ALFA ROMEO "8C COMPETIZIONE"
ALL COMPOSITE BODY AND INTERIORS

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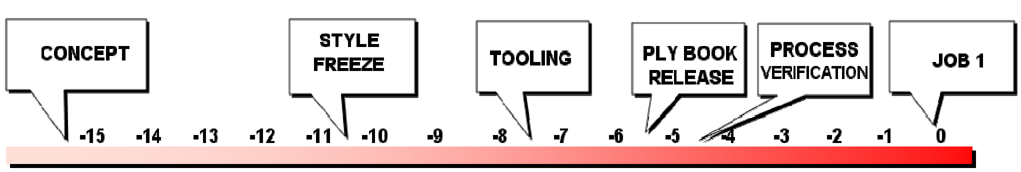
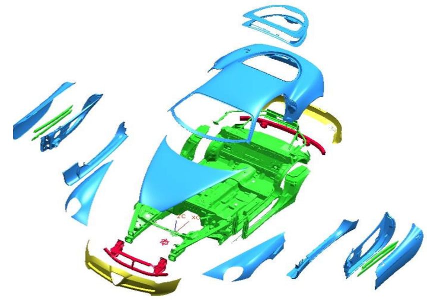
INTRODUCTION

The limited edition Alfa Romeo 8C is based on a shortened Maserati Coupe platform; it will be produced in a total of 500 cars, completely sold out.
The car is driven by a Maserati-sourced aluminium 4.2-liter V8 engine making more than 400 horsepower. A six-speed gearbox with paddle shifters transfers power to the rear wheels; it can also be operated in full automatic mode.
The shape of the car comes from Alfa Romeo "Centro stile", and the structural design has been carried out by "Elasis" (Pomigliano D'Arco-Naples), a FIAT group Company. The composite body and interiors are being manufactured by ITCA, another FIAT group Company, in Colonnella (Teramo) and the steel chassis in Grugliasco (Turin). ITCA, in Colonnella, is running a division of ATR GROUP, which was responsible to finalize the prototype production, starting from the design support and tooling and overall process definition. The final assembly of the body-in-white takes place in FIAT MIRAFIORI in Turin and the complete dressing of the car in Maserati (Modena).
The car's distinctive look comes from an extensive use, on the body and interior panels, of composite materials, which allows the monolithic design of large and complex components ; the entire upperbody, for instance, from the windshield to the rear bumper, is one piece only.
The use of carbon fibre has permitted construction of an exceptionally light body: CFRP components individually weigh up to 50% less than steel and 30% less than aluminium, while offering the same strength as steel or alloy counterpart, with consequently benefits of sparkling acceleration, short braking distances and reduced fuel consumption.
The timing of the program (see bar below) has been very stringent, especially on the last phase, as it usually happens. The overall program, starting from the concept definition to the first customer delivery (JOB 1), took 15 months and just 6 months for the design and manufacturing of models and moulds and for the production of the first prototype.



CARBON FIBER BODY AND INTERIORS COMPONENTS

An exploded view of the car body outlining all the components is shown below.
The different types of structure for the various composite parts (in blue in the picture) are outlined below:

