

Automotive Exterior Solutions

Optimised performance and surface
aesthetics

 BOREALIS

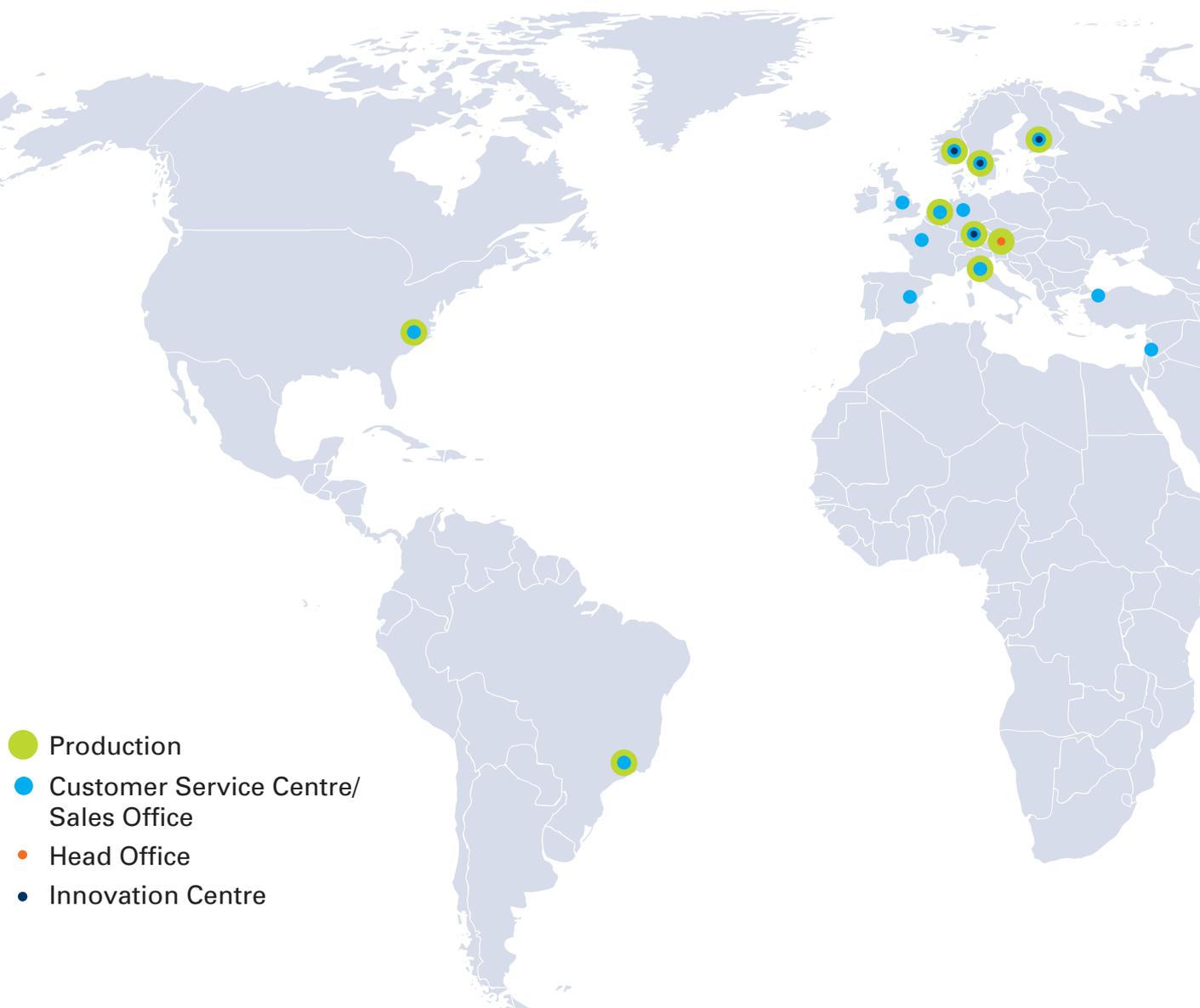
بروج
Borouge



Borealis and Borouge – partners for long-term success

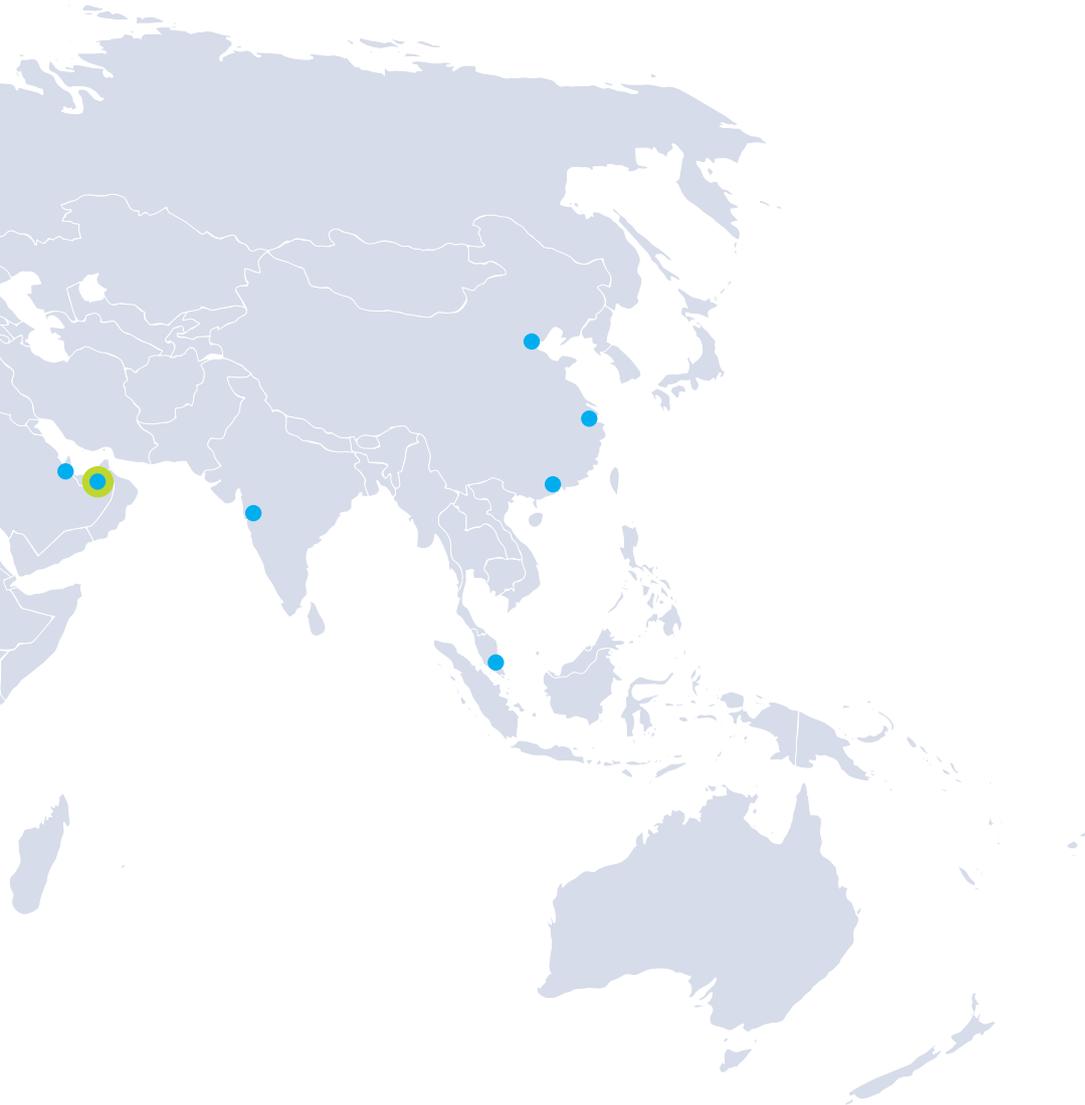
Building on Borealis' unique Borstar® technology and their experience in polyolefins of more than 50 years, Borealis and Borouge provide innovative, value creating plastics solutions for the infrastructure - pipe systems and power and communication cables - automotive and advanced packaging industries. In addition, Borealis offers a wide range of base chemicals from melamine and plant nutrients to phenol and acetone.

Borealis and Borouge are leading providers of chemical and innovative plastics solutions that create value for society. With sales of EUR 7.5 billion in 2012, customers in over 120 countries, and 5,300 employees worldwide, Borealis is owned 64% by the International Investment Company (IPIC) of Abu Dhabi and 36% by OMV, the leading energy group in the European growth belt. Borealis is headquartered in Vienna, Austria, and has production locations, innovation centres and customer service centres across Europe and



the Americas. Through Borouge, a joint venture between Borealis and the Abu Dhabi National Oil Company (ADNOC), one of the world's major oil and gas companies, the company's footprint reaches out of the Middle East to Asia Pacific, the Indian sub-continent and Africa, where it is also Borealis' exclusive distributor. Established in 1998, Borouge employs approximately 1,600 people, has customers in more than 50 countries and headquarters in Abu Dhabi, UAE and Singapore.

