Powered only by the sun: The energy-efficient Punch One solar car before heading to the world championship in Australia. The plasma bonding process reduced the weight of the CFRP bodywork by several kilos. (Image: KU Leuvens/Rob Stevens)

Bonding instead of lamination

Atmospheric pressure plasma makes CFRP solar car lighter

A team of students from KU Leuven University in Belgium saved a great deal of weight by treating the CFRP components of their new solar racing car with atmospheric pressure plasma prior to bonding. The car is now ready to compete in the World Solar Challenge in Australia from 18 to 25 October..

Production manager Dokus Soetemans and his fifteen Belgian colleagues who make up this year's '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 Solar Car Project – which takes place every two years – have just 15 months to build a single-seater racing car powered entirely by the sun and enter it in the contest for the world's most efficient electric car. The aim is to compete successfully in the longest and toughest solar car rally in the world: The World Solar Challenge in Australia.

Every gram counts

Less mass means less energy consumption. With a maximum overall weight of 165 kilograms the new Punch One solar car should be 10 kilograms lighter than its predecessor and a good 25 kilograms 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 low weight, they still amount to a total weight of 8 kilograms. The heaviest part of the car is the solar battery at 21 kilograms. Here, nothing could be shaved off. So to achieve the desired weight reduction, a single 5 kilowatt electric motor was installed instead of the previous two motors. The suspension and steering system are now made mainly from carbon-fiber-reinforced plastic (CFRP). But the car was still too heavy – the vehicle body had to be lighter.

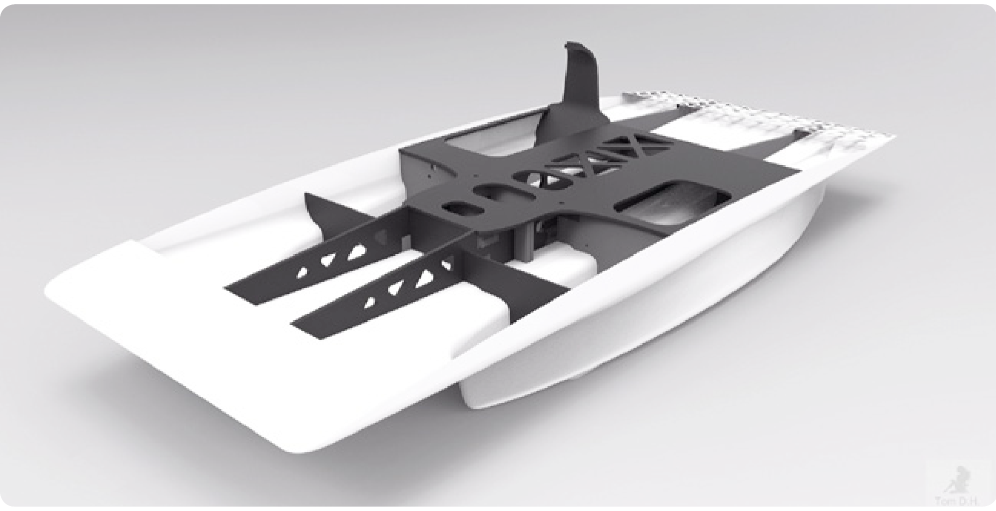
The self-supporting body made by the students is a 1.72 meter wide and 4.50 meter long monocoque construction comprising a top and a bottom shell also made from CFRP. Using a vacuum infusion process, the students manufactured the shells from different prepregs; a 0.0 8mm Textreme, a UD fabric and a 0.23mm twill. The core material is Rohacell. To resist bending moments, robust stiffening ribs are incorporated into the design.

In the solar cars built by previous student teams these static elements had been laminated. Multiple layers and lengths of prepreg strips were applied at each attachment point. This joining method is not only labor-intensive and time-consuming, it also increases the weight.

