Body and Safety Concept

The structural configuration of the body needed to take account of not only safety and comfort requirements, but also economical and ecological aspects. To keep the costs of purchasing and using the Polo as low as possible, cost and weight-saving concepts were favoured in the development of the body. Low weight means lower fuel consumption, and therefore reduced CO_2 emissions – an active contribution to improving the environmental properties.

1 Rigidity

The basis for good comfort in the vehicle as a whole is represented by a highly rigid body with rigidity distributed as homogenously as possible. The vehicle body is differentiated according to static, dynamic and local rigidities, thereby permitting classification.

The static rigidity of the body structure is not only a significant technical characteristic but also a relevant parameter for the subjective perception of safety and driving comfort. An important aspect in achieving high static torsional rigidity in the body involves achieving a balanced profile structure in accordance

with the principle of geometric lightweight construction.

The design of individual connection nodes represents a significant factor. These have profile cross sections appropriate for the load, with corresponding reinforcement measures. In the rear area, rigid node components with adequate cross sections and a monocoque construction have been continued far into the support area of the tailgate hinges. Additional bonded connections are used to ensure that the components are joined together over a large area. This optimises the effectiveness of the node rigidity and completes the homogenous structure in the upper area.

Similar examples of lightweight monocoque construction with intensive cross sections can be found throughout the body structure of the Polo, with consistent use being made of the available construction spaces. The static torsional rigidity of 18,000 Nm/° gives it a very good value in its competitive environment, **Figure 1**. The lightweight construction quality has an outstanding value of 3.6. The lower this absolute value, the more efficiently lightness and rigidity are implemented in a body structure.

Having a high dynamic rigidity is an important precondition for outstanding driving dynamics, good vibration comfort and balanced acoustics. This is characterised by the position of the natural frequencies and the corresponding vibration forms. Optimum configuration of the support member structure in combination with material use appropriate to requirements and joining technology appropriate for the load are the main factors that contribute to peak values of 43 Hz for the first natural torsion frequency and 46 Hz for the first natural bending frequency. High local rigidity values at the points where force is directed into the body are responsible for good solid-borne noise insulation, and therefore for a low interior noise level. The targeted use of material at the relevant points makes a further contribution to weight reduction.

2 Materials

Consistent implementation of lightweight steel construction in combination with high and ultra-high strength materials has made it possible to reduce the body weight by 7.5 % compared to the predecessor.

Based on the loads encountered during front-end, side and rear-end collisions as well as rollovers, metal sheets with corresponding steel grades and material thicknesses have been assembled to create a safety cell. Panels from hot-formed steel [Rp 0.2 > 1000 N/mm^2] are used in zones subject to extreme loads. **Figure 2**. These panels are lighter but offer significantly greater strength than conventional high-strength panels.

The excellent strength and rigidity properties of the Polo body can also be explained by targeted use of modern joining techniques. The broad range of joining technology provides an effective response to load and cost requirements

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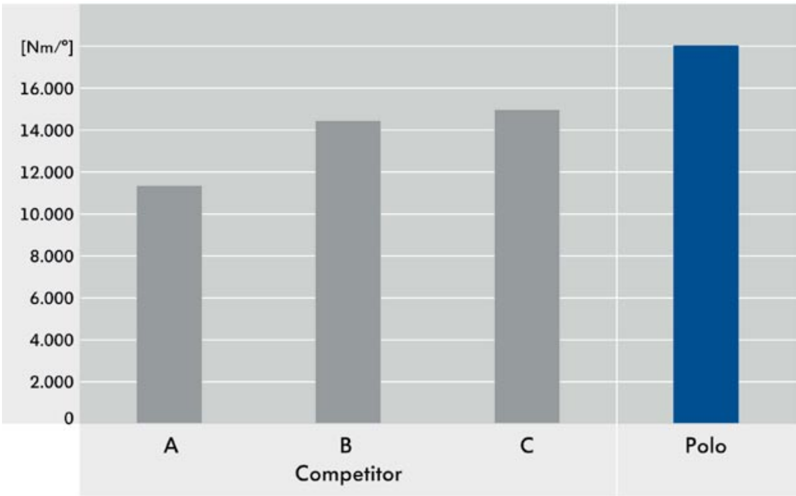

