

EOS Whitepaper

Part Property Management (PPM):
Standardization and comparability of
building processes and their results



Laser-sintering: the key technology for e-Manufacturing

The laser-sintering systems offered by EOS are the key technology for e-Manufacturing – fast, flexible and cost-effective production directly from electronic data. Plastic and metal components are expertly manufactured on these systems – for the demanding medical technology, toolmaking and aerospace industries among others.

Within the context of solving a technical challenge, the decisive factor in the implementation of a production process is usually an attractive cost/quality ratio. The manufacturing costs of some processes, especially those involving moulds, are highly dependent on the number of units required. This is not the case with laser-sintering. Furthermore, laser-sintering makes it possible to produce parts which are significantly more complex than those that have so far emerged from conventional processes. It enables the reproduction of the functionalities contained in several conventionally produced components or even complete assemblies in one single laser-sintered part. Often, e-Manufacturing can still offer significant potential savings for 5-figure quantities, which one might not expect.

Given today's technology, e-Manufacturing can offer levels of high or even extremely high quality for the requirements of many applications, also the more demanding ones, thereby fulfilling the most important prerequisites for being selected as a manufacturing process. That is why we see laser-sintering being adopted more and more for the production of series parts. Certain companies have already gained a lot of experience with laser-sintered components and are producing parts with

e-Manufacturing for applications such as medical instruments and surgical tools, gripping elements in the robotics industry, lampshades or architects' models, tools for injection moulding and die casting or even dental prostheses and implants. Nevertheless, in proportion to its potential, laser-sintering is still being considered too seldom for use as a manufacturing process.

Reasons for this, apart from the technology not yet being universally known, are often found in the lack of standards and data, or insufficient availability of and access to them. It is usually the designer who decides on the production method right at the beginning of the design process. If material data are not available at this stage to predict the properties of the planned parts, then laser-sintering is often only authorized for the production of prototypes.

Standardization and comparability of building processes and their results

The laser-sintering process has been implemented in today's systems with centrally developed and tested parameter sets. Historically, due to the origins of Rapid Prototyping, these parameter sets were defined for use in as many and as varied applications as possible. Case-by-case customization was therefore often an advantage or even a necessity. In prototyping, this flexibility is the foundation for pragmatic solutions and is subsequently a crucial success factor. In series production processes, however, this route reveals weaknesses. Besides the general advantages of standards in series production, case-by-case parameter adjustments of course always influence part properties in various different ways. Determining and specifying the individual parameters can be very complex, though, due to their large number and manifold interactions.

The alteration of individual parameters for the purpose of optimizing subgoals can cause, as is usual in complex systems, slightly undesired and surprising side effects. The development of stable, balanced parameter sets therefore demands systematic investigation, which involves long and comprehensive series of tests as well as significant costs. In certain cases this investment can be worthwhile for the individual manufacturer. For instance in order to gain a competitive advantage over the competition. In the majority of cases, however, it is far more efficient to work with the aid of centrally developed and tested standards.

EOS has picked up on this idea. Standardized parameter sets have been developed, each with a distinctive profile, and EOS guarantees the availability of, and access to, the corresponding material values. An important goal here has been to make the use of these profiles independent of the laser-sintering system and of the manufacturing company.

Part Property Profiles (PPPs)

EOS is now offering this standardization for all systems as so-called Part Property Profiles (PPPs). They provide reliable values for the dimensioning of laser-sintering designs. Among these are values for tensile strength, elongation at break, and moduli of elasticity for the horizontal X/Y-direction. Values for the orthogonal Z-direction have thus far been rather scarce in the area of additive layer processes but have now become standard.