Bonding instead of lamination

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 to allow the work to be completed quickly. 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. "We were told", said Soetemans, "that the problem lay not with the adhesive, but with the material. It was thought that the poor adhesion was due partly to insufficient surface cleaning, but largely 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)." The team took this advice and immediately got in touch with the Belgian representative of the German plasma company Plasmatreat

Cleaning and activation with AP plasma

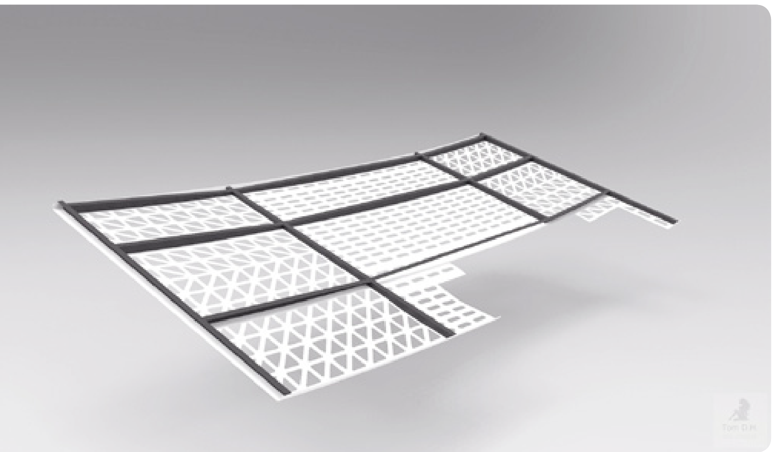


Monocoque bottom shell showing ribs and torsion box. (Image: Punch Power Solar Team)

The Openair plasma jet technology developed twenty years ago is employed in many branches of industry. The process uses a potential-free atmospheric plasma to pretreat surfaces. Produced inside plasma nozzles by an intensive, pulsed arc discharge, the plasma is conditioned at the nozzle outlet. The surface is activated through the chemical and physical interaction of the plasma with the substrate.

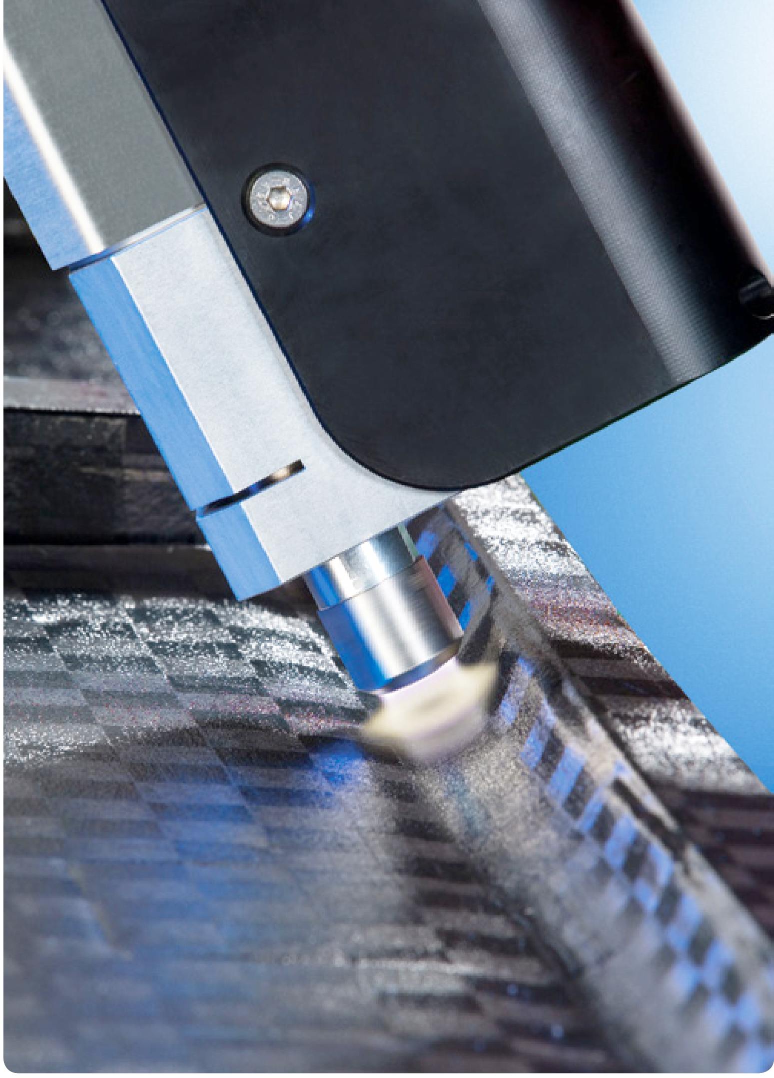
The process performs three operations in a single step lasting only a matter of seconds: It simultaneously brings about the microfine cleaning, electrostatic discharging and activation of the plastic surface. The result is homogeneous wettability of the material surface and long-time stable adhesion of the adhesive bond or coating even under challenging load conditions.

