# Impact modifiers: how to make your compound tougher

**Improving the impact strength of compounds is the role of an important group of additives. Impact modifiers compensate for inherent brittleness, or embrittlement occurring at sub-zero temperatures, notch-sensitivity and crack propagation. The mechanism normally involves introducing a component that is elastomeric or rubbery in nature, which can absorb the energy of an impact or dissipate it. Jennifer Markarian looks at some of the options for the compounder wanting to improve toughness.**

Impact modifiers are key additives for increasing flexibility and impact strength to meet physical property requirements of rigid parts. Some unmodified polymers such as rigid polyvinyl chloride (PVC), polystyrene (PS) or styrene acrylonitrile (SAN) are brittle at ambient temperatures. Others such as polyamides or polyolefins are ductile at ambient temperature but become brittle at low temperatures. Some, such as polycarbonate (PC), may have good dart impact but poor notch impact resistance. An impact modifier is needed whenever the polymer system does not meet the impact requirements for a particular application. A variety of impact modifiers are available depending on the host polymer and the required properties. Table 1 lists some of the common impact modifiers.

All impact modifiers are elastomeric or rubbery in nature, with a lower modulus than the host polymer. The dispersed rubber phase acts to absorb or dissipate the energy of impact in order to stop craze or crack propagation. In order to stop craze propagation and achieve good impact modification, the rubbery phase must be very well dispersed and the impact modifier must be compatible with the host polymer. Good adhesion is necessary to prevent the cracks from propagating around the elastomeric particle. The rubber particle should also have enough cohesive strength to prevent the crack from propagating easily through the rubber particle. To maintain impact at low temperatures, the glass transition temperature ($T_g$) of the impact modifier should be very low.

Impact modifiers are sometimes incorporated through polymerization in the reactor, such as grafting of styrene and acrylonitrile on polybutadiene rubber in the bulk ABS process. Impact modifiers may also be incorporated as additives in the compounding step. In some cases, the impact modifier and host polymer are naturally compatible, as are ethylene-propylene-diene terpolymer (EPDM) impact modifiers in polypropylene (PP). Often, chemical modification is required to compatibilize the two polymers and allow good dispersion and cohesion with the continuous phase. For example, SAN grafted to EPDM will make EPDM compatible with SAN and other polar polymers such as PC. In systems based on reactive engineering polymers such as polyamide and polyester, compatibility can be achieved with a reactive group, such as maleic anhydride (MA), grafted to the impact modifier. MA-modified EPDM, polyolefins, and styrene block copolymers (SBCs) are available for impact modification of polyamides and polyesters. While non-reactive impact modifiers can provide general purpose toughening, 'super-toughness' and low temperature toughness typically require a reactive impact modifier, says Karlheinz Hausmann, senior research associate at DuPont Packaging and Industrial Polymers.

Globally, the impact modifier market had a volume of 540 million kg (1.2 billion pounds) and a value of $1.25 billion in 2001, estimates Fred Gastrock, product manager for additives at BRG Townsend, a plastics industry consultancy. Styrenic copolymers such as ABS and methyl methacrylate-butadiene-styrene (MBS) make up the largest category of impact modifiers, with about 45% of the market, notes Mr. Gastrock. Acrylics have about 30% of the market. Elastomers, including EPDM and thermoplastic elastomers, make up about 10% of the market. Chlorinated polyethylenes (CPE) have another 10% share, and other types make up the remainder, says Mr. Gastrock. Styrenic



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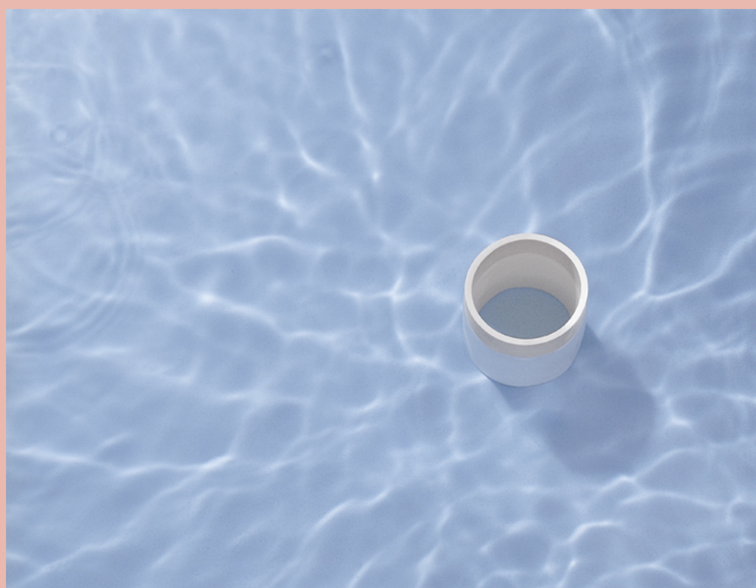
impact modifiers are growing at an AAGR of less than 3%, while other types are growing at rates of 5-6%, he estimates for 2001 to 2006. Since PVC is the largest user of impact modifiers, consuming about 80% of the volume, growth of impact modifiers is tied to PVC use. Engineering resins such as PC, polyamides, and polyesters, which consume about 10% of impact modifier volume, are growing strongly, boosting impact modifier use. Polyolefins consume the remaining 10% of impact modifier volume, concludes Mr. Gastrock. The continuing trend towards 'better, cheaper, faster' is helping drive use of impact modifiers, which can be used to either improve properties or maintain properties of thinner parts, comment industry experts.