The PPPs and their areas of application as exemplified by plastic laser-sintering

The definition of the PPPs arises from the typical requirements regularly requested today. Each planned part has to fulfil certain quality-relevant requirements to a varying degree and with varying focus with regard to surface quality, mechanical attributes, accuracy, detail resolution, to name just the important ones. Generally, quality targets and also cost targets have been prescribed. Since the quality requirements on the one hand mostly conflict with the need for low costs on the other, optimum compromises can be reached according to the individual part. The five PPPs, to which five parameter sets correspond, therefore focus upon the individual requirements, either on costs, on quality aspects, or on carefully balanced compromises.

1 TopSpeed, 180 µm layer thickness

TopSpeed is a very economical parameter set for parts with medium to high requirements of quality and mechanical load and high cost pressure. Particularly large and relatively thick-walled parts can usually profit from this layer thickness, mostly without any noticeable impairment from the fast build-up rates. In comparison with today's usual 120 µm layer thickness (EOSINT P 730) production costs are typically 15 - 20 percent lower. This layer thickness is ideal for parts which are sensitive to warpage whereby high levels of accuracy can be achieved.

2 Speed, 150 µm layer thickness

The Speed parameter set applies the classic 150 µm layer thickness (EOSINT P 390) which is popular and widespread on the market due to its all-round qualities. This parameter set offers slightly higher surface quality than TopSpeed and lowers production costs typically by 10 - 15 percent in comparison with the current 120 µm standard.



1 Balance, 120 µm layer thickness

The advantage of the Balance parameter set is equilibrium. The layer thickness of 120 µm offers a perfect balance between production costs, mechanical properties, surface quality and accuracy. It is therefore suitable for parts with varying geometries, dimensions and requirements.

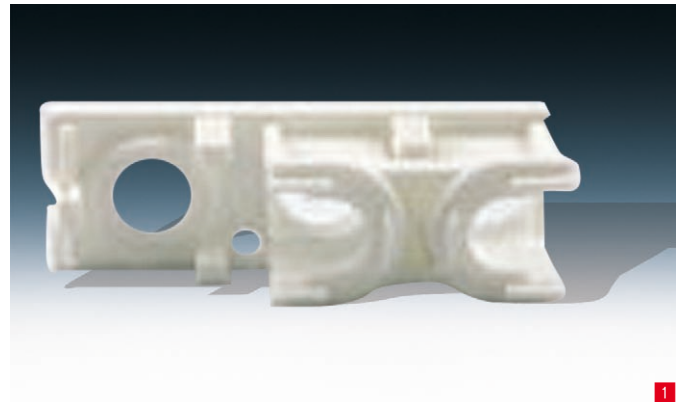
2 Performance, 100 µm layer thickness

Performance is the parameter set of choice for parts with high demands on mechanical properties and fracture behaviour, especially when the part is going to be subjected to multiaxial loading in all three directions. Performance parts are characterized by the highest degree of isotropic strength and rigidity. The choice of 100 µm layer thickness results in fine resolution and also very high surface quality and detail resolution.

3 TopQuality, 60 µm layer thickness

The parameter set **TopQuality** takes laser-sintering to completely new realms. Very small to medium-sized parts with extremely fine, fragile geometries and geometric elements and the strictest requirements in surface quality are best served by this parameter set. It applies a layer thickness of 60 µm, which is approximately the thickness of a grain of the plastic powder normally used today. The typical stair-step effect on upward and downward-pointing geometry elements can practically no longer be seen on TopQuality parts. The mechanical attributes of TopQuality parts are satisfyingly close to the levels of Performance parts.

The PPPs Balance, Performance and TopQuality are available for all EOSINT P and FORMIGA systems, TopSpeed and Speed for the EOSINT P 760 and EOSINT P 395. EOS will be making the entire characteristics of the Part Property Profiles available on M-Base, a public database which has been established by the plastics industry. To access it from the EOS website www.eos.info, please click on the link provided there to the **MaterialDataCenter**. Selecting EOS in the database will lead you to the PPPs.

