

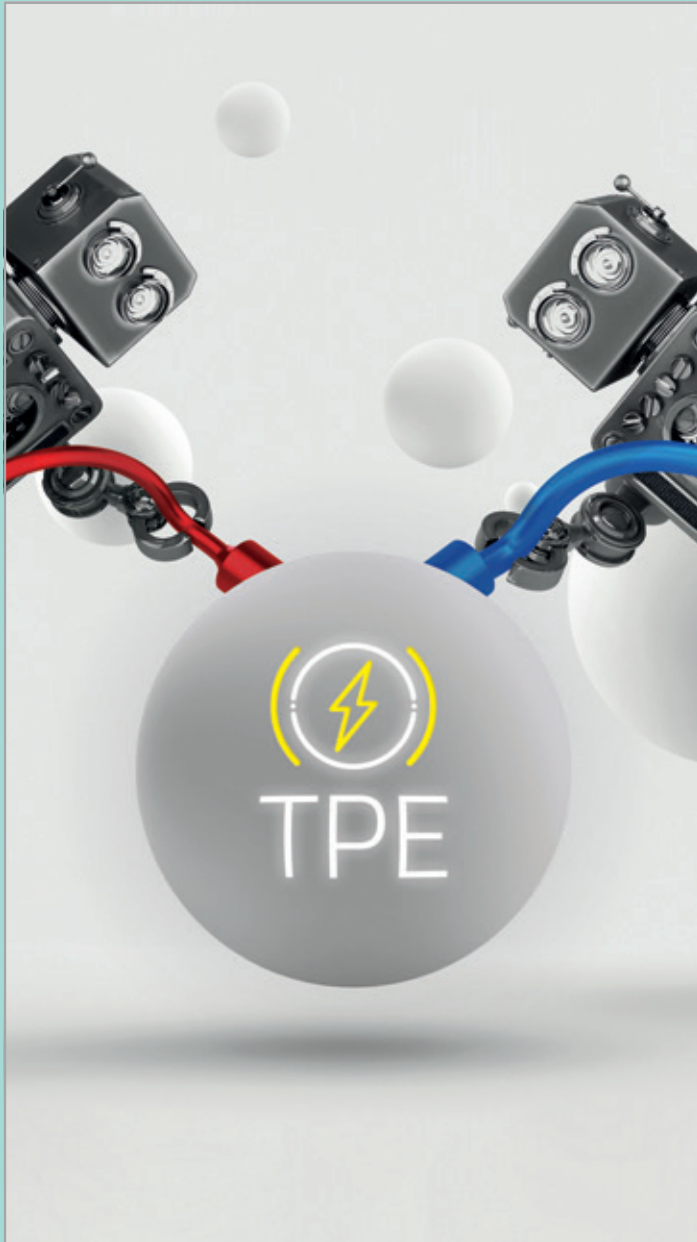
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Empowering TPE with additive manufacturing and conversely

Additive manufacturing (AM) is making giant strides in changing the world of the manufacturing industry. What once was limited to prototypes is today more and more often being used for smaller quantities and spare parts, in particular. Medium to large-scale production via additive manufacturing is being tackled and shall come to fruition and a foreseeable future. Thanks to the relatively straightforward and tool-free equipment of the devices, even sophisticated parts can be printed quickly and in the very place where they are needed. The technology provides enormous potential for significant savings of time, work and costs.

TPE in the AM landscape: the softer the harder

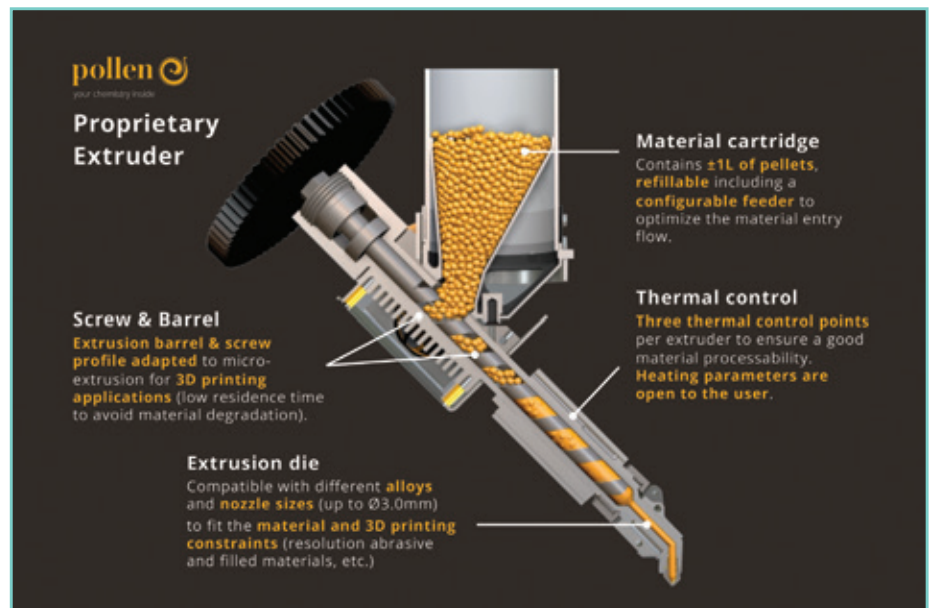
However, processing TPEs via additive manufacturing techniques is a highly complex and demanding task. Parts obtained using filament extrusion systems or powder based and stereolithography technologies focus essentially on higher Shore hardnesses (typically greater than 70 Shore A) and offer weaker properties than injection moulded counterparts. Often 3D printed parts flexibility degrades quickly over time and/or usage.

