EFFICIENT DESIGN AND MANUFACTURING OF THE SEATS OF THE SUPERBUS

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SUMMARY

The Superbus is a new public transport vehicle designed for fast, safe, comfortable, sustainable and flexible transportation. The vehicle travels at 250 km/h on its dedicated infrastructures and at conventional speed on existing roads, and transports passengers and goods from point to point, without the need to change transport during the journey.

Due to the challenging vehicle operational requirements, the seat design had to be optimized with regard to comfort, weight constrains, accessibility, attachments to the chassis, 3-point seatbelt attachments, manufacturability aspects and cost. For that, the seat features a new design and its structure is made of carbon fiber.

In this paper the analysis of the interior design will be discussed in correlation to the operational requirements. Then, the resulting overall interior layout of the vehicle will be described (Figure 1). Finally, the seat design, the relative material used and manufacturing processes will be described within the context of the interior design and manufacturing.

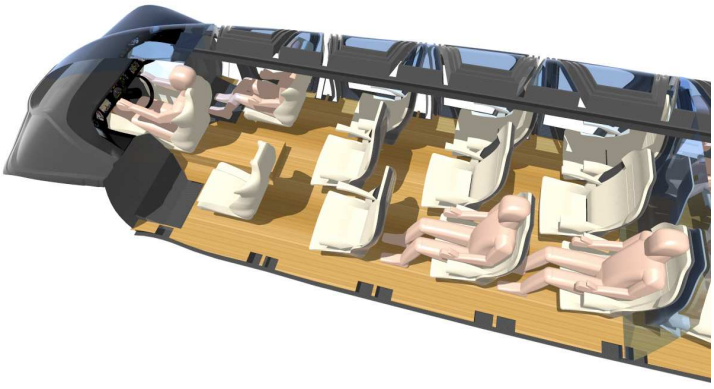

Figure 1:Rendering of the forward portion of the Superbus

1. INTRODUCTION

The *Superbus* is a concept from TU Delft [1] for the development of an innovative sustainable public transport system which consists of a new type of vehicle, new type of dedicated infrastructure and a new logistics. The *Superbus* programme is sponsored by the Dutch Ministry of Transport and Water Management for the realisation of a demonstrator for evaluation of the feasibility of the system.

The vehicle transports passengers from destination to arrival without the need to change transport during the journey. The Superbus is designed to create an environment that allows passengers to continue their activities, whether recreational or business, whilst moving from one place to another. For that, the personal space is designed to be comfortable and inviting, and fully equipped with a number of devices in a number of personal space layouts.

The vehicle has been designed with great attention to safety. The structure of the vehicle has been designed considering a number of crash conditions. Also, the vehicle uses a sophisticated navigation and control system alongside morphing structures and 3 parachutes for emergency braking. Alongside this, a multi-body model has been used to simulate 20g crash conditions and the results have been used to optimize seat design and seat belt attachments.

Figure 2: the Superbus

2. THE VEHICLE AND INTERIOR DESIGN

One of the primary aims of this new vehicle concept is to create a vehicle for public mobility that enraptures the passenger's desires for flexibility, privacy, comfort and safety. This is driven by the aim to enhance the utilization of a sustainable public transport so to reduce traffic jams and limit private polluting transportation.

The Superbus is 15 meters long and provides seating for 23 passengers. With the aim to improve comfort and to allow for individuality, it has 8 doors per side as showed in Fig 3. The vehicle is 15.00m long and 2.55m wide, to comply with European regulations. The vehicle height could be up to 4.00m, based on these regulations. However, height has been set at 1.60m. This was mainly due to 3 reasons: to reduce the frontal area with the aim to enhance aerodynamic performance at high speed, to lower the centre of gravity to

improve handling, to create a new interior design which emphasizes the realization of an individual environment.

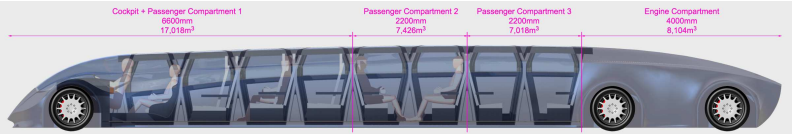

Figure 3: Superbus dimensions and interior space

3. LAYOUT OF THE INTERIOR

The demonstration vehicle that is currently under construction will have the layout shown in the Figure 6: eight rows of three seats per row, except for the front row which will have two Recaro sports seats to allow space for the driver to slide in and out of the cockpit.