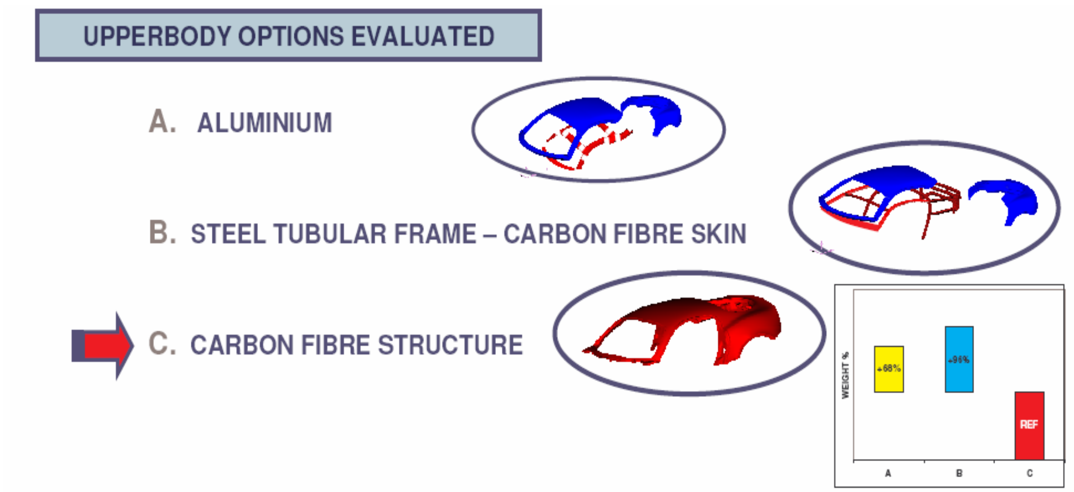


- Front fenders, under door longeron covers, wheel housings (not shown in the picture), rear closure and rear bumper (USA version only) are solid laminate
- Inner and outer door skins are solid laminate post-bonded and incorporate anti-intrusion steel bars
- Front hood is a honeycomb sandwich part
- Front and rear spoilers and rear window support structure are hollow sections one shot cured with the aid of inflated rubber tools to assure the necessary inner pressure
- The monolithic upper body is a co-cured very complex structure: it includes the windshield frame, the roof and the rear body. Honeycomb sandwich and hollow structures are both present.

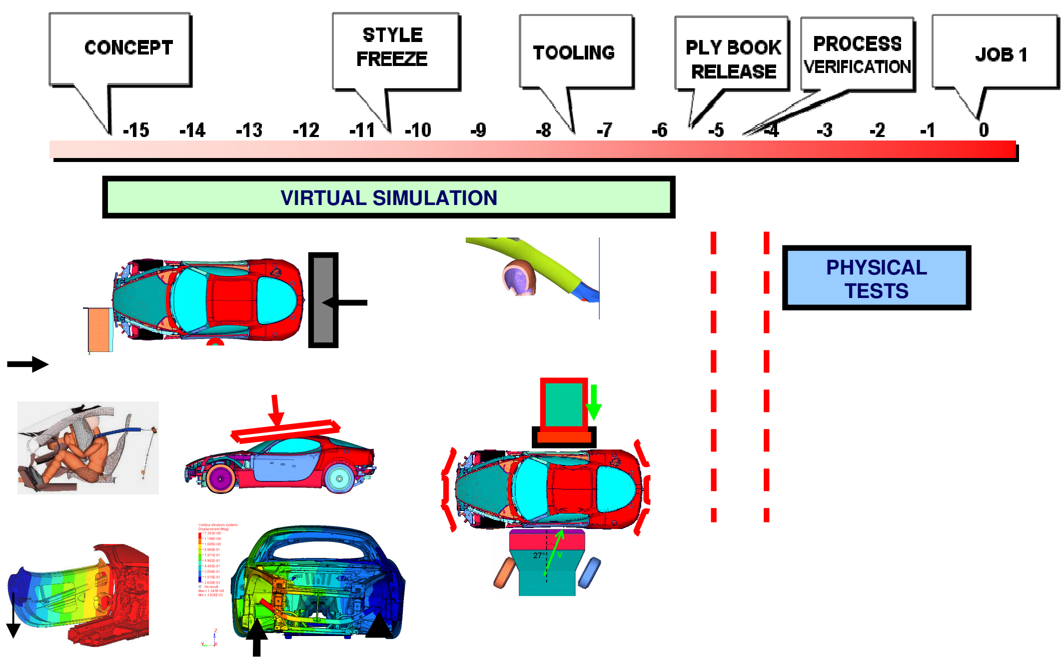
The 8C interior designers developed centre console, centre tunnel, door panels, rear panel, all made from exposed carbon (carbon look), which is the main reason that attracts customers and, at the same time, makes so difficult their manufacturing.
In fact, customers require a high level of aesthetical standard on a “hand made” product.

