Creep Modeling of 3D Printed 718 Nickel Based Superalloys

Harshal G Dhamade, Abhilash Gulhane, Jing Zhang*
Department of Mechanical and Energy Engineering
Indiana University - Purdue University Indianapolis, Indianapolis, Indiana, USA
*Corresponding author: jz29@iupiu.edu

ABSTRACT

In this work, a finite element model with subroutines is created to simulate the creep behavior for 3D printed nickel alloy 718. Using a multi-regime creep model, such as the Kachanov-Rabotnov model, the model is capable to simulate both the secondary and tertiary creep behaviors. Specifically, a continuum damage mechanics (CDM) approach is employed by a user-defined creep subroutine formulated to accurately capture the creep mechanisms in the alloy. Using a calibration code for the material constants, a creep rupture prediction model is created to simulate the creep test. The model developed in this work can reliably be used to predict the creep behavior for 3D printed metals under uniaxial tensile and high-temperature conditions.

INTRODUCTION

Turbomachinery is crucial for the energy generation industry. Its high-performance parts feature complex designs that need to be robust and powerful as the demand for energy increases. Besides, turbomachinery parts need to be resistant and reliable even at temperatures beyond the melting point. Additive manufactured turbine parts enable higher combustion temperatures and reduce maintenance times. During operation, the turbomachinery parts are subjected to failure mechanisms like fatigue, creep, corrosion, erosion, etc., and have a severe impact on the safety and reliability of the machine. 3D printing metal parts for turbomachinery like blades, vanes, inlet/outlet, etc. not only aids in manufacturing complex parts but can be incorporated with an optimized cooling strategy to achieve desired material properties and make material failure resistant.

Numerical modeling to predict material failure under deformations such as creep, fatigue, crack propagation for 3D printed specimens has picked up in the last few years. An immense number of models have been developed to predict the deformation, damage evolution, and rupture of structural alloys subjected to creep and creep-fatigue. Stewart [1] conducted experiments to develop a numerical model with the temperature dependence of tertiary creep damage of a Ni-based alloy. Haque[2] [3] compared the creep prediction capability of the Sine-Hyperbolic and the classical Kachanov-Rabotnov creep damage models. The models were fit to creep data for stainless steel 304. Hautfenne [4] studied the influence of heat treatments and build orientation on SLM manufactured nickel alloy 718 specimens. Short-term creep tests were performed and the creep curves were compared with conventionally produced nickel alloy 718 creep behavior. Another study by Kuo [5] showed the effect of post-processing on the microstructure-dependent creep properties of nickel alloy 718 manufactured by SLM. Xu [6] studied the creep performance of laser powder bed fusion