LIGHTWEIGHT DESIGN FOR THE LOWER PRICE SEGMENT

The body structure of the up! has consistently adhered to the development objectives of lightweight design, vehicle safety, variability and comfort. The focus of development was high crash safety with simultaneous low body weight and competitive costs. Together with a high level of body stiffness, this created the basis for low CO_2 emissions.

AUTHOR

DIPL.-ING. OLIVER MENDE
is Technical Group Spokesperson for the VW120 Body Department at Volkswagen AG in Wolfsburg (Germany).

LIGHTWEIGHT STEEL DESIGN

The demanding weight targets for the up! were achieved using a calculation-optimised design as well as the consistent application of ultra high-strength and hot-formed steel. As with all Volkswagen designs, this involved using the right materials in the right places, while still adhering to the project-specific weight, cost and stiffness targets, ❶.

The use of hot-formed components in the main floor and in the B-pillar offers the greatest potential for lightweight design. The manufacturing process achieves the properties of hot-formed components by forming the glowing red blank in just one stroke and then subjecting it to controlled cooling in the forming tool. These components with a yield point in excess of 1000 N/mm², were used in areas with high crash stresses, in order to safeguard the survival space of the passenger cell, even in the case of severe collisions. This material accounts for 8.1 % of the weight of the structure. This measure helped to reduce the weight of the body by around 13 kg.

Furthermore, dual-phase steels were used in the area of the front side member, in the sill and in the side roof frame, which, together with the hot-formed components, formed the basis of the safety passenger cell. With a ratio of 39.3 % ultra high-strength steels and 17.2 % high-strength steels, the up! is the new yardstick in its class. Deep-drawing steels account for only 24.9 % of the weight of the body structure; they were used for the components that demanded deep-drawing, like the outer side panels or the rear wheel housings.

INTENSELY PROFILED LIGHTWEIGHT DESIGN

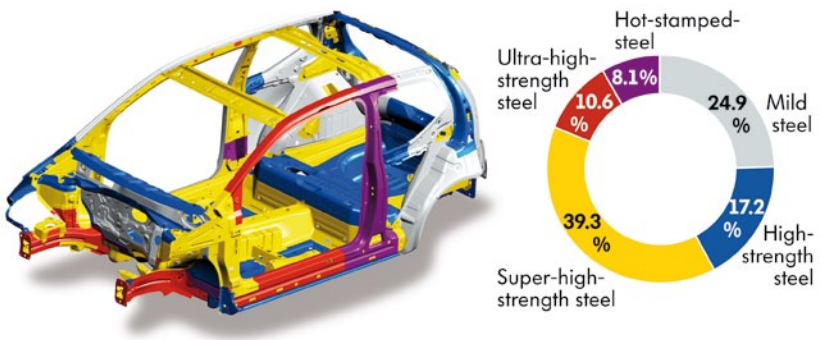
The particularly stiff body structure of the up! even complies with the enhanced comfort standards for acoustic and vibration behavior that apply to the next higher vehicle class. This is the result of a targeted design of the nodes and force application points. The available packaging space is optimally exploited by a three-shell structure, so the passenger compartment is surrounded by stable, calculation-optimised profiles. Despite the demanding stiffness and crash requirements, the lightweight quality index (a measure of weight efficiency) improved by 34 % compared with the Lupo, ❷.

At 19,800 Nm/°, the static torsional stiffness is “best in class”. Equally, the dynamic stiffness of the body structure increased by 20 % to 49 Hz for the first torsional mode shape, compared with the Lupo. These characteristics benefit the acoustics, the vibration behavior, and the outstanding driving comfort of the up! ❸.