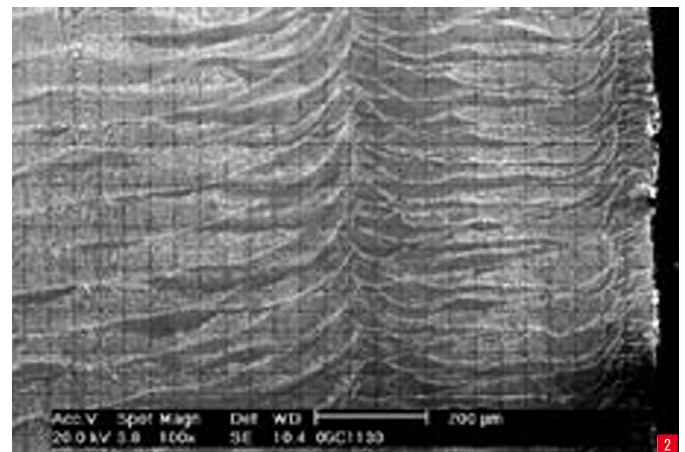
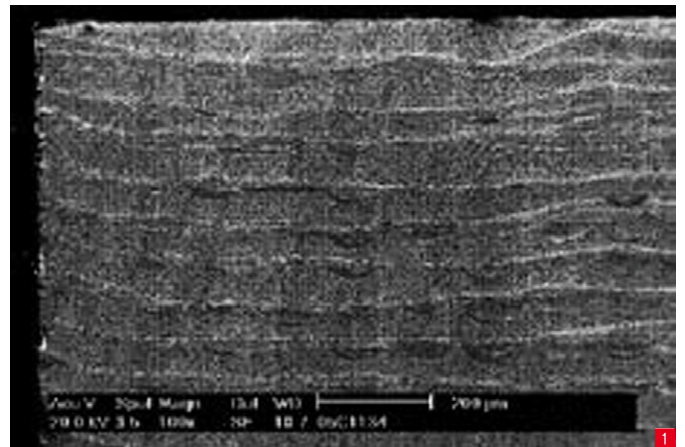


PPPs for Direct Metal Laser-Sintering (DMLS)

Similar parameter sets are also available for Direct Metal Laser-Sintering (DMLS) on EOSINT M 270 systems. Each material has a standard or reference parameter set with corresponding Part Property Profiles. Depending on application relevance, these PPPs typically include the following groups of properties:

- geometric properties such as minimum wall thickness and surface roughness
- mechanical properties such as tensile strength, yield strength, elongation at break, modulus of elasticity and hardness, and where applicable fatigue life
- thermal attributes such as thermal conductivity, specific heat capacity, thermal expansion coefficient
- properties affecting cost such as build-up rates (mm^3/s)

These properties are given for different states wherever relevant, for example before and after defined heat treatment. These PPPs can be obtained from the relevant material data sheets which are available from EOS on request. Parameter sets for the materials EOS StainlessSteel GP1, EOS StainlessSteel PH1, EOS MaragingSteel MS1 and EOS CobaltChrome MP1 are available for layer thicknesses of 20 μm and 40 μm . The parameter sets for 20 μm provide superior surface quality whereas those for 40 μm provide faster build-up rates. In general, the mechanical and thermal properties are almost identical for both parameter sets.



SEM micrographs of EOS CobaltChrome MP1 parts built with different parameter sets.

- 1 with 20 μm layer thickness throughout the entire object.
- 2 with 40 μm layer thickness in the core for rapid build-up combined with 20 μm layer thickness in the skin and contour regions for high surface quality. In both cases the metal was fully melted and the resulting parts are almost pore-free.

New hardware and software solutions enhance the PPPs

The new EOSINT P 760 and EOSINT P 395 systems – both of them evolutionary phases of the successful 7 and 3 series – can be upgraded with significantly improved process modules to optimally support the PPP strategy.

