Hybrid-Front End Ford Focus

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1 Introduction 1
2 Economically and highly versatile 1
3 Precision lightweight design.............................5
4 CAE-Models optimize hybrid designs, too 6
5 Polyamide meets extreme requirements 6
6 Automated production......................................7
7 Simple recycling process 7
8 Summary...8

1 Introduction

The Ford Focus (C170) was the first mass-produced vehicle to have a front end (Grill Opening Reinforcement short: GOR) as a structural component that was developed consistently in hybrid technology. All the succeeding models of this class have been equipped with hybrid front ends as well. The application of hybrid technology reduces component weight, increases quality and lowers production costs. Dependable computational methods employing the aid of finite elements support the design of these complex components during the design stage.

Figure 1 Ford Focus Front End

The GOR of the Ford Focus (Figure 2) is a part of the car body structure and helps in all driving and crash situations to stabilize the vehicle front. The GOR defines the positions of all assemblies fitted, e.g. headlamps, bonnet fenders, bumper, radiator grill during the non-adjust fitment. Consequently, to avoid time-consuming adjustment work during final assembly of the vehicle, the GOR must be made to very low tolerances. The diversity of these requirements, the enormous gain in quality of modern automobile production and the permanent aim of weight and cost reduction are pushing conventional designs to the limits of their development possibilities.

The pathbreaking hybrid technology developed and patented by LANXESS combines the advantages possessed by two completely different materials and the corresponding production methods and opens up totally new possibilities in structural development.

Intensive co-operation between the raw materials manufacturer LANXESS, the Ford automotive group, Plastal GmbH, Weißenburg, the sheet metal parts manufacturer Kirchhoff Kutsch GmbH and the moldmaker Misslbeck has resulted in a body part (Figure 1) that by then features the highest functional integration density.

Figure 2 As a component of the car body, the GOR of the Ford Focus helps in all driving and crash situations to stabilize the front of the vehicle.

2 Economically and highly versatile

Hybrid designs allow the production of complex, ready-to-assemble components in a few working steps and thus combine the economic process of sheet metal stamping with injection molding. A plastic structure is injection molded to a stamped, perforated sheet metal profile. The plastic melt passes through the punched openings of the profile and around its peripheral edges. It forms molded buttons and over molded edges (Figure 3) between the mold cavity and the inserted metal part.

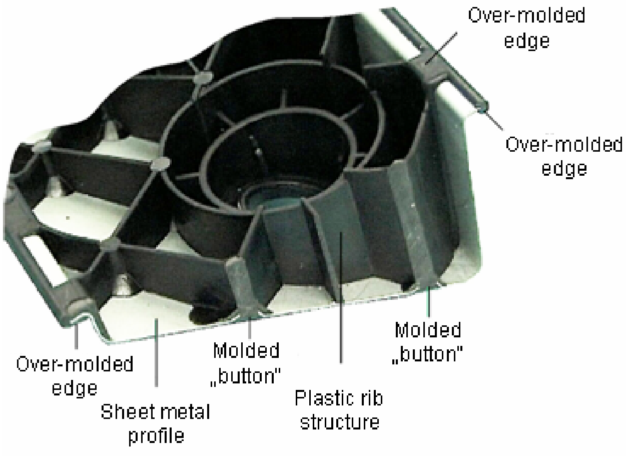

Figure 3 Profile cross-section of a hybrid structure with special structural parts labeled

The resultant positive connection can withstand high loads, even without the use of a bonding agent. The normal corrosion protection of an e-coating remains fully functional after injection molding and does not affect the intimacy of the dissimilar materials. The resultant composite material structure has physical characteristics that cannot be achieved with either the two materials.

The dimensional supporting metal structures of the composite structure can be designed with very thin walls because the filigree molded ribs of plastic dependably counteracts the inclination of such thin metal constructions to bend or buckle under load. As a result, the metal structures, in spite of the thin-nest of wall thicknesses, can be pushed more closely to yield stress of the material property with-out breaking down due to geometrical instability.