BODY DESIGN

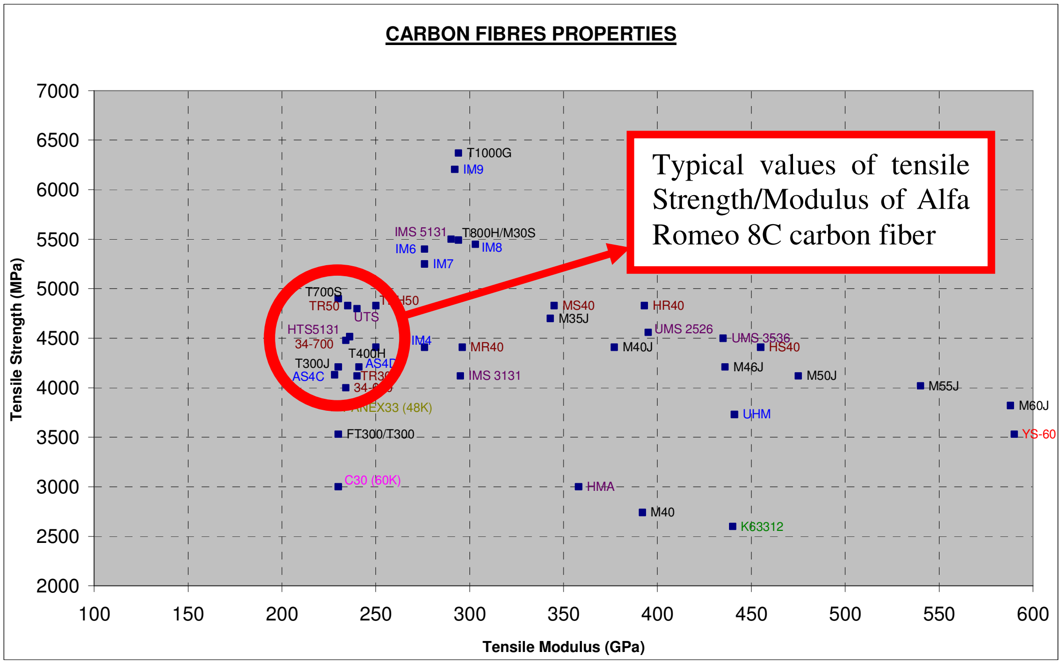
The design drivers of the body were mainly weight, stiffness, crashworthiness and surface appearance.
Together with the necessity to maintain the original concept shape of the Alfa Romeo style, one of the most important constraint for the structural design of the body was the steel underbody carry-over. Consequently, the way to minimize weight, while reaching the structural targets, was found through an extensive design work, leading to a carbon fibre upperbody structure with the most appropriate raw material selection.
A comparison in terms of weight performance of the different concepts evaluated during the design phase is displayed in the image below:



An optimized carbon fiber material lay-up has been designed for each component , with the integration of CAD-CAE virtual analysis and technological feasibility studies, including cost considerations.
Physical tests carried out on prototypes, following EU/USA requirements (ECE 94, ECE 95, Trias 33, Std 216 USA, etc.) highlighted an exceptional correlation between experimental and numerical results.
In the image below the time sequence of the project milestones is represented, with a total of 15 months of activity starting from the concept definition to JOB 1

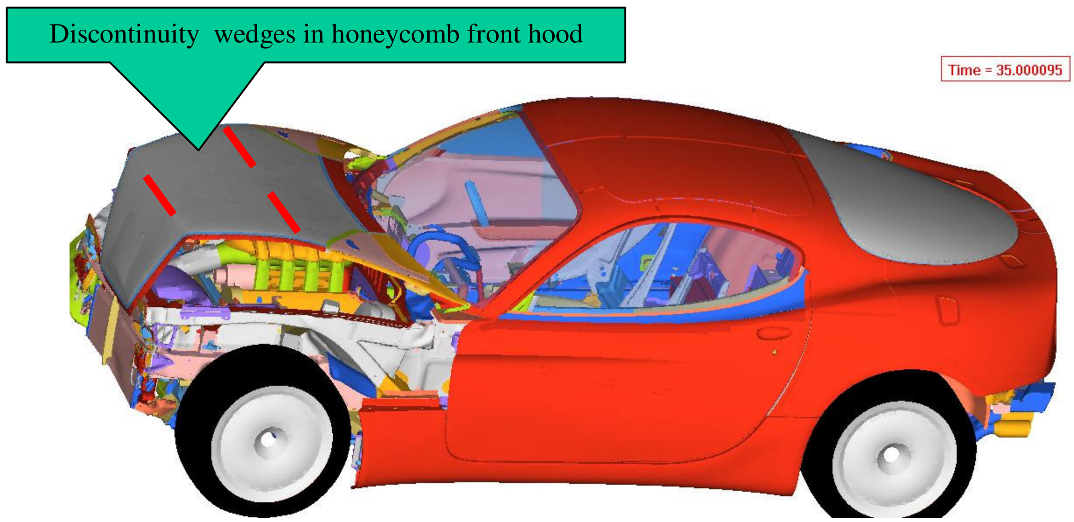


The fibers selected are mainly HS fibers , with typical values of tensile strength and tensile modulus shown in the table below:



The most used fabrics are the following:
-200gsm plain weave (PW) and 2x2twill, for esthetical reasons in the carbon look parts and to ease the painting process.
-380gsm and 600gsm 2x2twill, mainly for drapability and for reducing the number of layers and, hence, man hours.
-600gsm 45° biaxial, for cost reduction.