Figure 1: Torsional rigidity, competition comparison

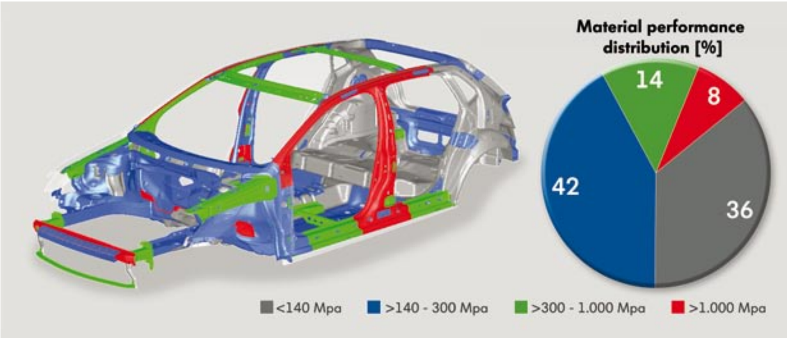

Figure 2: Material grades of body components

based on the innovative body production concept. The cost-effective method of resistance spot welding accounts for the major share of the component connections. In addition, bonding technology is used in complex node areas and for connecting components with increased requirements for rigidity. This means it is possible to design the components appropriately for the load, whilst still using cost-effective joining techniques.

3 Pedestrian Protection

The requirements of pedestrian protection were considered even from the design phase. Defined design of the inner panel in the bonnet area achieved a maximum amount of deformation space in order to prevent impacts against hard areas of the engine block in the event of a pedestrian being hit by the car. The bonnet hinges are optimised for pedestrian protection. Separate deformation elements are used in the wing areas. There are also deformation elements in the bumpers, in the area of the crossmember, which offer a significant protection potential. The configuration and functional method of various measures in the area of the bumper crossmember and bonnet are precisely adapted to one another. Pedestrian protection was optimised in the design of the front section of the vehicle by means of calculations and component tests.

4 Insurance Category

Significant damage can result even from minor accidents such as bumps in a car park. To minimise this, the front bumper system consists of an ultra-high strength, hot-formed crossmember which has softer deformation elements integrated within it. Specific reinforcement measures in the area of the lower side member systems have made it possible to increase the force level in the side member by 25 % compared to the predecessor. The energy can be dissipated in the easily exchangeable bumper system, whilst assemblies that are expensive to replace such as the radiator and air conditioning units are protected by the side members and remain undamaged. The resulting damage in case of an accident is significantly less, which tends to reduce repair costs and has a positive effect on the insurance category.

5 Crash Behaviour

A high priority was placed on crash safety in particular as part of development. This is based on a body structure that is very strong (sturdy passenger cell), with deformation zones to absorb energy all around and protection systems to match.

The extensive use of numerical stimulation methods made it possible to achieve the basic structural requirements in a specific manner and with a high level of quality. As a result, the body structure has been consistently designed with safety in mind.

In a head-on collision, the very rigid passenger cell helps to ensure survival space for the occupants. An ultra-high strength bumper crossmember at the front distributes the load in an offset crash to the side away from the impact point as well, which means that both side member areas are involved in absorbing energy, **Figure 3**. Optimisation of the side members means that the deceleration profile of the vehicle in a head-on collision minimises the effective load on the occupants.

The lower crossmember in the footwell of the new Polo is a hot-formed component. Not only does this halve the component weight, it also allows a very high strength level to be achieved. This means it has been possible to curtail intrusions by up to 50 % in the area of the footrest compared to the predecessor, therefore reducing the biomechanical loads on the lower extremities. Further protection potential is offered by the optimised pedals which leave the space clear for the feet and lower legs in case of a crash.

The side area of the safety cell has a kind of ring structure, which in combination with the door housed within it provides spatial stability, even in head-on