## *New elastomeric impact modifiers for polyolefins*

Use of thermoplastic elastomer (TPE) impact modifiers is increasing,

**Table 1: Some common impact modifiers**

| Impact modifier | Host polymer types | Producers (trade names) |
|---|---|---|
| ABS | PVC | Crompton (Blendex) |
| ASA | PVC | Crompton (Blendex) |
| MBS | PVC | Atofina (Clearstrength), Kaneka (Kane Ace) |
| SBS | PS, HIPS, PPE, SMMA | Atofina (FinaClear), KRATON Polymers (Kraton D) |
| SEBS | Polyolefins, PS, PC | KRATON Polymers (Kraton G) |
| MA-modified SEBS | Polyamides, polyesters | KRATON Polymers (Kraton FG) |
| Acrylic | PVC, engineering polymers | Atofina (Durastrength), DuPont (Elvaloy and Elvaloy HP) Rohm and Haas (Paraloid, Advastab, Advalube), Kaneka, |
| Crosslinked polyacrylate in a continuous phase | Polyolefins, polyamides, polyesters (depending on continuous phase) | Optatech (PACREL) |
| CPE | PVC | DuPont-Dow (Tyrin) |
| EPDM | Polyolefins | Crompton (Royalene), DuPont-Dow (Nordel) ExxonMobil (Vistalon) |
| MA-modified EPDM | Polyamides | Crompton (Royaltuf), DuPont (Fusabond) |
| SAN-modified EPDM | Engineering resins | Crompton (Royaltuf) |
| GMA modified ethylene-acrylate copolymers | Polyesters | DuPont (Elvaloy PTW) |
| Ionomers | Polyamides | DuPont (Surlyn) |
| Thermoplastic elastomers and plastomers | Polyolefins | Dow (AFFINITY Polyolefin Plastomers, VERSIFY), DuPont-Dow Elastomers (Engage), ExxonMobil (Vistamaxx) |
| Non-reactive, modified polyolefins | Polyolefins | Atofina (Lotryl), DuPont (Elvaloy AC) Crompton (Interloy) |
| Reactive, modified polyolefins | Polyamides, polyesters | Atofina (Lotader), DuPont (Fusabond, Elvaloy PTW) |



*Crompton Corporation is a major supplier of impact modifiers to the PVC industry.*

particularly in PP but also in other polyolefins and in polyamides, says Mr. Eller. Within the past eight years, polyolefin elastomers and plastomers have been replacing EPDM as impact modifiers in TPOs for automotive exterior and interior applications, industrial injection moulded goods, and other applications where very low temperature toughness performance is needed. The polyolefin-based impact modifiers have superior performance in heat and UV aging, cold temperature impact and flow properties. TPE pellets are also easier to handle and disperse than EPDM bales or crumbs.

Dow Chemical's VERSIFY® propylene-ethylene elastomers and plastomers, introduced in 2004, are made with Dow's INSITE® technology and solution process. "The propylene and ethylene content can be tailored to give the desired balance of impact, stiffness, clarity and processability," explains Mark Murphy, senior technical leader at Dow Chemical. Products with increased ethylene content and lower crystallinity can accept higher loadings of flame retardants or mineral modifiers such as talc.

ExxonMobil Chemical introduced Vistamaxx propylene-ethylene elastomers in August 2003. Vistamaxx elastomers are produced with Exxpol® metallocene catalyst technology in a new solution polymerization plant in Baton Rouge, Louisiana that started up in early 2004. While conventional plastomers have a high ethylene content, Vistamaxx is primarily propylene with a low amount of ethylene comonomer. The high propylene crystallinity results in a high degree of elasticity and higher temperature resistance.

## Obtaining a balance of impact resistance and other properties

When choosing impact modifiers, formulators must consider the balance of impact resistance, flow, stiffness, weatherability, low-temperature toughness, thermal stability and, of course, cost. Suppliers offer varying levels of impact modification so formulators can control costs by choosing the required level. For example, new SBCs, such Finaclear 540 from Atofina or KRATON 1403 from KRATON Polymers, are designed to provide impact resistance with clarity in lower-end crystal-PS food packaging at a relatively low cost. Costs can be reduced by looking for synergies in the whole formulation and finding the optimal balance of impact modifier, lubricant, processing aid and stabilizers, notes John Buckley, general manager for plastics additives in North America at Rohm and Haas. Processors are also finding cost-savings by using higher-efficiency impact modifiers, such as Paraloid 352 from Rohm and Haas, introduced in April 2004 for PVC building and construction applications. DuPont Dow has developed lower density CPE impact modifiers, such as Tyrin® 2500P, and lower density Enlite™ developmental products, which are inherently more efficient impact modifiers for rigid PVC in building and construction applications.

