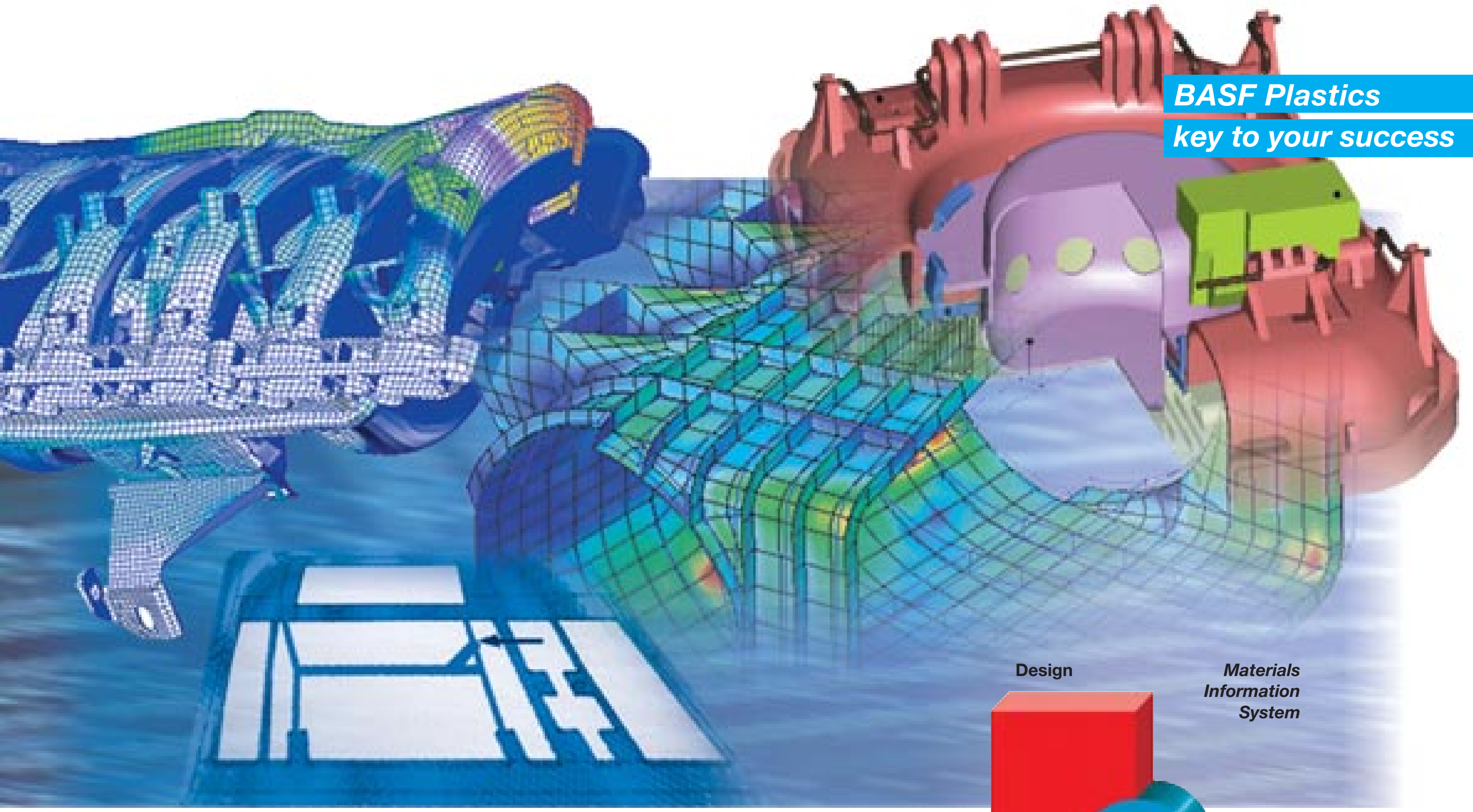


Technical Information for Experts 03/99e

CAE Development Service for Plastics Processors and Users

■ In the development of new plastic parts, early optimization is critical to the economics of the product. ■ Computer aided engineering (CAE) is currently used in all development phases. ■ The following presentation provides an overview of the CAE Development Service of BASF's Plastics Application Development Center (AWETA Thermoplastics). It includes material selection, design, structural analysis, acoustical analysis, mold filling simulation, blow molding simulation and design of extrusion dies. ■

BASF

CAE in parts development

Material selection

Because of the large number of available thermoplastics, characterized by numerous mechanical, thermal, electrical and other properties, the designer is confronted by a bewildering amount of data.

