Design Rules for DMLS

This document provides guidelines on how to design parts to be built using Direct Metal Laser Sintering (DMLS) with EOSINT M systems in order to ensure high quality and cost-effective results. It is aimed particularly at designers wishing to use DMLS for the first time or to compare it with other technologies, e. g. companies wishing to test the method, but it should also be useful as a reference guide to occasional or experienced DMLS users.

It particularly relates to tooling applications (DirectTool) such as building inserts for injection moulding tools, but the guidelines are also applicable to other applications such as building positive parts (DirectPart).

1   Geometries

The DMLS process creates parts additively by fusing powder particles rather than the conventional methods of material removal. This means that the conditions under which the DMLS process can be used cost-effectively depend strongly on the geometry to be built and attention should be paid to designing the geometry appropriately, as indeed it should be for any manufacturing method.
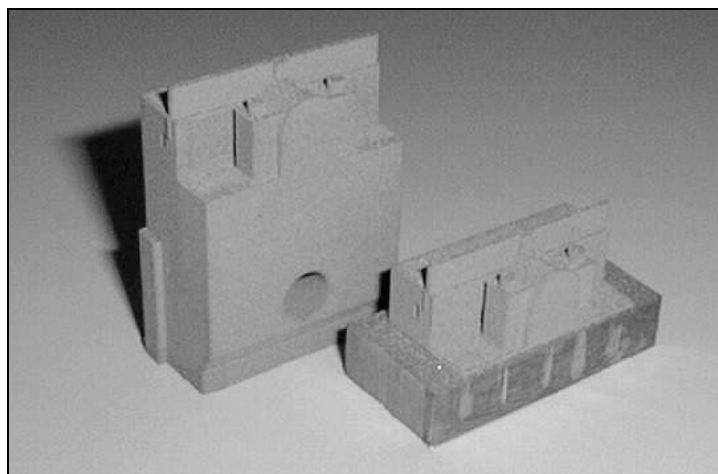

Fig. 1: left: bolt in original format   right: bolt optimized for building time

There is no general rule about when which fabrication process (e. g. milling, EDM, DMLS) should be used. A part that can be milled with little effort should generally be milled. It usually only makes sense to apply the laser-sintering process in cases where EDM (spark erosion), five axis milling or multiple clamping positions would normally be required. Before a decision is taken about how the corresponding tool or part can be fabricated in the most economical way, an estimate about the production times with the different processes must be made. Attention should be paid to the fact that in the DMLS process only the relevant geometries should be built and superfluous volume should be avoided if possible.

This is particularly relevant for tool inserts. As for all generative, layer-wise fabrication processes it is not the complexity of the geometry that determines production time and costs, but rather the build volume (amount of material to be solidified) and height (number of layers). The inserts should be as small as possible in x-, y- as well as in z-direction to keep the building process as short as possible and thus to save costs (Fig. 1).

The tool insert displayed in Fig. 2 left side, is produced much faster and thereby more cost-efficiently if only the relevant geometry, i. e. the actual cavity, is built. The optimized version is shown in Fig. 2 right side. As shown, it is also preferable for external corners to be round rather than sharp.
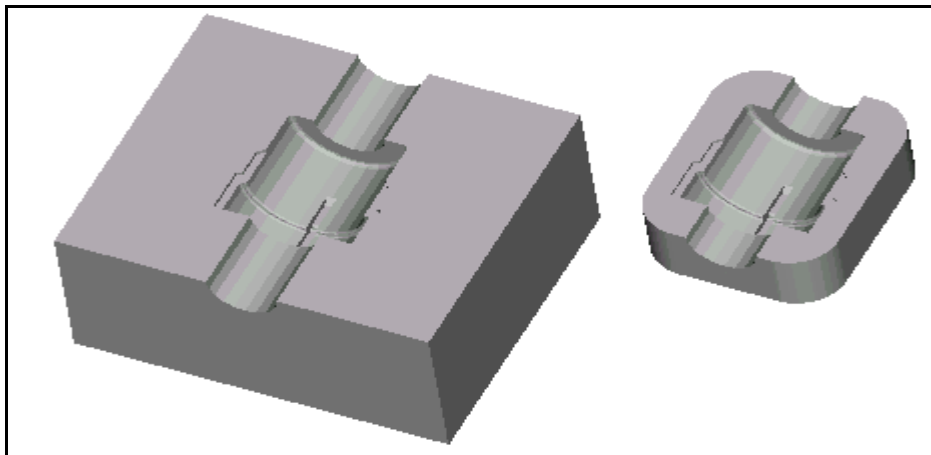