Figure 4 and Figure 5 compare the load-deformation characteristics of various test specimen under pressure and flexure as detailed in the right lower corner of the picture. The black line corresponds to the characteristical curve of a simple u-formed profile which is common in body design. The structural performance of a sheet metal profile can be increased when a closed profile is used (yellow curve). The increase of strength is evident when a plastic rib structure is added to the sheet metal by injection molding, in other words a hybrid structure is used (red curve). All test-specimen have a sheet-metal-wall thickness of 0.7 mm. Additional tests have confirmed that a lower wall thickness and a higher cross-section in hybrid design raises the relative stabilization effects between plastic and sheet metal. Hybrid parts not only perform with higher strength, their energy-absorption capabilities are far higher than those of sheet metal. The molded rib-structure may be used to increase the extremely low torsional rigidity of an open profile significantly, too (Figure 6).

Additional subassembled profiles are no longer necessary. This fact decisively improves the cost efficient production of profiled structures by using hybrid. Even if, in some loud-cases, the plastic ribs cannot fully cope with the rigidity of a closed profile, a smart hybrid design always raises the overall performance with lower weight and cost. Basic studies confirm the efficiency of the plastic-metal hybrid structures with respect to performance weight-ratio of the individual test profiles (Figure 7).

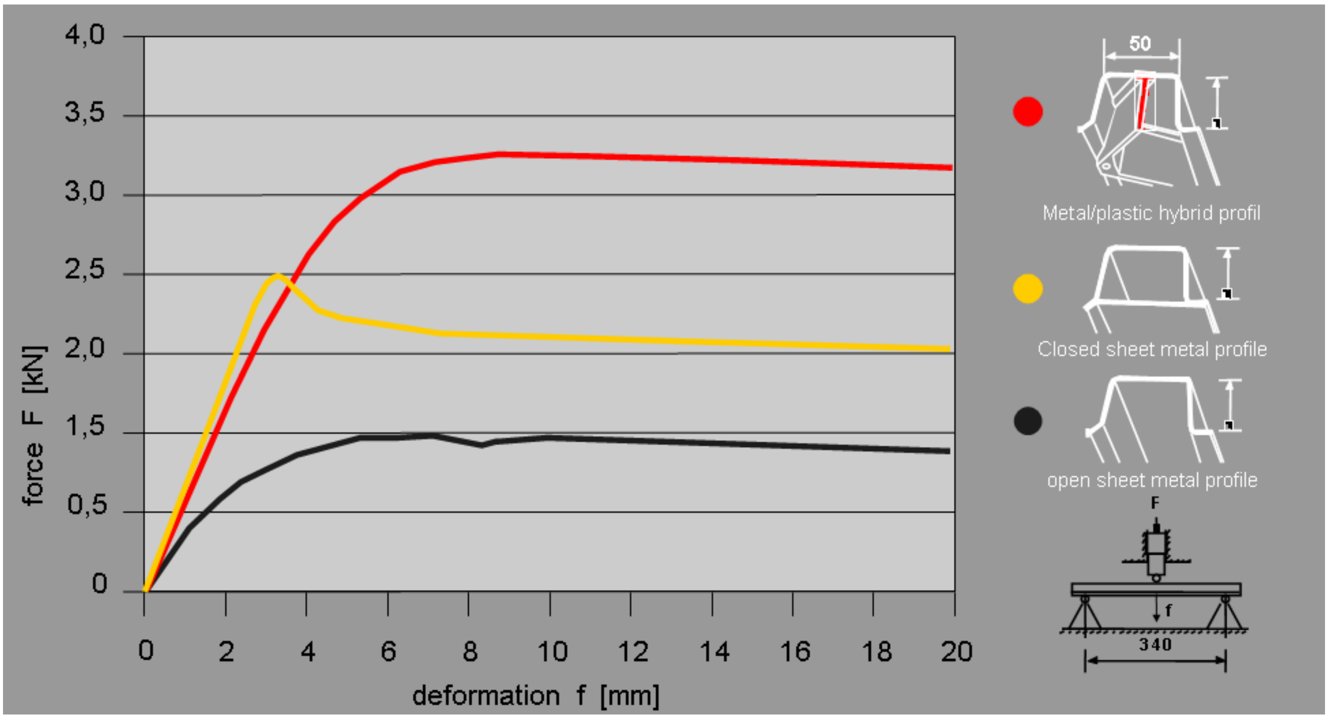

Figure 4 Load-deformation curve of various profile section specimens under flexure