Currently Borealis and Borouge have a manufacturing capacity of more than 5.4 million tonnes of polyolefins (polyethylene and polypropylene) per year. An additional 2.5 million tonnes is scheduled to come on-stream by the end of 2013, creating the world's largest integrated polyolefins plant. Both companies continue to invest to ensure that their customers throughout the value chain, around the world, can always rely on superior products and security of supply.



Contents

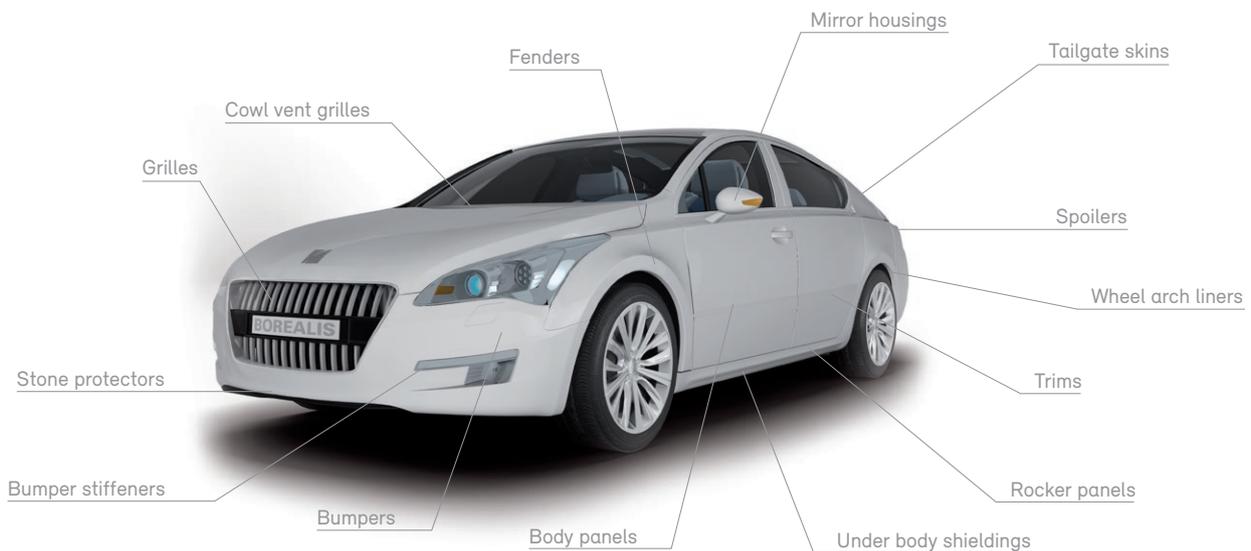
- 5 Dedicated to automotive solutions
- 7 Optimally balanced mechanical properties
- 8 Lowering the weight and costs of exterior applications
- 9 Committed to advancing performance
- 10 Ready-to-use versus open compound
- 11 Essential surface aesthetics
- 12 Continuing to build on success
- 13 Materials portfolio for exterior applications
- 14 Creative innovation
- 15 Contact



Dedicated to automotive solutions

Engineering Applications is our business segment particularly focused on the development of 'creative innovation' polypropylene (PP) and thermoplastic polyolefin (TPO) solutions for automotive applications. Whether you are producing bumpers, body panels, front grilles, rocker panels or exterior trims, Borealis is the right partner for you. Our comprehensive ranges of PP and TPO polymers and compounds have properties that are balanced and tailored to precisely match your application needs.

As such they add value through driving reductions in system costs, while providing excellent aesthetics and reliable performance to the highest global industry standards, as well as enabling faster production cycles. And, no less importantly, they reduce both material and energy inputs for enhanced sustainability.



Our close working partnerships with OEMs and Tier 1 suppliers over many years have given us a unique understanding of automotive value chain needs. Of special importance is that our ongoing dialogue with partners helps in the early identification of evolving market trends.

This allows us to focus the resources and scientific skill-sets of our Innovation Centres on ensuring you have the optimal, differentiated and integrated solutions that meet tomorrow's needs, before they become tomorrow's challenges.

Engineered to be more than the sum of its parts

Appearance, performance, integration and sustainability combine to make tomorrow's cars more than just the sum of their parts. From first sight a vehicle must have presence, its colour must be consistent and unblemished,

its lines fluid and seamless, and its surfaces smooth and dynamic. Achieving this requires a unique set of material properties balanced for peak performance in meeting the needs of each specific application.