These limitations come from the fact that the processed materials do not have the same chemistry as the injection grade materials. For instance, making additive manufacturing filaments involves heating the raw material, increasing its thermal history. Greater thermal history implies more reduction in the polymer chains, hence resulting in a degradation of the properties of the material. Material manufacturers for additive manufacturing are often obliged to add plasticizers or additive to mitigate this degradation, in which case the obtained materials are altered from their original chemistry.

Dr. Thomas Wagner, Product Management EMEA at Kraiburg TPE explains: "The techniques solely based on liquid polymers are technically impossible to use with TPE materials. This is due to the fact because TPE materials do not contain cross-linking components therefore they just cannot be cured. If a TPE would contain cross-linking components it would lose its thermoplastic's properties."

"It's only possible to draw fairly limited conclusions from prototypes made of spe-

Fig. 1: The PAM technology - focus on the extruder



cial 3D printing materials in relation to the performance of standard injection molding or extrusion compounds", Wagner says. "The challenge we faced was to precisely analyse the prerequisites for fused deposition modelling of soft TPEs. In order to find a suitable solution, we had to learn to separate the technical limitations of the printers from those of the materials."

The solution: Pellet Additive Manufacturing (PAM)

This is precisely what the PAM technology (Pellet Additive Manufacturing) addresses. Developed by Pollen AM, a French 3D printer manufacturer incorporated in 2013, the PAM systems rely on industrial injection grade granules to create parts without hardness limits. To this day PAM technology is the only one able to process TPEs ranging from Shore D (hardest) to Shore

00 (softest). Inspired by micro-extrusion techniques, PAM technology goes beyond TPEs, being capable of treating every polymer type.

Didier Fonta, Director of Operations at Pollen AM, explains: "Our industrial raw material undergoes the same number of transformations as in the injection moulding industry. As a result, the end user finds more precise chemical and mechanical properties adapted to their needs. This is particularly interesting on the elastomer part because it can print without limit of hardness, from very soft to very rigid."

Moreover, thanks to **New PAM Series P's** four retractable, autonomous and independent extruders, it is able to process up to four materials at the same time, typical hard-soft multicomponent composites made of TPEs in combination with polymers such as polypropylene (PP), acrylonitrile-butadi-

Tab. 1: Comparison between test specimens printed with PAM technology and injected. Printed test pieces develop similar stresses and elongations.

Properties	Unit	PAM tensile bar	Injection moulding	PAM performance
Hardness DIN ISO 27588 (D=6mm)	VLRH	45	51	88.24%
Density DIN EN ISO 1183-1	g/cm ³	0.874	0.873	100.11%
Tensile strength (DIN 53504/ISO 37)	Mpa	1.4	1.9	73.68%
Elongation at break DIN 53504/ISO 37	%	1,178	1,412	83.43%
Tear resistance (DIN 53504/ISO 37)	%	43954	43865	83.33%

ene-styrene (ABS) or polyamide (PA) are also possible. For applications requiring less versatility, the New PAM Series P is now also available with simply two and three extruders (**fig. 1**).

By harnessing the value of industrial grade materials, PAM technology eliminates filaments, powders, liquid resins or any other format specific to Additive Manufacturing. With a virtually infinite library of such compatible materials, two key benefits emerge:

- the lowest possible cost of materials,
- the genuine properties and norms (skin contact, fire-resistance...) of the materials are preserved.

Pollen AM's flagship product, the New PAM Series P, has undergone extensive tests and application validation. Collaborating with Kraiburg TPE, the results are convincing parts production, featuring mechanical properties that achieve up to 88 % percent of the hardness or 74 % of tensile strength values shown by comparable injection moldings, depending on the process parameters.

Fig. 2: a) Extensimetry video (still) b) constraints/ deformation within three axis. The characterization showcases a quasi-isotropic behaviour.