Data bases make it possible, with respect to known requirements, to find the "right" material in a short time. The best-known data base for thermoplastics is CAMPUS®2), a system permitting material selection based on physical property data determined by standardized methods.

Design

Regarding the design, the CAE development service includes

- designing of new plastic parts
- development of new design concepts (starting from a pre-determined available space and the conditions to be fullfilled; **Fig. 1**)

Because plastic parts often have very complicated geometry with free-formed surfaces, 3D-CAD (solid-modeling) systems are typically used. In contrast to two-dimensional drawings, they assure complete and unequivocal definition of the part geometry and facilitate the identification of problem areas (material accumulations, demolding problems, etc.).

Additionally, once generated, the CAD geometry can also be used for subsequent product development work (for example, finite element (FE) calculations, stereolithography, CAM, etc.).

Calculations with PC Software

For simple design elements, BASF offers within the framework of the WIS® Material Information System the following PC-based Windows programs:

- BEAMS
  for parts subjected to flexural stress
- SCREWS
  for screw connections by means of self-tapping metallic screws
- SNAPS
  for snap fit connections.

These programs are easy to use and are self explanatory. They allow quick calculations to be carried out and also give a lot of background knowledge.

The analysis and the optimization of plastic parts with complicated geometry normally requires the use of the finite element method (FEM).

Calculations by the FE Method

In the development of new plastic parts, the FE method makes it possible to answer many questions before prototype parts are made.

FE analysis can be used, for example, to estimate

- stresses and strains
- displacements
- reaction forces
- resonant frequencies and characteristic mode shapes
- accelerations
- deflection and buckling loads.

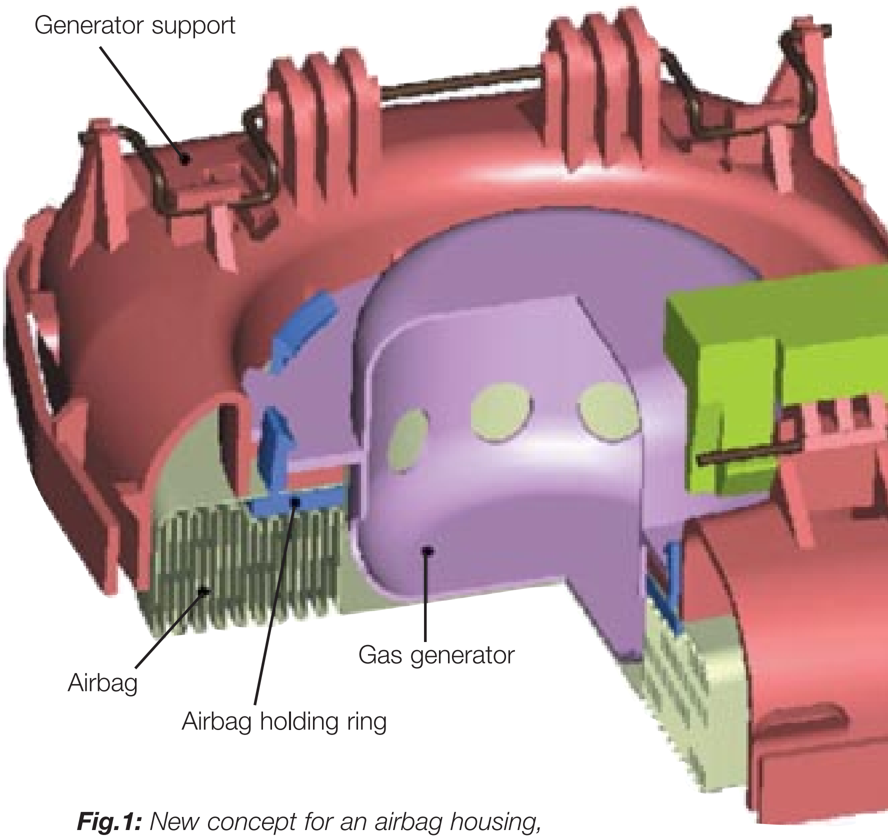


***Fig.1:** New concept for an airbag housing, integrated into the steering-wheel.*

In this manner, engineers can evaluate part performance and optimize design at an early stage. For example, it is possible to

- check the structural capability of a plastic part,
- detect the weak points of a design,
- optimize a preliminary design in terms of strength, rigidity and stability, and,
- investigate the dynamic and acoustical properties of a part.

