# Summary

The advancement of additive manufacturing (AM) technologies has opened new possibilities for the fabrication and repair of high-performance materials, including cold work tool steels, which are widely used in tooling applications, such as stamping and blanking, due to their exceptional hardness and mechanical performance. This dissertation presents a comprehensive study of one of these steels, referred as BÖHLER K340 isodur (C: 1.1%, Cr: 8.3%, Mo: 2.1%, V: 0.5%, Si: 0.9%, Mn: 0.4, + Al & Nb), focusing on its characterization, the tailoring of its performance for specific applications through heat treatment optimization, its processability in additive manufacturing (AM) and the related process optimization, the analysis of microstructure and mechanical performance of such material processed through Directed Energy Deposition (DED). The thesis addresses key challenges for such material in AM and demonstrates the potential in industrial applications of AM technology applied to such material.

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The study begins with an introduction to different categories of tool steels, their applications, and the common damage mechanisms. Furthermore, AM techniques capable of processing tool steels are presented. In this chapter, the application of AM and its challenges in processing tool steels for both new parts fabrication and component repair are covered.

In Chapter 2, the framework for this research is established by outlining the objectives, materials, and methodologies employed. The research objectives focus on developing a comprehensive understanding of K340 tool steel's behavior during heat treatment and DED process. This includes optimizing its mechanical properties through tailored heat treatment, producing high-quality feedstock powder, and evaluating the processability of the material under varying conditions, and optimizing the process. The methodology involves a series of experiments, including parameter optimization for the DED process, post-process heat treatment, and microstructural and mechanical characterization.

Chapter 3 focuses on understanding the microstructural evolution and mechanical properties, in terms of the fraction of retained austenite and hardness, of the conventional steel under different heat treatment conditions. The research develops a predictive model to assess the effects of heat treatment parameters—such as austenitizing and tempering temperatures—on the hardness and retained austenite content of the steel. By having this model, the heat treatment procedure can be designed easily based on the hardness requirement of the material for each specific application.

As the K340 powder, the feedstock for the DED process, is not commercially available on the market, the production of high-quality K340 steel powders through Vacuum Induction Gas Atomization (VIGA) process by melting metal scraps is explored in Chapter 4. This is also beneficial in providing a closed-loop supply chain and moving towards sustainability and circular economy. The study investigates the effects of atomizing gases and gas pressures on powder characteristics. Spherical powders with high sphericity and minimal internal gas pores and satellite formation were achieved.

In the last part, the processing window of the material using the DED process is initially investigated, with further focusing on the optimization of process parameters, fabrication of bulk samples, and replicating the repair of damaged components. Laser power, nozzle travel speed, and carrier gas flow rate were optimized to minimize porosity and surface roughness and maximize the dimensional accuracy. The results showed that near-full dense deposits with very low porosity levels could be achieved. Additionally, repairs on grooves of varying dimensions demonstrated the feasibility of DED for tool restoration. This chapter underscores the potential of DED for sustainable and efficient manufacturing, with a focus on optimizing processes to enhance the mechanical properties and reliability of fabricated and repaired components.

In summary, this work establishes the feasibility of employing DED for the fabrication and repair of K340 tool steel, offering sustainable and cost-effective solutions for tooling industries.