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Fabrication and characterization of low-alloyed tool steel obtained by Selective Laser Melting

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The present work explores the capability of fabbricating low-alloyed metal parts through the layer-by-layer Selective Laser Melting (SLM) technique. The alloy used was AISI S2, which is a carbide-free tool steel made of 0,49%wt of Carbon. Such kind of steels are not popular as for Additive Manufacturing process due to their unpromising welding properties. However, obtained results demonstrated the feasibility of printing fully dense, defects-free with good surface quality low-alloyed steels. A process map containing the optimum set of parameters for the realisation of the S2 metal parts will be presented. Indications for the use of the same process map in the situations of different process conditions or different manufactured steels will be provided as well. Later, the printed pieces were subject to microstructural investigation under their as-build and heat-treated conditions. The outcomes showed a epitaxial grain growth strongly influenced by the scan strategy. Moreover, the outermost top layer consisted of supersaturated martensite which was characterized in order to gain information about the prior microstructure which was present. Whereas the rest of the cross-sections of the as-built samples were found to have bands of tempered martensite at various degrees of tempering. The cause was related to the complex thermal history of the SLM process. In order to achieve all the results several unique techniques have been used such as reverse Differential Thermal Analysis, post-processing heat treatment and nanoindentation. The latters were used in less common ways to obtain a deeper knowledge of the microstructure of S2 metal parts printed through SLM techinque, showing promising results.

The following Figures will be used to explain the most important outcomes obtained in the project.