A completely re-engineered laser optics module (**Surface Module**) improves the quality of vertical surfaces into regions which until now have been exclusive to FORMIGA parts. For the PPPs with the highest quality requirements „Performance“ and „TopQuality“ the SurfaceModule is therefore obligatory. For the PPPs „Top-Speed“, „Speed“ and „Balance“ it is a highly recommended option.



The **OnlineLaserPowerControl (OLPC)** monitors and controls the laser's performance during the building process. The sensor's extremely high time resolution of several microseconds makes it possible for a CO₂ laser system of this kind to achieve hitherto unrealized laser performance consistency. It therefore fulfils the requirements of demanding applications for closed loop process control. The EOSINT P 760 can be optionally equipped with OLPC. EOS recommends the integration of OLPC for optimal use especially of the potential of the PPPs „Performance“ and „TopQuality“.

FlashRecoating, a new x-axis control, further increases productivity by accelerating the recoating speed up to 400 mm/s when the parameter sets for „TopSpeed“ and „Speed“ are implemented. With the appropriate packing density, build-up rates of up to 700 cm³/h are then realistic. FlashRecoating is available for the EOSINT P 760.

The recoating unit in the EOSINT P 395 has also been further improved. The introduction of PPPs has led to the integration into the EOSINT P 395 of EOS's highly successful blade cartridge concept that was introduced in 2007 in the EOSINT P 730, making it simple to carry out adjustments and change the layer thickness.

The new **EOSTATE 1.2** with its new array of report and analysis options is EOS's answer to the increase in demand for transparency and continuous quality assurance in series production processes. The software complements the PPPs perfectly.

Summary

The introduction of EOS PPPs will bring a wealth of advantages to all involved in the e-Manufacturing supply chain. These begin with the designer, who will now have access at all times to standardized property profiles as well as the corresponding material values relevant for dimensioning. People in purchasing and quoting will profit from the clearly defined quality levels. These will make quotes comparable, the quoting process more efficient and eliminate expensive misunderstandings. On the manufacturer's side, the PPPs will also exert efficiency-increasing and cost-reducing influence on the data preparation and production planning subprocesses. Other aspects of data preparation can be automated because the allocation of the parameter sets will already have been prescribed by the designer with the choice of PPP. The system-wide validity of the PPPs creates flexibility in production planning. Ultimately, the quality assurance processes also profit from the defined standards and improved transparency.

Laser-sintering is taking one more large step towards becoming a fully established manufacturing method which, due to its unique strengths, can help improve established products and processes and then enable the creation of completely new products.

Authors

Thomas Mattes, Vice President

Technical Management P and Crossfunctions

Thomas Mattes graduated in mechanical engineering/aerospace technology at the Technical University of Munich, institute for light-weight design and completed his studies with a thesis on novel calculation methods for anisotropic fibre composite components. Mattes joined EOS as a system developer in 1994. In this role Mattes was responsible for the basic conceptualization, the development of the first generation of metal laser-sintering systems and of the S Technology. At the same time he took over the project lead for the development of the EOSINT S 700. In 1998, Mattes took over full responsibility for the development department which included systems, materials and software. Since 2006 he is the Vice President Technical Management P as well as heading software development, quality management and production across systems. He has more than 15 years of experience in the Rapid Prototyping and Manufacturing industry and published a number of articles around and presented on RP and other topics related to laser-sintering.



Florian Pfefferkorn, Product Manager

Florian Pfefferkorn graduated in mechanical engineering at University of Applied Science Munich, where he also wrote his thesis on "production planning and control in the foundry industry".

After 2 years working in quality management for the Ariane-5-Booster-Production, Pfefferkorn started his career at EOS GmbH in 2001, where he developed customer applications for the plastic laser-sintering.

2003 he took over responsibility as team leader of the Product Support for plastic laser-sintering. In 2005 he became Product Manager for the EOS Product line plastic laser-sintering. He has more than 8 years of experience in the Rapid Prototyping & Manufacturing industry.

