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THE SUPERBUS IS TAKING SHAPE: MANUFACTURING AND ASSEMBLY PROCESSES FOR THE REALISATION OF THIS NEW VEHICLE

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ABSTRACT - The *Superbus* (Figure 1) was introduced as one of the option for the Zuiderzeelijn [1]: a fast connection between Amsterdam and Groningen and resulted to be the best option, the others being three different types of high speed train and the magnetic levitation train. In order evaluate the feasibility of its implementation, the Dutch Ministry of Transport and Water Management has decided to fund the realization of a demonstrator [2].

The *Superbus* is a new concept for public transportation. It is sustainable, fast, lightweight, and appealing and transports passengers and goods from point to point and drives at high speed (250 km/h) on its dedicated and relatively cheap infrastructure. The *Superbus* is 15 meter long, 2.5 m wide, 1.6m high and weighs less than 9 ton when fully loaded. The vehicle has to be able to brake or avoid an obstacle (detected by the navigation and control system) within a distance of 240m. Alongside that, static and dynamic loading conditions have rendered the structural design targets very demanding. For that, a new design has been implemented, which a uses cross-beams type of structure resulting in octagonal doors. Also, lightweight materials and construction processes have been implemented.

In this paper the material used, the manufacturing processes and the assembly processes for the construction of the *Superbus* are presented. First, the main characteristics of the design used for the achievement of the structural design targets in combination with the lightweight requirements will be described. The *Superbus* uses a composite chassis, IXIS thermoplastic bodywork and Lexan polycarbonate glazing. The materials used for the production of the *Superbus* will be discussed in terms of their properties and the reasoning for their utilization. Then, the moulds and the manufacturing processes utilized for the construction of the vehicle will be discussed. Finally, the assembly strategy will be described.

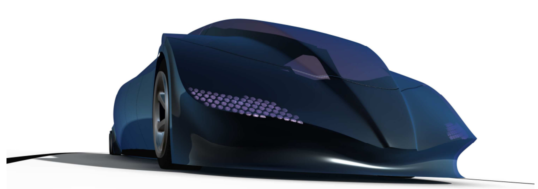

Fig 1: the *Superbus*

SUPERBUS STRUCTURAL DESIGN

The operational requirements have set a challenging target with respect to the achievement of the low weight restrictions of the chassis structure. The presence of the 16 openings (Fig 2) for the doors has increased such challenge.

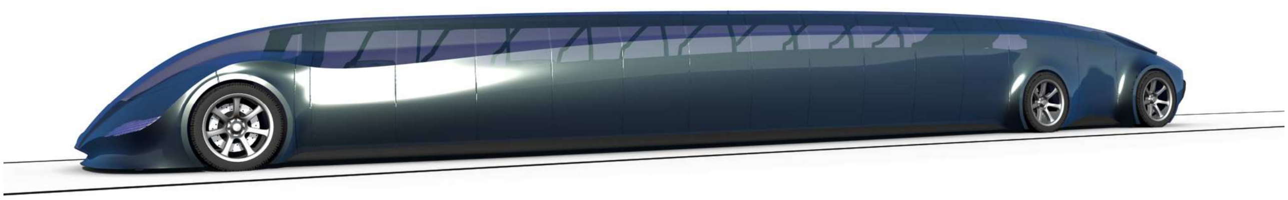

Fig 2: the *Superbus* with its 8 doors on each side

The chassis is formed by a floor - composed of two flat skins, 6 longitudinal beams and 16 transversal beams - connected to two side frames united by 8 roof beams, as showed in the assembled view of Figure 3.

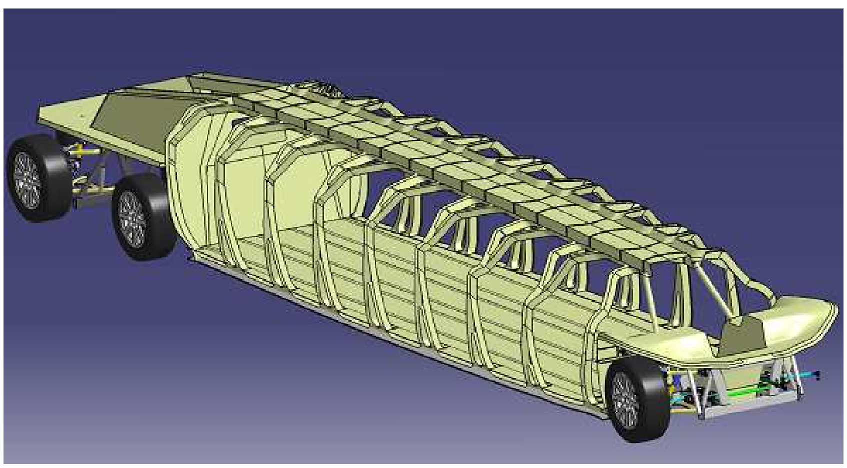

Figure 3: The assembled chassis and suspension system

In order to achieve the target weight of the carbon chassis, which was set to 1300kg, a new design has been implemented and optimised through the development of the design. Initially, a design that used horizontal beams between each door was evaluated. In order to reduce the weight, a crossbeam design has been implemented [3]. This design allows for the utilization of the entire vehicle cross section for torsion stiffness alongside being lighter. The crossbeams design alongside the optimisation of the lay-up of the carbon fibers has resulted in 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.