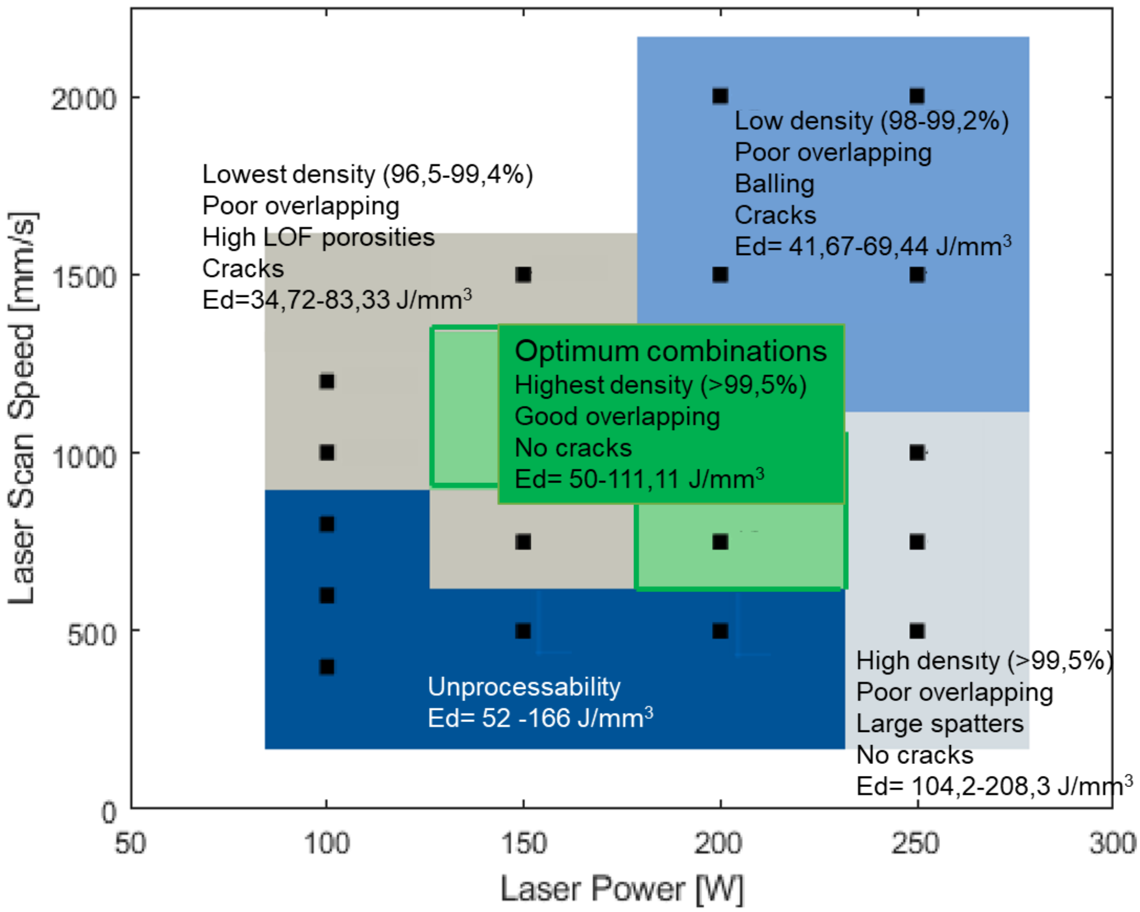
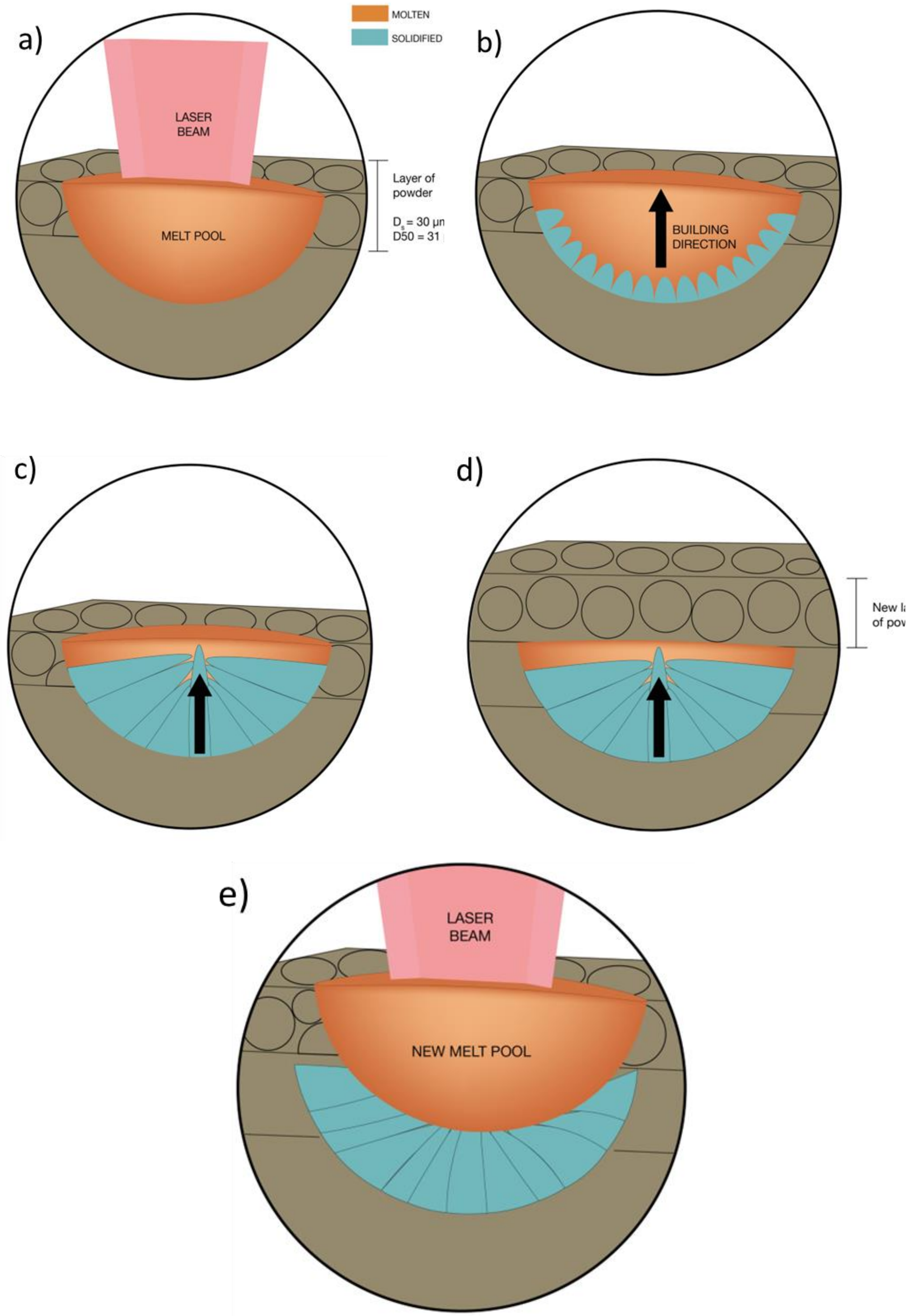


