SELECTIVE LASER MELTING OF A HIGH PRECISION TURBOMACHINERY APPLICATION IN IN718 ALLOY

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1. Introduction

The paper describes the manufacture of an outlet guide vane (OGV) component, in IN718 alloy, used in jet engines by Selective Laser Melting (SLM). The OGV component is a static part in the last stage of the compressor and is characterised as a series of airfoils or vanes secured by two flanged rings. The part tolerances at the leading and trailing edge require a high dimensional precision of ±0.072 µm whilst the profile tolerances are slightly more generous. The current challenge to manufacture a prototype OGV in IN718 alloy from a wrought stock involves a lengthy machining process in a hard-to-machine alloy. The tooling access is greatly restricted between the curved vanes, and the process involves careful fixturing and process management to mitigate residual stress in the component arising from the removal of material.

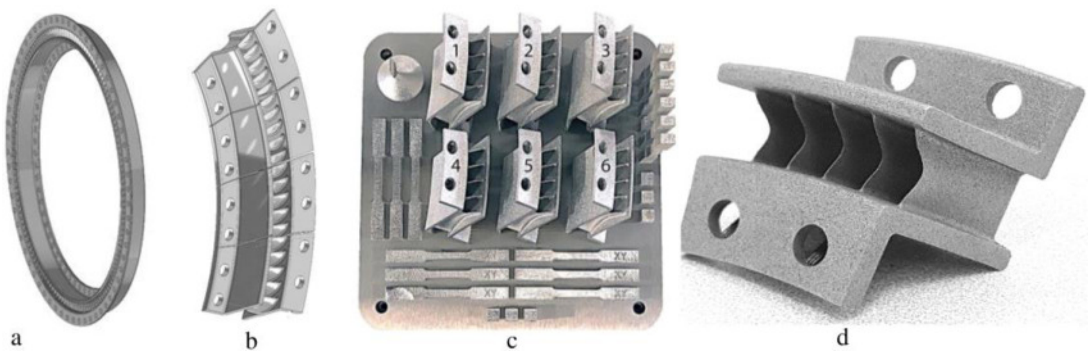

Fig. 1. (a) OGV; (b) Four segments; (c) Printed segments on build plate; (d) Printed segment

A case study OGV component with an outer diameter of 605mm was developed as displayed in figure 1a. There are 140 vanes equally spaced and the airfoil profile design was based on the NACA-6 series. The distance between the vanes with line of sight is roughly 6 mm. The OGV component was divided into an equal number of segments, each with five vanes and equal flow passages to enable the part to be printed by selective laser melting in a Renishaw AM250, see figure 1b. Parameter optimisation was performed with respect to the part orientation on the build plate, thickness change to the flanges, flange position and the influence of the support structure on print accuracy, to identify a build configuration which minimises dimensional error. The dimensions of interest were the inlet and exit angles at the leading edge, chord length, leading and trailing edge thickness, stagger angle and profile tolerance. In this paper, further refinements were performed, initially identifying the important laser process parameters in another build capable of achieving the precision required and then verifying the process in a following build, see figure 1c and d. The post-process dimensional analysis was performed using the GOM ATOS triple scanning system, and in order to ensure consistency and accuracy of scanning, photogrammetry technology with two reference scale bars, having an average deviation of 0.85 μm, was utilized to calibrate the measurement system. The Airfoil Gauge software was used to establish the best fit of the measured scanned data to the nominal design and the deviations established. Other measurements included hardness, static tensile properties, density, porosity, CTScan, X-ray and surface roughness. This work established the capability of the SLM process to fabricate a high precision turbomachinery part in a high temperature superalloy.

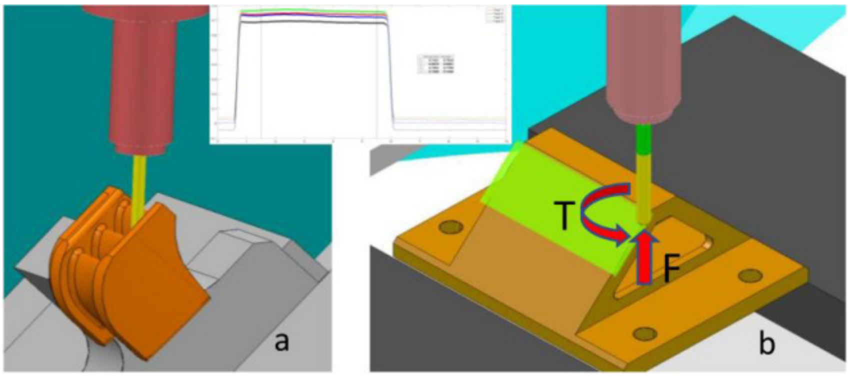

Fig. 2. (a) CAD model of printed segment; (b) Printed artefact to develop machining strategy

The paper further describes an approach to optimise the finishing by CNC machining to achieve the part tolerances and surface finish required of the SLM produced part. Within the study a suitable finish machining allowance was determined. An excessive allowance will consume more energy and tools and involves a multi-stage finishing process that could introduce residual stress in the part. If the allowance is too small, there is a risk of ploughing and smearing rather than cutting the alloy, which leads to rapid tool wear and a poor surface finish. A small diameter ball nose carbide cutting tool was used to machine the air foil profile surfaces between the vanes because tooling access was greatly restricted. The cutting tool stick out length is dictated by the distance to the midpoint of the air foil surface so that cutting forces must be minimized to limit tool deflection. The study uses an experimental approach to determine a suitable cutting strategy and process window for finish machining a high precision turbomachinery application in IN718 alloy produced by SLM. An artefact was printed in IN718 alloy that represents some of the challenges of machining the SLM OGV part. Experiments were performed using a precision machine tool instrumented with a rotating dynamometer to measure the torque, thrust and side cutting forces in machining the artefact. This paper reports the initial findings and identifies further work stages to develop an optimum machining protocol for SLM produced IN718 alloy.

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