MATERIALS

The *Superbus* structure is built from carbon-epoxy composites. The complete load carrying structure is built using a 12K carbon fiber Torayca T700 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.

The doors outer panel is manufactured from 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 from polycarbonate Lexan, supplied by SABIC, in two material specifications. For the blue side windows glazing, 6mm and IR-absorbtion treated sheets are used. The windshield, was formed from 10mm thick clear polycarbonate due to the structural requirements and the light transmission requirements which, for the windshield, must to be more than 75%.

MANUFACTURING

The floor structure consists of two sandwich plates which are produced by vacuum infusion on a flat mould. 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. The bottom plate has been divided in three parts to allow access to the cabling and systems placed in the floor. Figure 4 shows the floor structure, the manufacturing of the top plate and the manufacturing of one of the three parts of the lower plate.

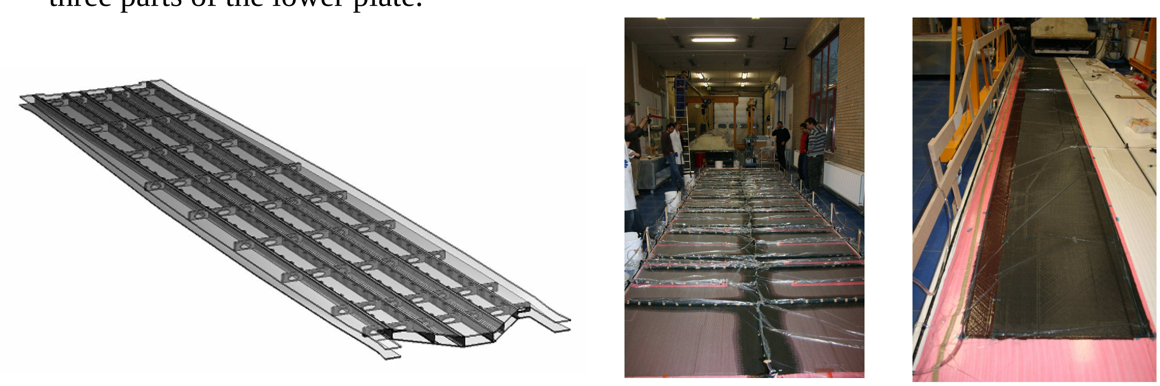

Figure 4: Floor assembly design (showing the top and lower plate, the 6 longitudinal beams and the 16 transversal beams) and the manufacturing of the top and bottom plates by vacuum infusion.

The whole floor (Fig 5) 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 5: Floor assembly

The longitudinal beams were manufactured by vacuum infusion in a simple U-shaped sheet metal mould. The transversal beams due to their large amount and relatively small dimensions were produced by hand lay-up. Each element presents a central hole to allow for installation of systems such as cables and air-conditioning in the floor structure.

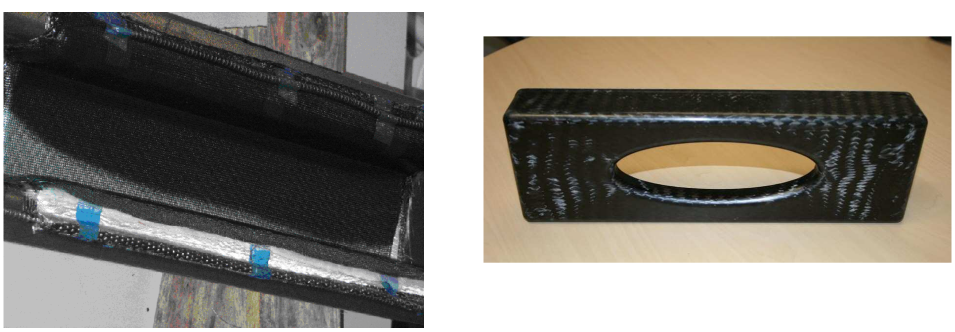

Figure 6: Manufacturing of one of the longitudinal beam by vacuum and one pert of the transversal beams by hand lay up.

The roof connectors are made from moulds produced from CIBA tool material and the parts are manufactured by vacuum infusion, one of which is showed in Fig 7.

Fig 7: Roof connectors mould and one of the 8 roof connectors manufactured

The frame structure is made by hand lay up, using a left and a right mould of the whole central cabin to produce the side cross frames and the doors (Fig 8). 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 surface.

Fig 8: Right hand side mould for the frame and doors, sample test of a cross beam, manufacturing of the full right hand side cross beam structure.

The doors (Fig 9) are manufactured from the same mould by a fist layer of hand lay up and the rest by vacuum infusion.

Figure 9: Manufacturing of door number 8, de-molding and finishing of the door with interior door panel.

The nose, driver house, rear bodywork and internal structure have also been manufactured by vacuum infusion. In some parts, fiber glass was used instead of carbon fiber due to the fact that on several parts of the vehicle radars were to be positioned. Figure 10 shows the nose. The light blue parts are the part required to be manufactured in glass fiber due to the presence of radars inside.