Fig. 2:   left: unfavourable tool geometry,   right: optimized geometry
as too much volume have to be sintered

For tool cavities, a wall thickness of about 10 mm around the relevant structures is in most cases sufficient (DirectSteel **H**20 about 5 mm). The design of the massive substructure for the ejector side of the tool in Fig. 3 is extremely time-consuming. Here it would make sense to fabricate only the complex rib structure in the upper tool area by DMLS and to insert it afterwards into a substructure fabricated in parallel using a conventional process.
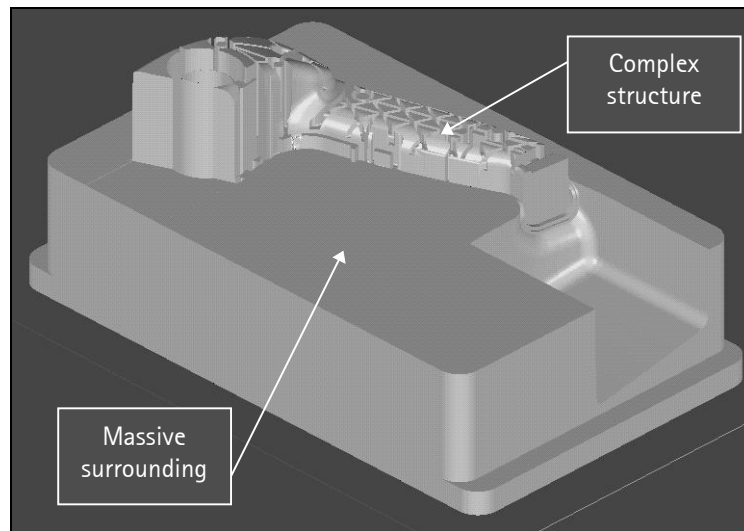

Fig. 3: Tool insert with unfavourable geometry

When designing the tool insert it must be taken into consideration to use the building platform, a steel plate of typically 22 or 36 mm thickness, as a part of the insert. The laser-sintered part is built on the steel plate and metallurgically attached to it, afterwards the surrounding part of the plate is removed by e.g. sawing and milling or wire cutting.
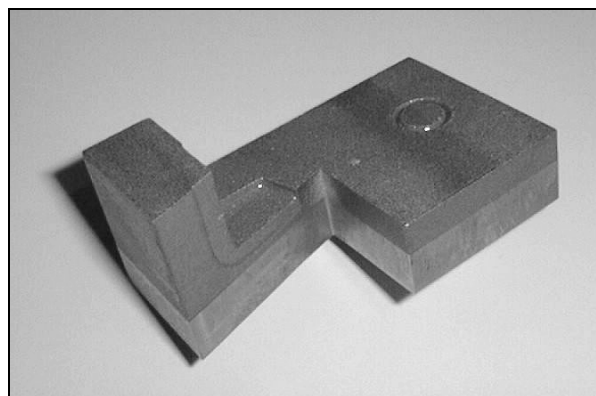

Fig. 4: Building platform as a part of the tool insert

This procedure offers the advantage that the stable steel plate can serve as a fixation in the mother tool, that highly stable guides are available for the ejectors and that fabrication time is saved as this part of the tool does not has to be built.

Of course it is also possible to build the parts on support structures, e. g. positive parts (DirectPart). These parts remain fixed to the base plate during the building process via a support structure and are separated afterwards by breaking away the supports. It is not possible to build "detached" parts as can be done for plastic laser sintering.