Ultimately, reliability in each particular respect is confirmed by the reality of day-to-day and long-term performance. For tough, practical and aesthetically important exterior applications our PP and TPO compounds provide the strength and surface characteristics to replace metals and

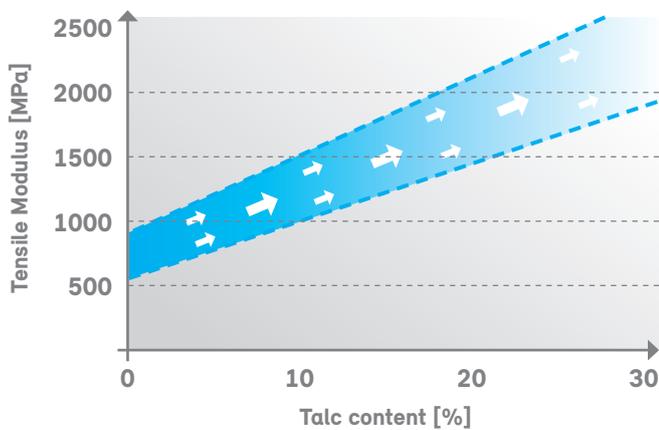
expensive plastic materials. Our materials do so without any compromises in mechanical performance to give corrosion-free reliability throughout a vehicle's lifespan. Moreover, they enable significant weight savings and greater vehicle fuel economy.

Optimally balanced mechanical properties

Exterior applications require good balance between stiffness and impact behaviour. These two main mechanical properties need to be in line with part functionality and are influenced by the polymer design, as well as elastomer and reinforcing filler content of the material. However, these two properties tend to show opposing effects.

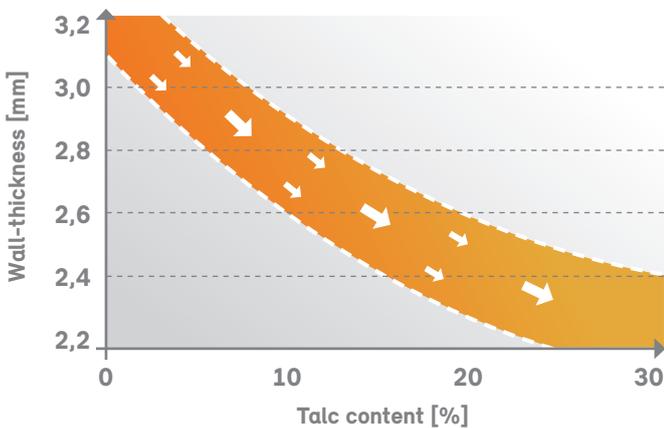
The material contribution to part stiffness is important for dimensional stability and to keep the part as-moulded shape. This property also allows reduction in wall thickness which is one of the key contributors to part lightweighting. However, for a number of exterior applications good impact resistance is an important requirement as well, allowing a part to absorb energy in the event of a collision.

While not mutually exclusive these two properties work partially against each other, meaning the higher the part stiffness the lower its impact value and vice versa. Nevertheless our in-depth understanding of these requirements means we are able to address them in such a way that product formulations are balanced to give the best possible performance levels for each specific application.



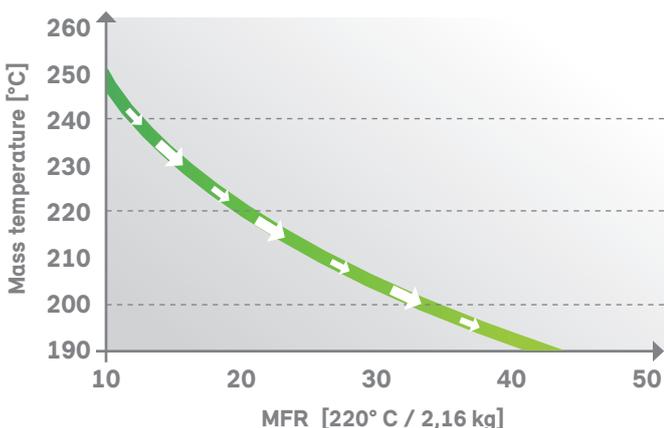
Stiffness vs. filler content

On the one hand, filler content increases material density and therefore weight. On the other hand, however, it improves stiffness, which may translate into lower part wall-thickness and thus lighter part weight.



Bumper wall-thickness vs. filler content

The optimum solution is to combine high stiffness with low density, combining a part's lowest possible wall-thickness with of low filler content material.



