MATERIALS AND MANUFACTURING PROCESSES OF THE SUPERBUS

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ABSTRACT

The *Superbus* is a new public transportation non polluting, fast, economic, and appealing vehicle developed in The Netherlands as proof of concept for the implementation of a new transportation system which includes totally new infrastructure and logistics.
This new vehicle is sustainable, can transport passengers and goods from point to point and drives at high speed (250 km/h cruising) on dedicated and relatively cheap infrastructures and at conventional speed on existing roads.
For the achievement of the structural design targets, the vehicle must be as light as possible. For that, the vehicle uses a composite chassis, HPPC thermoplastic bodywork and Lexan polycarbonate glazing.

In this paper the structural design of the *Superbus* (Figure1) is highlighted, then the materials used and the manufacturing processes of the *Superbus* are presented.
First the overall the best design in terms of achievement of the target torsional stiffness (30 kNm/deg) with respect to lightness and easiness of is described. Then, the manufacturing of the various parts, namely chassis, bodywork and glazing will be described.

KEY WORDS: Design, Applications – Automotive, Vacuum infusion, Carbon Fiber Composites

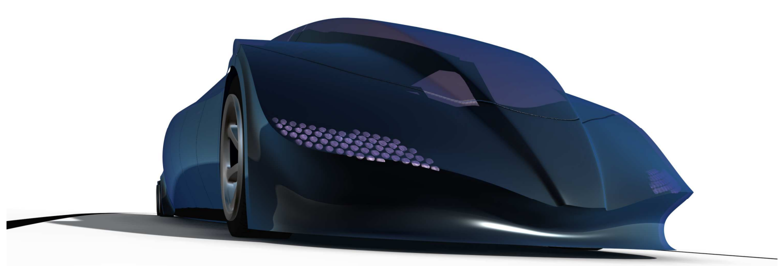

Figure 1 The Superbus.

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1. INTRODUCTION

The *Superbus* (Figure 2) is a concept from TU Delft [1] for the development of an innovative collective transport system. The design and manufacturing of the *Superbus* is managed, coordinated and integrated by a dedicated team at TU Delft, in collaboration with a number of other universities, institutions and companies. The *Superbus* programme is founded by the Dutch Ministry of Transport and Water Management for the realisation of a DEMONSTRATOR for evaluation of the feasibility of the system.

Figure 2 the Superbus

The Superbus concept [2] consists of a new vehicle, a new type of dedicated infrastructure and a new logistics. The Superbus is sustainable, safe, and transports passengers and goods from point to point traveling on both its dedicated roads and on existing roads. The Superbus is not only sustainable for that it does not produce CO2 emissions but for many other aspects. For example, it uses some recyclable materials, it is designed to increase the use of public transportation, thus limiting the ever growing private transportation, and it uses low power per passenger. The *Superbus* provides flexible transportation on request and therefore does not travel on a fixed schedule. One of the strengths of this new type on transport consists in the relatively economic dedicated roads – as it comprise concrete roads and sensors only - and on the ability to use existing roads, unlike trains, to reach any destination. A fundamental characteristic of the *Superbus* is its safety – both passive and active. The *Superbus* is designed to be very safe structurally and adopts a navigation system unique to land vehicles. Indeed, aerospace navigation instrumentations are implemented together with state of the art safety systems for road transport. Alongside that, a number of active safety systems are under consideration such as airbags, seatbelts, rear parachute and lateral morphing structures for emergency braking.

For the achievement of low consumption, the vehicle has been designed to achieve the target design requirements with the minimum weight. Also, the Superbus uses a composite chassis, IXIS bodywork (thermoplastic composite sandwich material which weighs half of the same part made of steal but it is equivalent in stiffness) and Lexan glazing (a polycarbonate based material preferred to glass for weight saving and safety).

2. SUPERBUS STRUCTURAL LAYOUT

The Superbus is 15m long, 2.5 m wide and 1.6 m high and carries 23 passengers and a driver. The vehicle has 16 doors, 8 per side, due to the required comfort, privacy, and accessibility aspects. The overall vehicle weight is 9 tons, including the payload. The importance of the weight limitation of the vehicle has enforced the implementation of a new design and the use of lightweight materials.

The structure of the vehicle is composed by a carbon fiber chassis. It uses IXIS for the central part of the bodywork, carbon fiber for the front and rear bodywork and Lexan for the glazing.

The structural design of the chassis has proven significantly challenging for the presence of the 16 doors. In order to limit the weight, a crossbeam design has been implemented [3] so to enable the utilization of the entire vehicle cross section for torsion stiffness. The crossbeams design equates to a 40% weight reduction for the achievement of the target 30kNm/deg torsional stiffness, when compared to a more conventional design formed by horizontal beams.

The chassis (Figure3) is formed by a floor connected to 2 side frames united by 8 top beams.