Checking the Structural Capability

Plastic parts must sometimes meet stringent strength and rigidity requirements. Because of the potentially complicated geometry of plastic parts, it is not always possible to determine via known analytical methods whether such requirements can be met. In such cases, reliable information can be obtained by FE calculations **(Fig. 2)**.

Finding the Weak Points

The method for detecting the weak points of a design by testing prototypes has a substantial disadvantage in that, for most cases, it detects only the weakest area of a part. After the weak area is removed, further testing will show the next-weakest area. By contrast, FE analysis makes it possible to find several weak spots simultaneously and remove them by geometry changes **(Fig. 3)**.

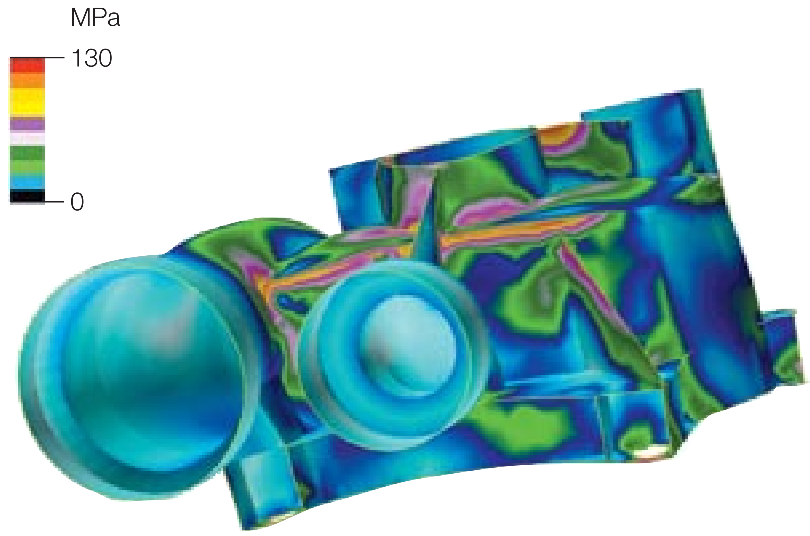


Fig. 2: *Deformation of an Ultramid® housing (automotive gear shift) under excessive load.*