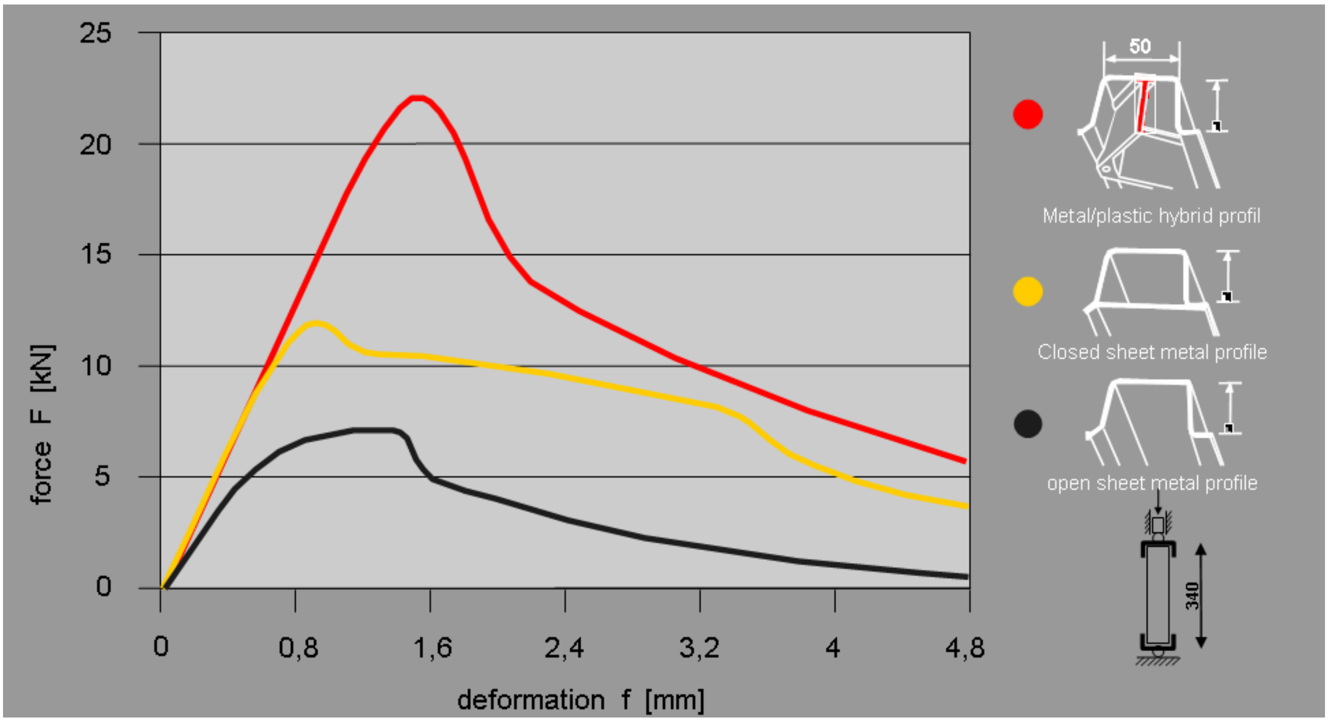

Figure 5 Load-deformation curve of various profile section specimens under pressure