Figure 1: Process map developed with regards to the printing of AISI S2 metal parts through SLM technology. In Green the combinations of parameters which resulted as optimum for the realisation of such steel in such conditions and therefore advised to be pursued.



MOLTEN
SOLIDIFIED
a)
LASER BEAM
MELT POOL
Layer of powder
b)
BUILDING DIRECTION
c)
d)
e)
LASER BEAM
NEW MELT POOL

Figure 2: Sketch of the process of melt pool solidification sequence as indication of what was found through the cross-combined analysis results of EBSD, DTA, SEM and OM.. (a) Melt pool with molten powders after the laser travels by; (b) primary nucleated grains following the orientation of the building direction within the melt pool border (c) epitaxial growth with side-branching phenomenon of the nucleated grains (d) addition of a new powder layer (e) the process new step, which affects the microstructure of the layers below.

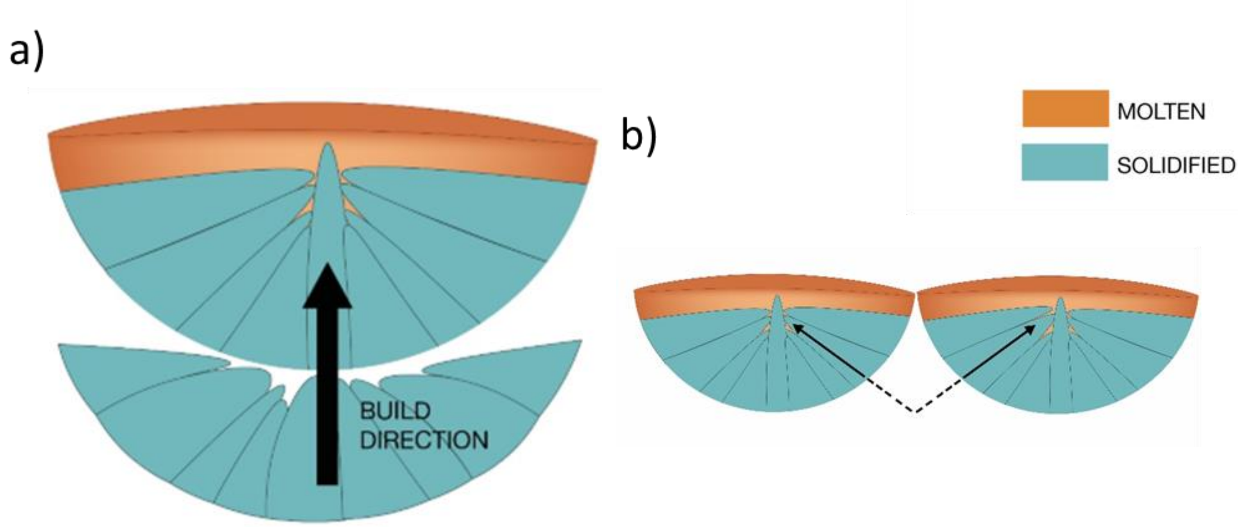


Figure 3: Sketches of two features of epitaxial growth: (a) of columnar grain growth which stays in the same direction along subsequent layers (b) of the side-branching phenomenon between two adjacent melt pools forming a 90° angulation.

