy resin adhesive.

However, in the first tensile-shear-force tests failure occurred as a result of an adhesive fracture instead of the expected cohesive fracture. At the fracture point there was no adhesive on the CFRP surface that was to be bonded, despite the fact that this had been pre-treated with a special cleaner.

"We were told", says Soetemans, "that the problem lay not with the adhesive, but with the material. It was thought that the poor adhesion was due to the surface energy, which was apparently too low. Henkel advised us to treat the plastic surfaces of the ribs with atmospheric pressure plasma (AP plasma) and recommended the nozzle technology of Plasmatreat." The team immediately got in touch with Rycobel, the Belgian representative of the German plasma system producer."

Plasma-treated monocoque bottom shell showing ribs and torsion box (left). Plasma-treated structure of the stiffening ribs in the top shell (middle), and assembly of the different car body layers (right) PHOTOS: PUNCH POWER SOLAR TEAM



Powered only by the sun: **The aerodynamic vehicle is covered with 391 ultra-thin silicon solar cells**

PHOTO: ROB STEVENS KU LEUVEN

Cleaning and activation with AP plasma

Openair-Plasma jet technology developed by Plasmatreat 20 years ago is employed today worldwide in almost all fields of industrial production. The process uses potential-free plasma for surface pre-treatment. Produced inside plasma nozzles by an intensive, pulsed arc discharge, the plasma is conditioned at the nozzle outlet. A targeted flow of air along the discharge path separates parts of the plasma and transports them via the nozzle head to the surface of the material being treated, whilst retaining the voltage-carrying parts of the plasma flow inside the nozzle head. The nozzle head also determines the geometry of the plasma beam being emitted.

The process performs three operations in a single step lasting only a matter of seconds: It simultaneously brings about the micro fine cleaning, electrostatic discharging and activation of the plastic surface. This triple action far outweighs the effectiveness of conventional pre-treatment systems. The result is homogeneous wettability of the material surface and long-time stable adhesion of the adhesive bond or coating even under challenging load conditions.

The surface is activated through the chemical and physical interaction of the plasma with the substrate. When the AP plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix. Plasma activation brings about an increase in surface energy, rendering the substrate polar.

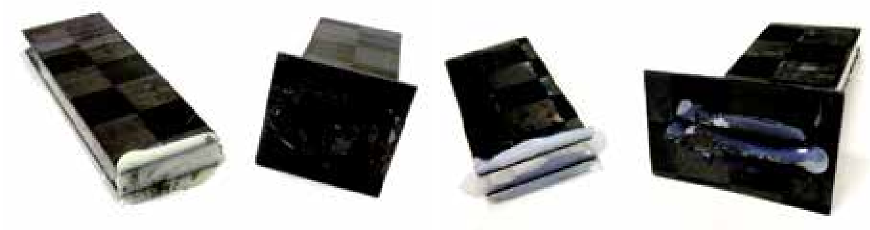
Convincing test results

Never before had the students experienced a material pre-treatment with plasma and they were keen to see the process. Two different tests had to be performed to verify the effect, one before and one after the bonding process. The aim of the first test was to determine the surface energy of the CFRP before and after plasma treatment. These were the results:

Before treatment, the smooth side of the CFRP sample which was to be bonded had a surface energy of only 24mJ/m² (24 dyne), but after plasma treatment this figure rose to 74mJ/m² (74 dyne) – ideal conditions for the subsequent adhesive process. The second test, a repeat of the tensile-shear-strength test provided the proof: The fracture behaviour had changed. Instead of the earlier adhesive fracture, this time the desired cohesive fracture was obtained.

Adhesive fracture before plasma treatment (left) and cohesive fracture after plasma treatment (right)

PHOTOS: PUNCH POWER SOLAR TEAM



Lighter and faster

The students carried out the plasma treatment and bonded all the stiffening ribs to the two body shells. To make the job easier, Plasmatreat provided a hand-held rotary nozzle jet normally used for laboratory work or small-scale applications which weighed only 2.5kg. The process proved to be very straightforward: Whilst one person guided the plasma nozzle across the surfaces to be treated, the next person followed on behind applying the adhesive. Some pressure was applied to the bonded ribs and off the shell went into the oven for one hour at 90°C to cure the adhesive.

While previously it had taken far longer than a week to laminate the stiffening ribs, now with the aid of plasma the job was completed in three days. But even more importantly: The new plasma bonding process had reduced the weight of the solar car body by almost three kilograms and the targeted 165kg overall weight had now been achieved.

- Plasmatreat GmbH is represented in SA by Resin Processing Solutions cc, Tel: 021 510 6903

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