High flowability enables lower part temperature

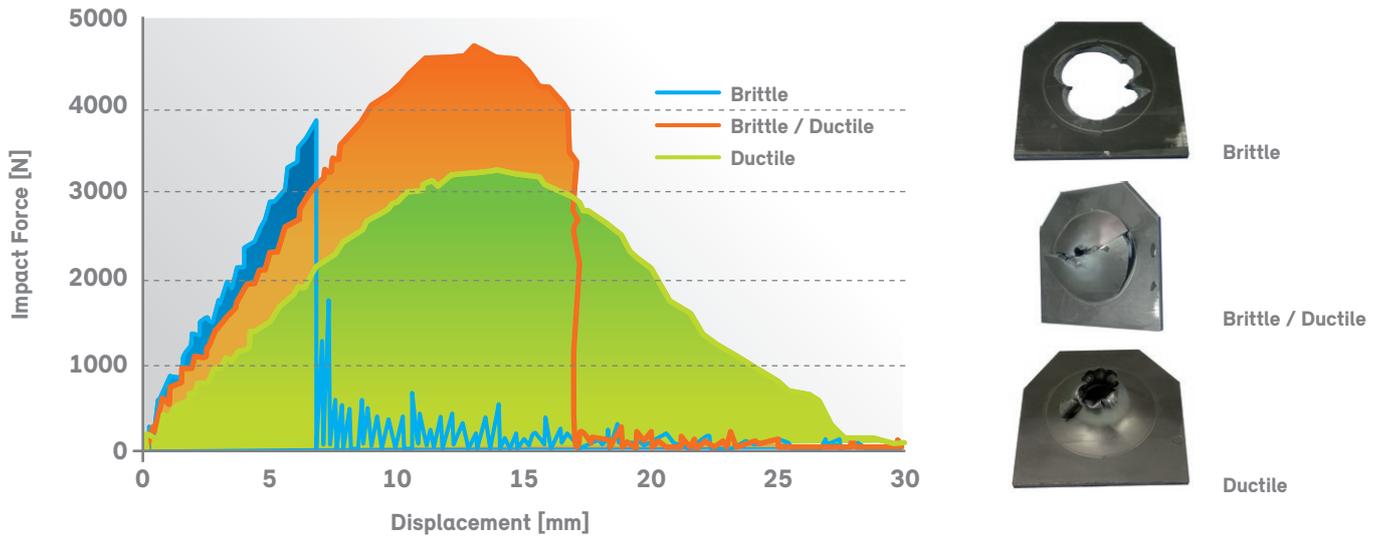
Improved flowability enables fast filling, reduced cycle time and lowers mass temperature, resulting in faster cooling time, thereby increasing productivity.

An increase in flow from MFR 10 to MFR 30 can enable a reduction of mass temperature by up to 50°C at the same viscosity.

Measuring impact performance

Impact resistance can be a significant safety factor in exterior parts. Because of this Borealis Engineering Applications has built up substantial expertise in developing compounds that answer the varying needs of OEMs and Tiers 1 and 2 suppliers in fulfilling application performance.

In addition to using standard Charpy and Izod test methods, we have also significantly invested in our dynamic testing capabilities in the field of biaxial and multiaxial impact tests. These better simulate actual part behaviour and provide useful insights into material brittleness and ductility.



Ductile brittle transition depends on a range of applied testing conditions. The illustrations above show material samples exhibiting different ductility performance at the same temperature.

Lowering the weight and costs of exterior applications

Today, vehicle weight reduction is central to automotive design. Overall, lighter weight translates into lower fuel consumption and CO₂ emissions, reduced running costs for the car owner and the lower, slower use of finite resources for the benefit of global society, as well as the improved sustainability of the auto industry itself.

Weight and cost reduction require a collaborative effort within the value chain. Material, design, tooling and processing each play a decisive role in achieving a positive outcome. And, while no one element of the mix is more important than the others, material composition is the enabler.

Material contribution to weight loss

- Decreasing filler content lowers material density
- Increasing stiffness of material and therefore the part allows for reduction of wall-thickness, using less material and lowering weight
- Improving flowability allows easy and fast filling of low wall-thickness moulds
- Integrated part design optimises space and lowers the number of additional joining elements and fittings
- Good processability minimises production scrap and brings cost savings

Committed to advancing performance

Daimler's Smart provides one example of weight and cost saving through collaborative effort. For the Smart, Borealis developed Daplen™ ED230HP, a 20% mineral filled TPO compound able to successfully replace the original PC/PBT material in the bumper, side panels, tailgate and bonnet, to achieve a 15% weight saving for the second generation Smart now in production.



Other benefits include:

- Moulded-in-colour – only a post-assembly painted top coat
- Very good scratch resistance
- High dimensional stability
- Excellent impact/stiffness balance
- Zero gap tolerance

Current Smart body panels made in Daplen™ ED230HP moulded in cherry red colour.

