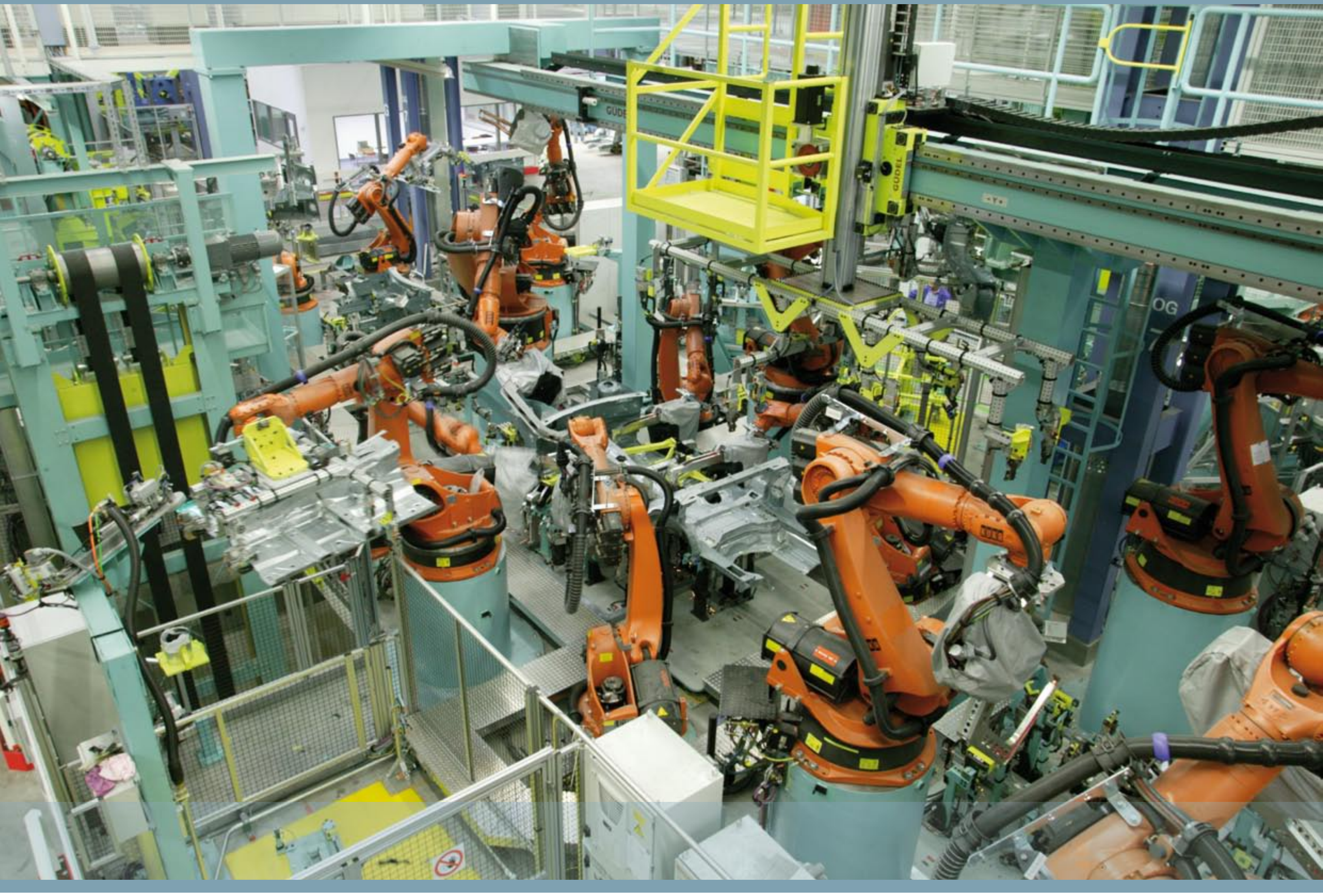

Quality and Efficiency in Production Due to Integrative Process Design

During the product creation process of the new E-Class, the production implementation factors played a particularly important role. At the same time, technology and model series cycles are becoming ever shorter. Processes such as production-compatible product design (PPG) and interdisciplinary production preparation (IPV) are of primary importance in order to fulfill the requirements in terms of quality and productivity.

