SIXTH FRAMEWORK PROGRAMME
Sustainable Surface Transport

litebus

MODULAR LIGHTWEIGHT SANDWICH BUS CONCEPT

Contract Number 03132 (TST5-CT-2006-031321)

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PUBLISHABLE EXECUTIVE SUMMARY

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Record of comments

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PUBLISHABLE EXECUTIVE SUMMARY

Increasing awareness by the public opinion about environmental issues, energy and material conservation at all stages of product life (from raw materials to disposal/recycling) is putting the industry in general and the transport industry in particular under increased pressure to reduce CO_2 emissions and save energy. Environmental protection and safety will be increasingly influenced by legislation.

The European transport industry is estimated to generate 22% of the carbon dioxide emission. As the car population is expected to grow 40% by the year 2010 new tough targets for reducing emissions by 30% in 2010 are being set by the EU, against the state of the art technologies of 1995. It is generally agreed by the industry that reductions of this size will require a change in current technologies.

Multimaterial technology (sandwich and/or hybrid materials) is becoming increasingly important in new vehicle design. It offers significant opportunities for enhancement of product performance in terms of strength, stiffness and crashworthiness, combined with weight reduction and space saving. Its use still lags far behind steel in the production of cars, buses, coaches and rail and marine applications. Public service vehicles (buses and coaches) are regarded as primary targets for application of sandwich construction and multi-materials.

Public service vehicles (PSV) play a major role in the transportation industry of both industrialized and developing countries. Although the share of passenger transportation in PSV is relatively small compared to private cars (10% for bus, 5% for train), environmental and energy conservation constraints will lead to an increased demand of PSV, mainly in cases with limited access (like city centers). As travel by car has increased at a steady rate, of 2% per year, whereas bus increased 0.9% and train 0.4%, the **EU White Paper on European transport Policy for 2010 establishes, as main goal, a shifting of balance from car to public transport**, through the development of high quality and safe transport, eliminating the root causes of pollution – the use of individual transportation

The project was focused on the development of a novel technology to manufacture bus/coach bodies using load carrying sandwich multimaterial panels that have to meet tough design requirements, such as: high static and dynamic performance, high flexural and torsional stiffness, adequate acoustics, crashworthiness, higher safety for passengers, reduced harm to pedestrians in case of accident, fire safety, corrosion resistance, easy repair characteristics and reduced assembly time.

The main overall objectives of the project were:

- Solving the problem of reducing weight and production costs of land transport vehicles through the development of a technology of modular bus/coach construction, using “all composite” multi-material load carrying sandwich panels instead of a steel/aluminium space-frame lined with sheets of different materials (metallic or non-metallic).

- Devise design methodologies that reduce production lead time through reduction of number of components, functional integration, and allowance for dismantling, easy repair and recycling.

- Developing high quality urban transport
- Contribute to the shifting of balance between modes of transport.
- Contribute to improve road safety.
- Contribute to improve quality in the road transport sector.

The main goals of the project were the reduction of weight and production costs through:

- Development of a new concept "all composite sandwich material "for the production of structurally resistant modular panels for the construction of "Body in White" structures, reinforced with fibre reinforced pultruded sections (FRP) sections.
- Development of a new concept vehicle architecture where "*load carrying modular sandwich panels*" are used instead of the traditional space-frame structure (in steel or aluminium) lined with sheets of steel or aluminium. The use of sandwich construction and composite materials means that a higher functional integration will be achieved through the incorporation, in the structure, at manufacturing stage of several functions, allowing more efficient space usage and cost efficient manufacturing.

This project adopted an innovative holistic approach since:

- A new concept structural sandwich material with FRP reinforcements (pultruded sections) and the technology to produce single modular panels was developed.
- New modular vehicle concept architecture, based on the use of *structurally resistant composite sandwich panels* to produce the structure (lateral, roof and floor panels), instead of the traditional space-frame concept, either in aluminium alloy or steel hollow sections, lined with metallic or composite sheets.
- Design of a new product using principles of Extended Product Responsibility (EPR), which extends responsibility to a life cycle stage, taking into account environmental impacts of the product system and principles of Design for Manufacturing and Recycling (that takes into consideration the constraints imposed by the composite sandwich material)
- The new concept reinforced sandwich material and modular panel architecture and respective connections were validated by experimental work, numerical modelling simulation and a rollover test on a Bodywork Section
- Design, implement, test and evaluate a new structural health monitoring concept relying on novel optical fibre sensing heads and readout equipment, based on in-fibre gratings and micro-cavities for temperature and strain measurements in the body, for composite damage assessment.

