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Processing aids - users seek improved functionality

Lubricants and processing aids are vital for efficient polymer processing. However, compound producers are increasingly demanding additional functionality as well, writes ***Mark Holmes***

Making raw materials go further and delivering more efficient end-use processing – whether that be faster and thinner extrusions or shorter injection moulding cycles – are key roles of processing aids in the formulation of polymer compounds. A wide variety of chemicals, waxes and lubricants can be employed to this end but increasingly these additives are being required to be multi-functional. And as the Circular Economy moves up the agenda, lubricants and processing aids that can work effectively with recycled polymers are also finding important roles in the market.

German wax additive blend and montan wax supplier to the compounding industry **Völpker Spezialprodukte** highlights a number of significant factors in the current lubricant and wax market sector. "Polyethylene wax – mainly oxidised – is still in short supply," says Dr Lutz Matthies, Head of Business Development. "The recent global shortage of oxidised polyethylene waxes has caused users to search actively for adequate replacements. However, montan wax is in good demand, mainly for high-quality applications and is readily available. The market is open for new developments with montan wax. The demand problem for Fischer-Tropsch (FT) wax is now relaxing because of new Asian producers and new plants introduced by established players in the market. In addition, the biopolymers market now deserves effective bio-based lubricants."

Matthies identifies a number of key trends driving new developments in waxes and lubricants. ❯

Main image: Processing aids and lubricants are key elements in the preparation and processing of polymer compounds for performance applications

"Multi-functionality of wax additives – one additive with several functions – is an asset," he says. "In addition, plant-based chemically functionalised wax additives, available on a sustainable basis, are a growing requirement of the biopolymer market. There is also a need for special wax additive packages for recycled plastics: The multi-functionality of montan waxes in synergy with other additives, such as stabilisers and lubricants, can be used to produce compounds with property profiles that are very close to those of new products. These include the Voelkper plastic recycling series of wax additive blends and montan waxes – Cevo and Waradur. The products of the Voelpker plastic recycling series are also adapted to the processing conditions of specific recyclates."

Monitoring wax performance is also a key consideration, according to Matthies. "Many of the products that have been advertised in the past as 'drop in alternatives' to proven montan wax esters give sub-optimal results in practical applications because they do not provide the same properties and use characteristics," he says. "Un-derivatised vegetable ester waxes, for example rice bran wax, and also polyester waxes from polymer degradation do not provide the equivalent processing and performance characteristics such as those of montan esters. Their chemical characteristics do not fully meet most current specifications for montan waxes and they also show differing performance in volatility [Figure 1] and colour stability [Figure 2]."

Matthies adds that low priced standard commodity lubricants can often cause unwanted side effects such as 'blooming out', for example with EBS wax in TPU. He says that the solution in many cases is new montan wax derivatives that close the gap between oleo-based and montan-based structures and application properties, such as Waradur GSM and ESM. In addition, the company offers the Waradur OP*plus*, a saponified montan wax with a high calcium montanate content and further improved volatility. Its structure and chemical characteristics are shown in Figure 3.

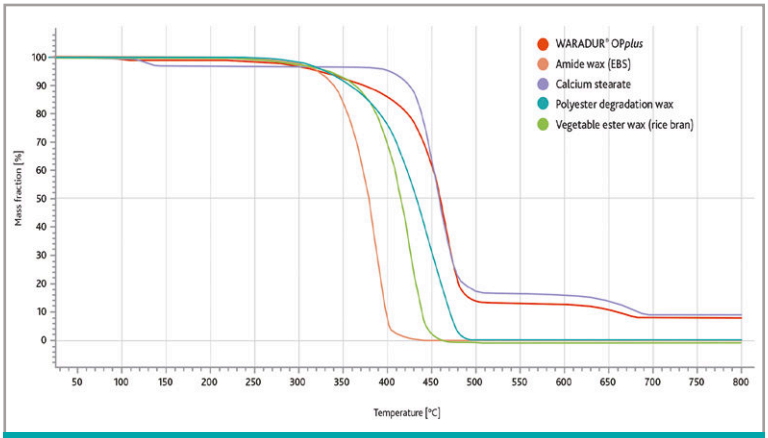


Figure 1: Volatility of Waradur OPplus high calcium saponified montan wax compared to some typical alternatives determined by Thermogravimetric analysis (Fraunhofer-Institut WKI, Braunschweig; Mettler, 10.00 K/min)
Source: Voelkper