1 Holistic Optimisation

The E-Class is one of the most sought-after classic business sedans; hence it is an important vehicle programme of Mercedes-Benz. Therefore, for the production it was vital to reach the highest level of aspirations in efficiency and at the same time to further optimise quality. This challenge could be solved by applying an integrated approach. This applies not only to the press shop, bodyshell construction, painting, vehicle assembly and logistics. The approach of combining all aspects of production and planning into an integrative process design leads to a holistic optimisation of both the product and the process. The following sections will deal with the main thrusts of this holistic optimisation in greater detail:

- production-compatible product design
- standardisation of production processes
- continuous improvement of production processes and technologies
- digital methods and systems.

The production-compatible design of the vehicle parts and components plays an especially important role. Clear aims are further improvements in ergonomics, efficiency and quality in the assembly processes for the new E-Class. At the start of the project, product planners and the development department jointly developed processes that have resulted in the synchronisation of the PPG activities during the course of the development process.

Standardisation as well as continuous improvement of the production processes and technologies were prerequisites for a once more improved process stability, quality and productivity during the subsequent production tests and during the run-up. In this case, the progress of the product design and the planning status of the factory had to be permanently compared.

As a matter of principle, all production-relevant processes for the bodyshell and assembly of the new E-Class, such as the accessibility of welding tongs or the ergonomics of the assembly process, for example, were simulated and validated using virtual product creation and product planning methods. This contributed to the high maturity level even during construction of the first physical test vehicles. Only by working together design, vehicle development and production planning departments achieved the objectives set. As has been demonstrated with the new E-Class, these departments use digital methods and systems to design the product in a production-compatible manner even at an early stage and take series production conditions into account in advance. This becomes clear from the digital bodyshell confirmation. In this case, a range of issues including the feasibility of the bodyshell was confirmed and the clamping and fixing concept was specified and coordinated in detail.

2 Digital Methods and Innovative Production Technologies

2.1 Digital Bodyshell Validation

After the planning processes had been successfully optimised in the C-Class with the help of digital method, it was essential to continue on this path for the E-Class bodyshell project and to optimise methods and processes. Along with the confirmation of the feasibility of the bodyshell by an early digital investigation using the relevant welding gun geometries, the subject of specifying the tack welds for the entire vehicle was conducted. Following an early detailed specification and coordination with the clamping and fixing concept for the E-Class, it was possible to avoid modification costs that were common in earlier model series. Along with the confirmation of weld points, the subjects of stud welding and clinching were digitally validated for the E-Class.

For the flexible configuration of the bodyshell production, consistent and structured data management of simulation data is an indispensable prerequisite. The bodyshell of the E-Class is therefore fully available in the digital planning world: from the three-dimensional (3D) layout through the quantity matrix to robot simulations, **Figure 1**. As a result, all robot simulations and offline programming are checked to ensure compliance with the guidelines to ensure that it is possible to continue working with this data. The final stage of this topic is the upload of the permanent data from the systems and robots. This ensures that the digital and the real world match. Even when the E-Class was commis-

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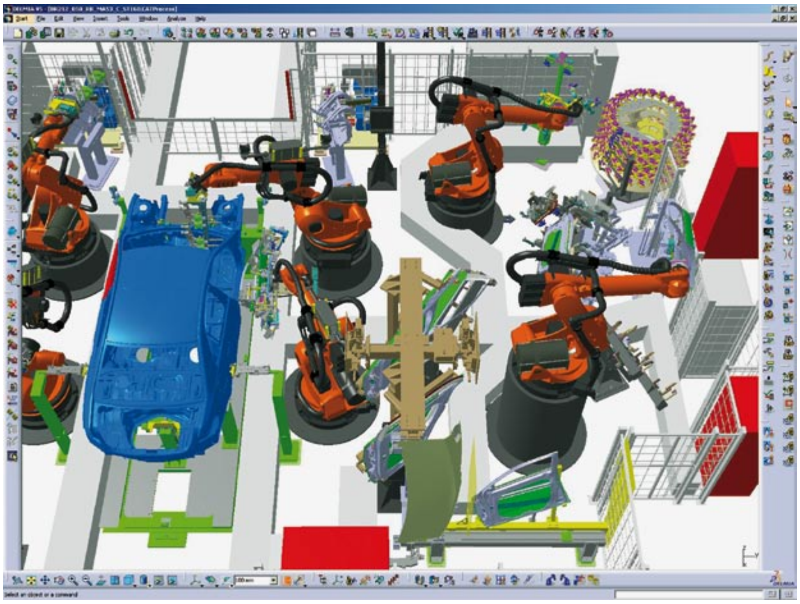

