Foaming of Hot Melt Adhesives

Foaming technologies have been known by the market for years. However, foamed hot melts have recently been gaining more interest as the industry moves towards more resource and cost-efficient solutions that can maintain or even improve performance.

Foaming has become an attractive alternative in various applications by increasing the volume of hot melt adhesives while reducing material usage. Evonik recognized this trend in amorphous-poly-alpha-olefins (APAO) and began extensive research on their foaming process, as well as, the foaming behavior of different polymers in order to provide customers with the best solution for their individual requests. A detailed evaluation focused on performance, application and machine parameters was conducted to get a better understanding of the conditions for foaming applications. The team also looked into old and new applications to gather more detailed insights and develop new markets and opportunities for foamed hot melts.

Foaming Process

For the foaming process, a standard hot melt unit can be utilized, which is sketched roughly in *Figure 1*. It consists of a tank where the hot melt is melted. The temperature of the tank can be adjusted according to the viscosity of the adhesive and the characteristics of the substrate where the foam line will be applied. Common temperatures are in the range of 150 °C to 170 °C. The molten adhesive is fed through a heated hose to a pumping unit which forces gas into the solution with the adhesive under pressure. A high pumping speed results in high pressure within the unit, therefore experienced and trained handling of the machine is necessary. Within the pumping unit, the molten adhesive is in constant circulation and the gas, usually nitrogen or air, can be added step by step through a needle valve. The ability of the hot melt to take up a certain amount of gas defines it's so called foamability, which can be up to 70 % depending on the used material. During application, the hot melt is released out of a heated dispense head and exposed to atmospheric pressure, which causes the dissolved gas to expand out of the solution and create a hot melt filled with small gas bubbles (*Figure 2*).

Properties of the adhesive

In order to achieve excellent foaming results, specific product properties are required. According to Evonik, the Vestoplast portfolio offers exactly these needed properties, which are necessary for the perfect foamed adhesive. Above all, the relation between flexibility and cohesion must be balanced. Good flexibility of the adhesive allows the gas bubbles to expand once the adhesive is released out of the dispense head, while cohesion keeps the gas bubbles inside the adhesive to create an excellent, stable foam. Only a perfect balance between these two properties allows the combination of gas and adhesive to form a foam. According to Evonik, this balance is a result of the crystalline and amorphous moieties of Vestoplast, an amorphous poly-alpha-olefin used as a raw material for hot melt adhesives. It is based on ethene, propene and 1-butene and provides a unique molecular weight distribution with both crystalline and amorphous parts. The amorphous parts are important for the flexibility and adhesion to different substrates. The crystalline parts are responsible for the inner strength, as well as, the good cohesion, which keeps the gas bubbles inside the hot melt as the foamed material cools to room temperature. This effect can be detected in the evenly dispersed gas bubble under the microscope (*Figure 3*).

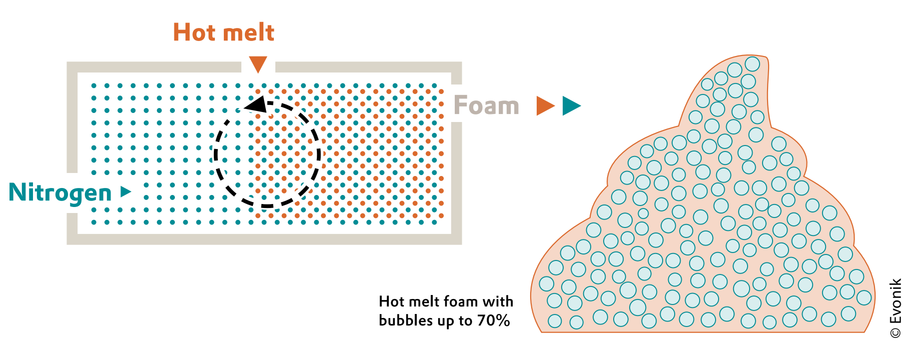

Figure 1 > Schematic diagram of the foaming process

Evaluation of the foaming bahvior

Further detailed analyses were conducted with various polymers. The foaming behavior of each material was evaluated step-by-step with a design of experiment (DoE). Every material has its own unique foaming behavior. Some start to take up the gas at a very early stage, while others need more gas and pressure inflow until the dispersion starts. Therefore, a deep understanding of the polymer, as well as, the process is very important.

