# ADDITIVE MANUFACTURING OF MEDIUM CARBON STEELS AND A COCR-ALLOY

**Since a decade, selective laser melting (SLM) has gained significant attention from academia and industry. This powder-bed based technology enables the manufacturing of highly complex and filigree parts in a near-net-shape** manner with a relative density of approximately 99.9 %. However, the material spectrum available for SLM has to be extended in order to further industrialize the process. In particular, martensitic steels, with a medium carbon content of approximately 0.5 ma.-%, represent a class which has rarely been addressed so far.So far, almost all research has addressed austenitic-, precipitation hardenable stainless-, maraging-, and martensitic steels.

## PROJECT OVERVIEW

DURATION

01/2018 - 12/2018

PARTNER

Industrial Consortium of DMRC

FUNDED BY

Industrial Consortium of DMRC

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## Objective

The aim of this research project is to process and characterize hard to weld materials. Since a martensitic transformation, which usually occurs during cooling, is accompanied by a volume increase of approx. 2 % - 4 %, hot cracking may prevail. In order to avoid hot cracking the fabrication temperature was increased from 200 °C to 400 °C.
The martensitic steel H13 (1.2344) is widely known for the additive manufacturing of components, primarily tools[1]. Despite this, medium carbon steel obtains a limited hot hardness, which is of utmost importance during molding or hot forming operations. Thus, another martensitic steel is required for the SLM process, which satisfies this expectation. In this project, W360 Isobloc has been chosen to investigate the microstructure and mechanical properties. This high molybdenum-chromium-vanadium tool steel is suited for applications in which highest toughness and hot hardness is needed, i.e., in cold work, hot work, and plastics tools.
One further medium carbon steel group, which has rarely been investigated, can be identified as quenched and tempered (QT) steel. These steels exhibit high toughness accompanied by high strength. Thus, QT steels are employed in machinery and structures in which an increased yield strength and an abrasion resistance is demanded, e.g., as gears, cutting edges, or camshafts. Within this project, the quenched and tempered steel 1.6773 was processed and analysed in terms of processability, microstructure and mechanical properties.
The third material processed within this project was the CoCr-alloy Stellite 6. Generally, stellite materials possess superior tribological and corrosion properties under aggressive conditions. Both steels, the martensitic steel W360 and the QT steel 1.6773, possess medium carbon contents of approximately 0.5 wt.%, which has not successfully been processed at larger diameters, e.g., >50 mm. Evolving high residual stresses lead to numerous liquidation cracks as well as solidification cracks during SLM fabrication. A promising approach to avoid the undesired cracks is the modification of the scan-strategy in combination with the variation of the build platform temperature up to 400 °C.
Until now, these materials are processed by casting methods or powder metallurgy [2]. Nonetheless, based on the processing technologies available, the geometrical freedom is restricted, and the machining is extremely challenging.

## Approach

By employing an infrared-heating system (Figure 2), which was set-up in cooperation with the company Heraeus, it was possible to build dense parts with the addressed materials. Based on the homogeneous temperature distribution in the build chamber the tempertaure gradients have been minimized, resulting in less (hot) cracking and reduced pores. For 1.6773 (QT steel) dense specimens were built at a temperature of 200 °C in the build chamber. Regarding W360 a high hardness (> 635 HV) could be achieved for this hot tool working steel when heating the chamber to 450 °C. In this case the standard parameter set for 316L has been utilized. Finally, it was proven, that Stellite 6 is processible with selective laser melting using the infrared-heating system at a tempertaure of 530 °C (Figure 3).

## Outlook

For these material groups corrosion tests have to be conducted in elctrolytes, which suit the applications and further investigations concerning the fatigue behavior are planned.

[1] Holzweissig MJ, Taube A, Brenne F, Schaper M, Niendorf T. Microstructural Characterization and Mechanical Performance of Hot Work Tool Steel Processed by Selective Laser Melting. Metall and Materi Trans B 2015; 46 (2):545-9.
[2] Yadroitsev I, Sumrov I, Selective laser melting technology: from the single laser melted track stability to 3D parts of complex shape, Physics Procedia 2010, 5, 551-60.

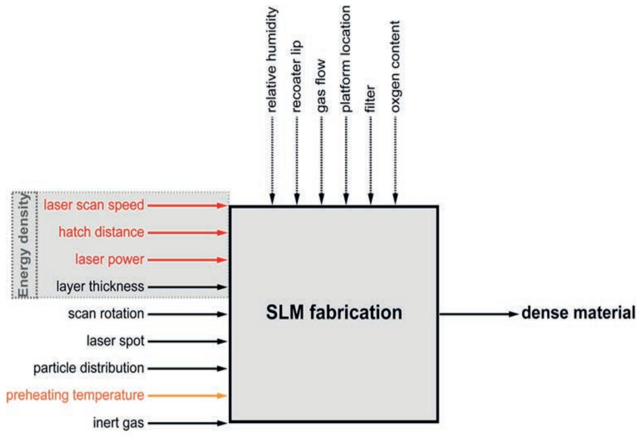


FIGURE 1 Influencing process parameters for selective laser melting

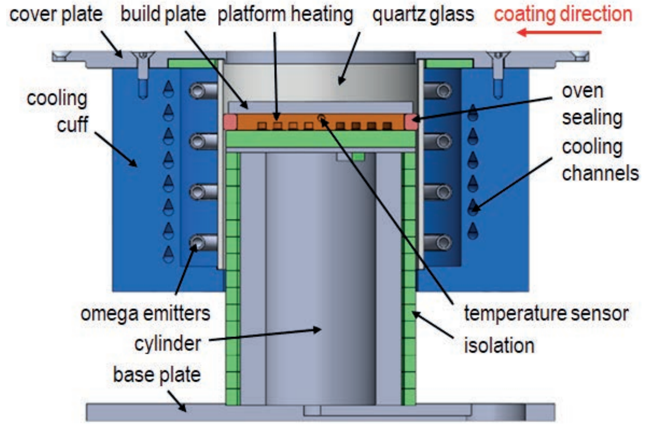


FIGURE 2 Prototype of the developed infrared-heating system

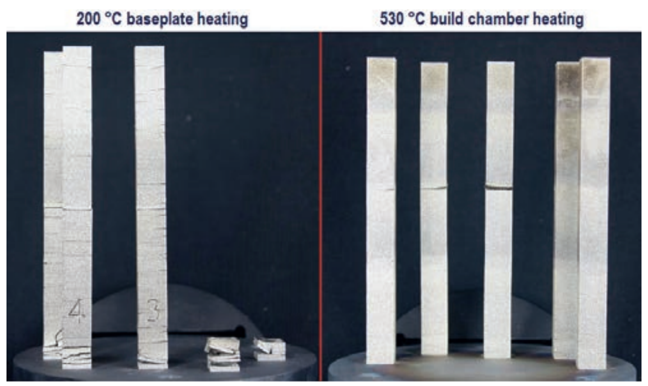


FIGURE 3 Comparison of the influence of a platform heating and a build chamber heating with the example of Stellite 6