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# Experimental fatigue endurance testing of a high-torque wrench tool made by metal Additive manufacturing

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## Abstract

This abstract presents the development and experimental fatigue endurance testing of the ”Nutcracker”, an LPBF-manufactured tightening tool designed for improved accessibility and safety when tightening methanol fuel pipes. Conventional tools have struggled with limited access and operator safety, often requiring multiple open-end wrenches and awkward working positions. The Nutcracker introduces an enclosed, modular high-torque design that enhances usability and reduces operational risk. The tool was engineered to meet required torque levels using EOS MS1 material and tested through overload and fatigue procedures.

A realistic tightening setup was built using an industrial robot to apply controlled tightening/untightening cycles with repeatable kinematics and boundary conditions. The test program combined monotonic tightening cycles for assessing low-cycle fatigue (LCF) endurance of the tool with nominal load of approx. 420Nm. 5 tools were tested to (i) measure structural reliability under the target torque spectrum, (ii) identify the main factors that drive LCF behavior in the printed tool, and (iii) validate the design and simulation practices used during development. Overload tests showed that the tool carried the specified load without visible deformation. Cyclic tests provided consistent loading and contact conditions, enabling a clear assessment of damage accumulation and durability. Accessory components tested in the same setup revealed local weaknesses that inform reinforcement in next designs.

The results indicate that an LPBF, enclosed high-torque tool concept can meet functional torque demands while supporting safer and more ergonomic maintenance work. The robot-based method and the measured responses offer a practical path to correlate simulations with test data, increase confidence in reliability, and systematically improve fatigue performance of additively manufactured service tools.

Additional testing of accessory components highlighted areas for future reinforcement. Overall, the project demonstrates the potential of LPBF manufacturing to deliver safer, more ergonomic and reliable service tools for modern industrial needs.


**Figure 1. Tested wrench tool 3D printed of MS1 maraging steel.**

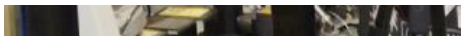

**Figure 2. Test setup for applied fatigue testing with a nominal load of 420Nm**