An extensive use of UD prepregs has been done in order to optimize the structural performances, thanks to fibre orientation lining with the specific load patterns, for example in the A –pillar (for front crash impact) or in the door outer and inner shells (for the side impact).
In order to achieve the structural performances, in particular to guarantee the needed toughness a specific epoxy resin system with 130°C curing temperature has been used for body structural components.
The sandwich configuration has been adopted in order to achieve the stiffness target in large and almost flat components (as the front hood and the central part of the roof), with an enormous weight saving in comparison with the classical inner and outer steel panel solution, requiring a considerable stiffening structure, giving great surface marking problems.
For example, the front hood sandwich structure has shown a 20% weight reduction, compared with the classic skin-stiffeners solution, with the structural targets (strength and torsion and lateral stiffness) respected and with the energy absorption and deformed shape (guided through the three discontinuity wedges created in the honeycomb of the front hood, as shown in the figure below), required in crash impact, achieved.
In the image below it is shown an example of the deformed shape from virtual analysis, which very well matches the physical crash test situation.



PRODUCTION PROCESS AND TOOLINGS

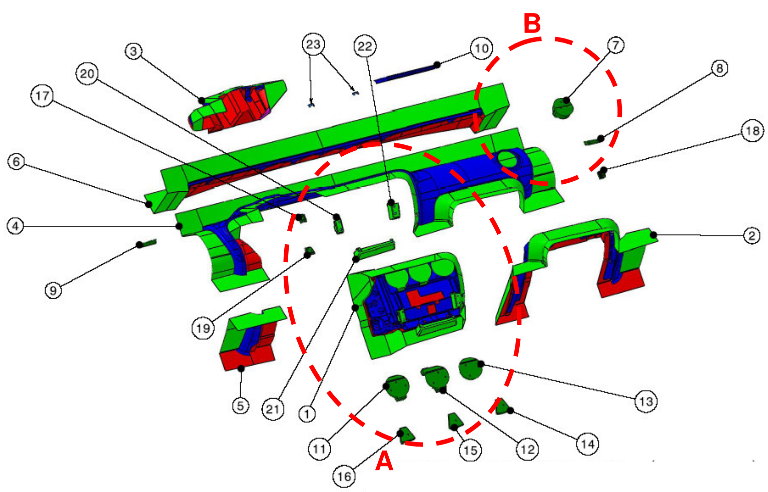
The manufacturing process is a well known and consolidated hand lay-up process, vacuum bagged and autoclave cured at pressures ranging from 0.2 to 0.6 Mpa.
The moulds, following a very long tradition and experience of the manufacturing Company, are mainly made out of low temperature epoxy resin with carbon fiber reinforcements, post cured at 180°C. The adoption of composite moulds, avoiding thermal shrinkage differences, allows the production of very accurate and dimensionally stable components. In addition, composite moulds are less expensive and lighter than metal moulds.
The material chosen for the models is an epoxy tooling board, ideal for hand laminating pre-preg moulds and vacuum forming. We have selected boards with shore strength of 75D, density ranging between 0.72-0.75 g/cm3, compressive strength of 50-55 MPa; they offer high dimensional stability, good temperature resistance, easy machining and a good surface finish after CNC milling, reducing the final hand polishing operations and, subsequently, speeding up the entire manufacturing process.
The very rapid timing for tooling design and manufacturing was mandatory to match with the overall very short time to market, especially considering the very limited time allocated to the last production phase.
Once the models were milled from CAD data, properly finished and painted, several layers of carbon fiber fabrics, pre-impregnated with low temperature epoxy resin, were laid over the models by hand and autoclave cured at low temperature (60°C), just enough to cure the resin and confer the required strength and toughness. The entire composite structure was then post-cured at 180°C to withstand, in use, the curing temperatures.
Due to the high car rate production (2.5 kit/day) it has been necessary to produce more than one mould for each component, the exact number depending on the production capability of each of them. For example, to assure the desired car rate production, 8 upperbody CFR moulds will be necessary.
The duplication of the moulds took place from CFR master models, which guarantee the preservation of surface quality and of dimensional stability, after more and more autoclave cycles.

