Efficient Use of Materials through Recyclable Powder Mixtures

On the Road to a Circular Economy

Laser sintering has established itself in the industrial environment as one of the main additive manufacturing processes for functional prototypes and end-use parts made of plastic. However, there is still plenty of untapped potential for making more efficient use of cost-intensive starting material.

Many laser sintering (LS) users are failing to optimize the sustainable use of resources and avoid waste completely in this process. This failure results in squandered cost savings opportunities and the implementation of a closed-loop economy. The primary reason is that equipment and material manufacturers suggest that laser sintering needs an abundance of virgin material to yield replicable results. The unusable waste powder material that remains is all too frequently overlooked, but it can amount to two tons per LS machine per year.

There is a better option: GS-Pro GmbH processes waste material and returns it to the LS process in a closed material loop. The outcome is more efficient material use, waste minimization, and cost savings that combine similar levels of aesthetic and mechanical properties of the additively manufactured parts for improved overall quality.

Improved mechanical properties of PA12 parts as a result of closing the laser-sintering material loop. © Oerlikon AM Europe GmbH

Rising Demand for LS Standard Parts

Laser sintering keeps opening up new fields of application to a wide variety of industries. Aside from the creation of prototypes, which was the original application area for which volume demand is mostly low now, laser sintering is being increasingly called on to additively produce small series. In this connection, industries such as mechanical engineering and medical technology are becoming more and more prominent. These sectors are increasingly on the lookout for customizable, more-versatile production methods, and are mainly finding these in laser sintering.

The growing demand for standard parts and wider areas of application combined with greater production numbers and batch sizes means that the machine-utilization rate and the number of systems in use are increasing. However, a consequence of this trend is a sharp increase in additional consumption of starting materials.

Untapped Resources

Unfilled polyamide 12 (PA12) is the material most frequently employed for laser sintering because of its great ease of processing. Due to the nature of the LS process, only 5 to 15 % of the powder material used in a run can be converted into parts in an industrial production environment. The non-sintered waste powder will have been thermally stressed and is therefore of limited suitability for further use in downstream build jobs. For this reason, up to 45 % of the waste powder generated in conventional laser sintering applications usually winds up being either disposed of or routed to lower-value processes.

Given the high prices for PA12 virgin powder ranging from 45 to 100 EUR/kg, not only is the economic potential being poorly exploited by the absence of a material reprocessing system; but important resources are also being used inefficiently. To reduce the environmental impact and keep waste volumes down while exploiting existing cost-saving potential, the growing market for additive manufacturing must make efficient use of resources [1].

Circular Economy through Powder Reprocessing

Figure 1 shows an example of the powder loop for processing unfilled PA12 on EOS GmbH equipment. In conventional laser sintering, after a build process has been completed, large quantities of polymer powder are disposed of. With sustainability and the economics of industrial processes in mind, the goal of laser sintering should be operating a cyclical, completely closed material loop. GS-Pro's reprocessing technology for used waste powder fully closes this material loop and diminishes the levels of powder scrap.

Technology users should aim for closed material cycles that reduce waste to an absolute minimum and result in » material cost savings. This can be achieved by reprocessing and reusing the excess and thermally stressed waste material from the LS process, instead of sending it for disposal or repurposing to uneconomical industrial processes, as was previously the case. Simply stated, only that amount of virgin material is used for one LS build cycle, which on average is removed from the process in the form of a part over the many production cycles.

Excess Powder in the LS Process

In the course of the research project, it was asked: why has it not proved possible to completely reuse the powder material in a closed-loop process, so far? And why do typical surface defects occur when the content of waste material is too high? To clarify this issue, studies aimed at characterizing the powder material were carried out in conjunction with processing trials on different types of equipment.

The results of the thermo-analytical studies allow the conclusion that the PA12 powder employed is not demonstrably damaged during laser sintering. However, the rheological measurements observed have an increase in the melt viscosity for the old material compared to the new material. Scientifically, the increase in viscosity of the polymer melt induced by laser sintering is explained by a lengthening of the polymer chains in response to the long thermal stress on the powder material that is needed by the process. Thus the readings obtained provide information about the processing and service properties of the polymer powder samples that were investigated.

The changes which have occurred in the waste powder allow for surface defects in the powder mixture when excessive amounts of waste powder are used, as is the case in conventional laser sintering. These defects are known as orange peel.

Reducing Material Costs and Energy Consumption

Process implementation and processing of the GS-Pro reprocessed powder were carried out at Oerlikon AM Europe GmbH. It is proven that the powder reprocessing method employed and the adjustments made to the process parameters enable parts to be repeatedly manufactured with good quality and without surface defects. Moreover, the mechanical properties of manufactured parts possess improved elongation at break and impact strength, especially in the build direction. The results are shown in **Table 1**.

