Borealis Polypropylene – helping to shape the future of the white goods industry

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ABSTRACT

*Corrosion resistant materials such as stainless steel, represent an important cost factor in dishwasher production.
Borealis developed together with one of the leading white goods manufacturer a polypropylene compound for a new dishwasher tub, which is suitable for the replacement of stainless steel in the interior of a dishwasher.*

Apart from the request of the stabilization systems against detergent contact, also the mechanical characteristics of the material, had to meet the requirements of our customer.

*A drop test is to be particularly emphasized:
The complete assembled dishwasher, has to withstand a half meter fall on a concrete ground, without any damages in the dishwasher tub.*

Since the development of this new dishwasher tub has to be done within shortest time, the drop tests were simulated by Borealis by means of dynamic computer simulation programs, such as used in the automobile industry for the simulation of crash tests.

INTRODUCTION

A moulded polypropylene tub offers significant cost advantages over a stainless steel tub. Other advantages include a reduction in finishing requirements (particularly tub welding and tub forming operations), a longer tub life due to corrosion resistance, and a decrease in thermal and acoustic transmission, which minimises the need for separate heat and sound insulation. Borealis developed and tested a new polypropylene compound capable of providing these advantages.

1. THE INCREASING USE OF PLASTICS IN WHITE GOODS

In white goods applications, plastics have grown from less than 1 percent of material content in the early 1960s, to almost 30 percent by weight today. Many different plastics are used; the commonest being ABS, polystyrene and polypropylene (Figure 1).

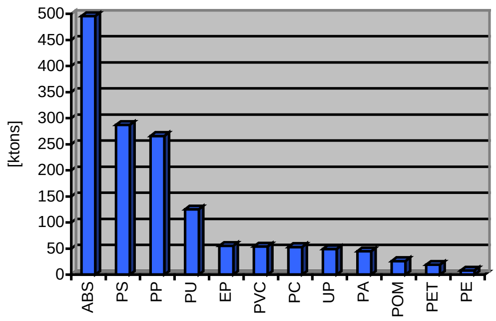

Figure 1. Plastic consumption in appliance industry; Western Europe 2000.

There are many reasons for this growth. The ease with which plastics can be fabricated into complex shapes by injection moulding, thermoforming, extrusion and blow moulding, and the thousands of possibilities for specific compounds, each with a tailored set of properties, has made possible:

- Many new product features
- Improved product performance
- Significantly reduced product costs.

The white goods industry is highly competitive and is continually striving to increase productivity and reduce costs. Modern plastics meet these requirements as they are lightweight, provide specific property profiles and are corrosion resistant.

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2. THE USE OF POLYPROPYLENE IN A DISHWASHER TUB

Stainless steel is traditionally used for dishwasher tubs. While providing excellent corrosion resistance, it does however represent an important cost factor in dishwasher production. To reduce this high cost of a stainless steel dishwasher tub, two possibilities are open:

- Combine normal steel with a plastic coating
- Make the tub from polypropylene.

The second solution was considered to be more advantageous than the first due to the significant cost advantages that a moulded polypropylene tub could offer over a stainless steel tub. Borealis therefore conducted research to develop a new polypropylene grade suitable for a dishwasher tub.

3. NEW BOREALIS GRADE

Working closely with a leading white goods manufacturer, Borealis developed a polypropylene compound suitable for the replacement of stainless steel in the interior of a dishwasher.

3.1 Mechanical properties

The material - grade MB350WG - is a talc-filled polypropylene with excellent impact/stiffness behaviour and an excellent stabilisation package against rinse aid, hot water and cleaner (Fig.2).

PROPERTY	UNIT	MB350WG
Tensile Modulus Yield stress Elongation at yield Break stress Elongation at break	[MPa] [MPa] [%] [Mpa [%]	2900 28 5,7 6,4 21,8
Flexural modulus	[MPa]	2890
ISO 179 / +23°C 1eU 1eA	 [kJ/m²] [kJ/m²]	 85 5,5
ISO 180 / +23°C 1eU 1eA	 [kJ/m²] [kJ/m²]	 60 7
ISO 75 A (1,8N/mm²) B (0,45N/mm²)	 [°C] [°C]	 64 117
VICAT A (10N)	 [°C]	 151
MFR 230°C / 2,16kg	 [g/10min]	 2,3
MVR 230°C / 2,16kg	 [cm³/10min]	 2,4
Shrinkage Tpl. 150x80x2mm Cross In flow direction Anisotropie	 [%] [%] [%]	 0,9 0,9 0,0

Figure 2. Mechanical properties of MB350WG.