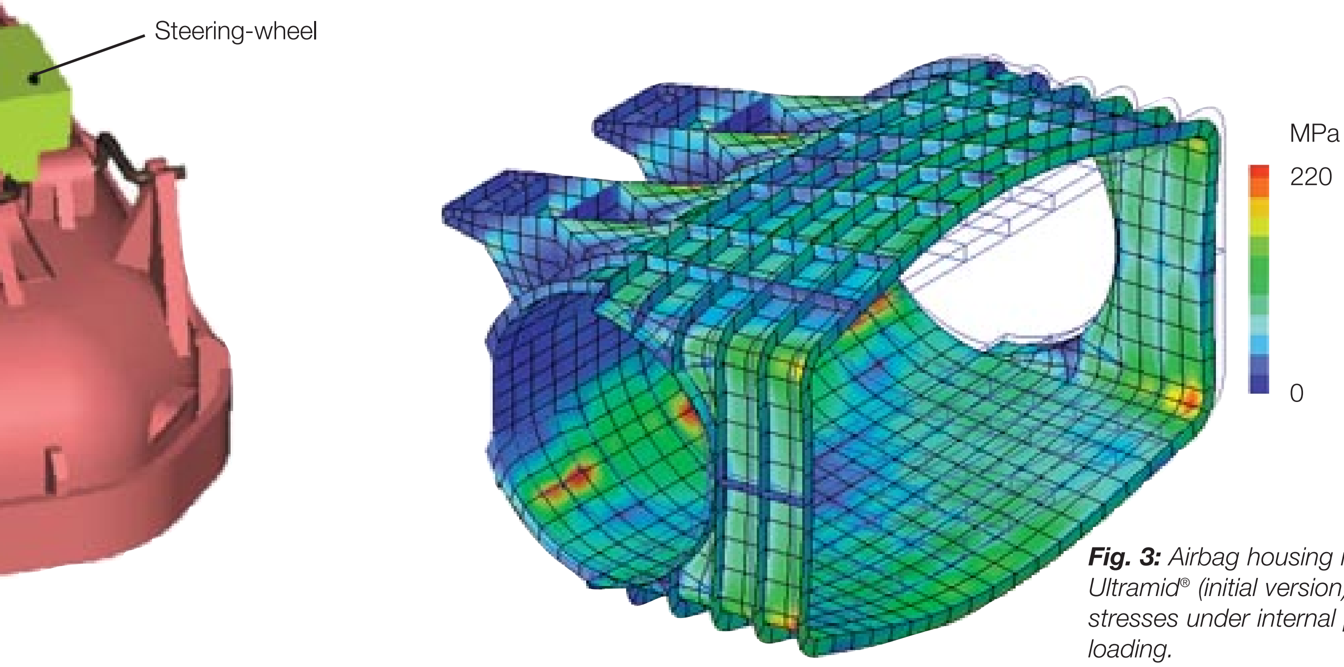


Fig. 3: *Airbag housing made of Ultramid® (initial version); effective stresses under internal pressure loading.*

Optimization in Terms of Strength, Rigidity and Stability

Because of the relatively low strength and stiffness of thermoplastics (as compared to metals), it is often necessary to use a complex geometry in order to meet requirements concerning loading, deformation characteristics, and/or stability (deflection or buckling) **(Figs. 4 and 5)**. This optimized geometry can be costly and time-consuming to obtain.

In parts made of fiber-reinforced thermoplastics, it is possible to optimize the geometry of the part and sprue system so that the fibers are preferentially oriented in order to maximize the performance of the part under load. In this manner, the fiber orientation-dependent anisotropic material properties are utilized to optimize performance for a specific purpose. This problem can also be solved using a structural analysis in combination with a mold filling simulation (both based on the FE method).

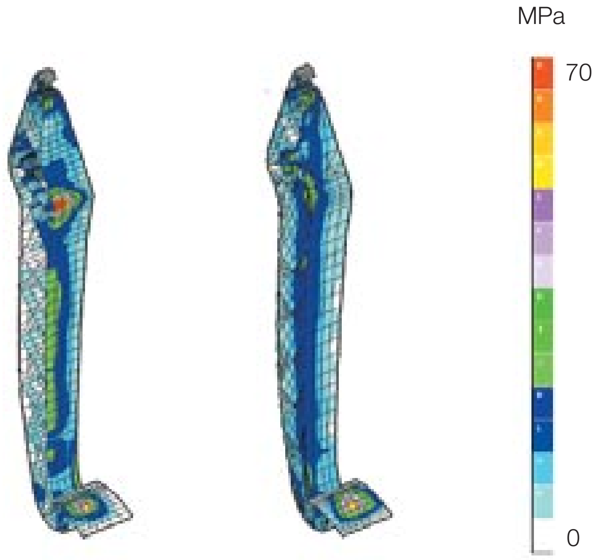


__Fig. 4:__ Ultramid® clutch pedal. Left: initial version; right: version optimized for rigidity and strength; effective stresses under test load.

__Fig. 5:__ Stabilizer link made of Ultramid®; deformation beyond buckling load; top: 1. eigenmode, bottom: 3. eigenmode.