Recycling challenges

The company says that its Voelpker plastic and plastic recycling series of wax additive blends and montan waxes are designed to overcome processing challenges and allow compounders to develop formulations offering optimised characteristic value profiles. "One goal is to complement the specific 'DNA' of the montan esters to the properties of oleo-based esters," says Matthies. "Waradur GSM and Waradur ESM are hybrid ester waxes consisting of a mixture of long chain (mainly C28-32) wax acids and fatty acids esterified with multihydroxyl alcohols. They

Figure 2: Colour stability under stress of Waradur E hard ester montan wax compared to some current alternatives (Heraeus UT 6120 laboratory air circulation oven; 250°C/ 30 min)
Source: Voelpker

combine the chemical properties of montan esters and classical oleo esters on a molecular level. They also combine in an ideal manner the application properties of montan esters including high thermal stability, low volatility, no blooming out and excellent release/anti-sticking, with those of oleo esters such as improved mould release."

The Voelpker bio-based series includes the processing aid Cevo-process J-4418. This wax additive is 95% bio-based and is designed to provide flow improvement, faster part production, reduced injection moulding ejection force and improved dispersion. It is an organic ester wax based on renewable plant material (it is predominantly derived from acids and alcohols in the C26–C30 range) making it suitable for formulation of bio-based thermoplastic compounds.

A particular advantage of Cevo-process J-4418 is its high effectiveness at low concentrations. Voelpker says that it is suitable for use as an additive in a wide range of plastics applications, including release agent, flow improver, dispersing agent and cycle time reducer. Typical results achieved in injection moulding applications are said to include a 46% reduction in cycle time, 15% improvement in flow and up to 49% reduction in ejection force. Cevo-process J-4418 can be used in thermoplastics such as PA, TPU, PLA, PBT, PC, PVC and PS. Thermoset applications include epoxy resins, phenolic resins and polyurethane. It can also be used as a dispersing agent for colour masterbatches and mineral or glass fibre-reinforced plastics.

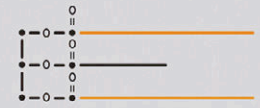
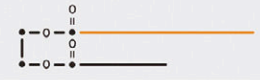
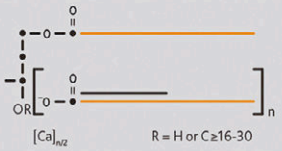
Name	Chemical Characteristics	Drop point [°C]	Acid value [mg KOH/g]	Visco-sity at 120°C [°C]
WARADUR® GSM		79	14	16
WARADUR® ESM		82	36	12
WARADUR® OP*plus*		n.a.	5	n.a.

Figure 3: Structural elements and typical chemical characteristics of Waradur montan derivatives
Source: Voelkper

Moulding trials

Voelpker says in a recent injection moulding study designed to demonstrate reduced cycle times and enhanced flow improvement, a number of PA6 matrices were investigated. Unmodified Durethan B 29 (Lanxess) was stabilised with Irgafos 168 (BASF) and Microtalc IT extra (from Mondo) added as a nucleating agent. Blank 1 (without nucleating agent) was tested as a control while the effect of adding Cevo-process J-4418 was compared against Waradur E, amide wax and calcium stearate.

In the applied experimental set-up, using standard tools and test specimens, the nucleating agent alone reduced cycle time by 7%. The 56% reduced cycle time compared to the Blank 1 control for the Waradur E sample is attributed to the proven dispersing effect of the wax, which leads to better distribution and effictiveness of the nucleating agent. Cevo-process J-4418 produced a similar cycle time reduction – 46% – and significantly outperformed both the amide wax and calcium stearate samples.

Spiral Flow Number, defined as the flow length, was determined by injecting the molten resin into a

Table 1. Spiral flow injection moulding analysis of CEVO-process J-4418 processing aid compared to alternatives in PA6 resin. Test formulations.

Matrix	Additives	%	Comments
PA 6 Durethan B 29-Irgafos 168 [0.2 wt.%]	–	–	Blank 1
PA 6 Durethan B 29-Irgafos 168 [0.2 wt.%]	Microtalc IT extra	0.2	Blank 2, with nucleating agent
PA 6 Durethan B 29-Irgafos 168 [0.2 wt.%]	Microtalc IT extra CEVO-process J-4418	0.2 0.5	Renewable long-chain ester wax
PA 6 Durethan B 29-Irgafos 168 [0.2 wt.%]	Microtalc IT extra WARADUR E	0.2 0.5	Montan ester wax
PA 6 Durethan B 29-Irgafos 168 [0.2 wt.%]	Microtalc IT extra Amide wax	0.2 0.5	Ethylenebisstearamide (EBS)
PA 6 Durethan B 29-Irgafos 168 [0.2 wt.%]	Microtalc IT extra Ca-stearate	0.2 0.5	Calcium saponified fatty acid

Source: Voelkper

spiral channel testing mould. The results demonstrated that flow can be significantly increased by using wax additives, with the best result of 15% longer than the control Blank 1 achieved with Cevo- process J-4418. The flow extension with Waradur E was around 8% and for both calcium stearate and amide wax between 5.0 and 5.5%. The results are shown in Table 1.