4. THE DROP TEST

In addition to the need for a stabilisation system to resist detergent contact, the mechanical characteristics of the material also had to meet the requirements of the customer. A drop test is particularly important in this respect.

The completely assembled dishwasher had to withstand a half-meter drop at an angle of inclination of 10 degrees onto a concrete floor, without the dishwasher tub incurring any damage. Different impact situations were tested:

- Impact on the front side edge
- Impact on the back side edge
- Impact on the right side edge.

The impact velocity of the dishwasher is calculated by:

Impact velocity v (rate of fall):

$v = (2*a*s)^{0.5} = (2*9.81*0.5)^{0.5} =$ 3.13 m/s = 11.3 km/h

s= 0.5 m
a= 9.81 m/s²

s is the distance [m]
v is the velocity [m/s]
a is the acceleration [m/s²]

Since the dishwasher tub had to be developed in the shortest possible time, Borealis simulated the drop tests by means of dynamic computer simulation programs, similar to those used by the automotive industry to simulate crash tests.

MSC.Dytran was used for these calculations. This is a general purpose, explicit finite element analysis program for simulating the nonlinear dynamic response of structures and mechanical components.

Based on the results of these dynamic calculations, the final construction of the dishwasher tub was fixed, without practice attempts. This meant that development time and costs could be significantly reduced.

4.1 Required material data for the calculation

Engineering polymers are currently used in many structural applications for which a detailed knowledge of their strain rate and temperature dependent plastic deformation response is required.

The appliance industry is forced to shorten development time and save development costs. CAE methods such as crash simulations are therefore becoming increasingly important in the development process.

However, traditional CAE tools and methods are built around simulating the material characteristics of steel and other metals. Plastics have greater viscoelastic and viscoplastic behaviour than metals and this is not adequately reflected in the material models within common CAE solver codes.

Currently, due to the absence of material data at high strain rates, most crash simulations use material data based on quasi-static testing. The results of these simulations are in general not optimal as the behaviour of polymers at high stressed, the strain rate or loading rate, greatly affects the mechanical behaviour of plastics. Parts are exposed to a variety of loading rates throughout their life cycle, from very low, static loading to high-speed impact loading.

In general, thermoplastics become stiffer and fail at smaller strain levels as the strain rate increases (Figure 3).

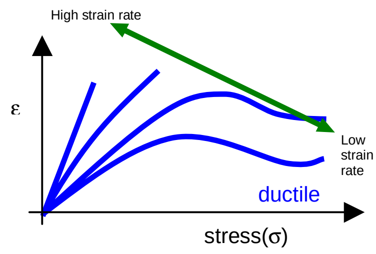

Figure 3. Effects on strain rate of material behaviour

Therefore it was necessary to provide material data at varying strain rates and temperatures for the material. This became possible by a cooperation between Borealis and the University of Leoben. The University developed a method for Borealis to determine material data at high strain rates. This data formed the basis for the successful calculations (Figure 4).

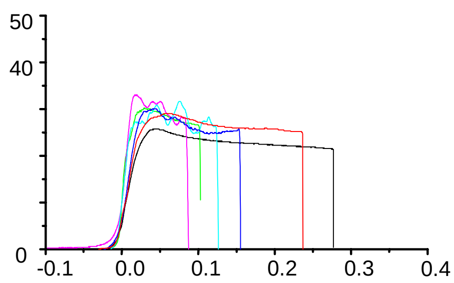

Figure 4. Engineering stress-strain diagram of MB350WG.

4.2 Examination of the reliability of the materials data

The accuracy of the materials data mentioned above was checked on a simple injection moulded part with the following dimensions:

- Length: 230 mm
- Width: 115 mm
- Height: 75 mm
- Wall thickness: 2 mm.

This box was loaded dynamically and force-time diagrams were recorded.

These real deformations were then compared with the result of the simulation of the dynamic loading of this part (Figure 5).

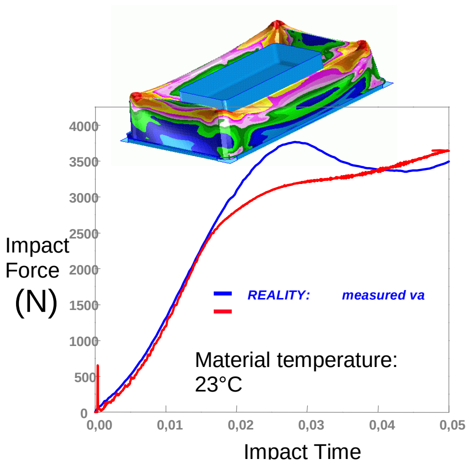

Figure 5. Measured and simulated values.