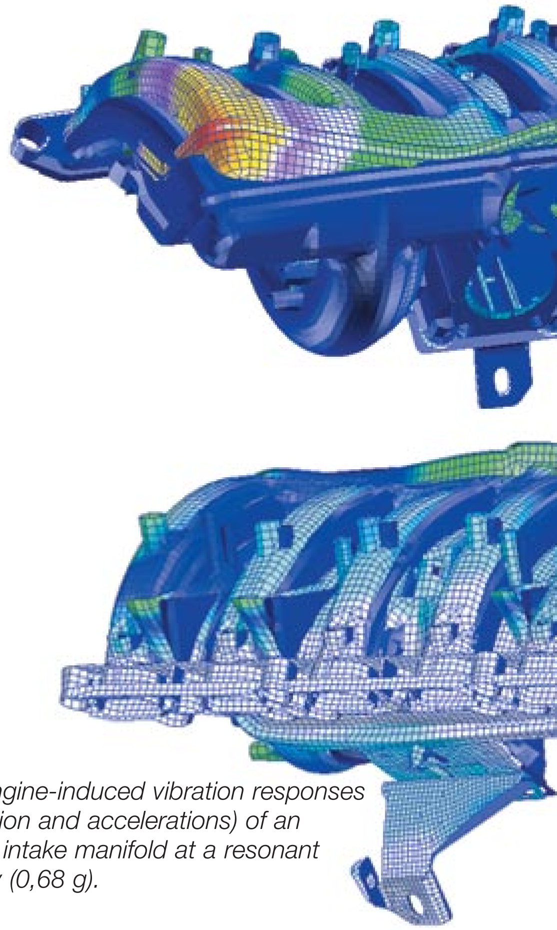


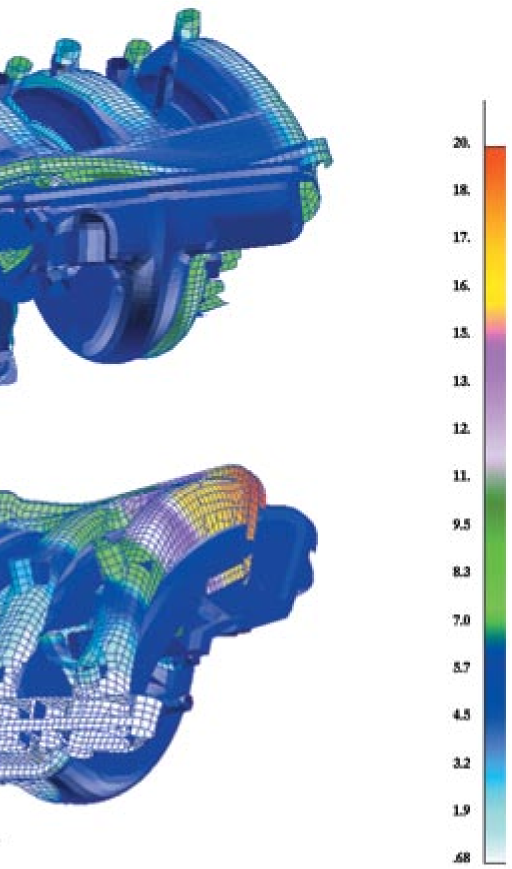
Fig. 6: *Engine-induced vibration responses (deformation and accelerations) of an Ultramid® intake manifold at a resonant frequency (0,68 g).*

Optimization of Dynamic Performance

In the case of plastic parts exposed to vibration during use, the dynamic behavior can be very important. A typical example is a plastic air intake manifold for automotive engines. Such systems must meet special requirements in terms of vibration characteristics (vibration amplitudes and accelerations for both the manifold and assembled parts).

In such problems, too, FE analysis gives reliable information about the performance of the part. Thus, it is possible to calculate the resonant frequencies, characteristic mode shapes and vibration responses of the system to a pre-determined forcing function. Design features such as ribbing can be used to alter the parts natural frequencies to values where less excitation is found **(Fig. 6)**.

Use of CAE in preventing process-dependent problems



The part development process requires early detection of potential processing problems so that they may be taken into consideration during the design stage. For mechanically stressed parts, it is also useful to understand the effects that the processing method has on material properties. For example, besides the fiber orientation, the strength reduction of knit lines in the part geometry should be taken into consideration. For such purposes, efficient numerical simulation tools are available whereby many processing problems can be identified and the processes optimized.

Simulation of Injection Molding Processes

The injection molding process presents a whole spectrum of individual problems ranging from filling difficulties and questions concerning mold cooling to part warpage. Simulation of the filling process **(Fig. 8)** gives information about knit lines, air inclusions, melt flow front hesitation and excessive pressure-to-fill situations.