Overhangs up to an angle of approx. 25° can be built without requiring a support structure.
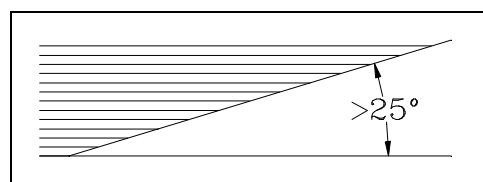

Fig. 5: minimum building angle
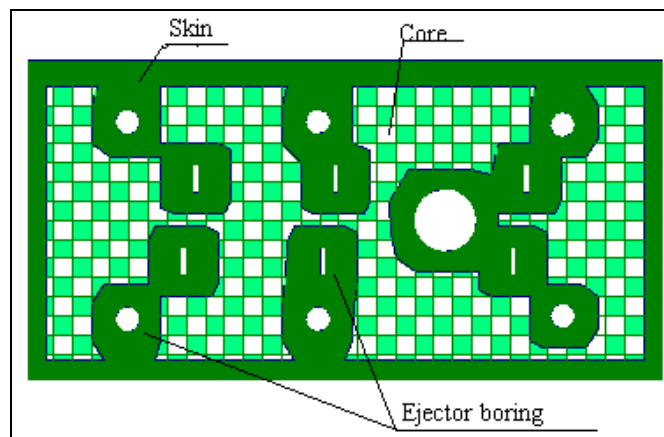
2 Drill holes / Skin & Core

Fig. 6: View of one layer in skin & core structure with integrated ejector bores

All drill holes for ejector pins, holes for fastening screws or similar features should already be provided in the CAD design. This is necessary as DMLS tools are typically built in a so-called Skin & Core structure.

Here the part volume is divided into a so-called Skin area (shaded area in Fig. 6) and Core area (chequered area in Fig. 6), which are exposed with different parameters during the building process and can even be built up with differing layer thicknesses. Typically, the Skin is selected to be 1mm thick (3 mm for DirectMetal 50) in x, y and z direction and built in a layer thickness of 0.02...0.05 mm (e. g. 0.02 mm for DirectMetal 20, 0.05 mm for DirectMetal 50). The layer thickness of the Core is 0.06 … 0.1 mm. The Skin is exposed with building parameters which give maximum strength and hardness, while the Core is exposed faster. In this way the building time can be significantly decreased without loss of surface quality while maintaining a high part stability.

If drill holes have not been provided in the CAD file and are added later, the hole is located in the mechanically less stable core area. This can for example lead to the subsequently tapped thread breaking out.

Additionally the external boundaries of each layer are exposed as a Contour with a very high laser power which leads to a very high stability. The area of increased stability is about 0.5 mm deep below the surface. When post-processing up to this depth, the best results concerning surface quality and surface hardness are obtained (Fig. 7).
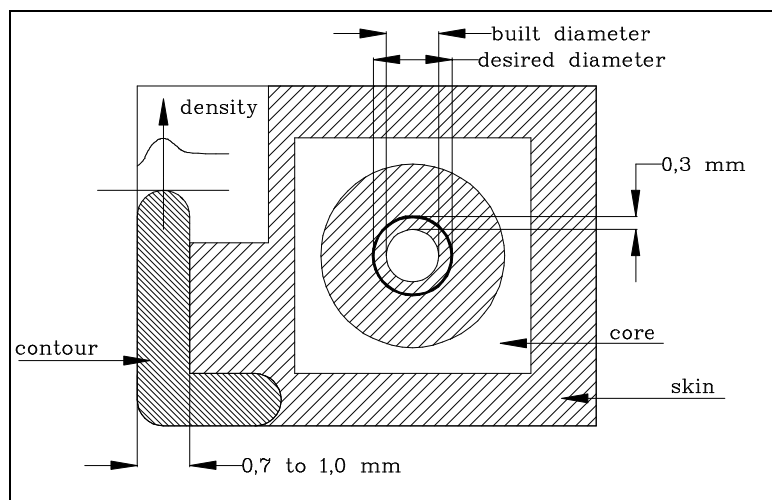

Fig. 7: Drill holes and increased density in the marginal area through Contour exposure

We recommend therefore to design the diameter of the desired drill-holes in the CAD file about 0.6 mm undersized and to rebore them afterwards. The side walls of the drill-hole are then within the highest solidity area of the contour (Fig. 7).

3 Accuracy

As the parts are generated from metal powder, the surface roughness and the geometrical accuracy lies within the range of the powder grain size.

The achievable part accuracy depends on which powder material is used, varying from about ± 50 µm for DirectMetal 20 to about ± 100 µm for DirectSteel 50.

The resolution in the vertical direction (perpendicular to the layers) is determined by the layer thickness. For DirectMetal 20, DirectSteel 20 and DirectSteel **H**20 it is typically 0.02 mm, for DirectMetal 50 and DirectSteel 50 it is 0.05 mm. You will find further details in the Material Data Sheet.

