Direct Manufacturing Design Rules

Additive manufacturing creates parts in layers and without formative tools. Thereby, new freedoms and restrictions arise. To publish these, comprehensive design rules are required. Such design rules were developed in the Direct Manufacturing Design Rules (DMDR) project. Because the validity of these design rules was limited to only a few considered boundary conditions, the Direct Manufacturing Design Rules 2.0 project has the aim to extend the range of validity. Therefore, the tests of the DMDR project were repeated with various machines, materials and parameters. As result, a design rule catalogue for various boundary conditions is given.

1. Objectives

Within a first project, named Direct Manufacturing Design Rules (DMDR), design rules have been developed that point out possibilities and restrictions for additive manufacturing. These design rules were developed based on standard elements. 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 Laser Sintering, Laser Melting and Fused Deposition Modeling. For each technology, one common combination of material and parameter setting was considered. This proceeding fostered the design rule development but limited the range of validity for the developed design rules.

In general, design rules for additive manufacturing technologies, which shall 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. It shall be proven if the developed design rules apply for different boundary conditions, too. Therefore, different materials, manufacturing machines and parameter settings shall be considered.

2. Procedure

In order to extend the range of validity for the prior developed design rules, the tests of from the DMDR project will be repeated with other boundary conditions. These comprise different boundary conditions in Laser Sintering, Laser Melting and Fused Deposition Modeling.

Within the tests, standard elements have been built with different attribute value variations and different manufacturing boundary conditions. For instance a wall was built with a thickness of t = 0.2, 0.4, 0.6 … 5.0 mm. Next, the thickness of the manufactured wall was measured and the thickness-deviation calculated. By displaying the measurement curves in one diagram, commonalities, differences and general trends can be investigated (Figure 12).

3. Latest results

Within the year 2016 investigations for Fused Deposition Modeling were mainly in focus. Therefore, geometrical test specimens – standard elements – were manufactured with different combinations of the materials Ultem, PC and ABS with the machines Fortus 400mc and Fortus 900mc and parameter settings for tip sizes T10, T12 and T16. Afterwards, the measurement results were

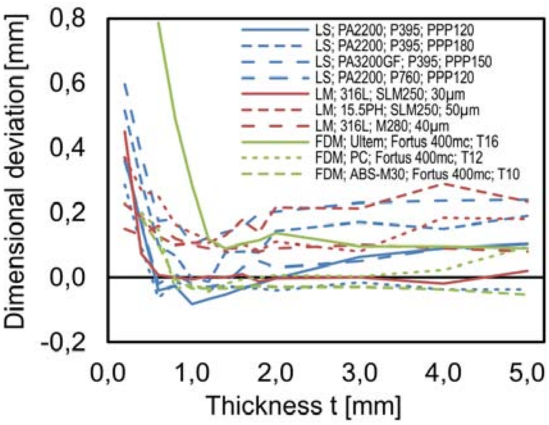

Figure 12: Dimensional deviations for walls manufactured with different thicknesses and boundary conditions

compared to results from Laser Sintering and Laser Melting (Figure 12).

Based on the comparison of the measurement results, crossprocess analysis of the results were possible. Thereby, in nearly all cases, the developed findings proved that the textual descriptions of the design rules are applicable for different boundary conditions while the numerical values change in dependence of the boundary condition. This is exactly the same finding like for Laser Sintering and Laser Melting (Figure 13).

Summarizing, the Direct Manufacturing Design Rules 2.0 project now provides a design rule catalogue for Laser Sintering, Laser Melting and Fused Deposition Modeling, which contains design infomation for various manufacturing boundary conditions.

4. Outlook

Within the next step, a general proceeding for the design rule development will be deduced. This will give guidance on how to develop individual design rules.

Also the results and findings will be implemented in seminars, publications and lectures in order to spread the developed knowledge.

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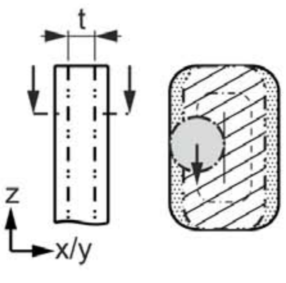
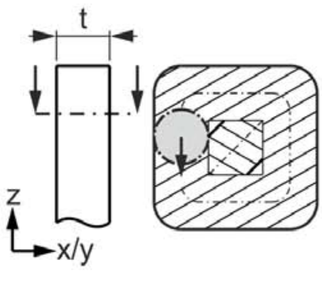
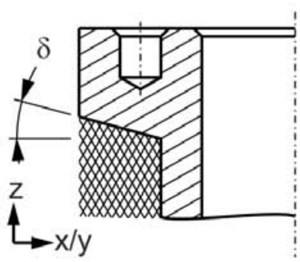
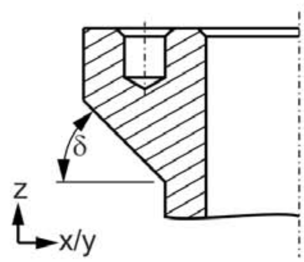
Description		Not suitable for manufacturing	Suitable for manufacturing
Thicknesses of non-curved elements should be thick enough to structure each layer with contour and raster lines			
LS (Pa2200, PPP120)	t > 1.0 mm		
LS (...)	t > ...		
LM (316L, 30 µm)	t > 0.6 mm		
LM (...)	t > ...		
FDM (Ultem, T16)	t > 1.5 mm		
FDM (...)	t > ...		
Angle of a downward facing surfaces should be large enough to avoid solid support structures			
LM (316L, 30 µm)	d > 45°		
LM (...)	d > ...		
FDM (Ultem, T16)	d > 35°		
FDM (...)	d > ...		

Figure 13: Design rule examples for the thickness of walls and the angle on a downward facing surface