Figure 1: Digital confirmation of "Best-Fit" door assembly

sioned, the benefit of consistent offline programming and the associated time benefit were apparent.

2.2 Bodyshell Standardisation

The planning process was not the only one that could be further optimised. The continuation of systems and component standards also delivered corresponding potentials at the start of the production test phase in terms of deadline processing and the maturity level of the body shell systems. The standardisation starts with individual components and ends with standardised system concepts into which the experience gained from the previous model series has flowed.

This is possible because the concepts from the C-Class model series were partially adopted. This meant that it was possible, for the joining technology for example, to use the same gun catalogue with new geometries only being used in special cases. It was also possible to use the existing standard to reach the maturity level of the product quickly at other technology stations such as the Daimler standard framer, which is used to join the inner and outer side walls to the vehicle, **Figure 2**. One key to success is the use of precisely this clamping frame of the standard framer in the prototype and null series phase, **Figure 3**. Issues are detected in good time and resolved. The first vehicles on the production line start off with a higher maturity level.

It is not just mechanical standards that lead to an improved start-up maturity level of the system technology. The Integra controlling standard used achieves a maturity level with the E-Class such that the commissioning time and the modification cost potential could be measurably reduced. Together with the product and system standards, the modules of the control standard provide a complete package for current and pending bodyshells.

2.3 Improvement of the Production Technologies in Series Production

Robot-guided laser remote welding "RobScan" can be cited here as an example of a system that has been continued from the C-Class. Continuous improvement refers to the replacement of a two-dimensional (2D) laser optic with a three-dimensional (3D) laser optic. As was the case with the 2D laser, this enables Welding-on-the-Fly. The simultaneous superposition of the movement of the scanning mirrors and robots enables remote welding at high speeds to be achieved. With the 3D optic in use for the E-Class, this is now possible for component flanges with different clearances to the optic – without the robot having to change its path. The use of the 3D optic therefore results in an increase in efficiency and offers additional process and quality advantages. Only in conjunction with a 3D scanner was it possible to translate the higher power of the 6 kW laser (which is now in service) into greater speed and therefore reduced cycle times. Regarding laser soldering, the Laserline diode lasers were implemented in the E-Class for locating seams. Compared with the C-Class, a reduction in the required surface and the investment resulted in a higher efficiency factor that improved energy efficiency by 30 %.