For DirectMetal 50 (grain size approx. 50 µm) accuracies of ± (0.05 % + 50 µm) are obtainable. Due to the slightly higher shrinkage during exposure and the smaller powder particle size the obtainable accuracy for DirectMetal 20, DirectSteel 20, DirectSteel **H**20 and DirectSteel 50 ± (0.07 % + 50 µm). [Wiederholung des letzten Absatzes!]

4 Minimum structures

For the DMLS process, the focussed laser beam with a diameter of approx. 0.4 mm is equivalent to the tool for fabricating the geometry. The sintering width is a little higher than the focal diameter due to heat conductivity effects.

As with other processes, structures smaller than the used tool cannot be produced, although with DMLS the "tool" size defines the minimum external feature size (e. g. wall thickness) rather than internal feature size (e. g. slot width). The minimum sintering width is approx. 0.6 mm for DirectMetal 20, 0.7 mm for DirectMetal 50 and DirectSteel 20, 0.8 mm for DirectSteel H20 and 0.9 mm for DirectSteel 50.

If structures smaller than this are contained in the geometry to be built, they cannot be built correctly. This must be considered carefully, especially for sharp corners and edges.

5 Slots

If there are deep slots in the geometry, it has to be taken into consideration that due to the surface roughness of vertical planes, post-processing will be necessary or draft angles must be adapted. For slots which are accessible for grinding and polishing, draft angles of 0.5° to 1.0° are sufficient. If the slot is not accessible, this value must be increased. If this is not possible for geometrical reasons, the tool should be split at this feature and the planes should be treated afterwards. The inserts are then assembled afterwards.
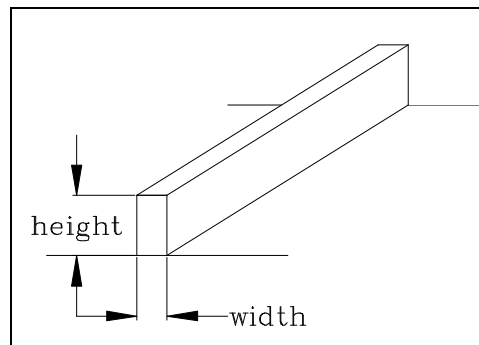
6 Ribs

Fig. 8: Ribs

To ensure reliable performance of injection moulding tools even under high loading, it is recommended not to exceed the height-width ratios marked white in Fig. 9 for DirectSteel **H**20 (Fig. 10 DirectSteel 20, DirectSteel 50, DirectMetal 20 Fig. 11 for DirectMetal 50)

	Height [mm]					
	<5	5	10	30	50	>50
Width <1						
1						
2						
3						
5						
>5						

Fig. 9: Rib Structure DirectSteel **H**20

	Height [mm]					
	<1	1	10	20	30	>30
Width <1						
1						
2						
3						
5						
>5						

Fig. 10: Rib Structure DirectSteel 50, DirectSteel 20, DirectMetal 20

	Height [mm]					
	<1	1	2	5	10	>10
Width <1						
1						
2						
3						
5						
>5						

Fig. 11: Rib Structure DirectMetal 50

If higher height-width ratios are required it is recommended to use steel inserts, as shown for example in Fig. 12.
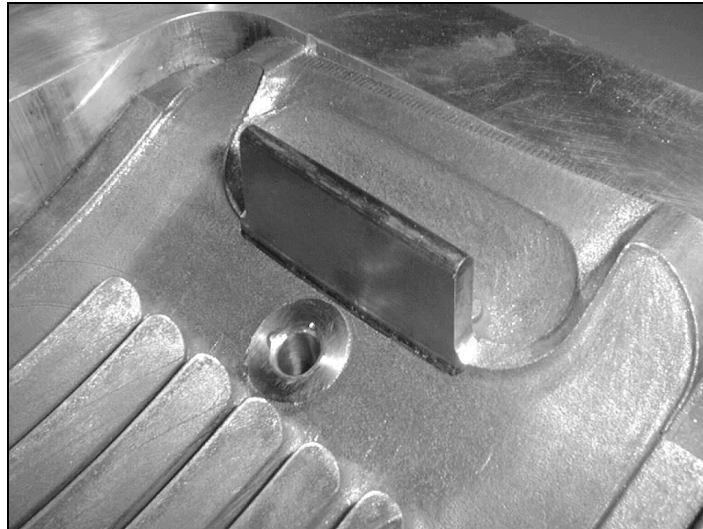

Fig. 12: Machined steel insert

7 Pins

The same is valid for pins located in the tool to be fabricated.