The extensive tests have shown that not only the physical properties of the polymer influence the foaming behavior, but also the polymer structure itself. Most of the tested polymers are foamable but the maximum ratio of gas solubility varies. It is a huge difference if a hot melt is able to take in 40 % or 70 % gas. The results are shown in *Figure 4*. Two butene rich and two propene rich Vestoplast grades with different viscosities, softening points and crystallinities were tested. As the results clearly indicate, all four grades can be foamed with up to ~70 % gas, resulting in a reduction of the actual polymer content down to ~30 %. The three tested polymers in the control group show significantly less intake of gas, with a maximum of ~35 %, which only results in a reduction of the polymer content down to ~65 %. All polymers were tested purely with the same foaming unit. With Vestoplast, the application window proved to be significantly wider, allowing for more freedom in various application.

Since Vestoplast showed excellent foamability results, two grades were chosen from the portfolio for more detailed analysis. Depending on the properties which are required for the application, in gen-

Figure 2 > Hot melt filled with small gas bubbles

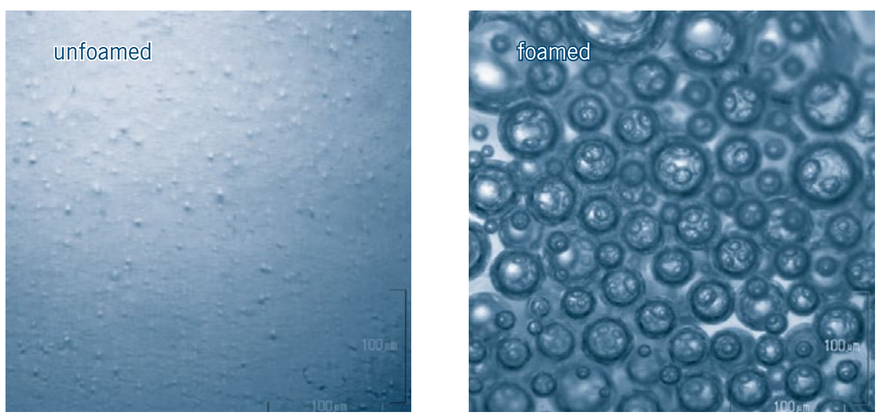

Figure 3 > Unfoamed and foamed Vestoplast under 125x magnification – without gas (left), with 65 % gas (right)

Properties	Unit	Vestoplast 703	Vestoplast 408
		Propene-rich	Butene-rich
Softening point	[°C]	124 (+/- 6)	118 (+/- 4)
Needle penetration	[0,1 mm]	12 (+/- 3)	5 (+/- 2)
Melt viscosity @190 °C	[mPa*s]	2700 (+/- 700)	8000 (+/- 2000)
S.A.F.T. acc. to WPS 68	[°C]	75-80	85-90
Open time	[s]	15	65
Tensile strength	[MPa]	2,1	6,8
Elongation @break	[%]	43	80
Tg (acc. to DSC method)	[°C]	-28	-27

Table 1 > Technical details of selected Vestoplast grades

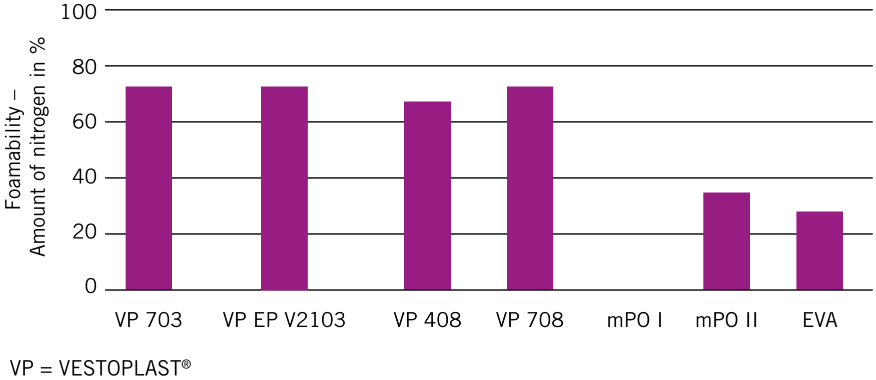

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Figure 4 > Foamability of different polymers