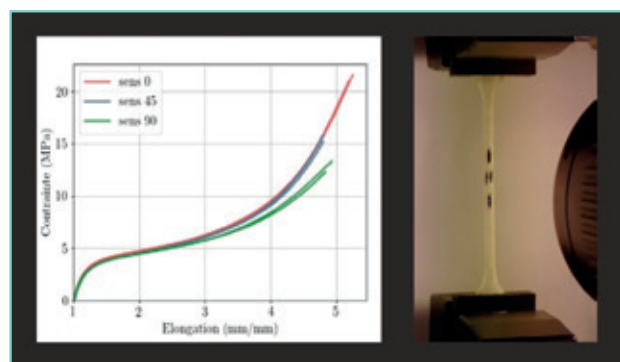
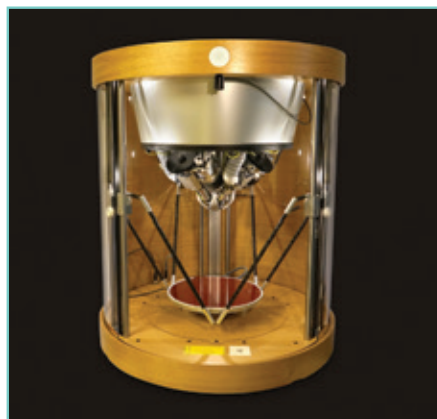


Fig. 3: New PAM Series P



All parts are with extremely detailed surfaces even with very soft TPEs. This means that the provided TPE compounds are carefully chosen and processed, so the technology is suitable for producing both demonstration samples and also functional parts and is thus able to reduce the costs of developing new applications. Since almost all thermoplastic elastomers that Kraiburg TPE has in its portfolio are potential materials for direct processing on PAM pellets printers, no special compounds are needed. Additionally, all

features of the materials, especially their adhesion possibilities on various thermoplastics, are maintained in 3D printing with PAM pellets printers. Residues that may arise during production can be recycled in local waste streams (**tab. 1, fig. 2**).

"Our PAM systems ensure the shortest possible residence times to avoid affecting the specific ad-

Fig. 4: New PAM Series P HT



vantages of soft elastomers", explains **Didier Fonta**. "This also ensures excellent peel strength, particularly for multicomponent applications with thermoplastic elastomers in the low Shore hardness range." No matter where the TPE sits on the scale of softness, it can be used in the New PAM series P (**fig. 3**).

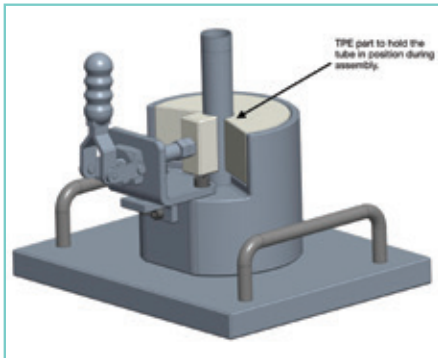
If the New PAM series P can process the large families of TPE and standard thermoplastics, for more demanding applications the **New PAM series P HT** is here to handle performance thermoplastics, characterized by high glass transition and melting temperatures, by taking special care of high temperatures (**fig. 4**). This system opens the possibility of printing parts in PPS, PESU, PEI and PEEK, while retaining the processability of the TPE. This is made possible thanks to its high sheer extruders optimized for semi-crystalline materials for better flow control, generating temperatures up to 450 °C, a interlayer heating device (up to 300 °C) to further increase Z direction mechanical performances and preserve good adhesion between layers, a heated build plate (up to 250 °C) and a heated fabrication chamber to ensure thermal stability.

Finally, for metals and ceramics applications, Pollen AM offers the **New PAM series MC**, which offers the advantage of using industrial injection moulding materials and do not require specific formats or adjusting recipes (powder/organic binder ratio). By using the same post-processing equipment as traditional production of PIM parts, debinding and sintering cycles are identical and part withdrawals are equivalent.

Applying PAM technology to key applications

Whether TPE materials are intended for their shock absorption, sealing or comfort fitting properties, the innovation rate within

Fig. 5: Schematics of the assembled tooling equipment



the TPE family is superior to that of other thermoplastics and rubbers. This represents an opportunity which PAM technology opens to the additive manufacturing landscape, allowing to design parts that require maximum flexibility. Let's review a few applications benefitting from the PAM technology.

E.M.I. – industrial tooling

E.M.I. (Etude Moulage Injection) is a specialist in the injection of thermoplastic materials, which encountered difficulties to produce a part that could hold a tube in position without causing the slightest scratch to the part to be assembled. The specifications established hardness between 60 and 80 Shore A with the use of a material compatible with the hygiene standards of an ISO 8 clean room. After receiving rejections from machinists to produce the parts, E.M.I. turned to Pollen AM and PAM technology for its ability to process elastomers without hardness limits.

Following receipt of EMI's specifications, a TPU was identified for its compatibility with the criteria required by the ISO 8 standard. As this TPU has a hardness of 85 Shore A, a 40 % filling was proposed in order to respect the flexibility of the part while optimizing its printing time and cost (fig. 5).

