ICTP2017 Industry Workshop 1 Briefing note.

Future Car Bodies:

Beyond material comparison to holistic engineered material solutions

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In pursuit of automotive light-weighing there has been much debate about whether one material is better than another. Each material-producing industry argues strongly for its own solution. However, different components in the vehicle have different performance requirements which, in addition to weight, include strength, stiffness and formability. In addition, a good solution must be easy to manufacture, affordable, globally available and compatible with future environmental sustainability. It is unlikely that any single-material solution will provide the optimal combination of all these characteristics. This workshop therefore explored opportunities to combine materials to create efficient solutions and this note summarises the discussion.

The forces driving choices about future car body construction include:

- The rapidly evolving and already complex regulatory framework within which cars are certified for public use.
- Evolving consumer preferences, including the as yet uncertain public response to both electric drive trains and autonomous vehicles, and the need for thermal and other comforts.
- The future of safety which may be determined as at present by an energy-absorbing ‘exo-skeleton’ or which might be provided by much higher levels of sensing and automation to reduce the possibility of high speed impact.
- Legislation and public interest in greenhouse gas emissions reduction in both the use and production of cars.
- Legislative requirements on end-of-life vehicle handling.

Regardless of material selection and design, future car bodies must be produced efficiently, which entails:

- Ensuring cost reduction through improved quality, particularly for lower batch sizes where “settling times” are as important as the maintenance of quality in a steady-state.

- Managing the whole system of tooling, lubrication, press shop management as much as producing a single part.
- Balancing the design benefits of different material selections against the production requirements of formability, joining, properties in service (including crash performance).
- Predictable and well-characterised material behaviour to allow manufacturing simulation to be completed ahead of physical production.

There are many competing material alternatives including: single metals; sandwich materials (metal-metal, metal-polymer, metal-fibre); structured materials (with corrugated or truss-like cores); thermoplastics; thermosets; glass/carbon fibre composites; fabric; natural materials (such as the exemplar flax and sugar-cane car built by students at the University of Eindhoven). Selection between these alternatives involves many criteria including:

- Their mechanical properties: the trade-off between strength and ductility, stiffness, density, energy absorption. Materials suppliers have tended to emphasise improvements in strength as a key competitive advantage, but for many components in the car, stiffness or density is more important than strength.
- The energy and emissions required to produce the materials.
- Options to process the material at end of life. Generally the simpler the material composition of a vehicle the easier it us to recover benefit in recycling. For example combining metal with polymers may have advantages in weight saving, but requires difficult separation and sorting at end of life. Furthermore, thermo-plastics are easier to recycle than thermosets, which are in effect, one-way materials.
- Availability and cost.
- The degree to which their properties and performance are understood and characterised: contemporary manufacturing practice depends heavily on simulation both for manufacturing process development and for evaluation of components in use, and this in turn depends on the reliability of material models.
- Some materials, particularly polymers, may be coloured in preparation, to avoid the need for a subsequent painting stage in production.

For many components in the car body, although providing stiffness in service is important, the need to absorb energy during a crash is more critical. An ideally optimised component would exploit its material perfectly, so that at the limit of its performance requirements, the whole component would reach every material limit. This is an unattainable ideal for most circumstances, but there are many opportunities to modify component designs to exploit more of the performance capacity of the materials of which they are made:

- Single-material components with constant-cross-section will generally be inefficient, through having excess stiffness and strength in areas that will never be subject to maximum load. However, advanced processing – for example through new heat treatments or severe plastic deformation can allow significant increases in strength for many metals. These effects can be global, or may be localised to create tailored performance.

- Stamping or embossing ribs in single-material parts can increase their second moment of area usefully to create substantial increases in their second moment of area.
- Variable thickness single-material components, made for example by tailor-welding or tailor-rolling, can provide variable bending stiffness to match anticipated loads under crash conditions.
- There is great potential for creative endeavour and innovation in the design and processing of light weight inner structures made with sandwich structures Sandwich panels allow the optimal placement of higher strength material far from the neutral plane, but are often difficult to form due to differences in the ductile behaviour of the skin and core materials. Higher density more ductile polymer core materials would help to balance the ductile behaviour of metal skins. Blanking and trimming of such materials in mass production may be a serious issue which must be addressed early in the development stage.
- Structured materials, with truss-like cores, offer tremendous increases in stiffness/weight, but can be difficult to manufacture and shape.

The selection of materials depends on and affects the whole system of car design and production:

- A transition to electric power trains (if adopted) and the possibility of increasing sensing reducing the need for full-impact crash safety could lead to radical changes in the design specifications of cars, which in turn could favour the selection of quite different material combinations for the body structure. For example, heavy battery packs may lead to a different configuration of passengers and crumple zones, while a reduced requirement for crash performance could allow an inside-to-outside model of assembly, in contrast to the current outside-to-inside approach.
- Some functions, such as thermal insulation or the transmission of information through the vehicle, which are currently separate from the body structure could be incorporated within it.
- The intense time pressure on car manufacturers when introducing new models leads to a conservative preference for using familiar designs and manufacturing processes. New material combinations must provide a substantial overall benefit to motivate the risk and cost of overcoming the benefits of experience in past approaches.

In looking for inspiration for new options to select materials, design vehicles and their manufacturing systems, car manufacturers could look to:

- The aerospace industry which already uses a wider range of materials to exact all possible weight saving for fuel saving, and in particular is developing wide expertise in the combination of fibres with metals.
- Silversmiths and other craft industries, where design, manufacturing and tooling manufacture are inextricably integrated in the skill, knowledge and experience of an artisan, in contrast to the wide separation of these functions in large OEMs.