Since then we have been partnering with Daimler for the next generation of Smart cars due to come on-stream in 2014. This has led to the development of Daplen™ EF150HP, a successor material to ED230HP. Daplen™ EF150HP brings a number of significant advances for body panel applications, including:

- More than doubled flowability (MFR 10 to MFR 22) for improved processing
- Significant density reduction (talcum filler content lowered from 20 to 15%), while at the same time increasing stiffness
- Reduction in wall thickness resulting in approximately 18–25% weight savings on the average part
- Stable shrinkage and CLTE, supporting narrow gap demands
- Excellent dimensional stability allowing wide freedom of design
- Support of Borealis CAED in film gate design to enable even distribution of material and shear forces, and faster filling
- Moulded-in colour solutions, supporting electrostatic painting processes

Wide possibilities

Our materials can also provide advantages in, amongst others, the replacement of ASA in external components. Examples include the VW Transporter lower grille or the Daimler AMG and C-Class front grilles. In addition to meeting challenging OEM specifications, our PP delivers:

- A cost competitive solution compared with ASA
- Improved surface aesthetics and very low CLTE
- Very low density resulting in lower weight
- Easy processing
- High impact/stiffness balance

Ready-to-use versus open compound

The primary focus of Borealis' product development has been on ready-to-use compound solutions, matching OEM/Tier 1 and 2 specifications and supplied conversion-ready. However, there has been an interest among some converters in 'open compound' (OC) solutions; the purchase of base resin and performance masterbatch from the polymer and compound producers and for them to undertake the final material blending themselves, during the injection moulding process.

Because choice has an important influence on final outcomes it is worth considering the pros and cons of the alternative material compounding solution.

Is open compound the right solution?

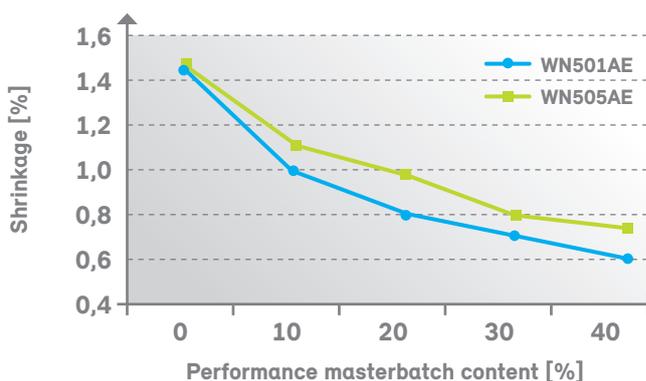
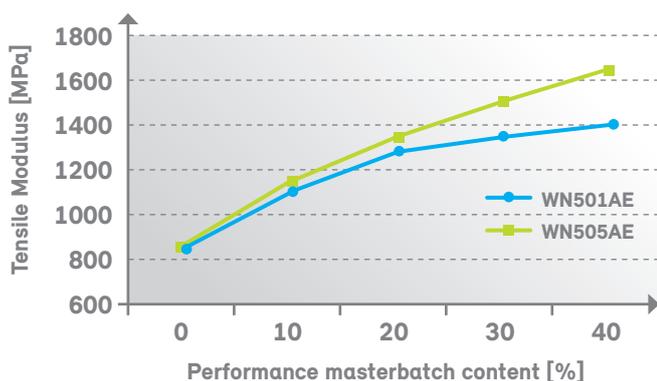
Advantages	Disadvantages
<ul style="list-style-type: none"> - Sourcing flexibility - Material cost reduction potential - Moulding process 	<ul style="list-style-type: none"> - Additional sourcing/logistics demands on customer side - Global availability possibly becoming a concern for the Tier/OEM - Commoditisation of products resulting in reduced R&D and availability of technical support - Solution available only in black colour for painted applications - Transferred responsibility for the final material solution (from supplier to converter) - Approval procedure changes - Mixing know-how (e.g. dispersion) and performance deviation risks - Claims complexity - Not every specification can be matched with the open compound option

On balance, we believe that the ready-to-use solution supported by advanced compounding technology and know-how remains the secure option for efficient and economic application specified performance. However, we also recognise and accept the converters' right to choose a solution based on their own criteria. Therefore, should you opt for the open compound concept, we have developed performance masterbatch solutions which we supply

together with selected base resins.

As the following graphs show, if properly blended, the two masterbatches in conjunction with the dilution polymer EF015AE deliver key performance strength in line with principal exterior application demands: WN505AE for required higher stiffness and WN501AE, providing low shrinkage and very good impact resistance.