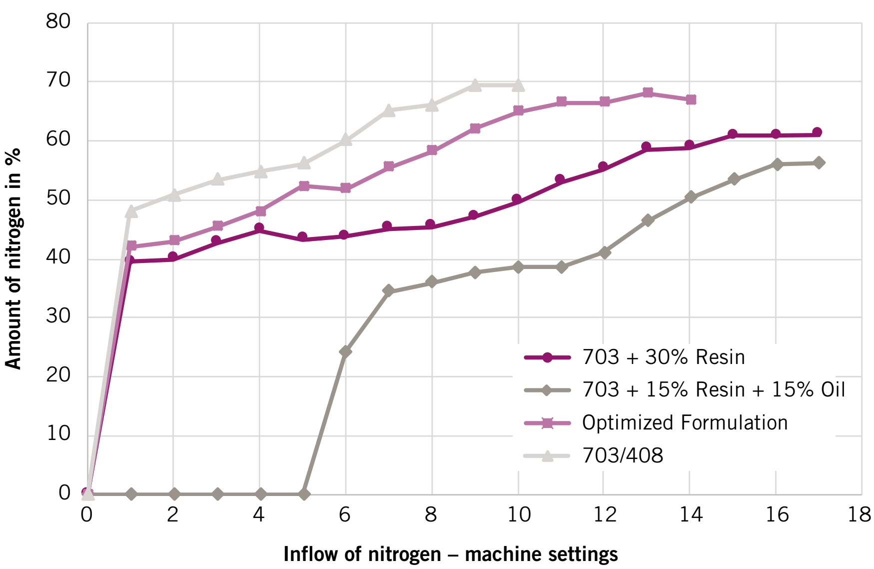

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Figure 5 > Comparison of foaming behavior of different Vestoplast grades at 150 °C

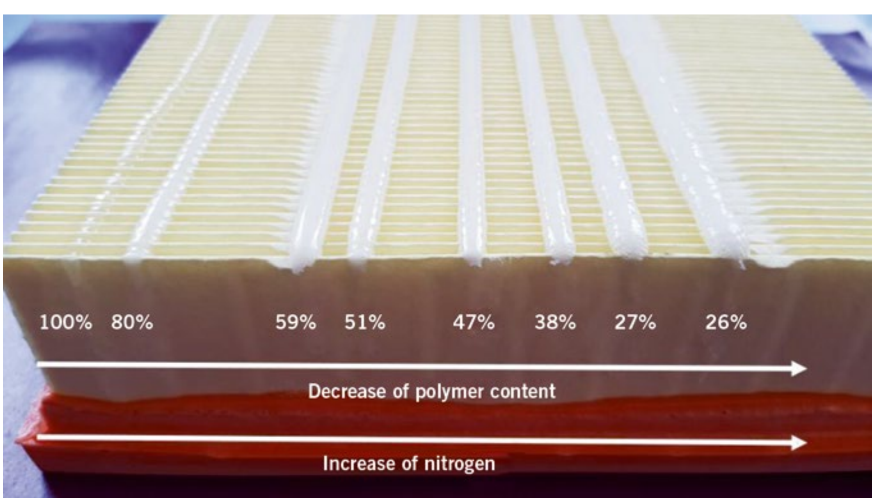

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Figure 6 > Automotive filters with hot melt adhesive lines made of Vestoplast 703 with different foam concentrations: increasing gas content / decreasing polymer content from left to right

eral, all grades are feasible for the foaming process. However, the viscosity can be a limitation, as high viscous grades are more difficult to feed through the hose and the dispenser. Vestoplast 703 is a low viscous, propene-rich grade exhibiting high flexibility and a fast setting time. Vestoplast 408, as a counterpart, is a butene-rich grade with a slightly higher viscosity and more crystalline moieties, thus providing excellent cohesion properties. Technical details of both grades can be found in *Table 1*.