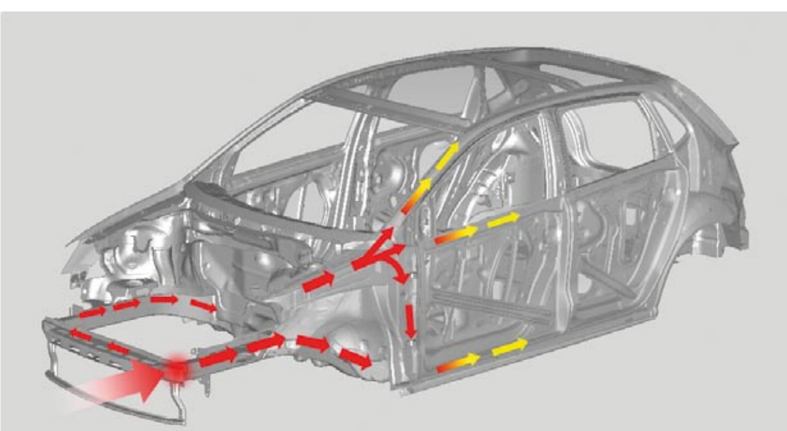

Figure 3: Front-end structure with graduated deformation zones

Figure 4: EuroNCAP front-on collision; comparison between simulation and test

collisions with a very slight level of overlap. Ultra-high strength, partially hot-formed panel reinforcements are used in the load paths of the A-pillar, roof frame, sills as well as the door shoulder that is supported on the B-pillar.

The optimised deceleration, reduced intrusions and associated remaining survival space means the body forms a very good basis for low loads on the occupants, **Figure 4**. Restraint systems adapted to the body performance minimize the probability of injury.

Development of effective side protection has been an important component of crash safety in the new Polo. Here, it is necessary to square the circle of exacting requirements for safety on the one hand and demands for weight optimisation on the other.

In a side impact, the load is carried along the hot-formed B-pillar and the profiled impact bars arranged diagonally in the door. Other central elements are the seat crossmember and sills which are uprated compared to the predecessor.

In this way, if a side-on crash occurs then not only are the penetration speeds reduced but also intrusion into the passenger compartment is curtailed by 20 %

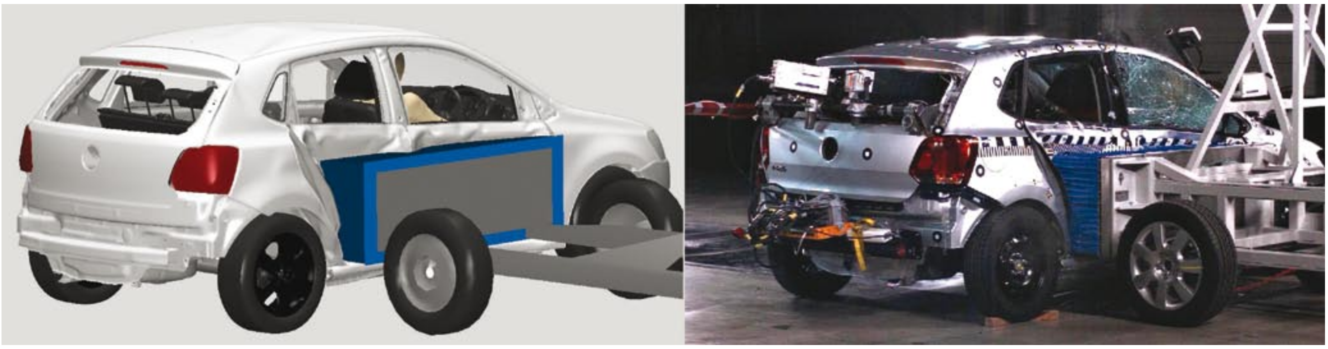

Figure 5: EuroNCAP side-on collision; comparison between simulation and test

in standardized tests compared to the predecessor, **Figure 5**.

To cope with a side-on impact against a post, the body has been developed to offer the optimum survival space by means of a hot-formed roof frame and the rigid sill, **Figure 6**. This allows intrusion to be reduced by 15 % compared to the previous model.

The structure of the rear end of the Polo has been reinforced by wide-section side members which, in conjunction with the sturdy passenger cell, help preserve the survival space for passengers as well as protecting the fuel system in case of a rear-end collision, thereby satisfying the most exacting safety requirements.

6 Systems for Occupant Protection

Simulation processes used in the configuration of body structures and restraint systems make it possible to evaluate a wide range of designs within a comparatively short time and optimise them.

The simulation processes, CAE infrastructure and the processes undergo continuous development based on experience from previous developments. In the design model of the Polo, not only the restraint systems but also the entire interior structures were represented as structural mechanical models, **Figure 7**. This made it possible to adjust all system parameters with regard to the variety of different crash load situations.

The Polo therefore continues to maintain the high standard set by Volkswagen vehicles with regard to restraint systems, **Figure 8**.

The front airbag system provides optimum restraint of the driver and front seat passenger in case of a head-on collision, with risk of injury minimized. The passenger airbag is installed in the top part of the dashboard, and can be deactivated by a key switch. The status is indicated to the driver by a display. This means it is possible to install a rear-facing child seat on the front passenger seat. Safety for children is supplemented by Isofix anchor points installed in the rear seats as standard.