As shown in Figure 14, an outstanding correlation between the simulation and the real deformation was obtained. After this successful test the material models were used for the calculation, whereby a very reliable calculation was ensured.

4.3 Results of the dynamic calculation

The computer model for the calculations was combined with those from the 29 most important parts that constitute the dishwasher. The CAD data of the individual parts was sent to Borealis by the customer. The individual parts were designed in CADDS 5.

The communication of data between customer and Borealis took place by means of Odette data transfer. Subsequently, all parts were transferred into Patran 9.0 and meshed.

The entire model consists of approximately 26,000 elements and 28,000 nodes.
Dytran 4.7 was used as solver; this is a crash solver from MSC.

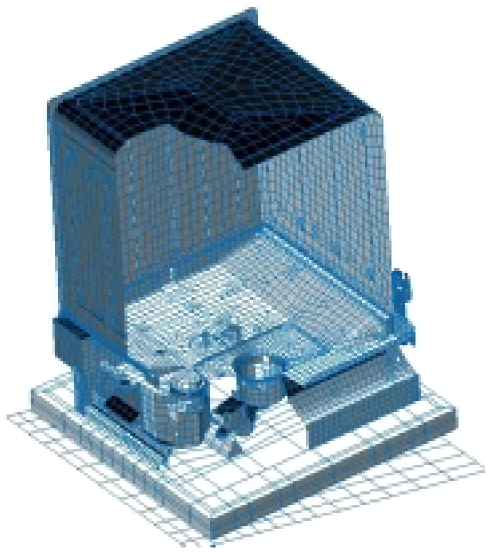

Figure 6. CAD model of the dishwasher (cross section).

By means of this calculation the loads on the individual components could be determined accurately. In addition, areas with too high deformation were also localised and improved by suitable constructional methods.

The sequence in the following illustrations represents the stress distribution during the impact of the dishwasher. With the calculation it was possible to check the stress for each part used inside the dishwasher. The calculated impact time was 0.0285 sec.

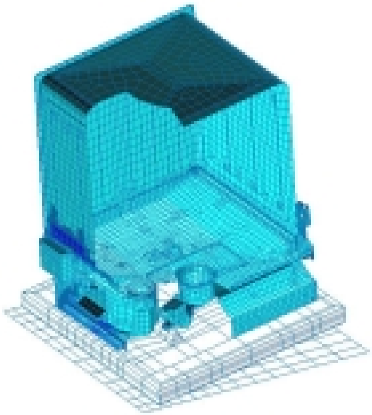

Figure 7. Stress distribution after 0.0015 sec.

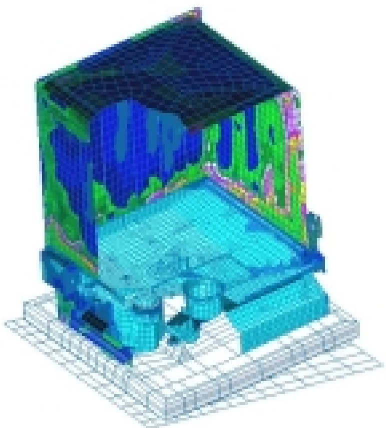

Figure 8. Stress distribution after 0.0045 sec.

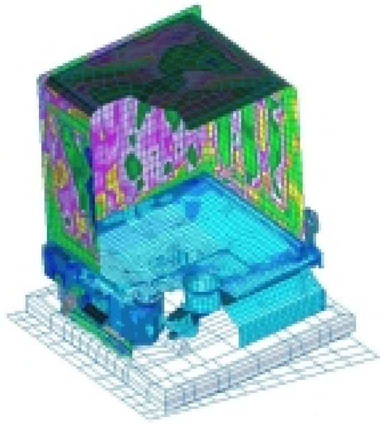

Figure 9. Stress distribution after 0.0075 sec.

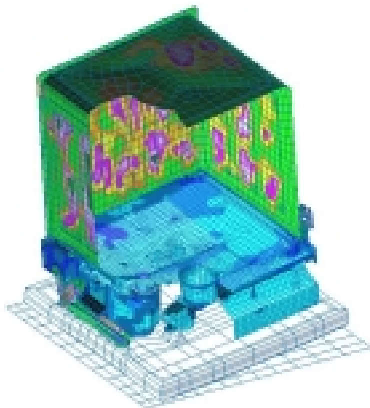

Figure 10. Stress distribution after 0.0105 sec.