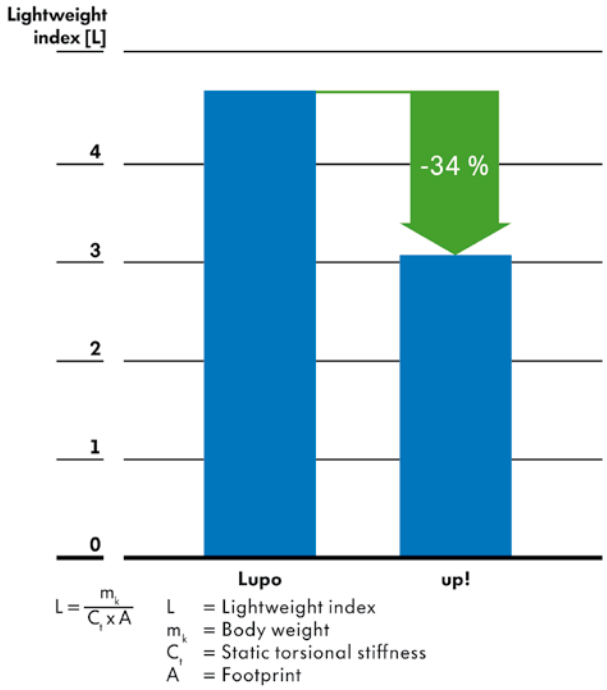
TAILGATE

The tailgate with its generously dimensioned glass surface is a special feature of the up! design study that was showcased for the first time at the IAA 2007. It visualised the modernity and high-quality of the up!, and the hybrid glazed tailgate that was developed was adopted by the series vehicle virtually without any modifications.

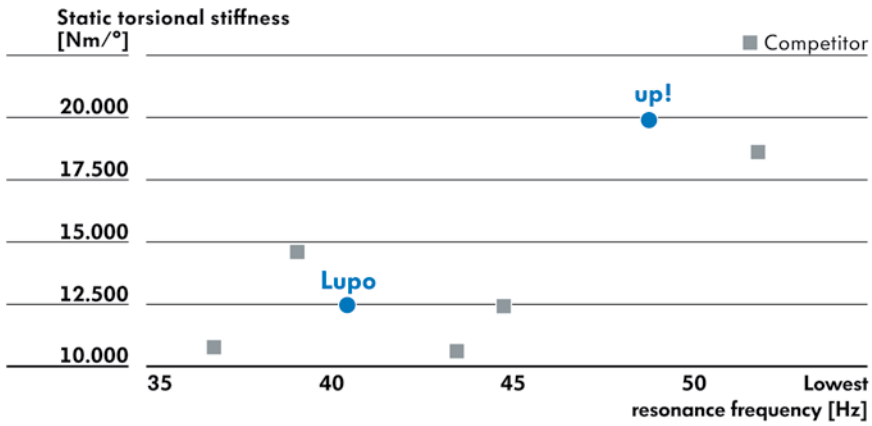
The development performance specifications derived from this comprised numerous parameters. Based on the New Small Family approach, it was essential



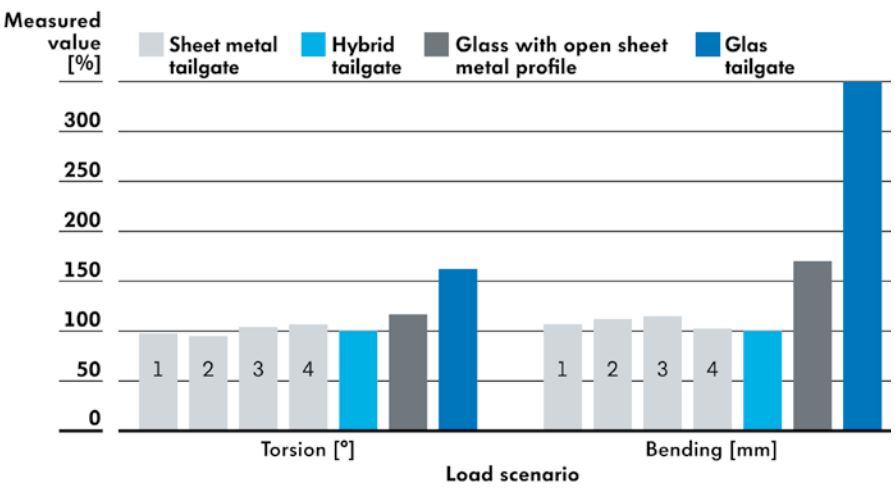
❶ Steel grade distribution in the body structure



❷ Lightweight quality index: The applied material efficiently increases body stiffness