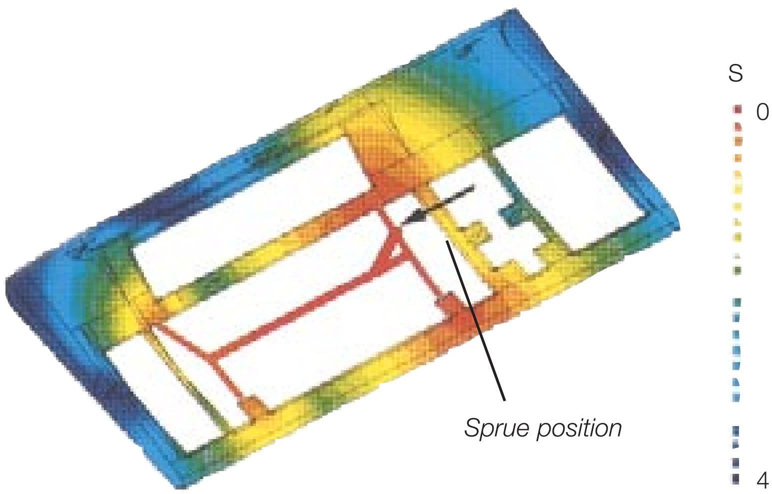


Fig. 8: *Melt flow pattern of the upper part of a keyboard.*

If the dynamic performance is known, a subsequent calculation step can yield information about sound emission. The propagation of sound waves in an air space is calculated by the boundary element method (BEM). It is possible to represent, for example, the frequency-dependent sound pressures and sound intensities at any point in the space and optimize them at an early stage of the development **(Figs. 7a and 7b)**.

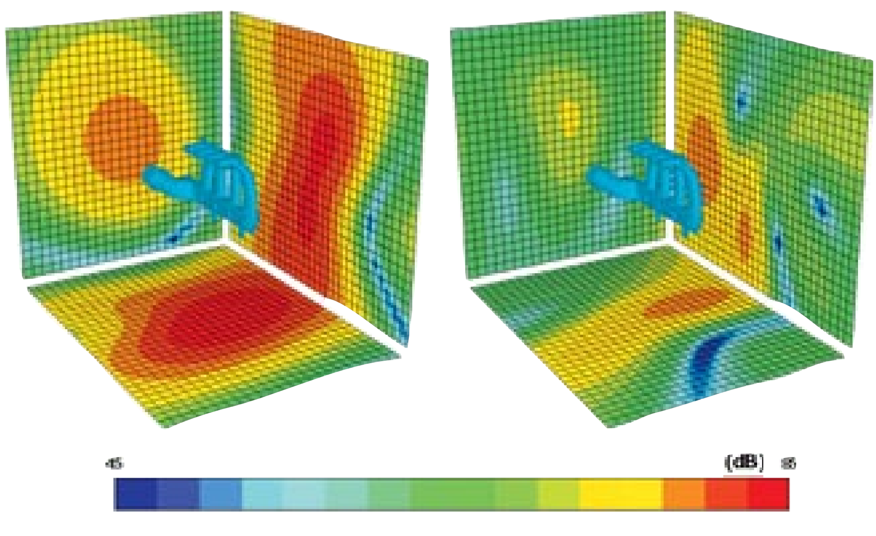


Fig. 7a: *Sound pressure distribution for an air intake manifold. This part was not optimized.*

Fig. 7b: *As in Fig. 7a, after part optimization.*

Measures for improving the filling process are either a change in part geometry (most often a modification of wall thickness) or the optimization of the runner. For rapid changes, direct feedback to the mold and part designers is needed.

A mold filling simulation allows the computation of fiber orientation at the same time. This information is needed to determine how the material mechanical properties are affected. Also, knowledge of this orientation is an prerequisite in the analysis of warpage, a significant problem of the injection molding process. The numerical calculation of warpage, based directly on the results of the mold filling simulation, makes it possible to evaluate different countermeasures for reducing undesirable part deformation **(Figs. 9a and 9b)**.

When temperature problems are expected, a mold cooling simulation can provide an insight into the temperature distribution expected in the mold. If necessary, it is also possible to determine the effect of cooling on warpage.