## Flow

While impact modifiers typically reduce processability through the extruder for engineering polymers, demand is increasing for higher flow properties, particularly for injection moulding applications. DuPont recently introduced Fusabond AEB560, a MA-modified polyolefin impact modifier that gives good low temperature toughness without adversely affecting flow properties of engineering polymers such as polyamides and polyesters, says Dr. Hausmann. Reactivity in impact modifiers tends to reduce flow. Using a combination of reactive and non-reactive impact modifiers can improve the impact-flow balance while also reducing cost, notes Richard Perrinaud, commercial development manager for functionalized polyolefins at Atofina. Atofina introduced a non-reactive modified polyolefin impact modifier, Lotader XX1336, for use in combination with reactive modified polyolefin impact modifiers to improve the impact-flow balance in nylon-6. "The non-reactive modifier works at the interface of the reactive modifier and nylon, going deep into both phases and changing the crystallization at the interface of the phases," explains Mr. Perrinaud. In other systems, non-reactive Lotryl acrylate-ethylene copolymers can be used in combination with reactive Lotader modifiers, he adds. Likewise, combinations of maleated KRATON FG1901 and KRATON G 1657, a non-functionalized styrene-ethylene/butylene-styrene (SEBS), give improved impact performance in nylon 6 or nylon 6,6, says KRATON Polymers. Formulators can also choose among reactive modifiers of varying maleic anhydride (MA) content to obtain the desired impact-flow balance. Higher levels of MA improve dispersion and impact but have a negative effect on flow.

Ease of impact modifier dispersion is a concern for compounders. While twin-screw extruders are the preferred equipment for good dispersion, some compounders want to be able to use single-screw extruders. A wide temperature range of processability is also desirable. Lotader MAH modifiers have been designed to be processed on both single and twin screw extruders, says Mr. Perrinaud. Surlyn ethylene methacrylic acid ionomer resins are characterized by good dispersability in a single screw extruder process, comments Dr. Hausmann.

## Stiffness

While impact modifiers by nature reduce the modulus or stiffness of the polymer, various technologies can improve the balance. Mineral fillers are used to increase stiffness, but have traditionally degraded impact resistance. Improved mineral modifiers have less of a negative effect, or in some cases actually work with impact modifiers to improve impact resistance. Coupling agents can also be used to improve impact resistance in the presence of fillers. "In addition, new SEBS and metallocene-catalyzed polyolefins have the capability of greatly extending the stiffness-impact balance without a significant processing penalty," comments Bob Eller, president of Robert Eller Associates, Inc., a plastics consultancy firm.

## Weatherability and low-temperature impact

For some applications, weatherability, which is the ability to retain impact and colour when exposed to ultraviolet light, is also important. Of the major impact modifiers for PVC, EPDM and acrylic modifiers are weatherable, while MBS and ABS are not. Use of weatherable impact modifiers for PVC is growing significantly, driven by use in the construction market in applications such as siding and door and window profiles, notes George McCarty, market manager of polymer modifiers at Crompton Corporation. One problem with acrylic modifiers is that although they are weatherable, they have poor low temperature impact resistance. A solution is to use coextrusion with either an all-acrylic or acrylic-modified cap layer over a core layer containing an impact modifier with good low temperature performance. As use of vinyl fencing grows in more critical applications, such as balcony railings, standards for low temperature impact strength are being tightened, adds Mr. McCarty.

## Thermal properties

Thermal stability for maintaining end-use properties is an increasing concern for areas such as automotive applications. While EPDM is known to degrade thermal stability, other modifiers have less of a detrimental effect. Processors are also working with stabilizer producers in developing better stabilizer packages to meet heat aging requirements, notes Mr. Perrinaud.

Resistance to sagging and warping at high temperatures is also important. In building and construction applications, increased heat resistance is needed with the trend towards darker colours that absorb more heat. Impact modifiers typically reduce heat resistance. Heat modifiers can be added to increase service temperature, but these typically reduce impact resistance, explains Mr. McCarty. Crompton offers a balanced heat and impact modifier, Blendex 703, an alpha methyl styrene-acrylonitrile-butadiene styrene (AMSABS).

PACREL crosslinked polyacrylates from technology developer Optatech are relatively new impact modifiers with good thermal properties. PACREL grades consist of crosslinked polyacrylate dispersed in a continuous phase of PP, EBA, polyester, polyurethane or polyamide, depending on the desired host resin. Because the polyacrylate phase is crosslinked, it will not deform at high temperature and is inherently resistant to heat and UV-degradation, explains Christer Bergstrom, vice president of technology and business development at Optatech.

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