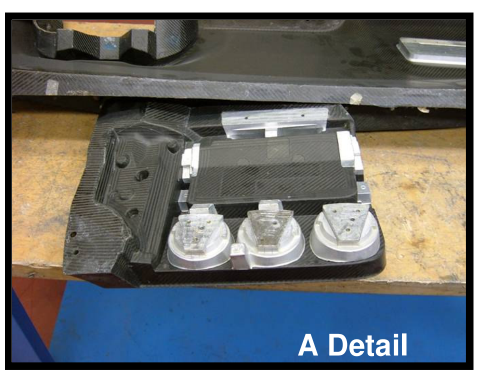
INTERIOR PART FOCUS

The parts are produced with an appropriate epoxy resin system featuring a very high transparency and an excellent UV rays resistance. The autoclave process is the same of the body structural parts but with a lower curing temperature (125° C) due to the aesthetical nature of the part compared with the structural ones. The prepreg reinforcement fibers used are graphite, kevlar and glass, the mixture of which comes out from a very delicate design process as requested to meet the human body impact requirements.

For carbon look esthetical parts the use of moulds machined from solid aluminium alloys has been preferred, due to the better surface quality achievable and also their longer life. For very big components, like the central console, conventional composite moulds have been adopted, because of the considerable mass of the metal moulds and also for possible dimensional problems due to very different thermal expansion coefficient between aluminium (α=24x10-6°C^{-1}) and carbon fiber (α=-0.1x10-6°C^{-1})

In the case of the central console, the mould is very complex, resulting from the assembly of many different composite and aluminium parts, as shown in the images below:



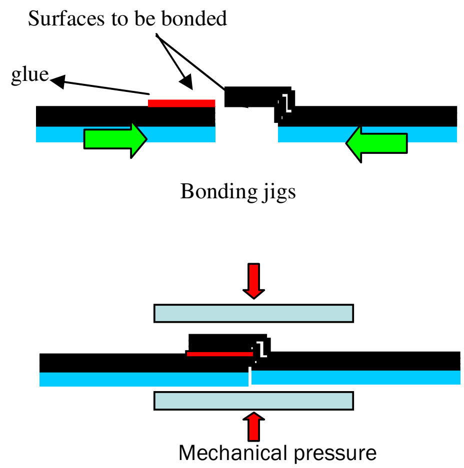


BONDING SOLUTIONS

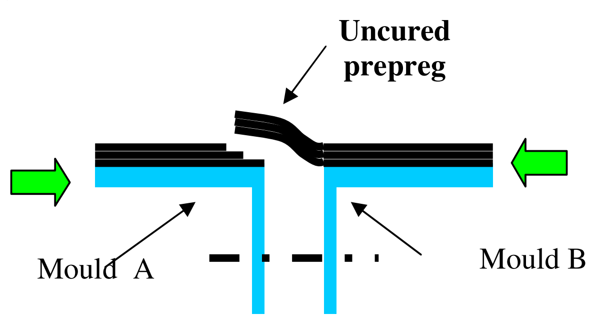
For body components two kinds of bonding solutions have been adopted:

- Post-bonding: it is the "classical" one, in which the two parts have to be first cured and then bonded each other, trough the application of structural glue and a thermal cycle at 80°C for about 1.5 hours. The structural glue typically used is a black,

thixotropic, gap filling two component epoxy adhesive, very easy to handle. It is designed for use where toughness and high strength are required and shows special benefits in the construction of composite assemblies (the typical assumed value of shear strength is 20 N/mm^2).
The bonded surfaces need to be prepared, in order to have a correct geometrical matching of the joining surfaces and, hence, the correct adherence between the glue and the carbon fibre surfaces; the use of specific bonding jigs guarantees the mechanical application of pressure, giving to the joint the appropriate strength. In the Alfa Romeo "8C Competizione" this bonding solution has been used for the inner and outer door skins and also for the front fenders.