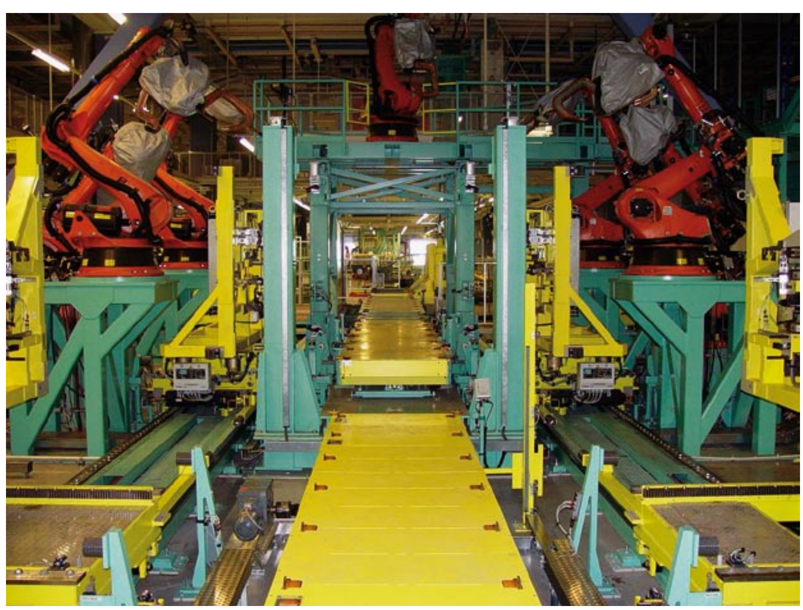

Figure 2: Daimler standard framer

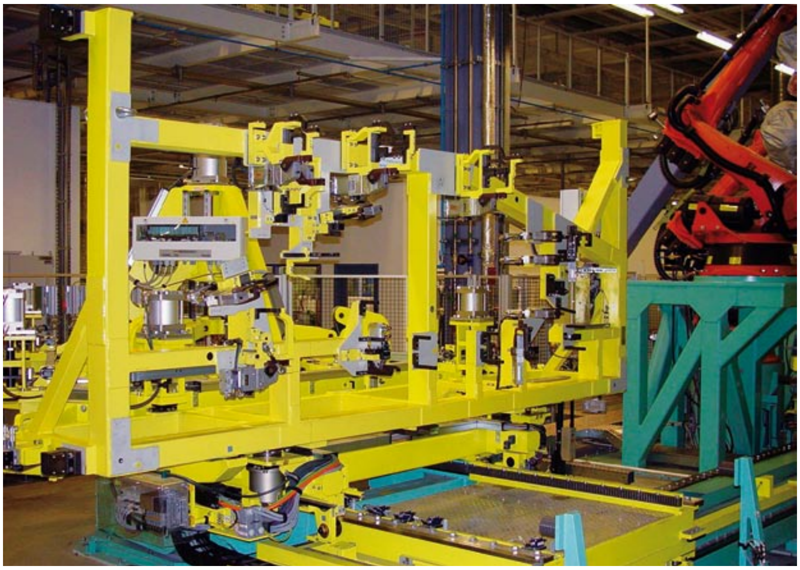

Figure 3: The clamping frame of the standard framer for the inner side wall. Version as per standard clamping and fixing concept

Figure 4: LCA (Low Cost Automation) type used in the E-Class

The automated assembly of add-on parts with "Best-Fit" technology could be further optimised compared with the most recent vehicle projects. The "Best-Fit" process uses laser triangulation sensors to measure the gaps and transitions between add-on parts and the bodyshell quickly and precisely, before they are optimally mounted in the installation position.

The measurement sensors are robot guided and are positioned at the relevant installation grippers for the add-on parts. After assembly, the system performs once again a quality measurement of the gaps and transitions. The results are displayed on the downstream finish in order to control any manual settings that may be required. The use of the complete line of add-on parts in the null series phase allowed the assembly quality at the start of the production test to be significantly improved. This not only results in a high first time capability during the earliest run-up phases – it also reduces the start-up costs for the personnel that would otherwise be required.

2.4 Further Increased Quality Requirements

As a consequence of the further increased demand for higher product quality, an ever-increasing number of measurement and monitoring systems are being used in the area of quality monitoring.

The classic monitoring system is inline measurement technology. In this case, optical measurement processes are used to check the dimensional accuracy of the bodyshell. The robot-guided systems used for the new E-Class provide for a flexible response to different vehicle variants. Particularly during the start-up phase, inline measurement technology acts as a support for achieving the required degree of dimensional accuracy. If the measured values are outside the tolerance, the system comes to a halt.

Another familiar system is the adaptive welding control during resistance point welding, which detects external perturbations and process fluctuations of the welding process and then compensates for them during the current welding operation by adjusting the welding parameters. The quality aspect comes into play with the Q module, which reports excessive deviations from the target process and causes the system to halt.

In the case of bonded connections that have to fulfil crash or leaktightness requirements, the seam position of the adhesive beads is checked using optical systems. In general, the quantity of adhesive is monitored in each adhesive control sequence. Deviations from the target process when the adhesive is applied also lead to corresponding messages.

When it comes to monitoring the quality of the laser welding process using "Rob-Scan", a system for detecting strength faults is also used in the welded connection. All of the monitoring systems used increase the product quality of the new E-Class. However, they also require highly qualified personnel.