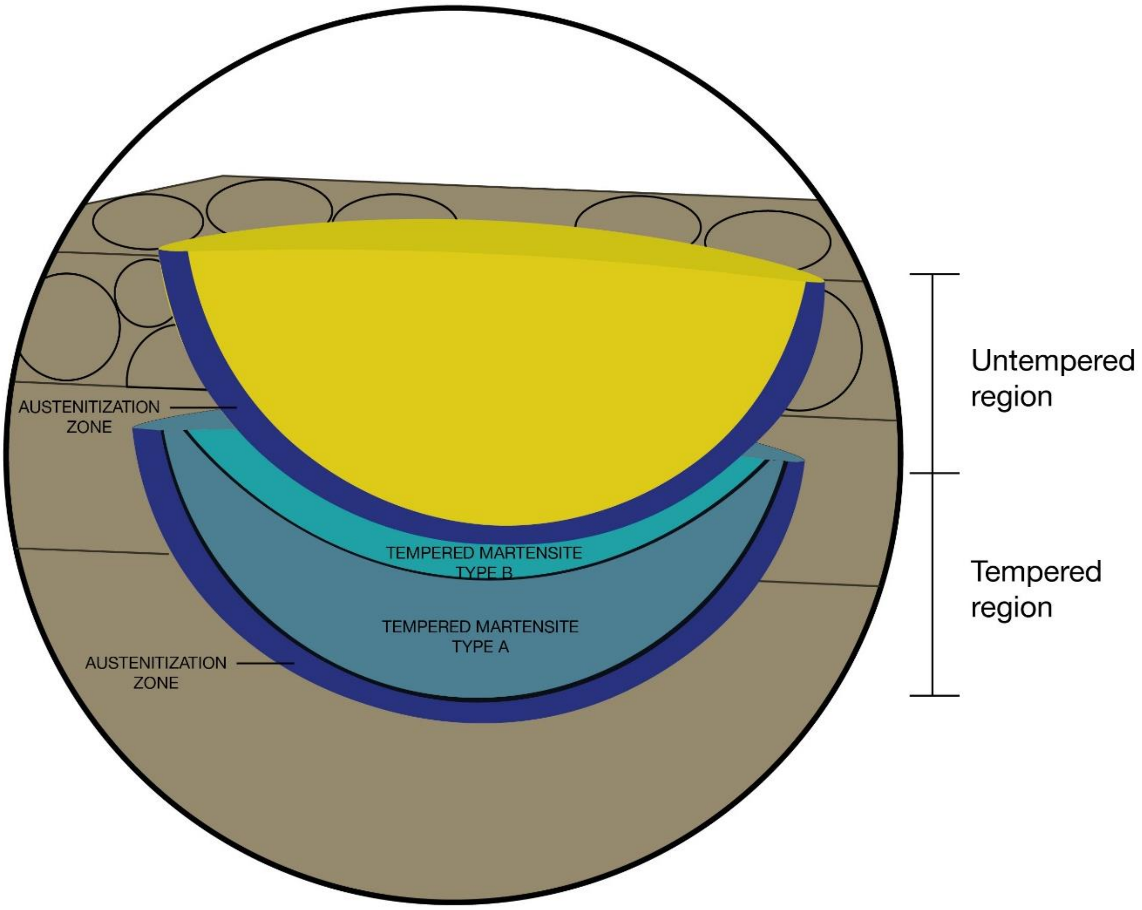


Figure 4: Model of the in-situ tempering effect which was found to develop during the SLM process, generating an untempered state of martensite in the upper layer and bands of tempered martensite in the inner part of the cross-section.