MATERIAL CHARACTERIZATION – MECHANICAL AND CORROSIVE PERFORMANCE OF SLM PARTS (MatCharact)

So far, just a fraction of steels and metallic alloys conventionally available are processible via selective laser melting (SLM) in a defect free fashion. Weldable metallic alloys can be SLM processed defect free without severe process or alloy modifications. Still, processing parameters must be developed, and material properties must be characterized for the SLM materials. Thus, in this project, three weldable materials are investigated in order to expand the material spectrum in the field of SLM. Microstructural and mechanichal properties are determined for the martensitic tool steel W360, ths quench and tempering steel 36NiCrMo16, and the cobalt-base alloy Ultimet.

PROJECT OVERVIEW

DURATION

01/2019 – 01/2020

PARTNER

Industrial Consortium of DMRC

FUNDED BY

Industrial Consortium of DMRC

RESEACHER

Research Leader
Prof. Dr.-Ing. habil. Mirko Schaper

Research Assistant
Florian Hengsbach, M.Sc.

DMRC DIRECT MANUFACTURING RESEARCH CENTER RESEARCH INNOVATION EDUCATION

Motivation and objective

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 must be extended in order to industrialize this process further. Based on the latter requirement, this project analyzes the SLM processing as well as the material performance of two steels and one cobalt-based alloy: hot working tool steel W360, quench and tempering (QT) steel 36NiCrMo16, and the cobalt-base alloy Ultimet. The hot working tool steel W360 AMPO is mainly known for the successful additive manufacturing of tools-inserts [1]. The printability of the W360 is thoroughly investigated since the steel must be processed at temperatures above 200°C based on the special alloy design. The second medium carbon steel addressed is the QT steel 36NiCrMo16. This steel exhibits high toughness accompanied by high strength. Thus, the QT steel is utilized in machinery and structures in which an increased yield strength and an abrasion resistance are demanded, e.g., as gears, cutting edges, or camshafts. The third material investigated is the cobalt-base CoCrNiMoW-alloy Ultimet (Figure 1). This alloy possesses superior corrosion properties under aggressive aqueous conditions.

The materials described are microstructurally and mechanically investigated in the as-built as well as the heat-treated condition. Finally, the results obtained are summarized in a material-datasheet.

Approach

The materials investigated were processed with a commercially available SLM Solutions 280 HL machine at a preheating temperature of 200 °C. A standard build-job with tensile-, fatigue-, Charpy-impact-, and cuboid-specimens was designed (as can be seen in Fig 2). Subsequent to the SLM processing, a part of the specimens were machined; thus, the impact of the surface roughness on the fatigue life could be determined. Microstructural investigations were conducted utilizing light microsciópy, scanning electron microscopy (including energy dispersive spectroscopy, electron backscatter diffraction), and transmission electron microscopy.

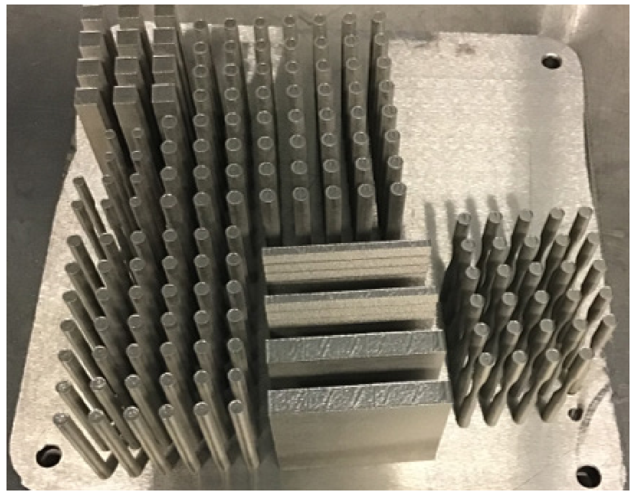

FIGURE 1: Standard build job for microstructural and mechanical characterization for the three addressed materials Ultimet, 36NiCrMo16 and W360.

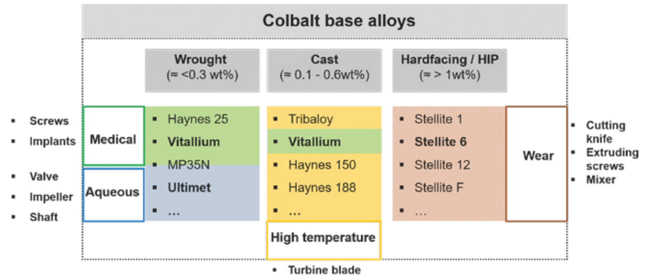

FIGURE 2: Classification of cobalt-based materials and possible areas of application.

State of project

A relative density of 99.99 % was achieved in the SLM processed specimens for the three materials analyzed in this project. In addition to the successful SLM processing, a thorough heat treatment study was applied. Generally, additively manufactured materials possess a unique microstructure such that the conventional heat treatment procedure has to be adjusted accordingly. Regarding the martensitic tool steel, the austenitization temperature, as well as the tempering temperature, was modified to obtain the desired hardness in the final component. A case hardening was employed for the 36NiCrMo16 resulting in high surface hardness. The Ulitmet does not require further heat treatment; however, a stress relief procedure is optional.

Hardness measurements and quasi-static tests were conducted an revealed the desired mechanical properties, which are comparable and also increase the mechanical performance of their conventional counterparts. Still, the SLM processing parameters, as well as specimen size geometry, has to be considered.

Moreover, the materials fatigue performance was determined by conducting S-N-curves comparing various material conditions, e.g., as-built and heat-treated.
Along the entire heat treatment procedure development and mechanical characterization, the microstructure of the materials was analyzed in detail. Finally, the material performance was summarized in a material datasheet.