Customized manufacturing of expandable polystyrene

Flexible foam production

The properties of expandable polystyrene (EPS), one of the most important foamed plastics in the world, can be significantly influenced by additives. Such additives can repel insects, make the material flame resistant, or improve thermal insulation. Sulzer Chemtech has developed a flexible process particularly suited for the economical production of customized, special-grade EPS.

The industrial polymerization of styrene to polystyrene (PS) started in the early 20th century and was followed by the development of expandable PS beads around 60 years ago. EPS is a particle foam made by expanding PS beads that contain a blowing agent—usually pentane. Steam heating causes the beads to expand, and the final shape is achieved by molding the pre-expanded beads with steam and pressure. There are numerous applications for EPS on the market, and block and shape molding are the most important conversion processes currently employed to fabricate foam products from EPS. In particular, by using shape molding, various products can be obtained—for example, packaging solutions, plaster, or sports equipment—many of which profit from customized EPS formulations that add color or mechanical properties.

Melt impregnation allows customized production

In the common process chain, EPS resin suppliers produce impregnated polystyrene resin granulates with the blowing agent in large-scale industrial facilities. The EPS is then sold to EPS molders. They manufacture end products—such as packaging, construction material, or drinking cups—according to customer specifications.

Sulzer's EPS pilot plant allows process optimization, sample production, and feasibility testing for customers.

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Sulzer Chemtech offers a continuous process for producing EPS granulates from PS on an industrial scale of up to 100 000 t per year (see *STR 1/2009*, p. 6). In this process, the melt is directly impregnated with the blowing agent and the required additives, and it is then sent to an underwater pelletization process. The melt impregnation has several advantages over the conventional suspension process. The product quality is consistent and can be easily controlled, as the additives and the blowing agent are directly injected into the melt.

Environmental benefits and energy savings

The environmental benefits include:

- Lower water consumption
- Straightforward recycling of excess material

On an industrial scale, the hardware for this process includes Sulzer Chemtech static mixers and heat exchangers. In particular, when connecting the Sulzer EPS process directly to a polystyrene melt plant, the static mixing approach results in significant energy savings, as the resin does not need to be melted again. This offers the possibility of operating competitive styrene-to-EPS plants for global-scale production of EPS commodities, for example, for innovative insulation solutions. In fact, with the introduction of a melt-based EPS process in the late 1990s by Sulzer, the technological basis for the production of pigmented, flame-resistant EPS for housing insulation was established, and this gave rise to the development of a number of innovative materials using different additives.

Sulzer's melt impregnation process is the basis for the production of pigmented EPS.

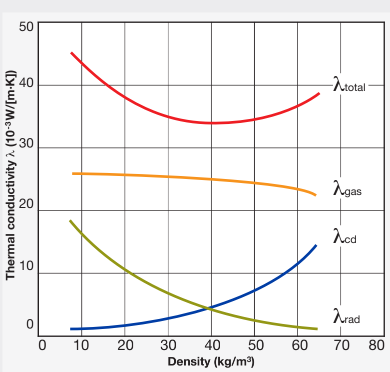
Improving thermal insulation with pigments

Several parameters, such as foam density, choice of blowing agent, and cell size distribution, can influence the thermal-insulation properties of EPS foam. The genuine advantage of EPS foam as insulation material over competing insulation solutions like polyurethane, mineral wool, or extruded polystyrene foam (XPS) is its low density and, hence, its relatively low price. However, the insulative properties significantly deteriorate with decreasing density. Three mechanisms contribute to the thermal conductivity of EPS (see info box):

- Conduction
- Convection
- Radiation (mainly infrared).

With decreasing EPS density, the share of infrared radiation strongly increases. This effect can be avoided through pigmentation. Pigments, e.g., graphite, carbon, or aluminum particles, added to

Low-lambda development



The thermal conductivity κ or λ (measured in watts per meter kelvin W/[m·K]) describes the ability of materials to conduct heat.
Materials of high thermal conductivity transmit heat at a higher rate than materials of low thermal conductivity. Therefore, materials of low thermal conductivity are used as thermal insulation.

The thermal conductivity of EPS comprises:

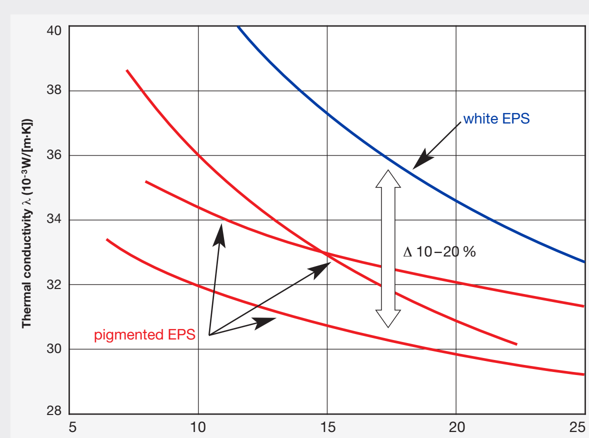
- Conduction in polystyrene cell walls and struts (λ_{cd})
- Convection by gas contained in cells (λ_{gas})
- Radiation, mainly infrared (λ_{rad})