❸ Body stiffness in the competitive environment



❹ Deformation comparison of various concepts

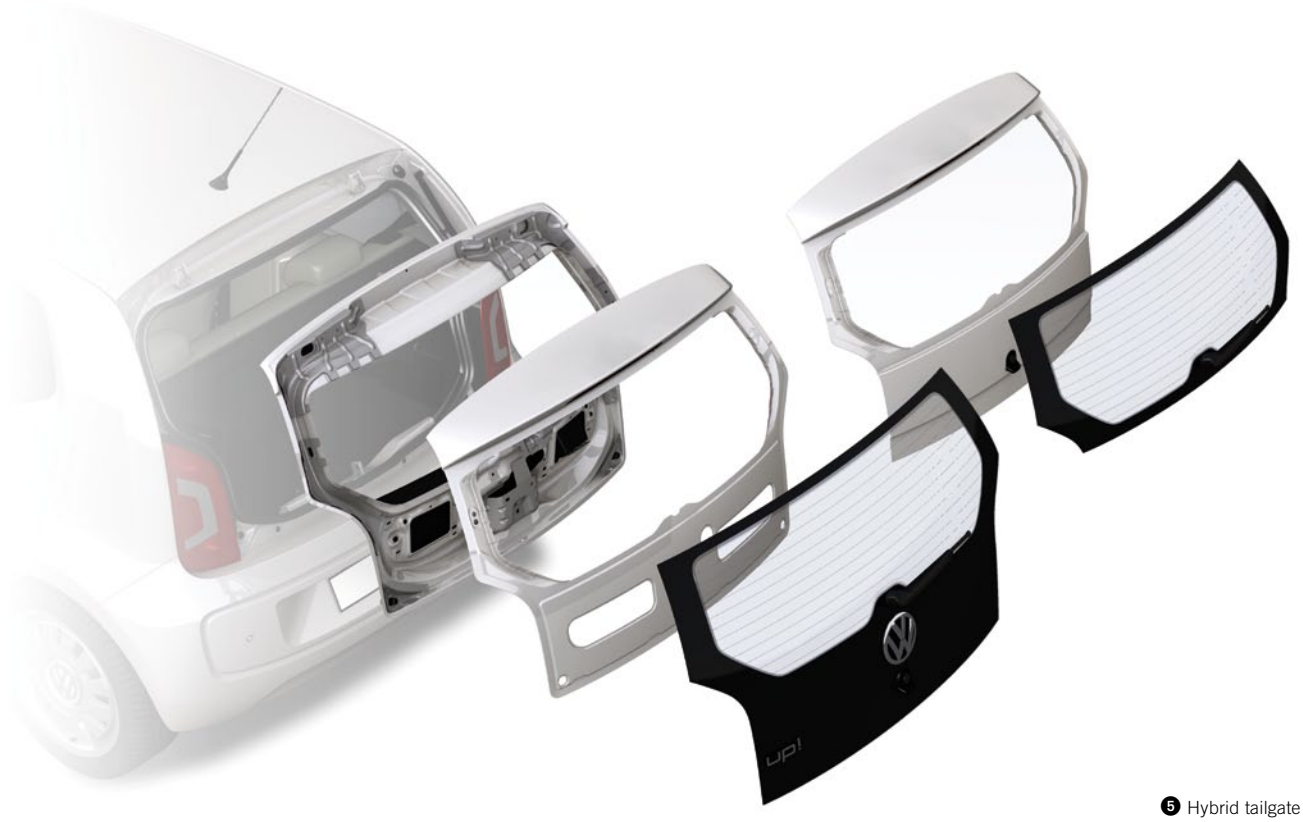
to maintain the compatibility with a uniform body structure as well as to realise classic tailgate concepts and the resulting identical point of force applications and pivot points. In addition, add-on parts like hinges, locking systems and rear wiper systems needed to be adopted from the modular Group assembly matrix. The performance specifications also stipulated a uniform inner trim as well as a modularised operating concept for the tailgate.

Various approaches are already known from existing systems regarding the technical realisation of a glazed tailgate. They range from pure glazed solutions up to sheet metal structures of various designs with glass elements mounted onto them. After consideration of both the above-mentioned and additional boundary conditions, a supporting, sealed sheet steel structure surrounding a large, yet thin rear window glass was chosen. The sheet steel structure of the design assures the necessary rigidity and compatibility with conventional systems, while the bonded glass forms the design element. Compared to conventional tailgates at Volkswagen, the same design specifications applied to this hybrid construction.

This is clearly illustrated in the deformation comparison, ❹. The different possible tailgate concepts of a full glass appearance are compared with a conventional sheet steel concept. The compared load cases are the parameters which the customer perceives from the daily use of the tailgate as a measure for the stiffness, thus the quality of the structure.