A cost calculation shows that approximately 30 % of the material costs arising from laser sintering can be recuperated by reusing the powder in a closed loop. Furthermore, energy consumption falls by nearly 45 % along the entire laser-sintering value chain because the materials are used more efficiently.

Based on the knowledge gained from the joint project, Oerlikon AM has decided to combine material processing with a closed-loop process to be able to offer its customers more efficiently produced and enhanced part properties with the same level of aesthetic part quality.

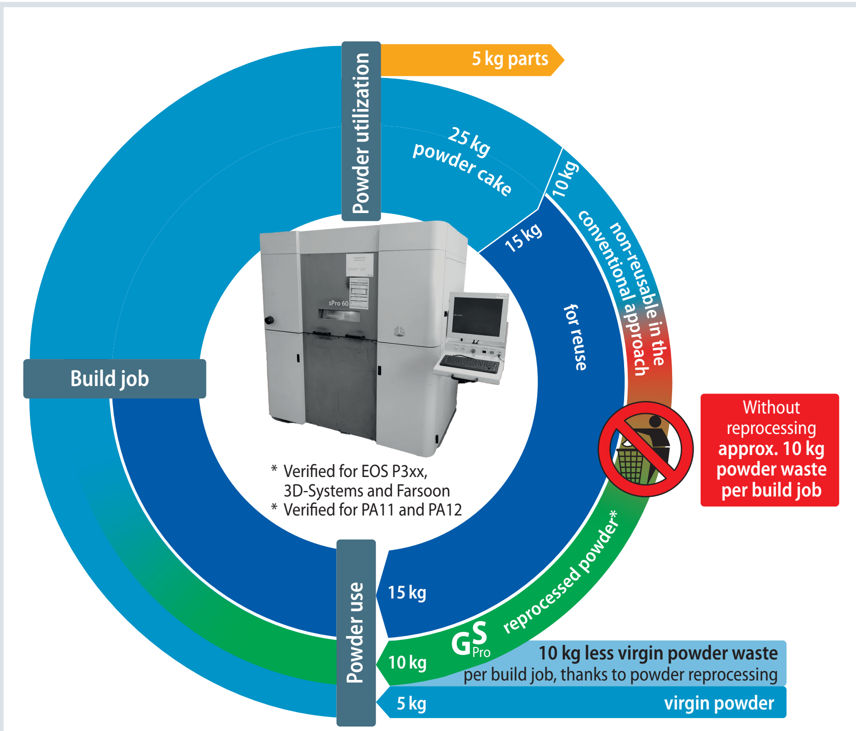

Fig. 1. Powder loop for PA12: without processing, almost 10 kg of potential material is lost per build job. Source: GS-Pro GmbH, graphic: © Hanser

Info

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Acknowledgments

The authors would like to thank the Federal Ministry of Education and Research (BMBF) for funding the "PowdeR²eSint" research project (FKZ 033R221) as part of the r+Impuls funding program.

References & Digital Version

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Mechanical properties	Unit	Standard	Alignment	Specification in material data sheet (EOS PA2201)	LS standard process (EOS PA2201 on EOSP3XX with 50 % virgin powder use)	LS process with powder recycling (EOS PA2201 on EOSP3XX with ≤ 25 % virgin powder input)
Elastic modulus	MPa	DIN EN ISO 527	X	1700	1720	1840
			Y		1710	1780
			Z		1770	1750
Tensile strength	MPa	DIN EN ISO 527	X	48	48.7	50.7
			Y		48.9	49.6
			Z		46.7	48.1
Charpy notched impact strength	kJ/m^2	ISO 179-1/1eA	X	4.8	3.96	4.01
			Y	N/A	3.87	3.93
			Z	N/A	2.38	3.96
Elongation at break	%	DIN EN ISO 527	X	15	19	22
			Y	N/A	20	21
			Z	N/A	6	15

Table 1. Results of the mechanical tests of the manufactured test specimens. Source: GS-Pro GmbH

Conclusion and Outlook

For years, powder reprocessing by GS-Pro has been an industrially applicable and proven development in laser sintering. The reprocessed PA12 material can already be used in all kinds of industrial production systems. Aside from PA12, reprocessing has been implemented for PA11 and PA12–12, thus avoiding powder waste for these polymers as well.

Powder reprocessing also makes for a more efficient use of resources. In some cases, it yields parts with improved mechanical properties, cost savings in production, and more stable laser sintering processes by lowering batch variations influence from virgin powder production.

Thus, greater production and cost efficiency while maintaining the same quality standards with greater sustainability is achieved. ■