The main scientific/technical objectives were:

- Reduction of 10-15 % of total unladen weight of a bus through a 60% reduction of "body in white" weight (which represents typically 20-25 % of the total bus weight), in comparison with current steel bodies. The stiffness of the bus structure will be equivalent to a steel body. Crashworthiness under rollover will be greater than bolted aluminum structure and better than steel structures.

- Manufacturing lead time was reduced 30%, through the use of fewer components, easier and faster to assemble and join together and through integration of several functions in panel components.
- Tooling and jigging costs reduced 30%, since sandwich panels are considerably less expensive than stamping dies or jigs for welded construction.
- Reduction of 20% of noise and enhanced vibration properties.
- Greater corrosion resistance with adequate fire safety.
- Increased passive safety for passengers
- Reduce harm to pedestrians in case of accident
- Improved interior packaging and space (minimum of 10 %)
- Better aesthetics and aerodynamics of the body.
- Exterior and interior faces with better finishing ready to be painted.
- Servicing and repair of damaged structures easier to perform.
- Improved know-how in the use of FEM modeling of sandwich structures for bus and automotive applications.
- Validate software tools applicable to crashworthiness evaluation to the special case of sandwich structures.
- Develop fatigue design curves applicable to sandwich structures.
- Demonstrate the capability to remotely monitor ‘structural health’ of an ‘in-service’ transport vehicle and validate the integration of event sensor systems.

The main technical achievements are summarised below:

- Design, manufacture and validation of a sandwich material concept with high stiffness and energy absorption suitable for surface transport vehicle.
- Generation of new concept vehicle architecture, using systematic product development methodologies and Integrated Product Policy for a more environment friendly vehicle.
- Develop a new manufacturing technology for the production of large panels with functional integration. The materials, conceptual design methodologies, design philosophy and assembly methods can be applicable to other industry sectors in particular train rolling stock, ship/boats, and trucks and self-supported refrigerated containers.

During first year the research effort was placed in the development of the Bus Body Concept, materials to be used and respective production technologies. Aspects related with static and dynamic behavior of the structure, crashworthiness and durability and life cycle cost analysis, although addressed in the identification of the vehicle attributes and specifications did not play the major role of the research effort during the first year.

Figure 1 – Rendering and mock-up

During the second year, the research work concentrated on the static and dynamic analysis of the proposed structure and design/production of the die to be used in the manufacturing of the pultruded rail floor section and start of pilot production tests.

Initial components were manufactured and tested. Particular attention was devoted to the design and production of the pultruded section. Static and fatigue tests on materials and components were performed. A numerical model was developed for composite-composite bonded joints. The activities were developed with the active collaboration of all partners, both during specific work-package meetings, exchanges through email and during the Steering Committee meetings.During the third year several pillar rings were built and test in conditions corresponding to annex 8 of R66.

Figure 2 – Quasi-static tests

A new clamping system was developed to fix the pillars to the lower steel structure of the bus. This system was used in most of the quasi-static tests of the pillar rings and they were used to clamp short straight pillars to test and study the effect of the lateral panels and pultruded profiles on the stiffness of the cell.

The pillar core reinforcement was reviewed and two glass/carbon fibre reinforced pillar rings were built to be assembled in the prototype cell. The panels (roof, lateral and floor) were also produced and window glasses were cut.

The prototype cell was then assembled and tested in real roll-over.

Figure 3 – Complete cell section

The test consists of tilting the platform on which the structure is placed. The angular velocity must be very low so the structure falls with minimum initial velocity and solely due to loss of equilibrium. The test set-up is shown in Figure 4.

Figure 4 Test set-up

Residual (survival) space was preserved during the test. Figure 5 shows the most critical moment on the right side. Thus, the roll-over test validated the proposed new concept of bus body, as far as crashworthiness is concerned. Flexural and torsional stiffness were also demonstrated to be at least equal to equivalent steel bodies.

Figure 5 Test events

The result after the first test is shown in Figure 6.

Figure 6 Test result


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