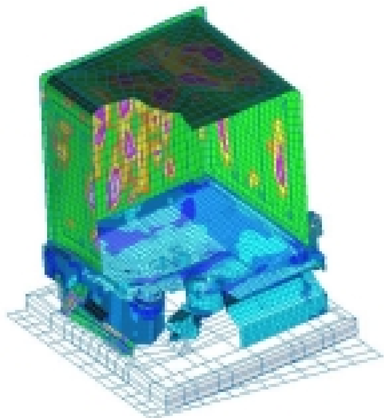

Figure 11. Stress distribution after 0.0135 sec.

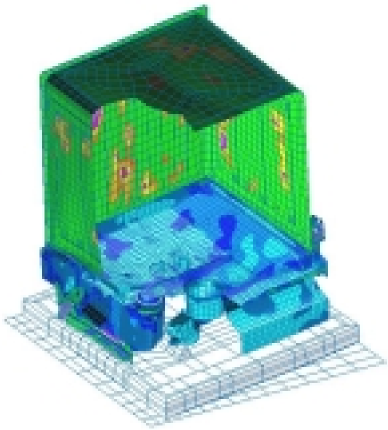

Figure 12. Stress distribution after 0.0165 sec.

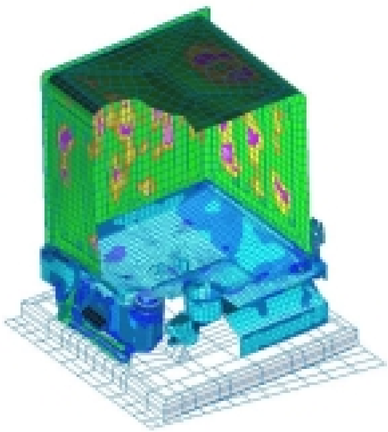

Figure 13. Stress distribution after 0.0195 sec

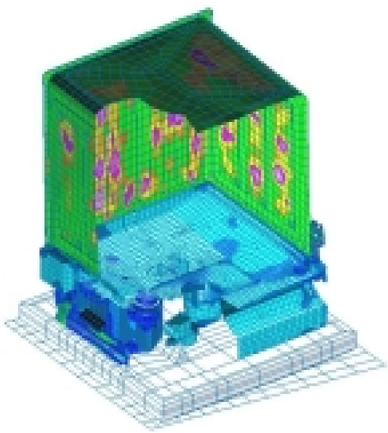

Figure 14. Stress distribution after 0.0225 sec.

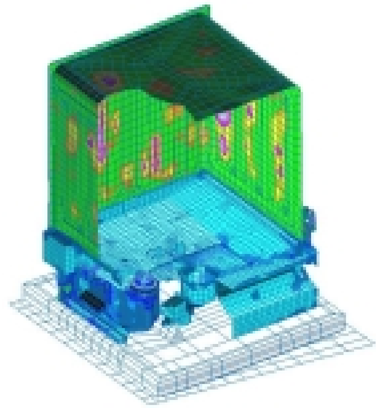

Figure 15. Stress distribution after 0.0255 sec.

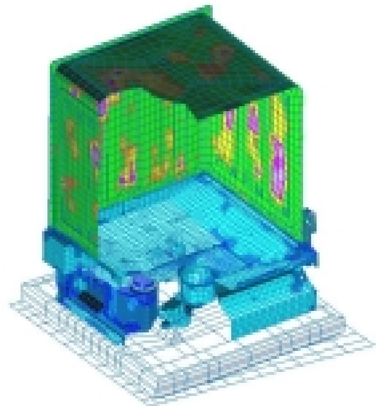

Figure 16. Stress distribution after 0.0285 sec.

5. CONCLUSION

With this project, a strongly stressed part of a dishwasher - the tub – was designed in polypropylene thanks to dynamic calculations. The part was then tested without the necessity for practical trials - and all the tests were completed successfully. The determination of the necessary material parameters was also completed successfully and these are now able to be used, without significant financial expenditure, in future projects.

8. ABOUT THE AUTHORS

Werner Posch studied plastics engineering at the University of Leoben, Austria. Since completing his education in 1994, he worked in the product development of the PCD Polymere. Since the merger between PCD Polymere and Borealis in the year 1998 he has been working in the market development for the white goods sector of Borealis.

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Anton Sageder has been working in the CAED department of the Borealis since 1988. Since this time he built up his experience in the calculation of plastics parts for engineering applications. During this time he has been completed a lot of project for the automotive and the electro industry.

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