For round geometries it is generally recommended that pins are inserted into drill-holes previously designed in the CAD file, as this enables highly accurate and very strong pins to be obtained with minimal effort.
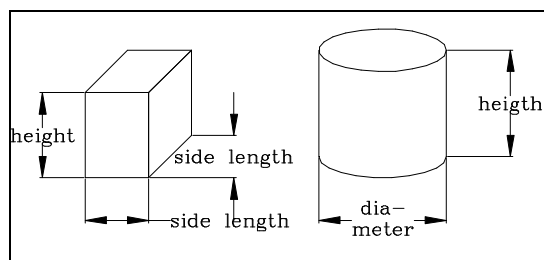

Fig. 13: Pins and domes

For non-cylindrical geometries inserts should also be used for the height-length ratios marked grey in Fig. 14, Fig. 15 and Fig. 16.

	Height [mm]					
	<5	5	10	15	20	>20
Side length / <1						
Diameter 1						
2						
3						
5						
>5						

Fig. 14: Design of pins DirectSteel H20

	Height [mm]					
	<1	1	2	5	10	>10
Side length / <1						
Diameter 1						
2						
3						
5						
>5						

Fig. 15: Design of pins DirectSteel 20, DirectSteel 50, DirectMetal 20

	Height [mm]					
	<1	1	2	5	10	>10
Side length / <1						
Diameter 1						
2						
3						
5						
>5						

Fig. 16: Design of pins DirectMetal 50

8 Gating channel

To avoid erosion at the gating channel when using abrasive plastics, this should also be prepared already in the CAD file. The Contour exposure increases the surface hardness and thus an improvement of wear behaviour is achieved.
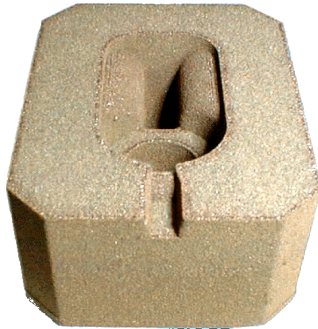

Fig. 17: Tool insert with integrated gating channel

9 Cooling channels

Using the layer-wise building technique it is possible to create 3-dimensionally curved cooling channels within the tool, adapted to the injection mould geometry (conformal cooling). This enables a much more effective cooling to be obtained during injection moulding (Fig. 18).

When designing the cooling channels, care should be taken to plan the connections in such a way that no unnecessary volume has to be built. For example it is possible to lay the connections directly into the steel plate. After the laser-sintering the holes are bored at the corresponding places through the steel plate and the loose powder is removed from the channels. Afterwards the cooling channels can be sealed with Epoxy resin.
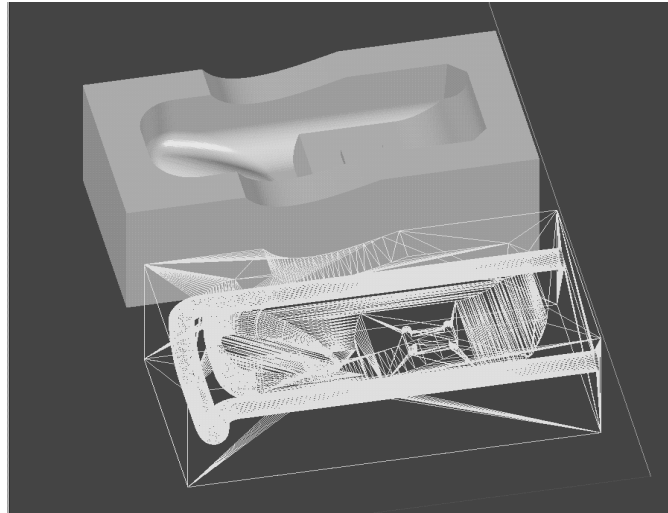
Fig. 18: Tool insert with integrated 3D conformal cooling channels

10 Machining allowances

When fitting the inserts into the mother tool, the edges are usually milled. A machining allowance of 0.1 mm to 0.5 mm should be planned on every relevant area.