Both grades were tested at application temperatures of 130 °C and 150 °C with outstanding results. Although the application temperature is typically in the range of 150 °C to 170 °C, a reduction down to 130 °C is feasible and can save melting time and energy. Additionally, a low application temperature protects the product while reducing the thermal load and decreasing the need for maintenance of the machine. Furthermore, it is very well suited for application on temperature sensitive substrates.

As shown in *Figure 5*, it can be observed that Vestoplast 408 needs higher gas pressure until it starts to adapt the gas. However, once this point is reached, the polymer content immediately decreases to a very low level of ~30 % at a temperature of 150 °C, hence the polymer has taken in ~70 % of the gas. With Vestoplast 703, this process already starts at an earlier stage with a slightly higher level of ~40 % gas and ~60 % polymer at 150 °C, but a gradual decrease takes place until the polymer/gas solution has reached its stable maximum at ~30 % polymer and ~70 % gas content.

Depending on the targeted end application and the individual needs of the end application, different combinations of polymers with additives and gas content can be achieved, thus making it a suitable polymer for a wide range of applications.

Application examples for foamed adhesives

- **Filter**

Some well-known applications for foamed adhesives can be found in the filter market. For example, hot melts can be used for pleat stabilization in air filters used in passenger cars, big filter sheets for ventilation systems or air conditioning systems. The folded filter pleats are secured with a line of hot melt to keep the pleats together for the next production step or to build up the different filter layers. By using foamed hot melts instead of common hot melts, filter producers can save a significant amount of material and costs by lowering the head density, since the

Figure 7 > Use of foamed hot melts for mattresses

foamed hot melt adhesive contains less mass when compared to an unfoamed one (*Figure 6*) The heat will dissipate faster and prevent the thermal distortion of the substrate. Furthermore, the foamed Vestoplast line has a white, clean color and no odor.

- **White goods**

Another application can be gap filling for white appliances. The gaps between the metal sheets of a refrigerator or a washing machine can be filled with the foamed material. The ability to add up to 70 % gas saves costs, without compromising the application demand of a good adhesion to coated metal plates and a white appearance. It also provides a good heat and cold resistance, as well as, water and moisture resistance.

- **Mattresses**

The bonding of mattresses is a huge market. The adhesive demand for one mattress is very high due to its large surface area. Foaming Vestoplast can help to reduce the penetration of hot melt into the mattress material. The foamed adhesive lightly lays on the substrate surface until the second layer is laminated to it (*Figure 7*). Thus, significantly reducing the loss of hot melt which can penetrate inside the substrate and no longer be available for bonding the second substrate. In addition, the foamed adhesive line is very flexible and will not lead to noise.

Conclusions

The above-mentioned applications are selected examples for the foaming technology in the adhesive industry. Even more industries and applications can be suitable candidates for the foaming technique. Using a foamed hot melt instead of a regular hot melt can provide several advantages for the end user, as well as players along the value chain. One of the main benefits is cost savings, which can be achieved by reducing the amount of adhesive, while keeping the same or even better performance, as well as reducing energy consumption due to low application temperatures.

In addition to energy savings, a low application temperature allows for a greater variety of substrates, such as heat sensitive or very thin substrates. Since the foamed adhesive also contains less adhesive mass, quicker cooling takes place as the heat dissipates faster, thus enabling the use of more demanding substrates.

Foaming an adhesive provides several benefits from a processing standpoint too. The reduction in set time can lead to accelerated production rates. Simultaneously, the open time is prolonged by the gas bubbles insulating the adhesive which allows for adjustments to be made over a longer period of time to the bonded substrates (e.g. mattress bonding) and hence offers a greater flexibility. Furthermore, an increased surface size can be achieved. Once the adhesive is dispensed, the material expands, providing more volume and the ability to fill even small gaps on an uneven or porous substrate.

Overall, foamed adhesives provide an attractive alternative to the common hot melt in various applications, allowing for greater flexibility and efficiency during the process and with the materials used. //

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