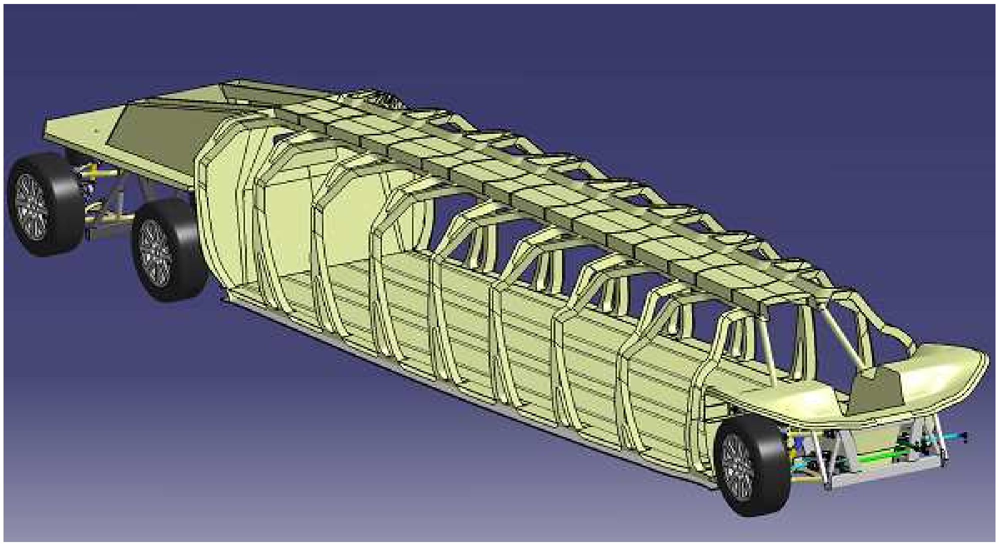

Figure 3: Chassis and suspension system

The floor is made of two skins inside which there are six longitudinal beams and 16 transversal beams. Each transversal beam is divided in seven parts to intersect the longitudinal beams. The central part of the chassis is connected to the forward chassis part, the driver house, and the rear chassis part, which envelopes the powertrain compartment.

3. MATERIALS

The Superbus structure is built almost completely from carbon-epoxy composites. This allows the weight of the bare structure to be kept to 1300 kilograms, which is exceptional for a 15 meter vehicle. The carbon fiber used throughout is Torayca T700.

The complete load carrying structure is built using a 12K carbon fiber unidirectional tape and stitched tri-axial fabric of 0° and +/-45° carbon fibers, which allows the lay-up to be more efficient compared to a standard lay-up of unidirectional tape and 45° rotated fabric.

The carbon fiber is used in combination with the latest development of epoxy resin developed for vacuum-assisted resin infusion molding by Dow Automotive. This epoxy resin has a very low viscosity and a long pot life, making it ideal for the main Superbus manufacturing process.

For the floor skins and for the front and rear bodywork, Soric core material supplied by Lantor BV (Netherlands) is used. This pressure stable polyester non-woven is ideal as core material for components that are in the area between monolithic parts and sandwich panels using foam or honeycomb.

A large part of the exterior bodywork is manufactured from SABIC's latest development in automotive materials: IXIS, which is a thin sandwich consisting of skins of unidirectional glass fibers in a polypropylene matrix and a core of random glass fibers in a polypropylene matrix. This combination results in light-weight panels with excellent impact quality and a Class A finish.

The glazing of Superbus is made of polycarbonate Lexan, supplied by SABIC, in two material specifications. For the blue side windows glazing, 6mm and IR-absorbtion treated sheets are used. The same material specification could not be used for the front windshield for two reasons. First, because of the structural requirements, that enforced the use of a 10mm thick glazing. Second, because of the light transmission requirements which, for the windshield, must to be more than 75%. Therefore, for the windshield, a clear 10mm clear polycarbonate Lexan is used.

4. MANUFACTURING

The floor structure, shown in Figure 4, consists of two sandwich plates, namely top and bottom of the floor plates, which are produced by vacuum infusion on a flat mould.

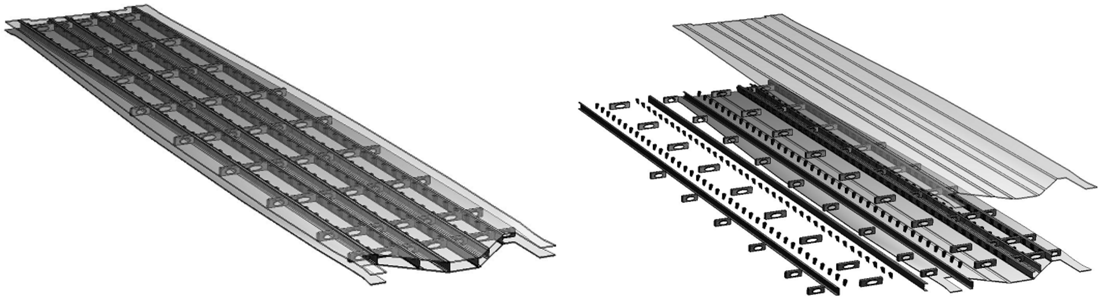

Figure 4: Floor assembly

The floor skins have been optimized in weight, height and stiffness through the utilization of a two millimeter thick type of Soric pressure stable polyester non-woven, used as core material. A number of tests have been carried out in order to ensure that the established stiffness would also comply with passengers comfort level. Figure 5 shows the manufacturing of the 10x2.5m top plate by vacuum infusion.