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. Plasmatreat measured the contact



Structure of the stiffening ribs in the top shell. (Image: Punch Power Solar Team)

angles using a Mobile Surface Analyzer (MSA) from Krüss. The portable instrument automatically applies two parallel drops, then measures the contact angle and calculates the free surface energy in a process which lasts no more than a second. The results provide valuable information about the wettability of the surface by aqueous or organic liquids. The findings: The smooth side of the CFRP sample which was to be bonded had a surface energy of only 24mJ/m² (24 dyne) before treatment, but after plasma treatment this figure rose to 74mJ/m² (74 dyne) – ideal conditions for the subsequent adhesive process.



Pretreating the CFRP bodywork with Openair plasma. Microfine cleaning and simultaneous activation of the plasma significantly enhances the wettability and the adhesive properties of the plastic surface. (Image: Plasmatreat)

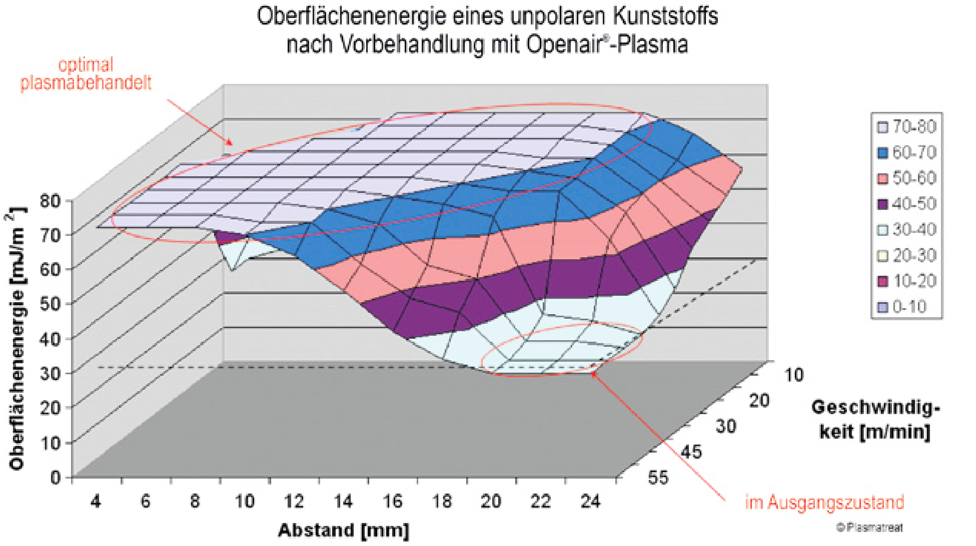
A repeat of the tensile-shear-strength test provided the proof: The fracture behavior had changed. Instead of the earlier

Diagram showing the different layers of construction of the solar car. (Image: Punch Power Solar Team)

KM Info

„Punch One“ – technical facts

Designer: Punch Powertrain Solar Team, KU-Leuven
Dimensions: 1,72 m x 4,50 m
Overall weight: 165 Kg
Bodywork: CFRP monocoque, pretreated with Openair plasma (Plasmatreat)
Solar cells: Silicon cells, 391 units, 6 m² (SunPower))
Battery: Li-ion 155V, 5.1kWh, 36Ah, 21 kg, range 400-500 km (Panasonic)
Electric motor: 5KW (Mitsuba), reduced to max. 120 km/h (energy efficiency)
www.solarteam.be



The diagram shows a non-polar plastic surface that was pretreated as a function of distance and speed with plasma. Treatment renders the surface polar and the surface energy rises to >72 dyne with a large process window. (Diagram: Plasmatreat)

adhesive fracture, this time the desired cohesive fracture was obtained.

Lighter and faster

Under the direction and supervision of their production manager, members of the team then 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 normally used for laboratory work or small-scale applications which weighed only 2.5 kilograms. 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 a week to laminate all the stiffening ribs, now with the aid of plasma the new process was completed in three days. The joining process also reduced the weight by almost three kilograms: The targeted 165 kilogram overall weight had now been achieved. In October the car will head to Australia. The young students are pinning all their hopes on the sun.

This article is based on one written by specialist journalist Inès A. Melamies.

Surface activation CFRP bonding
Plasmatreat, www.plasmatreat.de