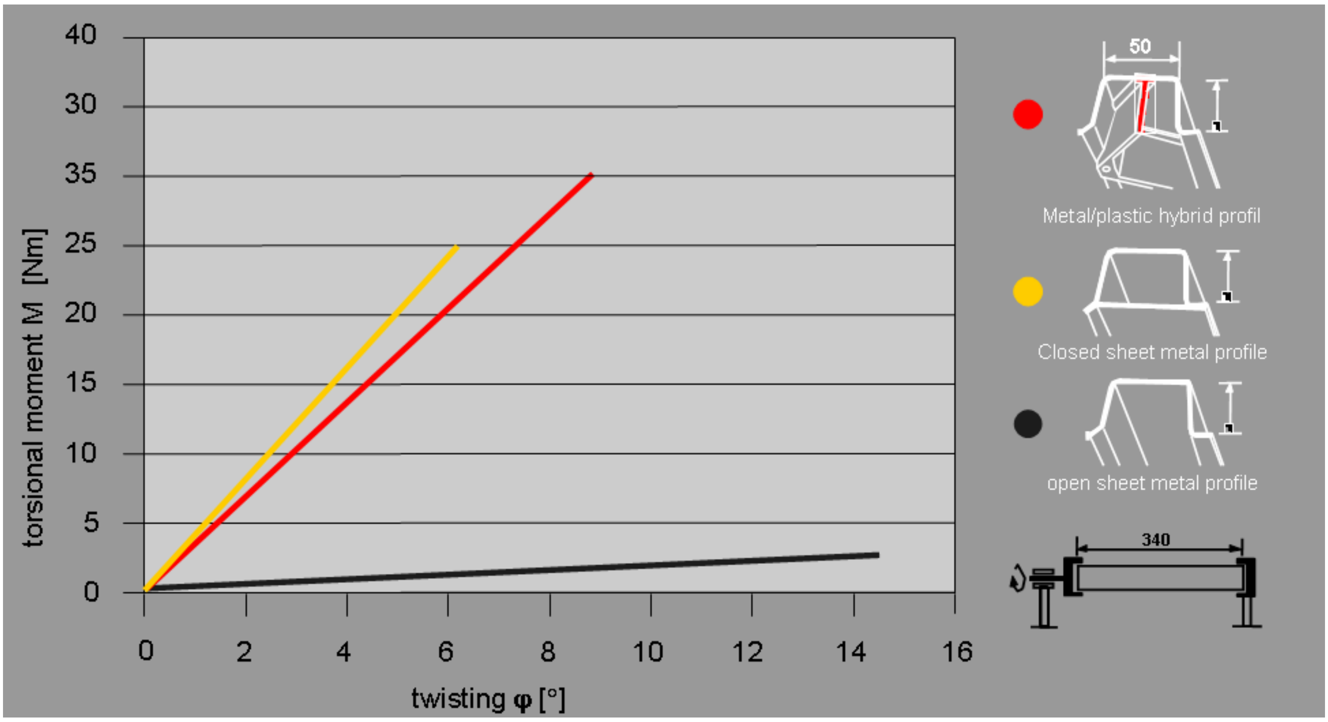

Figure 6 Force-deformation curve of various profile section specimens under torsion

Load / *Profile style*	Bending Loading capacity	Pressure Loading capacity	Torsion Stiffness
PA-GF 30 % x-ribbed Steel s = 0.7 mm	1.8	1.8	13
Steel s = 0.7 mm	1.1	1	28 closed 5 open
Steel s = 0.7 mm	1	1	1

Figure 7 Weight-related stabilization factors under flexure, pressure and torsion for different profile section specimens

3 Precision lightweight design

The increasing quality objectives in car-body-construction necessitate a highly precise GOR in the front of the Ford Focus. This precision in combination with high structural performance could only be met by a hybrid GOR design. The GOR is mounted in the body construction area. This allows to position all front end exterior parts none adjust to one precise body part. Using these setups the vehicles get the lowest possible body-tolerances for gaps and flushness.

This hybrid design GOR consists of three profiled sheet metal stampings, supplemented by and joined to a plastic rib structure in an injection molding process. The sheet metal surface does not have to be covered by plastic. The wall thickness of the stampings is lower as in a pure sleet metal design. The GOR of the Ford Focus uses high strength steel stampings. Together with the polyamide it sustains higher loads. With the hybrid GOR Ford meets lowest possible tolerances for positionings and fixings, which are not possible to reach with a sheet metal structure with similar weight and cost. In comparison to a plastic part the hybrid design is much less dependent on influences as shrinkage and distortion caused by climate and temperature changes. It also benefits from the higher Young's modulus of steel.