PAM technology has enabled E.M.I. to produce parts that are perfectly suited to the required application (fig. 6). All thanks to the ability to use a material that meets the functional and hygienic requirements without having to go through the process of making a mould when no other manufacturer could meet this demand. The manufactured parts are operational and allow the assembly of 200,000 parts per year.

Fig. 6: Part obtained via PAM technology



This case highlights the contribution of additive manufacturing as a support to the industrial tool for the production of custom-made tools.

Decathlon – multi-material soft soles

Pollen AM and the Decathlon Add Lab collaborated to produce a sole composed of two different TPEs, a TPE 70 Shore A, a TPE 45 Shore A and a support material based on HIPS (fig. 7). By using PAM technology, Decathlon has been able to quickly from proof of concept to actual product, without extra tooling investment and with the same material as convention-

Fig. 7: Shoe sole printed in two different TPE materials



al production tools. Didier Fonta adds: "Our machine makes it possible to combine several elastomers at the same time which will offer the manufacturer fairly broad ranges of properties. In the case of a sole, for example, we are able to have several cushioning characteristics."

Delta Plasturgy – protective gears

Delta Plasturgy uses PAM technology to produce protective equipment in small series (handling gloves, knee pads, etc.). Its patented Hexaflex geometry solution combines pyramidal and hexagonal shapes with TPE materials (fig. 8, 9).

Delta Plasturgy turned to Pollen AM's solution because of the high diversity of their portfolio of shapes and also because

Fig. 8: Hexaflex printed geometry for protective equipment



personalization and adaptation is key to their equipment. Allowing them to start production on day one, without having the need to wait a long period of time to test validate and exploit their invention.

Fig. 9: Kneepad made of Hexaflex

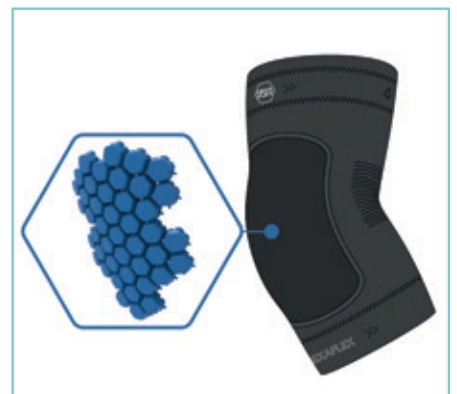


Fig. 10: Cable pass produced on New PAM Series P



Fig. 11 a, b: Haute Couture top and short in TPE produced via PAM technology



Fig. 12: Toys accessories (capes) (TPE 45 Shore A)



Fig. 13: Multi-material gripper (ABS, TPU 33 Shore D)

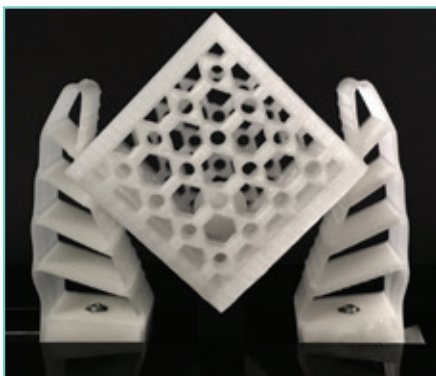


Fig. 14: Long belt (TPU 33 Shore D)



Fig. 15: Car headlight (TPE 33 Shore D)



COVID 19 – from protective visors to accelerating reallocation of factory

During the first phase of the COVID pandemic, Pollen AM teamed up with physiotherapists working in French hospitals to equip them with protective visors. 400 visors were produced and distributed to the professionals in need.

At the same time, one of Pollen AM's client and partner decided to shift one of its factory's production to manufacture hydroalcoholic gel. However, they were not geared to produce small personal bottles, and they used PAM technology to print the seals with a TPE 60 Shore A, allowing them to tremendously reduce their down time.

Pollen AM – in-house production of cable pass

Some of the parts in the New PAM series P are being manufactured directly by Pollen AM. This includes the cable pass, made of a TPU 33 Shore D (fig. 10). This direct production method allows Pollen AM not only

to be autonomous, but to adapt quickly its parts for special developments. So far 800 pass cables have been produced.

From fashion to the automotive sector, adaptation is key

With the versatility of additive manufacturing and the ability to process almost all (if not all) TPEs with the PAM technology, it is now possible to produce prototypes, tools, jigs and fixtures, parts in small and medium series using the same material as in injection molding without investing in specific tools. And shifting to large-scale manufacturing is made seamless, since the exact same materials are being used. The figures 12-17 show further examples of parts successfully produced with the PAM technology.

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All figures and tables, unless otherwise stated, have been kindly provided by the company Pollen AM.