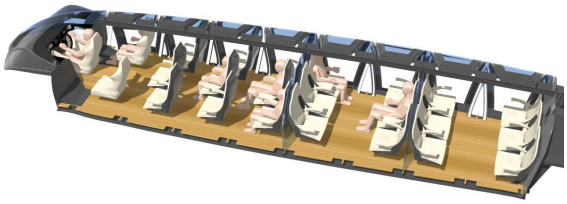

Figure 4: seat configuration

The passenger compartment is divided into three cabins by two transparent dividing screens. The first four rows offer individual, forward facing seats in one compartment. The two rear compartments have two rows of seats that face each other, with a large foldable conference table in the middle.

The Superbus has 680mm wide seats. Besides offering more space in a lateral direction, the Superbus has a seat pitch of 1100mm which is comparable to the back seat of a Rolls Royce Phantom. Also, in the front passenger compartment, extra privacy is created by shifting the middle seat in each row by 200mm forward. In this way, passengers are not seated directly next to their neighbours, as shown if Figure 5.

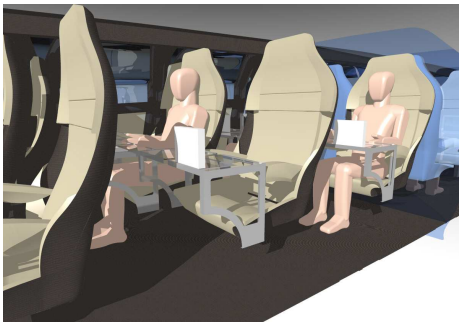

Figure 5: front cabin

The seat is being specifically designed for Superbus and has to be comfortable and safe as well as extremely lightweight to keep the total vehicle weight under 9000kg (including passengers and luggage).

4. STRUCTURAL DESIGN OF THE SEAT

Through the design process of the Superbus seat (Figure 6), three main aspects have set the requirements for the structural design part of the seat, namely operational requirements of Superbus, safety factors and comfort.

According to the operational requirements of the vehicle, the seat should be as light as possible in order to contribute to the weight target of Superbus. Thus, the maximum weight of the Superbus seat was set to 12 kg; including the structural frames, cushions, armrests, headrest and the upholstery. Regarding the safety factors, the Superbus seat has been developed considering two cases: the typical journey and the crash conditions.

For the analyses, the passenger mass has been set to 120 kg and the ultimate load has been set to 140 kg. Both of these masses exclude the mass of the seat itself. In respect to the stiffness of the seat pan and the seat back the range between L/100-L/250 has been admitted. The Superbus seat has been developed according to M1 regulations which has the anchorage loads of diagonal 13.5 kN, lap 13.5 kN + 20 X weight of the seat. The load cases were considered for 20g frontal impact load and 4g side impact. The reclining mechanism of the seat is made by using an inner shell which slides on rails and it is designed in order to comply with the requirements mentioned above.