The injection molding process allows a high grade of integration without on cost. In the hybrid GOR design functions like positioning and or fixing of the following modules are integrated: radiator, AC-condenser, hood latch, hood lack, fenders, headlamps, radiator grill, intercooler, intercooler air duct, dirty air duct, headlamps washer jets, bumper facia and hood bumps stops. Clips fixings for bumper facia, hood latch and hood lock are integrated as well as a security shielding for the latch (Figure 8).

This economic production process makes it possible to even integrate further innovative functions into the hybrid GOR as shieldings for upstream ducting or further security shields for latch and locking cylinder. All modular parts can be assembled quickly and simply non adjust. The locators provide precise presetting of the modules. This fact has a positive effect on assembly cost and -quality of the vehicle.

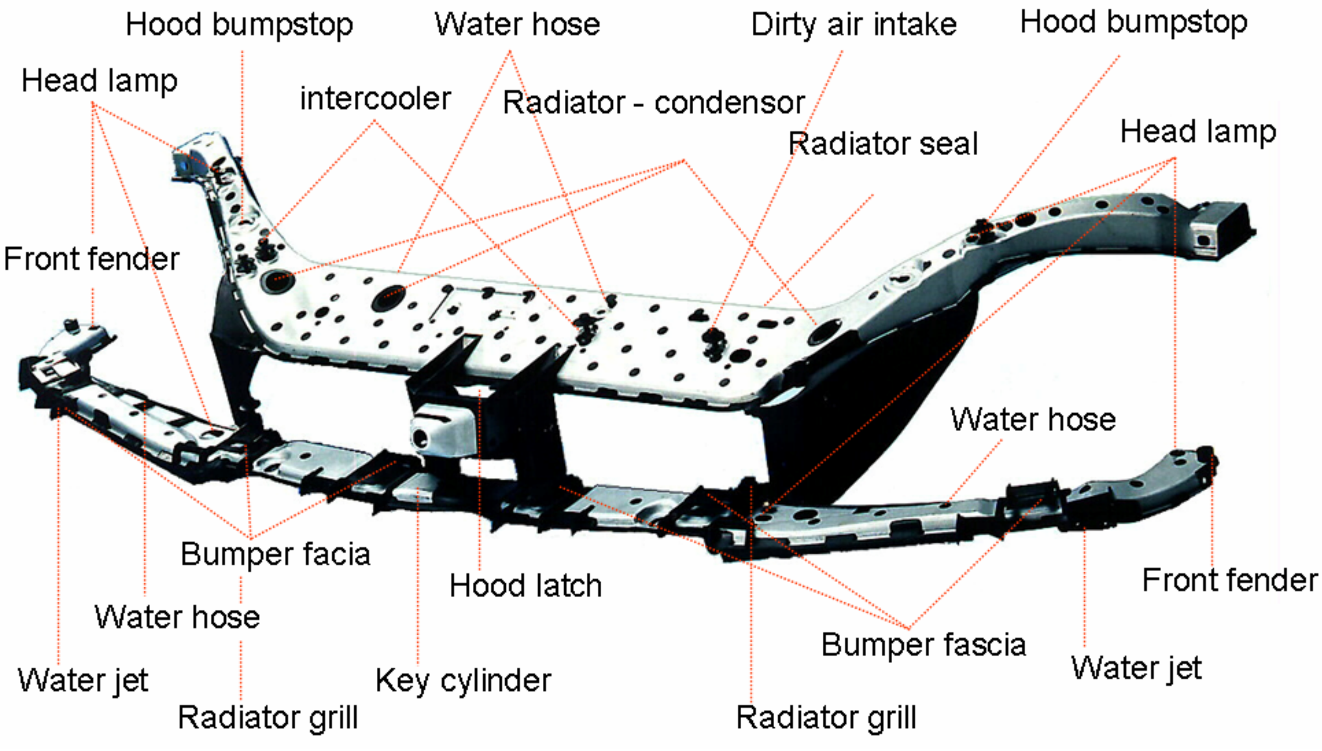

Figure 8 Functions integrated into the GOR of the Ford Focus

4 CAE-Models optimize hybrid designs, too

One challenge in hybrid designs is caused by the shrinkage behavior of the polymer materials. Stresses are particularly likely to occur wherever the metal and plastic are joined together. This could lead to deformations in the hybrid part. This makes distortion, warpage and shrinkage CAE-modeling extremely important. In the case of the Ford Focus GOR where a glass filled polyamide is used, these figures can be influenced to a certain degree by changing the orientation of the fibers. A complete CAE model developed by LANXESS AG offers the possibility of modeling the distortion in the hybrid structure caused by material shrinkage in order to compensate for it as much as the design allows.

The first step was to devise two separate FE-models, one for the metal, another one for the plastic portion of the structure. The fiber orientation is determined by performing a filling simulation. Information about the fiber orientation are very important for CAE modeling the distortion, because the polyamide melt shrinks more square to the fibers than in fiber direction.