The gas-assisted injection molding process (GAIM process) extends the freedom of part geometry, but at the same time can bring up additional questions for the part designer. Besides the filling characteristics of the melt, a GAIM simulation also calculates the location and size of the gas bubble **(Fig. 10)**. In this manner, it is possible to study the effect of different gas introduction points and gas flow channel geometries to ensure the correct position of the air cavities in the finished part.

The fusible core process is sometimes used in the production of complicated, hollow injection-molded parts. This process involves the use of fusible cores of tin-bismuth alloy which melt at a relatively low temperature. Due to the low rigidity of these cores, the problem of core shifting assumes special importance. In non-uniform filling, core deflection, which can result in either contact of the core to the outer mold wall or core fracture, can occur relatively rapidly. Critical for such deflections are the pressures acting on the core during the filling and holding phase of the injection molding process. The analysis of these pressures makes it possible to determine core deflections and to evaluate various measures to reduce core shifting.

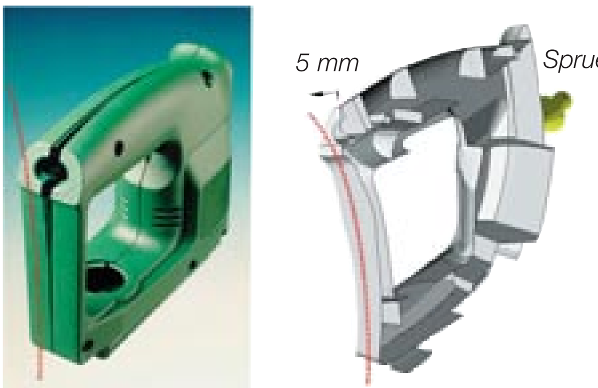


Fig. 9a: *Warpage of a housing of an electrical tool; left: plastic part; right: results of simulation.*

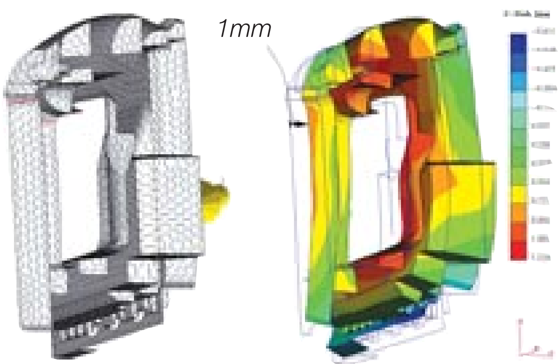


Fig. 9b: *Fibre orientation and warpage analysis for the part shown in fig. 9a with changed sprue position.*

Fig. 10: *Glove compartment door with gas channel.*

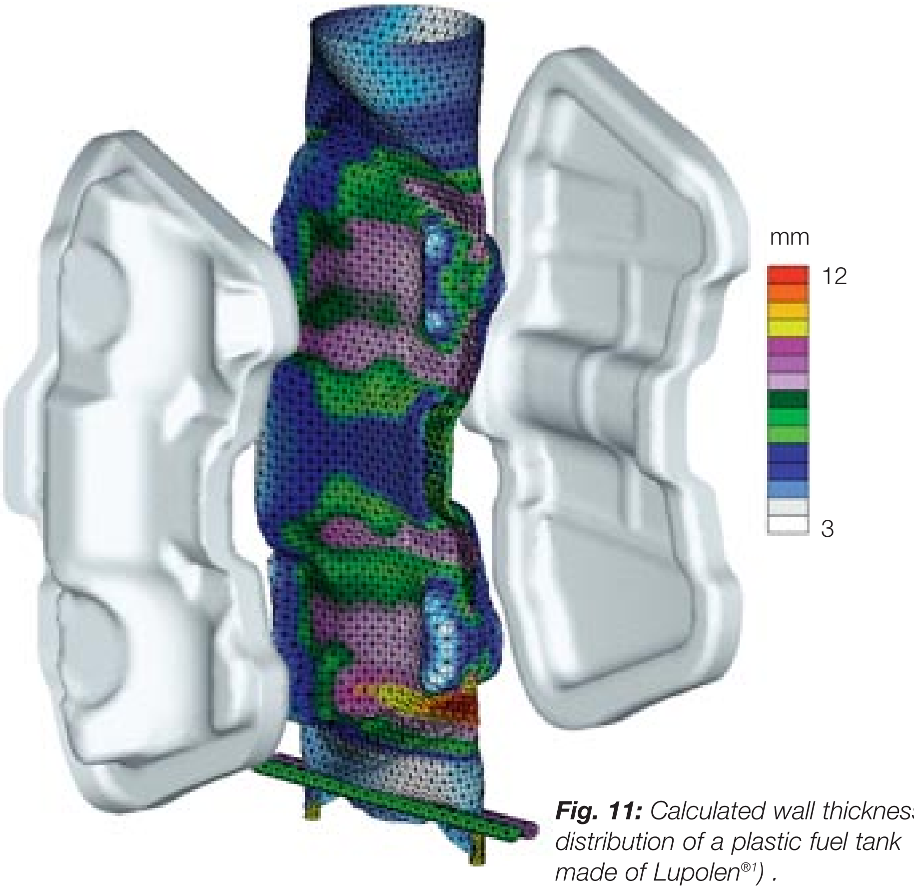
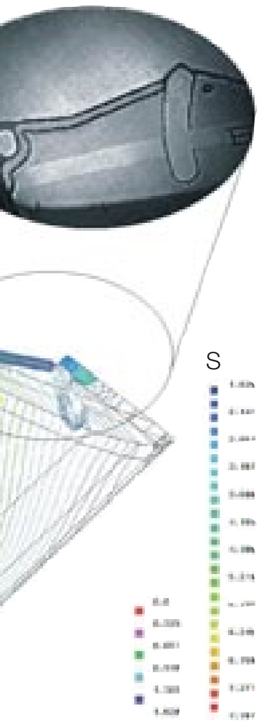