Figure 10: Nose of the vehicle. All carbon fiber apart from some areas in glass fiber (light blue) required for radars functioning.

The doors exterior panels are made from a thermoplastic glass fiber reinforced sandwich laminate called IXIS, produced by SABIC. Such material is formed at high temperatures. Thus, the moulds used for manufacturing these parts are laminated with a high temperature resistant resin from positive moulds. This is done so to obtain high temperature resistant mounds at a relatively low cost. Figure 11 shows the positive mould and the realization of a sample of the exterior bodywork formed to the shape of the 5th door of the Superbus.

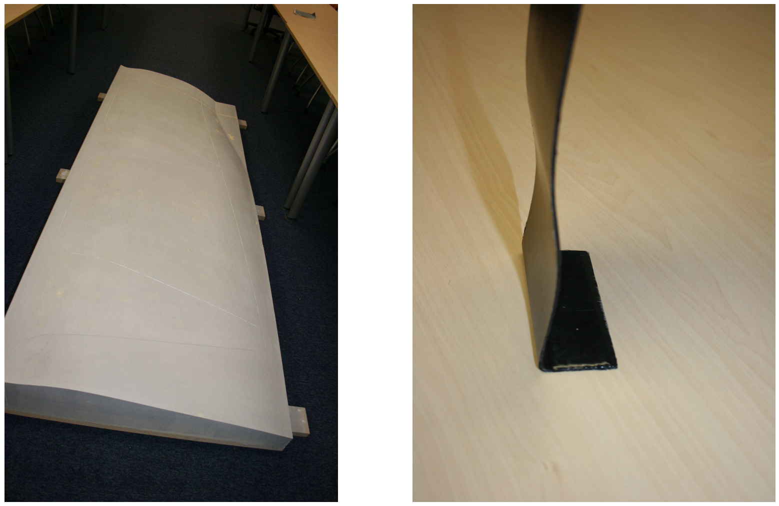

Fig 11: Positive mould of the exterior side body panels and a sample of IXIS strip shaped to the contour of 5th door of Superbus

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

ASSEMBLY PROCESS

The assembly of the vehicle is done is two steps. First and hybrid vehicle is assembled, which is made of a structural frame that simulates the vehicle chassis (Fig 12). The suspensions system, the motors the cooling system and the driving line alongside all the required cablings are then assembled on to such frame. The complete system is used to tune the suspension system, the rear steer by wire system, the motors and the hydraulic lifting system.

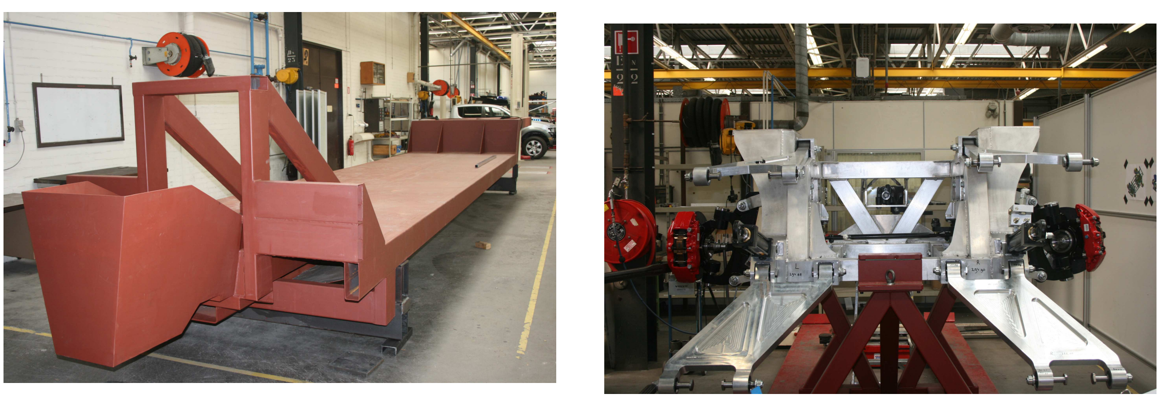

Fig 12: Hybrid vehicle and front suspensions assembly

During the assembly, testing and tuning of the hybrid vehicle, the composites parts of the vehicle are assembled so that after the testing of the hybrid vehicle the complete vehicle is assembled. For the final assembly of the vehicle a laser tracker device is used alongside with jigs to ensure correct fitting of all parts and perfectly smooth finishing.

CONCLUSION

The design and manufacturing of this new vehicle has been significantly challenging due to the absence of a vehicle similar to it, the required realization time and needless to say its unique operational characteristics. With regard to the structural design, the implementation of the crossbeams design, the lay-up optimization on critical areas and the use of lightweight materials, have enabled the achievement of the target low weight, whilst compiling with the target strength and stiffness. The assembly strategy, consisting of utilizing and hybrid vehicle for systems tuning along side with composites parts assembly has allowed for parallel assembly, tuning and verification so to reduced the overall time of vehicle readiness.

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