Direct Manufacturing Design Rules 2.0

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As additive manufacturing processes create parts layer by layer without using formative tools, they have a great potential to provide new design freedoms to their users. To publish these freedoms and to support a suitable design for manufacturing, comprehensive design rules for additive manufacturing are required. Within the "Direct Manufacturing Design Rules" project (DMDR) design rules for additive manufacturing processes were developed. At the end of the DMDR project, the developed design rules applied only for the considered boundary conditions. Thus, the "Direct Manufacturing Design Rules 2.0" project has the aim to extend the range of validity for the developed design rules.

Design Rules given by the DMDR project

In order to develop design rules, standard elements were defined first. These are geometrical elements, which often reoccur by designing technical products. Based on these elements a process independent method for the development of design rules was set up. Using this method, design rules were developed for the laser sintering, laser melting and fused deposition modeling processes. Therefore the machines Eosint P395 (laser sintering), SLM 250HL (laser melting) and Fortus 400mc (fused deposition modeling) were used. For each machine one common parameter setting was considered with one material. So, for the laser sintering process the material PA2200, for the laser melting process stainless steel 316L and for the fused deposition modeling process Ultem were used.

How the material, the according parameter settings and the machine itself do influence the geometrical quality of the considered elements is unknown. Because of this, the developed design rules are only applicable for the described boundary conditions, which were considered within the DMDR project (Figure 1).

Objectives

In general, design rules for additive manufacturing technologies, which can

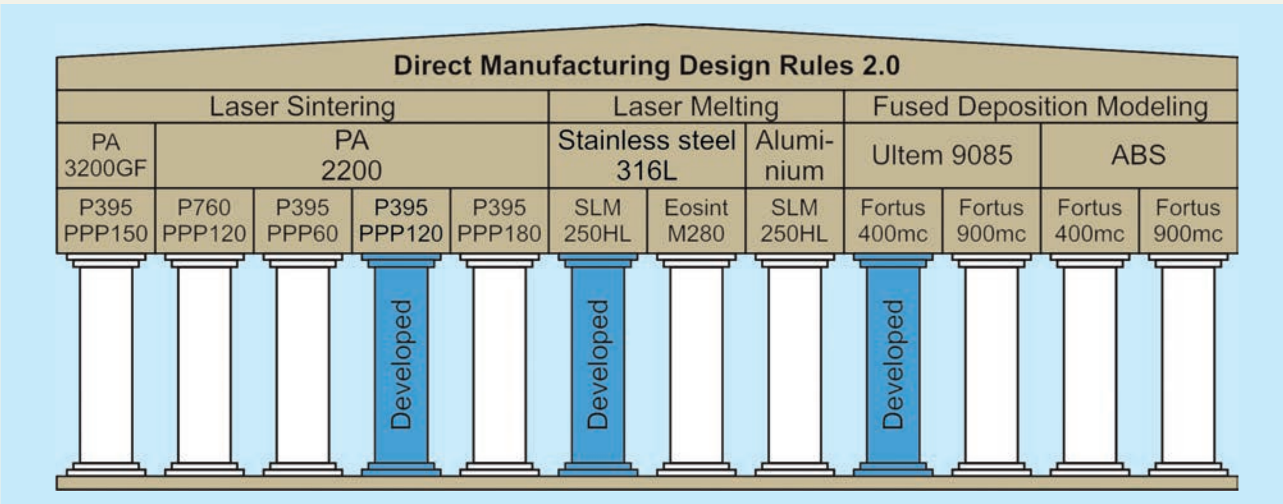


Figure 1: Range of validity for the developed design rules before (blue pillars) and after (white pillars) the DMDR 2.0 project.

be used for training and teaching, need to be applicable for different boundary conditions. Thus, the research project “Direct Manufacturing Design Rules 2.0” (DMDR 2.0) has the objective to extend the range of validity for the developed design rules.

Using the method given by the DMDR project, it shall be proven if the developed design rules apply for different boundary conditions, too. Different materials, manufacturing machines and parameter settings will be considered (Figure 1). As a result, the validity range will be extended and (in case of success) the transferability of the design rules to different boundary conditions is possible.

Adaption of the design rule catalogue

A main result will be the adaption of the design rule catalogue. The catalogue was developed within the DMDR project and will be adapted with the results of the DMDR 2.0 project. Therefore the results of both the DMDR project and the DMDR 2.0 project will be analyzed and compared. It will be analyzed if the design rules given by the DMDR project fit for all considered boundary conditions. The results will be interpreted and if necessary, the design rule catalogue will be extended with additional design rules.

Latest results

During this year, the extension of the design rules was investigated for laser melting. Therefore, the material was varied from the reference material 316L to aluminum (AlSi7Mg) and tool steel (15-5PH). Also, within spot-checks, the EOSINT M280 machine has been considered. Thereby, all measurement curves show very similar characteristics (Figure 2). For example, large deviations occur for small nominal thicknesses.

The analysis of the results clearly indicates that in most cases the regular descriptions of the prior developed design rules are applicable for different boundary conditions in laser melting. However, varied boundary conditions lead to different numerical values for which the general descriptions become valid. These numerical values are stated within the specific descriptions of the design rules (Figure 3). Both the regular and specific descriptions provide the information that is required to design parts that shall be manufactured with certain boundary conditions.

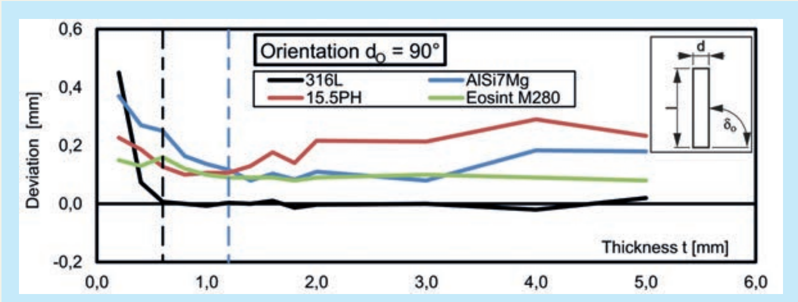
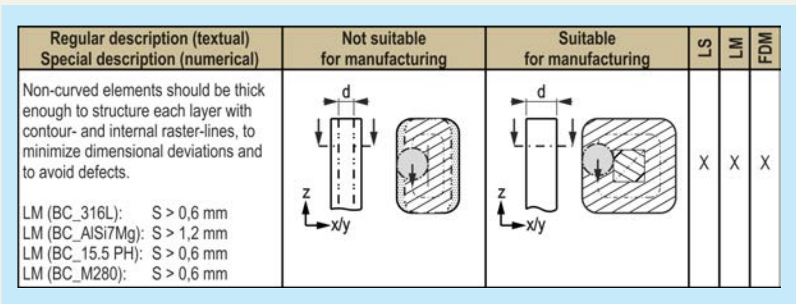


Figure 2: Measurement values for thicknesses of walls for different boundary conditions in laser melting.



Regular description (textual) Special description (numerical)	Not suitable for manufacturing	Suitable for manufacturing	LS	LM	FDM
Non-curved elements should be thick enough to structure each layer with contour- and internal raster-lines, to minimize dimensional deviations and to avoid defects. LM (BC_316L): S > 0,6 mm LM (BC_AlSi7Mg): S > 1,2 mm LM (BC_15.5 PH): S > 0,6 mm LM (BC_M280): S > 0,6 mm	d z x/y	d z x/y	X	X	X

Figure 3: Design rule for different boundary conditions for laser melting.