Pigmentation

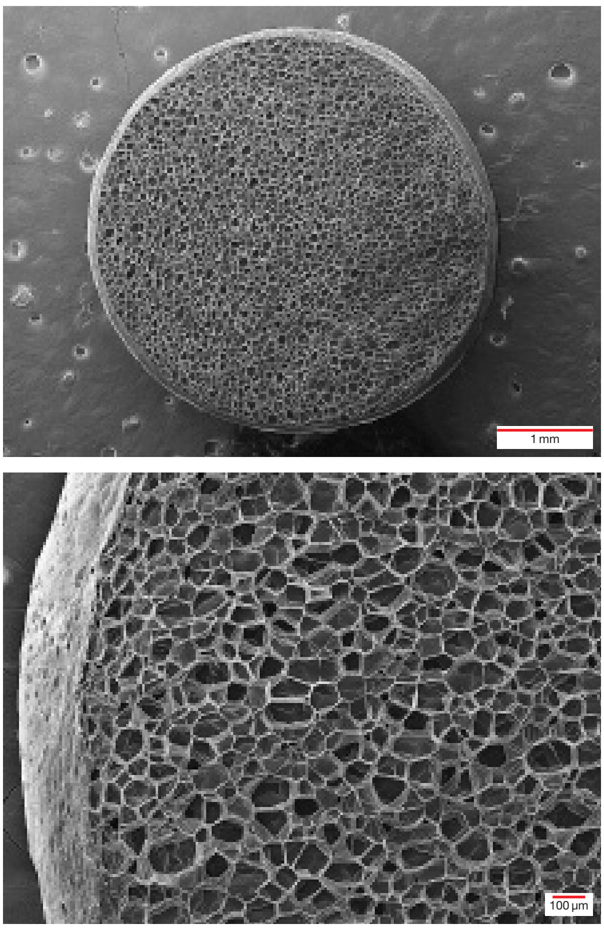
Added pigments in EPS material absorb and/or reflect heat radiation, so that λ_{rad} is reduced and thermal insulation is improved.

Comparison of insulating materials (thermal conductivity in W/[m·K]):

Concrete	White EPS	Pigmented EPS
0.8–1.28	0.032–0.044	0.029–0.033
	(depending on density)	(depending on density)



1 Adding pigments decreases the heat conductivity λ and improves the insulative properties of the EPS. This kind of "low-lambda" development allows access to markets for high-performance insulation materials.



[2] Prefoamed EPS beads from Sulzer's EPS process show excellent sphericity and cell size distribution.

the EPS can absorb and/or reflect infrared radiation and thus improve thermal insulation [1]. This way, the insulative property of low-density EPS can reach the same level as EPS with a density two to three times higher. Using optimized mixing technology as well as the right combination of additives in the process leads to an improved dispersion of the pigments in the final product and helps to lower the additive consumption in the Sulzer process compared to other processes.

Meeting environmental requirements: alternative flame retardants

A disadvantage of using plastics in construction is their flammability. Polystyrene, in particular, burns readily and EPS foam, unless equipped with flame retardants, does not fulfill common building codes relating to flame spread and smoke development. Therefore, the material has to be either used in combination with an additional flame barrier on the side of the construction method or impregnated with suitable flame retardants. The most widely used additive for this application is hexabromocyclododecane (HBCD), a highly brominated flame retardant with more than 70 wt% bromine per molecule. HBCD has been the flame retardant of choice in EPS for several decades now, because it is very efficient: Typically, HBCD levels between 0.7 % and 3 %—depending on the type of synergist and process used—are required for building insulation to reach the desired flame retardancy. In particular, the use of synergists imposes very efficient temperature and shear control on the production process. With decomposition temperatures as low as 150 °C, as is the case for commonly used peroxide synergists, it becomes a prerequisite in melt impregnation to cool and maintain a low temperature and shear profile. This factor has to be taken into account for the design of mixers, extruders, and pelletizers.

Flexible process allows the use of HBCD substitutes

Recently, the toxicity and the environmental impact of HBCD have become matters of concern. Measurements have shown that the material bioaccumulates and biomagnifies so that several environmental protection agencies have put the chemical on their lists of concerns. This development has prompted the EPS industry to start the search for a substitute for HBCD. Due to its ingenious design and efficient temperature control, the Sulzer EPS process is much more flexible than classic suspension technology as it allows the use of new flame retardants currently in development.