2.5 Implementing the Flexibility Strategy

The bodyshell of the new E-Class marked a further continuation of the flexible production strategy. This means that different vehicle variants of the E-Class can be produced on one manufacturing line. This flexibility throws up new challenges regarding the provision of parts to the systems. As a result, the smaller load contain-

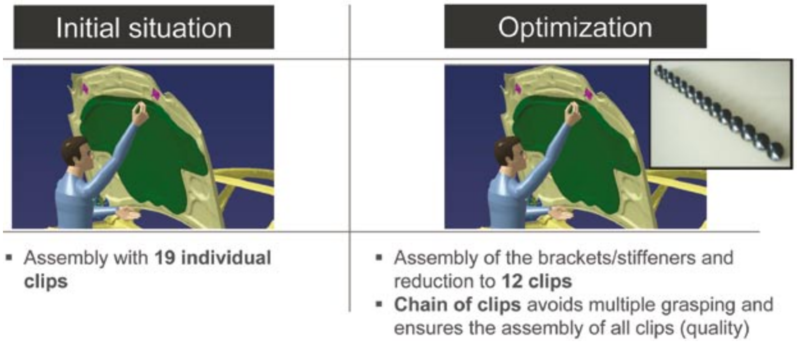

Figure 5: Optimisation of clips for engine cover soundproofing

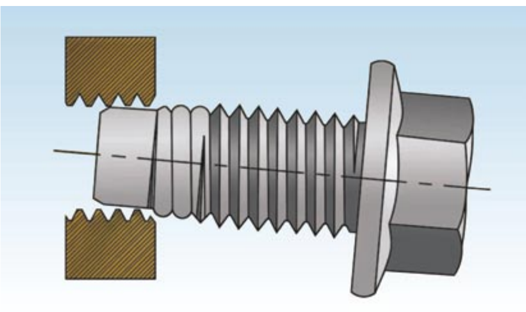

Figure 6: Bolting with self-tapping "MAThread"

ers also called for by the Mercedes-Benz production system are being used to a great extent. Despite the need to provide different component variants, this makes it possible to position parts at the systems in a manner that optimises production.

A second concept that has already been implemented many times in bodyshells in recent times is Low-Cost Automation (LCA) for supplying components to the bodyshell systems, **Figure 4**. This concept was fully implemented in the new E-Class. The use of introduction cycles of one-and-a-half hours enables a High Production Volume (HPV)-optimised deployment of bodyshell personnel.

Both the logistics concept of the bodyshell as well as the option to use LCA is strongly influenced by the product and variant structure. This is why the bodyshell planning and logistics planning departments work closely with the development department.

3 Ergonomics, Efficiency and Quality

3.1 Product Cycles

The technology and model series cycles in the automobile industry have become shorter and shorter. Nor is a slow-down in this trend over the coming years to be expected. As a result, the frequency of the product innovations will continuously increase and the development times will continue to reduce. This also means that the mechanisms to ensure the successful and timely market launch of a product will have to be put in place early in the development process.

While the first tests for the assembly of the new E-Class were running in the production halls in Sindelfingen (Germany), the stage was being set for further new product start-ups two floors up: assembly-compatible product design is the method, which delivers improved ergonomics, efficiency and quality to the production processes.

3.2 Assembly-Relevant Processes

The concept of analysing the assembly-relevant processes is the driving force behind the activities of a project group whose objective is to examine and optimise the processes in terms of assembly-compatible product design. Working in cooperation, this inter-disciplinary Team eHPV (engineered Hours per Vehicle) drawn from the Planning, Production and Development departments analyses all assembly-relevant processes in order to achieve the best possible result with regard to ergonomics, efficiency and quality.

3.3 Eliminating Assembly Difficulties

Fields of action derived from a benchmark focused on a central question: where in the process can assembly difficulties be identified and how must a component or a process be changed in order to eliminate these difficulties, **Figure 5**. An important source of knowledge about assembly-compatible product design is the IPV line (interdisciplinary production preparation) at the Sindelfingen plant. Here, assembly processes are simulated, evaluated and optimised under realistic conditions. The inter-disciplinary cooperation has already led to the suc-

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"The new E-Class epitomises the premium quality of the Mercedes-Benz brand. Intense collaboration between Development and Production also made it possible to achieve exemplary efficiency from a production standpoint."