Base resin EF015AE + Performance masterbatch



Essential surface aesthetics

Exterior appearance provides consumers with vehicle first-contact and the impression that will inform and condition their judgements and purchasing decisions. Without the initial positive influence of design and outstanding surface aesthetics, secondary and tertiary features such as interior comfort, light weight and fuel economy, durability and performance longevity, are undermined. Therefore, the presentation of a Class-A surface finish is essential for all exterior applications whether unpainted, painted or moulded-in colour.

Unpainted solutions

Flow marks, often referred to as tiger stripes, are frequently occurring surface defects in injection moulded thermoplastic materials. They result in defective surfaces that have a negative effect on the visual quality of unpainted parts and represent a production and cost challenge for Tiers and OEMs.

To address this problem Borealis has introduced a next-generation of PP compounds based on the latest Borstar technology polymers which prevent the appearance of tiger stripes across a very broad processing window, saving costs and delivering a premium surface appearance.

Primerless painted solutions

Borealis is also supporting a growing industry trend towards primerless paint systems for exterior plastic applications. Primerless painting addresses the need to reduce cycle time and system costs by moving from a 3-step process to a 2-step process in painting. In the past, plastic parts were mainly painted in 3 steps, i.e. application of a primer layer, a coloured base and a protective clear coat.

Recently, 2-step paint processes, i.e. without the use of primer have become more and more popular. These systems are economically attractive, however, less forgiving in terms process fluctuations. A feature of this trend has been increasingly stringent criteria in respect of paint adhesion performance. Hence, the polymer and paint system have to be well-tailored and adjusted to each other and production processes need to be reliable and robust. To help OEMs overcome this challenge and achieve greater economy, Borealis has undertaken a major R&D initiative to develop primerless two-layer paintable compounds for bumpers and body panels.

Moulded-in colour solutions

Moulded-in colour solutions enable cost reduction through elimination of painting cycles. To assist OEMs realise their vehicle aesthetics goals, we have the expertise and a dedicated colour department that works with pigment suppliers to develop narrow colour specifications for our PP compounds. These include the simulation of the quality special effects of other more expensive materials without having to use them.

The Daimler Smart car, mentioned previously, is an example of one of the first breakthrough moulded-in colour solutions for body panels, using colours ranging from blue, red and yellow to orange and white, as well as special solutions such as Smart City Flame. This is a limited edition colour for the current generation model, in which a unique effect is achieved by aligning colouration between substrate and semi-transparent clear top coat through the use of colour particles in both.



Newly installed flow mark testing equipment at Innovation Headquarters, Linz, Austria.



Newly installed fully automated paint robot at Innovation Headquarters, Linz, Austria.



Special solutions also include, for example, the moulded-in aluminium metallic effect used for the VW Tiguan stone protector and the Peugeot 206+ front grille (pictured).

Continuing to build on success

Borealis and Borouge, working in close co-operation with Tier 1 and 2 suppliers, are continuously engaged in extending the possibilities of PP and TPO compounds for automotive exterior applications that meet OEMs' global specifications. These developments focus on lower density and lighter weight materials which are uncompromising in their balanced stiffness and impact performance, and provide for easier and lower cost manufacturing.

Borcom™ WH107AE

Renault-Nissan

Global bumper solution for a broad range of models including for instance the Renault Clio, Renault Captur (pictured), Dacia Logan for Europe, and the Renault Sandero and Renault Duster for South American markets.

Customer added value:

- Very good processing at low injection pressure and with fewer injection points
- Weight reduction potential through thinner wall designs
- Low shrinkage and low CLTE
- Good surface aesthetics for both painted and unpainted parts
- System cost optimisation



© Renault Marketing 3D-Commerce: Renault Captur

Daplen™ EF155AE also available as open compound EF015AE + WN505AE

VW Group

Lightweight bumper solution for, among others, VW Golf (pictured) and SEAT Ibiza models.

Customer added value:

- Material combination allows both ready-to-use and open compound concept
- Reduced filler content provides for a lighter weight solution
- Good flowability requiring lower injection pressure, less energy input and reduced tool wear
- Low CLTE for zero-gap assembly



© VW Group: VW Golf

Daplen™ EF209AE/EF210AE

General Motors

Global bumper solution including, for example, the Opel Insignia and Zafira in Europe, the Chevrolet Onix (pictured) and Celta in South America and Buick Lacrosse and Cadillac CTS in Asia.

Customer added value:

- Very good processability and dimensional stability
- Excellent behaviour at multiaxial impact
- Low cycle time, low scrap rates and low system costs
- High level of surface aesthetics



© General Motors: Chevrolet Onix

Open compound EF015AE + WN501AE

Volvo Car Group

Volvo Y55x open compound painted bumpers for V40, XC40, XC60 and S60, among others.