A software interface combines the findings of the rheological calculation and the two finite-elements models of the plastic and sheet metal. A subsequent CAE modeling determines generated by shrinkage and gives figures for distortion of the hybrid structure (Figure 9).

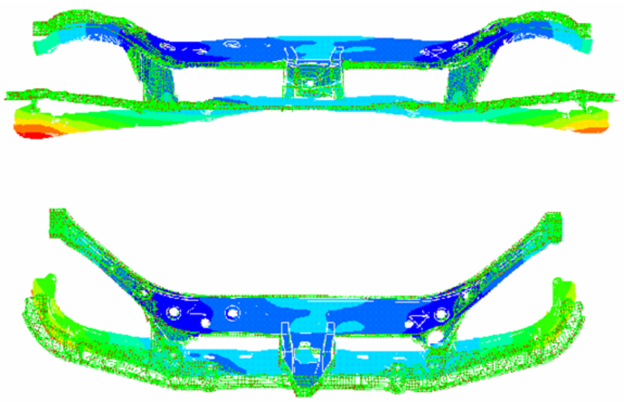

Figure 9 FEM simulation allows warpage behavior to be rendered highly visible and identifiable

The complex design of the Ford Focus hybrid GOR and others permit predictive CAE analysis. The tooling will be designed that the parts later on are nearest to nominal dimensions without the need for test or prototype tools.

The production process becomes more dependable and economical. The reliability of the CAE model was checked with test parts. This CAE model proved to be very reliable and realistic.

5 Polyamide meets extreme requirements

Very stringent requirements are imposed on the polymer material. Glass fiber-reinforced polyamide 6 (Durethan® BKV 30) was used in this application. Glass fiber reinforced polyamides have proved effective in a large number of applications over many years, especially for technical structural components. Depending on the glass fiber content and grade of condition, Durethan® grades offer tensile strengths of up to 150 MPa and rigidities with a Young's modulus up to 13 000 MPa (conditioned).

Owing to its ability to absorb water, polyamide is by far less brittle than other glass fiber-reinforced polymer materials. The toughness, particularly impact strength, can be increased further in the low temperature range through additional elastomer modification. The good toughness of the polyamide is responsible for good overloading behavior of the hybrid structures.

All semi-crystalline Durethan grades possess exceptionally good dynamic strength (fatigue strength). Used for the hybrid GORs, the polyamide shows good fatigue strength under cycled stress.

The partially crystalline polymer material is ideal for combining with metal. The ability to relieve residual stresses during injection molding and also in practical application through relaxation is crucial here.