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cessful implementation of more than half of about 600 individual measures. The importance of the interaction between the specialist departments becomes apparent from the IPV vehicles. In this way solutions that advance both the product as well as the processes can be found and implemented.

Initial successes have already been reported during the product development of the new E-Class (W212). In this context, the individual measures have made an impressive impact. In the tailgate handle strip, for example, it was possible to reduce the number of components compared with the predecessor model from 20 to three. Also consistently using screws with a self-tapping tip led to process times being significantly shortened, **Figure 6**. The same work package was provided with standardised screws and torques to minimise the risk of confusion and to avoid the need to switch tools.

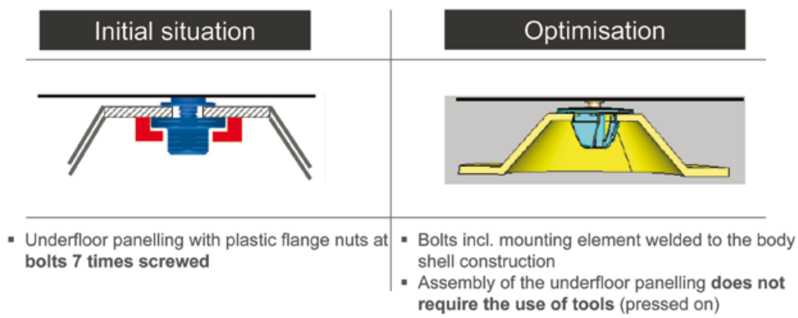

Figure 7: Assembly-optimised underfloor panelling

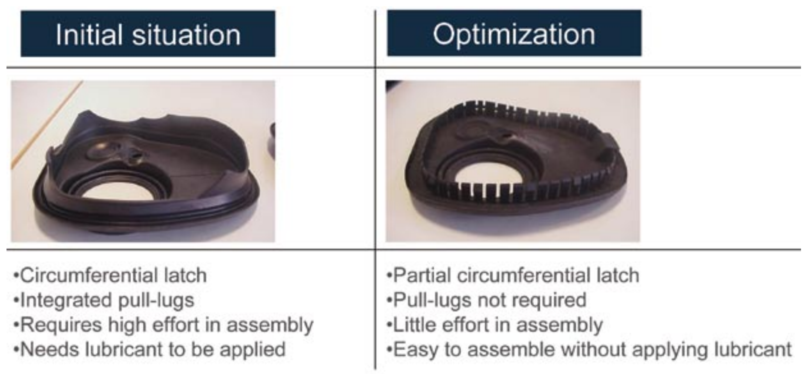

Figure 8: Assembly-optimised tank collar

Figure 9: Examples for assembly-compatible product design

3.4 Component-Specific Solutions

The fact that assembly-compatible product design requires component-specific solutions is demonstrated by two other successfully implemented measures. In the assembly of underfloor panelling, a redesign of the fastening concept allowed a significant optimisation to be achieved. Whereas the underfloor panelling was usually bolted using plastic flange nuts in the past, assembly of the panelling using a bolt clip already welded to the bodyshell construction did not require the use of tools. With this new measure dependent assembly work could be avoided and assembly time cut in half. A further advantage of the new fixing concept is that it enabled the use of lighter and softer panelling materials with better damping properties made of pentalaminate, which makes it economical, **Figure 7**. Equally convincing is the changed tank collar: Previously only installable by applying a lubricant, the new collar – a plastic frame with an injected rubber seal – dispenses with lubricant and can be fitted with considerably greater process consistency, **Figure 8**.

3.5 Early Inclusion of the Supplier

These examples demonstrate that three factors are of particular importance in relation to assembly-compatible product design: quality, ergonomics and production time, **Figure 9**. With this in mind, measures and processes will in future be defined in the component requirement specifications and coordinated with the suppliers at an early stage. In keeping with this, it is essential that assembly requirements are described in detail and that the process is defined well in advance to ensure that the best result can be jointly achieved. Similarly, suppliers work actively on introducing component integration or fastening material that is delivered along with the component.

The advancement of existing processes is not yet complete. On the contrary: it will continue to evolve hand-in-hand with the technology and model series cycles. ■