The “torsion” load scenario simulates a situation in which the gate is subjected to torsional stress during handling. The “bending” load scenario simulates a load on the transverse axis of the tailgate. If the measured values are small, the tailgate shows a good performance in these load cases. The values of the hybrid tailgate are for both characteristic values similar to those of conventional tailgates, designed in accordance with Volkswagen specifications.

Further design optimisation steps included the use of the glass pane as a supporting element, hence the sheet metal thickness could be reduced, and hole patterns could be used in neutral zones, ❺.



❺ Hybrid tailgate

REAR ILLUMINATION

Despite its compact structure, the taillamp assembly of the up! has a striking rear position lamp signature and also includes all the additional rear functions, like the braking and turn signal light, the rear fog lamp and a reversing lamp on each side. The retro-reflector was also incorporated in the lamp so that it is easily visible, ❻. The rear position lamp, which is represented as a symmetrically opposite C, consists of three light chambers, whereby the brake light function is simultaneously realised in the upper chamber. The lower chamber also performs two functions: The combination of rear position lamp and rear fog lamp. The computation of the external lens optics ensures that they generate the actual light distribution, in coordination with the reflectors. The retro-reflector is covered from behind by a shutter, therefore ensuring its precise separation from the rear position lamp.

Due to the compact structure and the integration of all functions, thermal management played a key role during development. Openings in the chambers, appropriately graduated reflectors as well as specifically designed lamp openings protect functional reliability.

HEADLAMPS

The headlamps fundamentally determine the face of the vehicle and, in the dark, perform both a safety and comfort function by providing good illumination. The headlamps of the up! integrate all the front lighting functions: Low beam, high beam, turn signal, position lamp and daytime running light.

The integrated daytime running lights ensure improved visibility of the vehicle for other traffic participants during the day and, with that, increased traffic safety. The low beam and high beam function in the up! is realised using H4 technology, which enables a compact assembly.

Front position/daytime running lights are provided by a two-thread bulb. Additional light surfaces were gained for the low/high beam by moving the front position lamp outside of the main reflector. This shows how important a role good light performance played in the development objectives.

The day styling incorporated new concepts in the up! headlamps. A key decorative element for example, has been incorporated in the H4 reflector, ❼. Here, the challenge was to design an element of high-quality appearance and respective mechanical characteristics (like, for example, stability) from the thermally stable reflector material. The reflectors for the indicators and daytime running lights were partially implemented as free-standing elements, therefore emphasising the statement of precision by the overall vehicle. To further increase safety in road traffic, the up! offers optional front fog lamps which ensure improved near-field illumination in poor weather conditions.

STRUCTURAL DESIGN

The strict Volkswagen safety standards also apply to the up!. The considerably stressed load paths of the body structure are designed using high-strength and ultra high-strength steels. The hot-formed panels offering very high material strength ensure that the robust passenger cell provides utmost protection for the occupants in the event of impact. The additional crash reinforcements in the area of the door waist rails increase the structural integrity of the small car, particularly in the event of serious accidents, ❽.

PROTECTION SYSTEMS

In the event of a frontal impact, an early crash sensor, which is fitted directly