Ejection gains

In another study, ejection force reduction enabled by the use of montan waxes in PBT (polybutylene terephthalate) was examined. Montan wax Waradur E acts as a thermally stable and low volatile release agent in PBT, with typical additions of 0.3-0.5% recommended for unfilled PBT resins and up to 1.0% for filled or reinforced formulations. The PBT formulations (Table 2) were compounded using a Brabender twin screw extruder and pre-dried at 110°C to a residual moisture content of 0.03%. The moulding trials were carried out on an Arburg Allrounder 420C 1000 at a melt temperature of 240°C and the ejection forces calculated from 20 measured injection mould cycles once the process had stabilised.

The force required for ejection was measured using a 5kN load cell from Hottinger Baldwin Messtechnik that was axially integrated into the ejector rod. An injection moulding tool with a particularly high shell surface was selected and the precise ejection force calculated using Katman software. The results showed that ejection forces were reduced by approximately 20% using Waradur E. PETS and calcium stearate only reduced the ejection forces by 8% and 11% respectively.

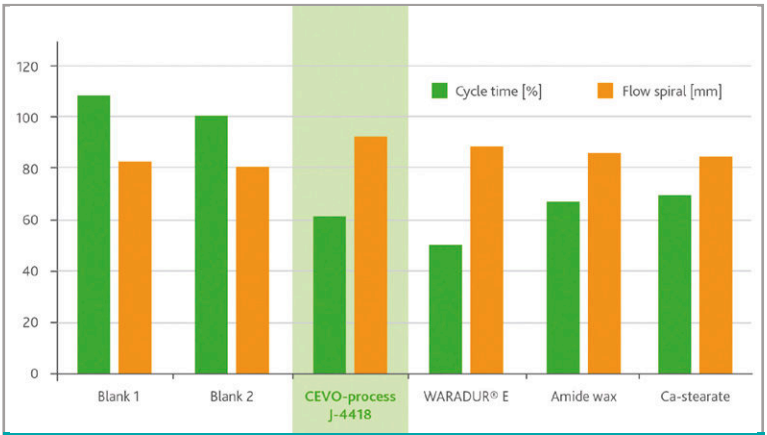


Figure 4: Cycle time reduction and flow improvement – spiral flow injection moulding trials
Source: Voelpker

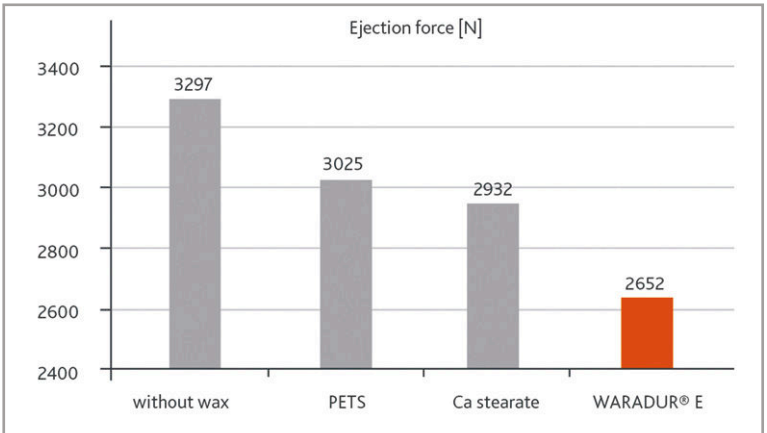


Figure 5: Ejection force results comparing Waradur E montan wax with alternatives
Source: Voelpker

Table 2: Ejection force analysis of montan wax and alternatives in PBT. Test formulations

Matrix	Additive	Additive [phr]	Comments
SHINITE	None	0.0	Reference/blank
D201NA	WARADUR E	0.4	Montan ester wax
(PBT Base polymer grade)	PETS	0.4	Pentaerythritolester
+ Irganox 1010 [0.5 wt.%]	Calcium stearate	0.4	

Source: Voelpker