__Fig. 11:__ Calculated wall thickness distribution of a plastic fuel tank made of Lupolen®¹) .

Blow Molding Simulation

The blow molding process is often used to fabricate very complicated hollow parts which must meet stringent wall thickness distribution requirements. Due to the nature of the process, undesirable thin areas can occur, particularly in the corners. These thin areas can be avoided by an optimization of the pre-forms. Simulation of the inflation process provides accurate information about the wall thickness to be expected **(Fig. 11)**.

In addition, the simulation process also permits an optimization of the container shape if the available methods for pre-form optimization are not sufficient to prevent the identified weak areas. This option can be used particularly in the design of containers for which only the part space and the maximum volume are defined. Typical of this problem category are automobile fuel tanks.



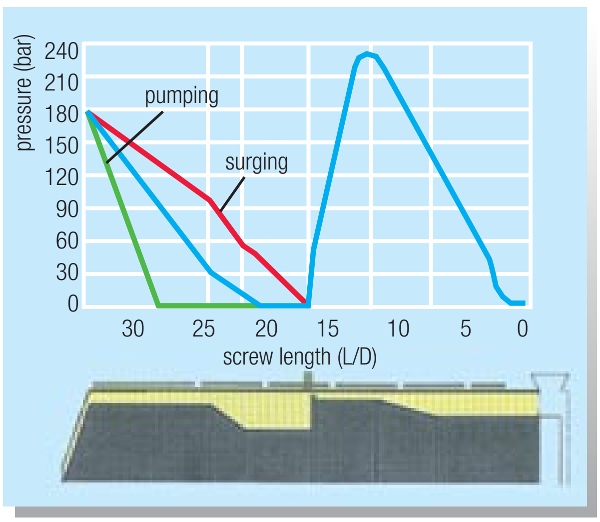


__Fig. 12:__ Pressure variation in a degassing screw.

Design of Extrusion Dies

Computational analysis of flow processes occurring in the screw has substantially improved extruder design. The calculations of material throughput, pressures and the melting process provide essential information for the optimization of screw geometry **(Fig. 12)**.

In the design of the dies that are connected to the extruder (parison heads, extrusion dies, etc.), questions can arise in regard to melt distribution, temperature variation and possible flow instability. Such questions can also be answered with the aid of appropriate computer programs.

Future developments

The market continuously demands a reduction in time and cost of development of new plastic parts. At the same time, calculations of part performance and simulation of the fabrication process are expected to become increasingly reliable. BASF's AWETA Thermoplastics is pursuing these goals by consistent utilization and further development of CAE techniques.

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