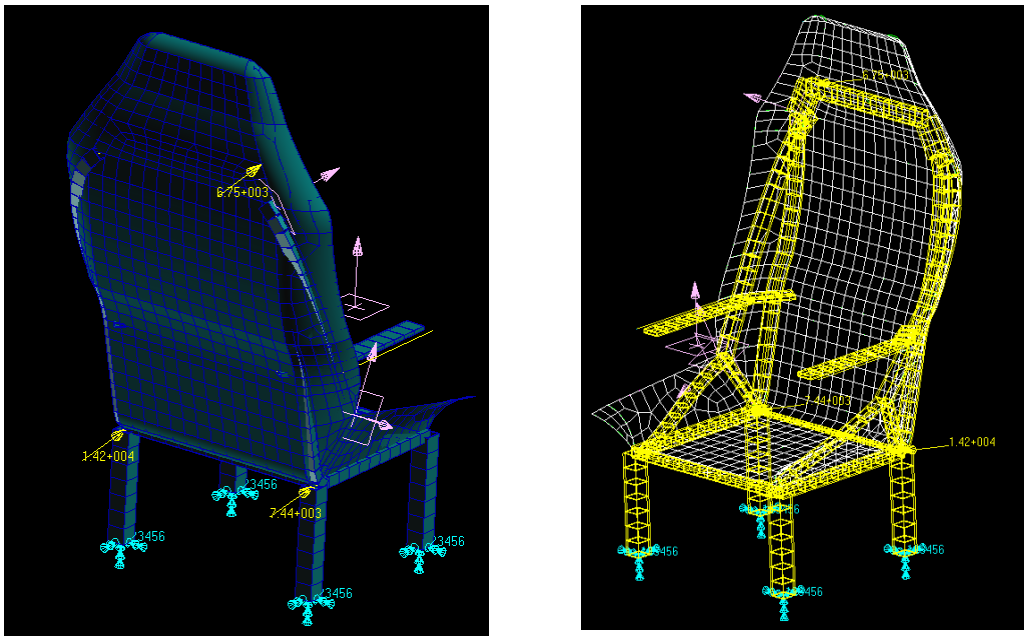

Figure 6: seat structural analyses

The structural design of the Superbus seat is made from two main elements: the beams for the legs and harm rest and the shells, the outer and inner shell which slides on rails for adjusting the back position as showed in Figure 7. The beams are made from composite tubes in square cross-sections with the thickness of 30-35 mm. Such beams are used to build the main skeleton of the seat and the armrests and the seat legs. The outer and the inner shell are both structural elements and form the outer shape of the seat.

Figure 7: sliding mechanism

Through the optimisations, the total mass of the structural elements have been reduced to 6.4 kg, excluding the upholstery, inner shell and adjustment systems. As for the other parts: 2.3 kg for the seat back, 2.3 kg for the seat sides, 1.1 kg for the seat pan and 0.7 kg for the seat legs.

5. MATERIALS OF THE INTERIORS

The Superbus seat is made of a composite shell similar to those used for racing seats. The seat cushions will move within the inner shell, also made in carbon fiber) to provide adjustability of the backrest angle. To give the seats the desired luxury appearance they will be covered with high quality leather.

Since the overall structure of Superbus is mainly constructed from carbon fiber to keep Superbus as lightweight as possible, it would be very inefficient to try and cover up the carbon parts that are visible in the interior. Therefore the interior of Superbus does show a lot of the structural carbon chassis, floor and doors (Figure 8).

Figure 8: Superbus door

6. MANUFACTURING OF THE SEATS

The seat has been specifically designed for Superbus to be very comfortable as extremely lightweight to keep the total vehicle weight to the 9000kg target [3].

The seat in all its components is manufactured by vacuum infusion using cost effective tooling. The outer shell of the seat is built and joined to the inner shell (to allow for the sliding of the inner shell inside the outer shell) by light weight aluminium rails attached to the inside of the outer shell. Foam and leather is then added to the inner shell, alongside all the equipment of the seat (table, screen integrated in the table, etc).

The seats are bolted to the floor. The latter has been optimised so to account for the seat structural requirements in the fixing parts and in order to limit at most the weight with respect to the structural requirements as showed in Figure 9.

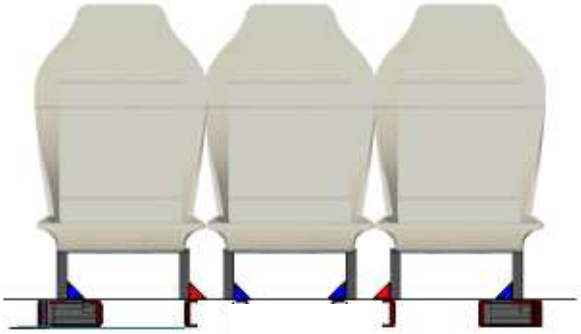

Fig 9: attachments to the floor

7. CONCLUSIONS

The *Superbus* interiors has been designed to be lightweight but also very comfortable and appealing.. Most of the vehicle is made of carbon epoxy to optimize weight with respect to structural requirements and the interiors reflect that, for which minimal panelling is added. For that, carbon epoxy seats and panelling are used, alongside CETEX interior door panelling. The *Superbus* will be launched at the Beijing Olympics in August 2008.

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