It is generally not necessary and not recommended to post-machine the parting surfaces of tool inserts. These are typically post-processed by micro shot-peening and if necessary touched up with manual filing and polishing. The surface offset is added during the data preparation of the laser-sintering job if necessary and therefore does not need to be included in the CAD file.

11 Assembly into the mother tool

When assembling the mother tool it is important to ensure that the parting plane load or the locking pressure of the injection moulding machine rests at least partially on the mother tool. For optimum moulding time it is also advisable to mount the inserts comprehensively in the mother tool and thus to have the pressure load rest on the mother tool during injection moulding, i. e. there should be no gap between the DMLS inserts and the mother tool.

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12 Data quality and transfer

A basic rule is: The higher the data quality is, i. e. the clearer the design is, the shorter is the time required for data preparation, and the higher is the part quality. It is therefore necessary to remove all superfluous information from the STL data generation, which means to clean the file. All planes must unequivocally intersect with each other and be trimmed etc.

Possible file formats are: *.STL, *.IGES, *.VDA.

The mesh density when generating *.STL data should be not coarser than one layer thickness (e. g. 50 µm resolution for DirectMetal 50 and 20 µm resolution for DirectSteel 20).

i	Using a resolution (triangulation) which is finer than necessary can lead to very large file sizes

Sensible CAD settings for STL export:

- Maximum triangle size: 10 mm
- Chord error: 0.01 mm.

12.1 Data transfer via e-mail

E-mail address: application_m@eos.info.

Data can be transferred as a file attachment to an e-mail.

The above-mentioned address is a collect account. From the subject line of the e-mail it must be clear for which recipient the message is destined.

Personalized e-mail addresses are also available (name@eos.info), but please send a copy also to Application_M@eos.info in order to avoid delay if the addressee is not in the office.

i	To speed up the data transfer and to keep transmission costs low the data should be compressed (e. g. *zip*, *arj*, *mgx*).

12.2 Physical data carriers

- CD-ROM: ISO 9660 format
- Disc: Preferred: 3.5", DOS formatted.

12.3 Alternative data transfer

If necessary you can transfer data also via ISDN with Euro File Transfer (EFT).

- Transfer protocol: EFT

- Access software: TELES, Fritz.

Please contact our IT department directly: Phone: +49 (0)89 / 893 36-254.

i	Data transfer according to ODETTE is not yet possible.

12.4 General

i	To speed up the data transfer and to keep transmission costs low the data should be compressed (e. g. *zip*, *arj*, *mgx*).

Compression programs: *PKZIP* or *ARJ*.

13 Check list

1 Part geometry	
Get only the moulding structures built?	
Are the exterior dimensions as small as possible?	
Wall thickness for cavities: 10 mm (5mm for DirectSteel **H**20)	
Inserts should have round corners (e. g. Fig. 2) Radius 10 or 20mm	
Is the building platform (thickness: 22mm or 36mm) to be used as part of the tool?	
2 Drill holes	
Are all drill holes designed into the CAD file?	
Ejector drill holes	
Gating system drill holes	
Threaded holes designed as simple holes (1mm smaller than destined diameter)	
Diameter of drill holes in CAD file 0.6 mm smaller than destined diameter	
4 Minimum structures	
Can sharp edges and corners be avoided?	
Are the structures smaller than 0.6 mm?	
5 Slots	
Are there draft angles for deep slots?	
Are the slots well accessible for grinding and polishing?	
Does the tool have to be split?	
6 Ribs	
Should steel ribs be inserted?	
Are the pockets required for this provided in the CAD data?	
7 Pins	
Plan cylindrical pins as inserts!	
Should non-cylindrical pins be planned as inserts?	
8 Gating channel	
Is there already a gating channel in the CAD file?	
9 Cooling channels	
Can 3-dimensionally laid cooling channels be used?	
Are these close to the modelling geometry?	
Can the building time be kept to a minimum?	
10 Operational overmeasures	
Has machining allowance been added for the fitting of the inserts into the mother tool?	
Has machining allowance been added to the parting planes?	
11 Mounting into mother tool	
Are the inserts mounted comprehensively?	
Does the locking pressure rest on the mother tool as well or only on the inserts?	
12 Data quality	
Do all planes intersect?	
Have all double planes been removed?	
Is the mesh density set to a suitable value for the STL generation (e. g. 0.02mm for DirectSteel 20 or 0.05 for DirectMetal 50)?	