- <u>Co-bonding</u>: the bonding of the two parts takes place when they are in their relative moulds and one part, or both parts, have not been cured yet. Between the two parts a high temperature film adhesive is interposed and the geometrical coupling of the two parts is made easier by the deformability of the uncured part. The autoclave pressure, evenly distributed on the joint, and the high temperature of the curing process (about 135°C) , make possible the correct evacuation of air or gasses from the joint and the reduction of adhesive viscosity, with a consequent homogeneous distribution of it. A monolithic joint is therefore created and its structural performances are optimal.
  When the resin system is sufficiently self-adhesive and the parts to be joined are both uncured, the film adhesive can be avoided.



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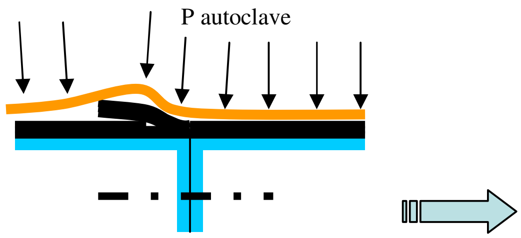
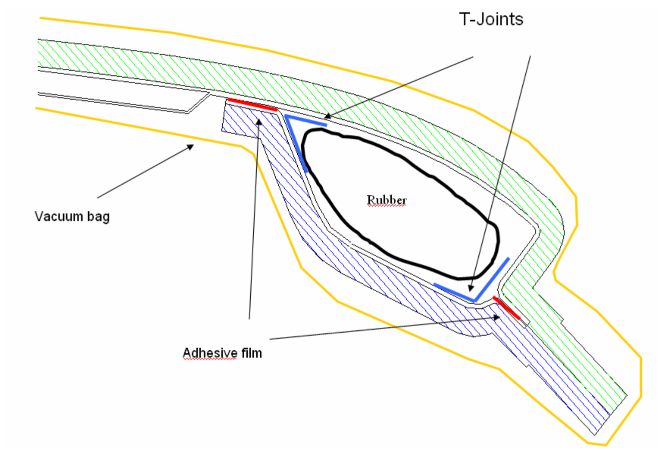


For closed hollow sections the use of rubber tools or tubular vacuum bags is mandatory to assure the internal pressure. In order to increase the structural performances, sometimes it is necessary to add CF reinforcements that generate typical T-Joints, like in the picture below.



Other advantages of the co-bonding are: the dimensional accuracy of the bonding, the repeatability of the results, and the reduction of costs, due to shorter production cycle times (the preparation of bonding surfaces and the operation of bonding itself with the use of specific jigs are completely eliminated from the cycle). On the other hand there are several geometrical constraints for the use of this bonding solution, like the minimum dimension of the hollow section for the feasibility of rubber tools and the creation of openings in the structure, needed for the extraction of rubbers after the autoclave curing process.
In the Alfa Romeo 8C the co-bonding is used for the complex monolithic upperbody and also for front and rear spoilers and rear window support structure.

SURFACE QUALITY

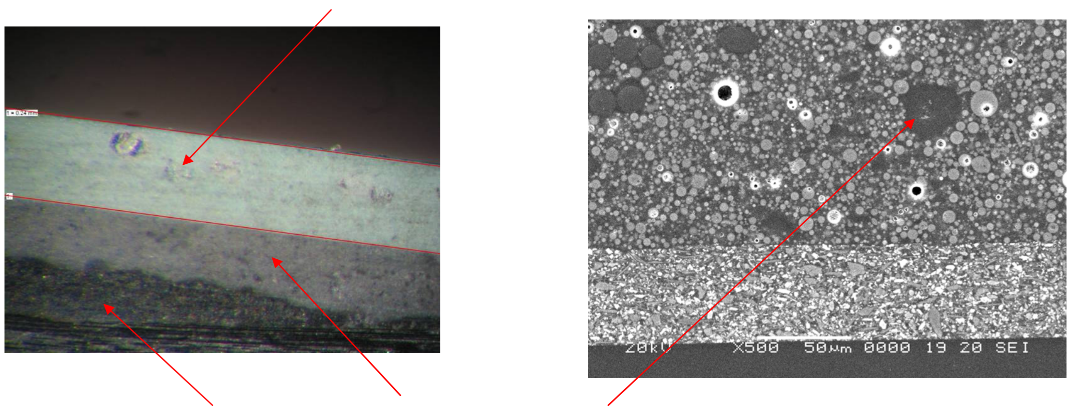
PAINTED SURFACES

One of the most important requirements of external painted body is the “Class A” quality surface , that means that the CFR components have to guarantee a very good support surface for the following phases of colour paintings; this implies very smooth surfaces without deformations and markings, no porosities due to micro air bubbles, and lack of impurities, of course. To achieve these results it was very important to define some critical project and process requirements:

- A specific surface film has been chosen, deposited as the first layer in the mould during the lay up sequence, that guarantees a better surface finish quality and a protection of the underneath carbon fibre layers during the sandpapering of the finishing work (see image below)
- The very important definition of the correct lay up immediately below the surface film , in terms of fabric style and fabric specific weight.
- The selection of the matrix , which has to guarantee thermal stability and no ageing surface defects at working temperatures for all the car life time.
- The manual application of an epoxy primer, in two distinct phases: the first directly on the mould, before the surface film, with the appropriate roughness required for air and gasses evacuation, and the second on the parts during finishing.

The result of these three steps is shown in the image below:

Gel coat epoxy primer



CFRP **Surface film**

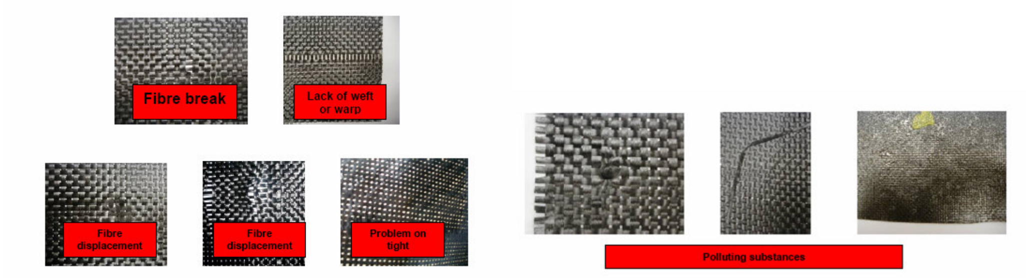
CARBON LOOK SURFACES

The “carbon look” interiors are painted to a variety of gloss finish with clear coat paint following a very complex and delicate process, which usually requires a three step operation: two primer and one paint layers, each followed by sanding and oven cycles.

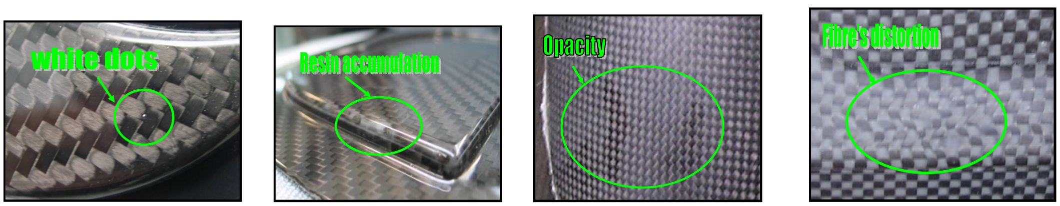
The gloss level is generally 15 (to minimize dangerous back light reflection) , except the push button central console (shown in the image beside) that has a gloss level of 80.

The surface quality of the carbon look parts must be almost perfect. Any visible defect leads to scrape the item, therefore, the process of manually laying down the first layer on the mould needs an extreme care and skill. Typical defects generated by the material itself or by the process are shown below.

Typical carbon look surface defects due to raw material defects:



Typical carbon look surface defects due to process (hand lay up and painting):



CONCLUSIONS

The body of the Alfa Romeo "8C competizione" has been designed and manufactured in composite materials in order to achieve the stringent weight and stiffness requirements of the project.

This concept has been also dictated by the economical targets of the non recurring investment costs for a very limited production lot of 500 vehicles. In addition, it has been possible to compress the total lead time to just 10 months from the style freezing to the first customer production unit, in comparison with a much larger lead time of a traditional metal body vehicle.

The massive use of carbon look in interior parts has been very challenging and, at the same time, very successful.

The entire process has its foundation on a well established, well proven process, developed along the years on similar projects by ATR GROUP (Ferrari F50, Ferrari Enzo, Porsche Carrera GT, Bugatti Veyron, Lamborghini Murcielago, etc.)

The manual hand lay up process has been demonstrated valid for very limited production rates (maximum 3-4/day). Higher rates, but still in niche programs (10-50/day), may still be wise for composite application, but they need different process, as for example, all kind of resin injection in dry fibre preforms.