MECHANICAL BEHAVIOR OF AM MATERIALS UNDER DIFFERENT TEMPERATURES

Additive Manufacturing (AM) technologies have a significant potential for the production of individual parts with high complexity and high design freedom. This technology is already widely used, especially in the areas of biomechanics, for example, to produce individual, patient-specific prostheses, in the aerospace area to produce structurally optimized brackets, in the field of passenger services and in the automotive industry. However, the number of possible materials is limited. The materials typically used are TiAl6V4, 316L, Inconel and AlSi10Mg.

PROJECT OVERVIEW

DURATION

2020: 12 month

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Industrial Consortium of DMRC

FUNDED BY

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Motivation and aim

Over the last few years, a large amount of AM material characteristics have been generated through various projects at the DMRC. For example, fundamental mechanical material properties (e.g. tensile strength, fatigue strength, and fatigue crack growth curves) were determined for different materials. In addition, the influence of essential process parameters (e.g., powder properties, process gas) on the mechanical properties have been investigated. However, the elongation at break or the contraction at fracture obtained from the tensile test show an estimation of the toughness of the material, but this only applies to a (quasi)- static load and only at room temperature. In many cases, components are also subjected to an impact or cyclic load and not always at room temperature. The ideal conditions of the tensile test do not reflect reality. For example, components that have a good toughness behavior in the tensile test become brittle at low temperatures which leads to premature material failure.

In particular, cubic-body-centered (bcc) materials such as ferritic steels and hexagonal lattice structures (hex) show a particularly strong dependence of the toughness on the temperature. The temperature dependence of the notch impact energy can thus be transferred to the fracture behavior of the materials. Therefore, the assumption can be made, that a complete material characterization also includes the knowledge of how the material behaves under different temperatures, for the practical application often takes place under certain temperatures which differ from laboratory conditions. As a result, an appropriate statement can be made for each application profile. By applying different temperatures during experimental investigations, the possible temperature dependence of the material can be identified at an early stage.

The temperature dependence has a significant influence on the stress-strain curves, as illustrated in Figure 1 by the example of σ-ε-curves of TiAl6V4 at varying temperatures. With increasing test temperatures, Ti6Al4V shows decreasing strengths and an increasing elongation at break. However, above 500 °C, a decrease in strength, as well as ductility can be observed. The increasing

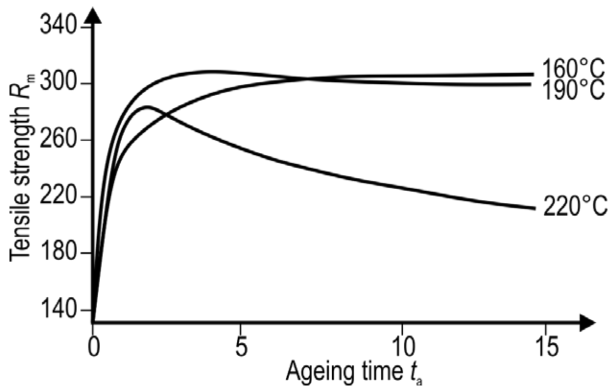

FIGURE 1 σ-ε-curve of TiAl6V4 showing the dependency of the mechanical behavior and the test temperature

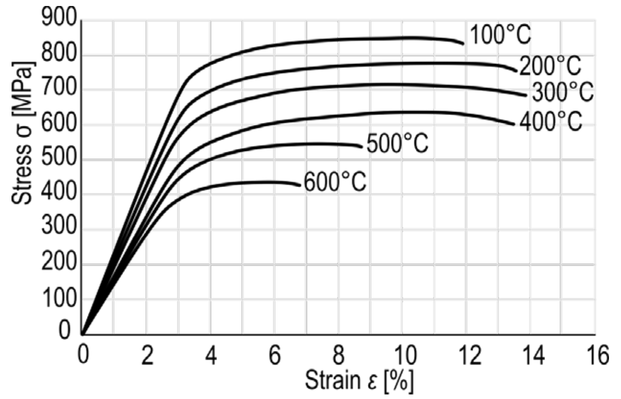

FIGURE 2 Tensile strength as a function of temperature and aging time for AlSi7Mg

embrittlement with increasing test temperature can be traced to the uptake of oxygen from the environment. Thus, it can be seen that other influencing factors have to be taken into account when changing the affected temperature. These examples reveal that the influence of the temperature on the material properties is not negligible. Studies have shown that for conventionally produced materials information focusing on the material behavior at higher temperatures is widely published. For additive manufactured materials, only limited information is available. Knowledge addressing the material behavior at very low temperatures (below 0°C) is missing completely.

Therefore, the scope of this project is to investigate the mechanical behavior of selected AM-materials under varying temperatures as well as the assembly of existing material data to create a complete and up-to-date AM-database. Because of these aspects, the project is separated into five work packages, which are presented in the following section.

Dependence of the material properties on the temperature can also be observed for the basic stainless steel 316L (1.4404) and the corrosion-resistant nickel-based alloy Inconel 718. When the temperature increases, the elastic modulus, the tensile strength as well as the yield point decrease. For aluminum-silicon casting alloys, for example AlSi7Mg, the strength values also decrease significantly at higher temperatures, especially above 250°C (Figure 2). Furthermore, a temperature increase has a negative effect on the mechanical properties during creep and cyclic stress.