Customer added value:

- Close co-operation with the Tier 1 in formulation fine-tuning
- Low scrap rate
- High quality perception
- Very good paintability
- Shrinkage adaption possible during injection moulding



© Volvo Car-Group: Volvo V40 CC

Materials portfolio for exterior applications

Borealis' and Borouge's comprehensive range of PP and TPO polymers and compounds for automotive applications offer lightweight material alternatives to steel/aluminium, PC/PBT, ASA, ABS, PA/PPE and SMC, with commensurate or higher mechanical properties.

Grade	Filler content [wt%]	Density [kg/m ³]	MFR 30°C/2.16kg [g/10 ¹]	Tensile modulus [MPa]	Tensile stress at yield [MPa]	Impact, Charpy notched 23°C [kJ/m ²]	Impact, Charpy notched -20°C [kJ/m ²]	HDT B (0.45Mpa) [°C]	CLTE (-30/+80°C) [µm/mK]	Shrinkage indication [%]	Typical applications
Copolymers											
EE002AE	-	905	11	950	19	65	9	76	100	1.45	Bumpers, exterior trims
EF015AE	-	905	18	870	19	35	7	68	86	1.5	For open compound solution
WE007AE	-	925	12	1,200	20	35	5.5	89	65	0.8	Bumpers, rocker panels, exterior trims
TPO Compounds											
EF005AE	10	950	25	1,060	16	52	6	85	65	0.8	Bumpers, exterior trims
EE103AE	10	950	12	1,400	19	50	7	92	72	1.15	Bumpers, exterior trims
EF155AE	10	950	16	1,400	20	35	5	90	74	1.05	Bumpers, exterior trims
EH104AE	10	970	40	1,150	16	31	5.5	80	68	0.8	Bumpers, exterior trims, stone protectors
WH107AE	13	980	40	1,600	19	47	6	98	70	0.8	Bumpers, rocker and body panels, trims
EF119AE	15	990	23	1,650	19	55	7	101	50	0.72	Bumpers, exterior trims
EG134AE	15	1,005	30	1,700	20	45	7	100	56	0.85	Bumpers, rocker panels, trims
EF150HP	15	1,005	22	2,000	23	23	5	110	54	0.7	Body and rocker panels, bumpers, trims
ED230HP	20	1,050	10	1,800	19	30	4	105	52	0.8	Body and rocker panels, tailgates, bumpers, trims
EE209AE	20	1,040	13	1,400	16	65	20	93	43	0.5	Bumpers, exterior trims
EF209AE	20	1,040	22	1,600	17	60	6.5	90	45	0.65	Bumpers, exterior trims
EH227AE	20	1,040	40	1,450	16	42	6	86	49	0.55	Rocker panels, exterior trims
EF109AE	20	1,040	20	1,400	16	38	5	90	47	0.7	Bumpers, spoilers, exterior trims
EH221AE	20	1,060	30	2,100	21	30	5	98	55	0.68	Bumpers, exterior trims
EE340AE	30	1,140	12	1,500	16	49	4.6	101	30	0.5	Rocker panels, grilles
EF341AE	30	1,140	15	3,100	25	7.5	2.5	123	54	0.75	Body panels, fenders, tailgates
EE342AE	30	1,140	15	2,200	19	29	3.5	100	50	0.6	Grilles, spoilers, tailgates, other exterior
Performance masterbatches											
WN501AE	50	1,350	-	-	-	-	-	-	-	-	For open compound solution
WN505AE	50	1,350	-	-	-	-	-	-	-	-	For open compound solution



Creative innovation

At Borealis and Borouge we are dedicated to developing materials' solutions which meet both existing and projected needs of the industries we serve.

This process is guided by creative innovation:

- Working with partners to identify needs before they become challenges and developing solutions that add value along the supply and production chain through to and including the end user
- Reducing the use of non-renewable resources through creative design and where possible their replacement with renewable raw materials
- Lowering energy consumption in both production and end-use, as well as the emissions of damaging by-products such as CO₂

- Minimising process dependence on fresh water reserves
- Limiting and eliminating waste through continuous efficiency improvements

To support these goals Borealis operates three world class Innovation Centres. These are engaged in the development of new materials and material improvements, as well as customer technical services ranging from part design and prototype simulation to the production and testing of batch samples and assistance with the initiation of series production. They are also tasked with the ongoing improvement of Borealis' own methodologies and processes.



Contact

www.borealisgroup.com

www.borouge.com

engineering.applications@borealisgroup.com