Figure 5: Floor top plate manufacturing

The bottom plate includes access hatches. The latter are infused separately on the flat mould, cured, trimmed and replaced on the mould cover by Teflon release film. Then, the bottom plate is infused over the hatches resulting in a flush outer surface.

The longitudinal beams (Figure 6) were also made by vacuum infusion in a simple U-shaped sheet metal mould. To ensure a proper mould filling, and to avoid fiber bridging in the negative mould radii, a patented pre-forming process is performed in a separate tool [4].

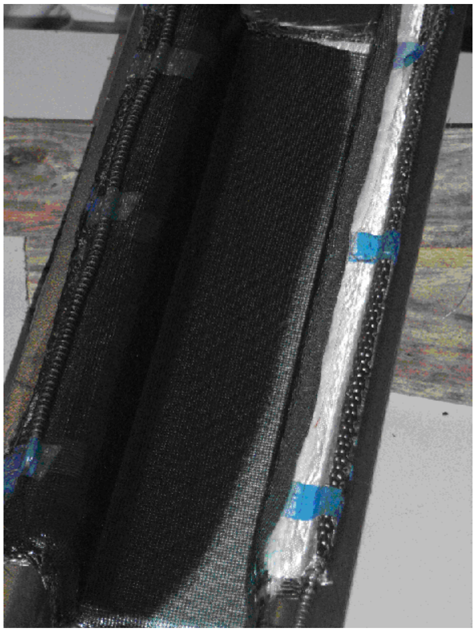

Figure 6: Manufacturing of a longitudinal beam by vacuum infusion

The transversal beams, one of which is showed in Figure 7, due to their large amount and relatively small dimensions, were produced by hand lay-up. Each element present a central hole to allow for installation of systems such as cables and air-conditioning in the floor structure.

Fig 7: part of one of the transverse floor beams

The whole floor is temporarily joined using mechanical fasteners to allow maximum flexibility during the assembly. The top plate is then bonded in the final assembly whereas the lower plate, which is divided in three parts, is bolted so to allow accessibility to the internal cabling and systems during testing of the vehicle. Figure 8 shows the assembly of the lower plate and the longitudinal and transversal beams.

Fig 8: assembly of the lower plate and longitudinal and transversal beams

The frame structure is made by hand lay up, using a left and a right mould of the whole central cabin to produce the various elements (Fig 9). The moulds were milled by a low-cost direct tooling route. The shape of the mould was milled with a 5 cm offset in polystyrene foam. A tooling paste was then applied over the complete surface which, after curing, was milled to the final contour. Finally, coating was applied to produce a smooth and air-tight tool surface

The crossbeam design has come with no little manufacturability challenges. A number of sections of the side structure have been manufactured during the design phase in order to improve manufacturing processes.

Fig 9 crossbeams side-frames mould

The doors exterior panels are made from a thermoplastic glass fiber reinforced sandwich laminate called IXIS and produced by SABIC. The moulds for these parts were laminated with a high temperature resistant resin from templates produced from positive moulds. Figure 10 shows the realization of a sample of the exterior bodywork formed to the shape of the 5th door of the Superbus.

Fig 10: sample of IXIS strip shaped to the contour of 5th door of Superbus

All glazing parts are formed from polycarbonate sheets. Due to the presence of double curved surfaces in the front windshield, the latter had to be produced in a number of parts due to optical requirements. To ensure wear and UV protection, a plasma coating was applied to the formed glazing in a subsequent step. Figure 11 shows a side window manufactured and coated.

Fig 11: side window manufacture by Lexan polycarbonate glazing

The body panels and glazing are adhesively bonded to the frame structure to comply with the required aerodynamic smooth surface. The assembled side panels are joined with the floor structure and roof beam elements to form the central part of the body work.

5. CONCLUSION

The *Superbus* will be officially launched at the 2008 Beijing Olympic Games.

The vehicle operational characteristics and geometrical definition have rendered the relative structural design and manufacturing of vehicle very challenging. The implementation of the crossbeams design, the lay-up optimization on critical areas and the use of lightweight materials, have enable the achievement of the target low weight, whilst compiling with the target strength and stiffness.

After the vehicle assembly, thorough testing will be performed to ensure and verify vehicle performances and safety.

6. ACKNOWLEDGMENTS

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