Combined head/thorax side airbags in the backrests of the front seats provide all-around protection in the Polo. Head airbags are available as an option for the rear seats as well.

Three-point automatic safety belts are fitted as standard for all seats. Belt tensioners with belt force limiters are provided at the front seats in order to reduce thorax loads. These are fired electrically by a central control unit given a particular severity of accident, and help the occupants are connected to the vehicle deceleration at an early stage. This means the restraint effect lasts longer, with the occupants exposed to lower load values. The belt shoulder height at the front seats can be adjusted optimally for all seat posi-

Figure 6: EuroNCAP post crash

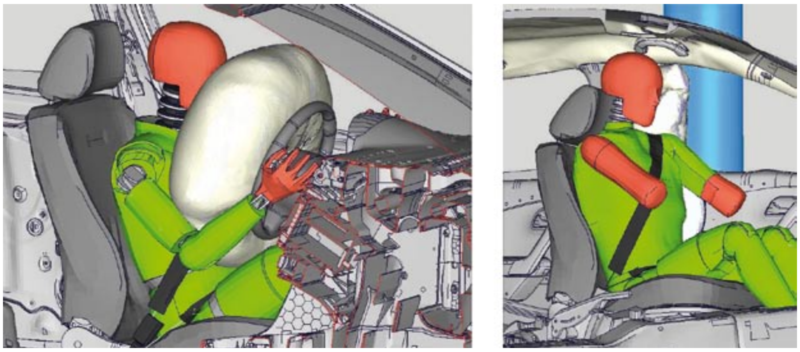

Figure 7: Simulation for configuring the restraint systems

tions and all sizes of occupant. Minimising friction in the belt system has made it possible to reduce the reel-in force, and therefore increase wearing comfort. The Polo is fitted as standard with a "seat belt reminder" (SBR) system to monitor the belt lock information at the front seats, and the system is also linked with an occupancy sensor which establishes the status of the front passenger seat. If the vehicle is driven at more than 25 km/h without the driver's belt lock connected, or if the front passenger seat is occupied but the occupant has not fastened his or her seat belt, then a warning sound and a warning light on the instrument cluster are activated to indicate that the seat belts have not been fastened.

The airbag release system consists of an airbag control unit in the front area of the frame tunnel with three internal acceleration sensors, two sensors in the longitudinal axis of the vehicle and one in the transverse axis, as well as four satellite sensors for detecting side crashes. Two satellite sensors are configured as pressure sensors and are located in the two "sensitive front doors". If a side-on collision develops, these sensors measure the increase in air pressure caused by deformation of the front doors. When collisions occur, which damage the front doors directly, this concept is significantly faster and more robust than the conventional method of measuring the transverse acceleration in this kind of vehicle. Furthermore, two acceleration sensors are used in the lower area of the C-pillar so that it is possible to detect side-on collisions in good time even if they do not involve deforming the front doors. When side-on collisions occur which exclusively involve the front section, the vehicle transverse acceleration measured in the airbag control unit is used for detecting the crash. Rear-end crash detection involves the two acceleration sensors integrated in the airbag control unit which operate in the longitudinal direction of the vehicle.

Ground-breaking simulation techniques were used for configuring the airbag triggering system, thereby enabling virtual integration of the body structure, restraint systems and airbag triggering system right from the concept phase.

This made it possible to establish the type, number and positioning of the sensors at an early stage, thereby allowing the expected triggering behaviour to be calculated with great precision even before crash tests involving prototypes and pilot series vehicles. Measures derived from this in order to achieve safety targets were thus implemented at an early stage in the development process.

As well as triggering the protective restraint systems of the belt tensioners and airbags, the airbag triggering system communicates with other control units; the hazard warning lights are activated, locked doors are unlocked, the interior light is switched on and the fuel pump switched off.

The concept of the energy-absorbing steering column already used in the Golf VI provides a further improvement in passive safety on the driver's side. The steering column has a clamp lock for adjustable rake and reach. This clamping, together with the telescopic steering column, helps to prevent the steering wheel from riding upwards both as a consequence of deformation to the front end and due to the occupant himself or herself. The underside of the steering column has been covered with energy-absorbing cladding in order to help reduce knee and thigh forces. ■

Figure 8: Occupant protection systems in the new Polo