Glass fiber reinforcements ensure high dimensional stability with equally exceptionally high thermal stability. The necessary strengths are also guaranteed at temperatures of more than 100 °C. In the Ford factory, as already described, the hybrid GOR is bolted to the body in body construction. The body shell has to pass through the e-coat, the drying ovens and the complete paint process where they are exposed to temperatures of up to 200 °C. Therefore, the plastic material must resist a temperature of more than 190 °C for at least 20 min.

6 Automated production

The GOR components were produced by Plastal GmbH in Pappenheim and Valencia. The production equipment consists of injection molding machines with peripheral equipment matched to the component. The production process begins with the manual positioning of the pre-assembled sheet metal parts on a chain conveyor system which can be loaded with several sets of inserts. The conveyor feeds at the same time the finished components back to the operating personnel.

The handling system, a linear robot takes the sheet metal parts and checks them for completeness and the defined dimensional accuracy with the aid of sensors. Then, the robot moves into the opened injection mold. It removes the finished component and, after this step, inserts the sheet metal parts straight into the mold (Figure 10), where they are fixed with the aid of the core pullers. On the way to the chain conveyor system, the GOR passes a sprue-cutting device where all sprues are cut off simultaneously. They are ground on location and returned immediately to the raw materials.

In spite of the complexity of the part and the high demand on dimensional accuracy, production is characterized by very low reject rates.

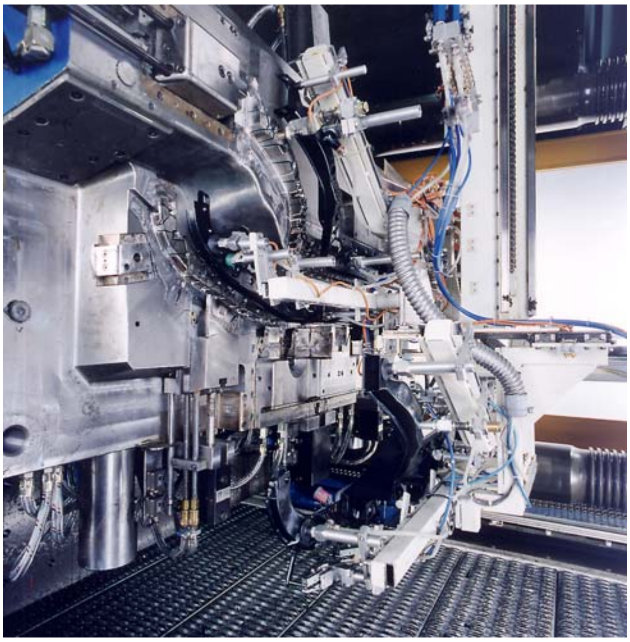

Figure 10 Production of the hybrid part is automated, from inserting the metal parts through cutting the sprues from the finished component

The front ends are removed manually from the chain convey or system and positioned into the adjacent bolt on round table. A robot bolts on fixing brackets in sequence that were attached previously by hand. The screws are fed automatically and are already fitted with a rolled on washer. After tightening, the robot loosens the screws to a defined extent so that the brackets remain movable and the GOR part can adjust to the rest of the car body during body assembly.

7 Simple recycling process

Although different materials are used, there is absolutely no problem with recycling the hybrid composite construction: it is comminuted in a hammer mill. The two components can be separated well through sieves and magnetic separators. The polymer purity of the material recovered in this way is over 98 %. The recovered materials can be cleaned up and fed directly into the production cycle or used for manufacturing other parts. Test specimens of recycled plastic have almost the same property profile as the original material.

8 Summary

Hybrid technology opens up great innovation potential for the automotive industry, particularly for producing assembly support parts for extensive system modules that feature a high level of integration. Principal characteristics are: excellent structural properties and good overloading behavior at low weight, high integration possibilities for functional elements as well as high precision in production and in practical use. Hybrid parts can be produced in high volumes by the most economical methods.

In addition to the GOR, there are other structural components that can be implemented in hybrid technology. These include as the cross beam beneath the dashboard, structural components in elaborately furnished vehicle seats, structures for the central console and the rear hat rack in the vehicle.

Hybrid design has been tested in mass automobile production – this paves the way for further applications.