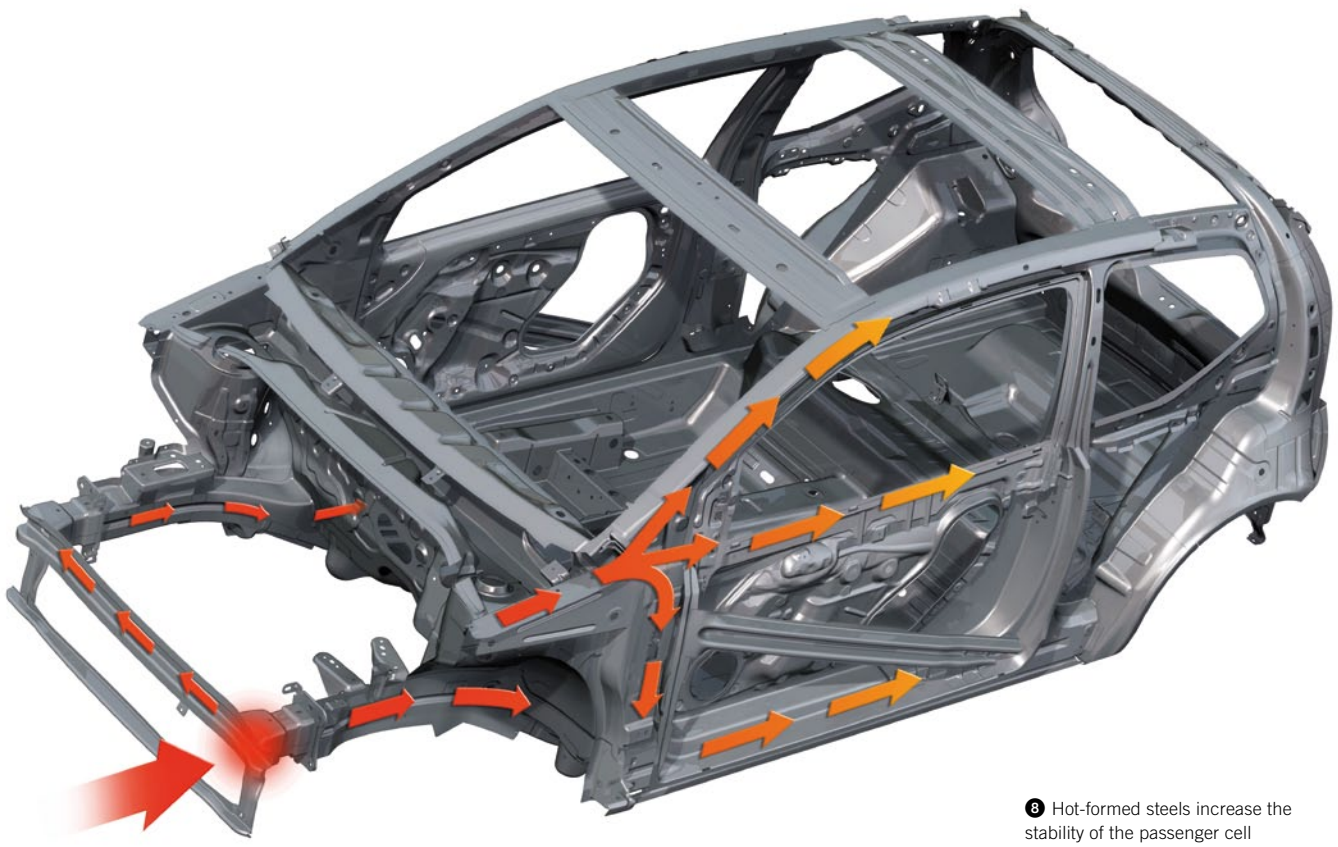
❻ Taillamp assembly

❼ Headlamp

behind the bumper, activates the restraint systems even before impact. Within just a few milliseconds, the seat-belt tensioners pull the seat belts tight so as to involve the driver and passenger in the vehicle deceleration early on. The belt force limiters minimise thorax stress on the occupants who are cushioned by the front air bags. The crash-active steering column also plays a role in minimising the driver's risk of injury. The development of the occupant protection started back in the early phase of the product emergence process with the aid of numerical simulations, way before the first prototype was subjected to crash testing, ❾.

In the event of side impact, the head and thorax side air bags, ❿, can protect both the head and the upper body. The air cushions fitted in the sidewalls of the backrests are adjusted to the occupant when the seat is adjusted and the backrest inclined, and can ensure maximum protection in the event of a side collision.

The pedestrian protection requirements were taken into consideration as early as the design phase of the up!. The engine



❽ Hot-formed steels increase the stability of the passenger cell

DOI: 10.1365/s40111-011-0278-3

❾ Frontal crash EuroNCAP; comparison test – simulation

hood, with its optimised hinges and defined styling of the deformation zone between the engine hood and the cylinder block, can reduce the risk of injury in the event of an accident involving pedestrians.

A child seat can be safely installed in the rear using the Isofix anchors and top tether fasteners. The standard belt status display in the multi-function display notifies the driver as to whether or not the rear seat passengers are belted up. There is also an acoustic seat belt reminder for the front seats.

ACTIVE SAFETY

The up! offers ABS with integrated traction control system and brake assist as standard. If desired, customers can chose not just ESC (standard equipment in some markets), but also a city emergency braking function. If the sensors detect obstacles in front of the up!, they automatically initiate a full braking at speeds up to 30 km/h so as to reduce the severity of the accident. In speed ranges up to 20 km/h, it can even avoid impact.

❿ Occupant protection systems in the VW up!