Defined distribution of particle sizes

The EPS quality is not only influenced by the composition of the material but also by the geometry of the molded beads. An even, spherical shape of the beads ensures the best particle fusion. The diameter required for the EPS particles depends on the intended use of the final product. Different size classes are typically defined for insulation, packaging, food containers, or cups. And an optimal mold fill is supported by a narrow, uniform bead size distribution.

An even, spherical shape of the beads ensures the best particle fusion.

Together with Automatik Pelletizing Systems, part of the MAAG group which was recently acquired by Dover Corporation, Sulzer Chemtech has further developed the existing underwater pelletization technology for stable production of uniform EPS, in particular, EPS containing pigments and flame retardants. Due to its outstanding sphericity and precise pellet size distribution [2], the product can be processed like suspension product without prior screening or sieving. Due to a unique die plate design and efficient heating, die freezing can be minimized even for small bead sizes below 1 mm.

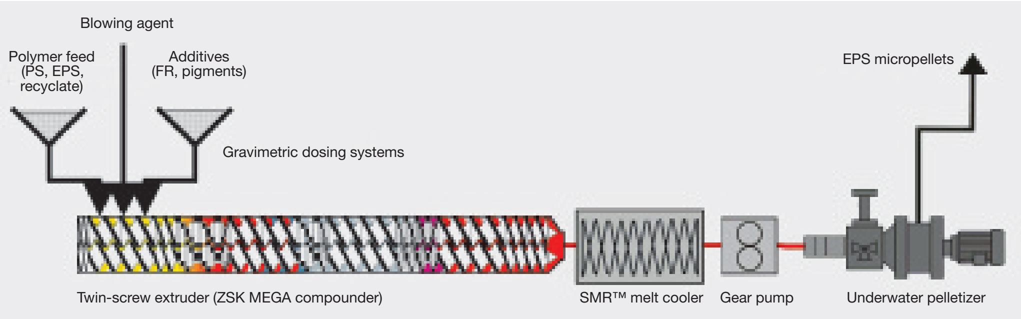
Premature foaming of the beads is avoided thanks to pressure and temperature control in the closed pelletization water circuit.

Small-scale, economical production

The melt impregnation technology represents a tremendous potential for product innovation in the PS foam business, not only on a large production scale but also on a scale suitable for specialized products. EPS converters, who are very closely connected to end customers, typically have vast knowledge of the product requirements and limitations of existing EPS products for the applications they serve. Unlike the big resin producers with their commodity-grade EPS, converters increasingly feel the need to differ from their competition and to develop niche products with special properties. Because annual consumption can easily reach 10 000 t per year, the production of their own EPS resin with a melt impregnation plant suddenly becomes attractive, in particular with PS resin widely available at relatively low prices.

Simplified extruder process

Applying the in-depth process expertise from a decade of EPS process development, Sulzer Chemtech has developed a second-generation EPS process suited, in particular, to small-scale production 3. Using a combination of a twin-screw extruder—in which PS or EPS, blowing agent, and all required additives are compounded—and Sulzer’s proprietary melt coolers, the engineers have designed a simplified manufacturing unit that is attractive for smaller capacities of about 500–3000 kg per hour. This extruder process, the result of a joint cooperation with the renowned German extruder manufacturer Coperion, allows for the economic production of EPS specialties even on scales adapted to the requirements of larger converters.



3 Sulzer’s EPS process is suited for small-scale EPS production (500–3000 kg/h).

Sulzer supports EPS converters who want to develop their own foam formulations. They can produce and test customized EPS grades with various additives in Sulzer’s pilot test facilities. The clients benefit from the broad experience that Sulzer Chemtech and its partners have gathered with melt impregnation technology.

Process innovation for the environment

From the very beginning, Sulzer has focused its process development on environmentally friendly solutions for EPS production. This designation encompasses two major areas: recycling capabilities and the use of alternative blowing agents. Because EPS is a lightweight, single-use product with a decomposition time of several thousand years in nature, the end-of-life debate has always had a negative imprint on the product image. At the same time, the commonly used blowing agent pentane for foaming EPS has a critical global warming potential and falls under strict regulations in many countries and legislations. While suspension polymerization is rather inflexible in view of addressing these aspects, melt impregnation offers a lot of room for process innovation. Sulzer Chemtech develops and offers technology for the recycling of both unfoamed, impregnated EPS from production (e.g., off-spec material, unsold material from stock, etc.) and compressed foam from consumer recycling or production internal sources (cut-off, blocks, etc.). Those materials can be used as feed stream and be 100 % reutilized for production of virgin EPS resin. By using alternative blowing agents, which do not fall under the regulations of volatile organic compounds (VOC) yet have similar properties to those of pentane, converters can save significant money on pentane abatement systems and VOC taxes that may apply in some countries. Development of these process innovations is currently ongoing within Sulzer Chemtech.

Sulzer Chemtech develops and offers technology for the recycling of EPS.

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