Assessment of As-Printed, Machined, and Post Processed Additive Layer Manufactured Ti-6Al-4V for Aerospace Applications

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THANK YOU to Curtiss-Wright Surface Technologies (CWST) for sharing a recent research project on Additive Layer Manufacturing (ALM) and shot peening. Additive manufacturing is an important topic in our industry, especially for aerospace applications.

The project was initiated by the helicopter division of the Leonardo company in the United Kingdom. Leonardo manages the design, development, testing, production, support and sales of the complete range of rotary aircraft available for commercial, public utility, security and defense use. Leonardo has used the services of the CWST facility in the U.K. for many years.

ALM is being successfully used to build metallic components under *static* loads; CWST and Leonardo explored the fatigue strength of ALM components under *cyclic* loads. The Ti-6Al-4V fatigue test specimens were either additive layer manufactured to the defined dimensions or were machined down to the dimensions from additive layer manufactured cylinders. The components were divided into five batches: As Machined; As Printed; As Printed and Shot Peened; As Printed, Shot Peened and/or Superfinished; and As Printed and Superfinished.

After fatigue testing, the As Printed fatigue samples exhibited substantial loss of fatigue life. Jochen Fuhr, one of the authors of the paper and General Manager for CWST North American Shot Peening, offered his thoughts on the results of the research program.

> ***The problem with AM/3D printed parts is mainly the surface roughness, possible defects, inclusions or thermal effects in the close surface area which can lead to early cracking under cyclic load. One way to overcome this weakness is to remove this surface by milling or turning after printing—which might be easy on a simple geometry like a fatigue probe, but impossible on the complex structures for which this printing technology is ideally suited. Our machined samples were 3D-printed cylinders that were turned/machined down to the required fatigue sample shape. After this machining process, all surface-related failures from the printing process were completely removed.***
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> ***Another way to improve the fatigue strength is to put the surface area in compressive stresses by shot peening which, on those samples, also reduced the overall roughness after printing. This shot peening process can also be used on more complex parts but there are limitations even here. As there are still subsurface defects from the printing process, the fatigue strength is not as high as the machined ones, but much higher than printed-only specimens. When it comes to cyclic loading, the aerospace industry will have to find a solution for the uncontrollable loss in fatigue strength and here shot peening and super finishing might be an ideal solution—technically and economically.***

CWST is currently working on R&D projects in additive manufacturing with INCONEL or stainless steel for other customers in order to find a solution.

The following excerpts from the paper provide much greater detail on the project and the complete paper is available for download from the online library at www.shotpeener.com.

ABSTRACT

Especially within the aerospace field there is a large interest in manufacturing increasingly complex components in the most economical way based on the relatively small volumes required by this industry. A very promising technology that may fulfil these requirements is the Additive Layer

Manufacturing (ALM) process which is already used for an increasing number of metallic and non-metallic components usually under static loads only.

Within this paper the focus is on the fatigue performance and cyclic loading of ALM components made of Ti-6Al-4V material widely used in the aerospace industry. Fatigue samples were treated by different processes including machining, shot peening and superfinishing after the "printing process". In addition, the post ALM treatments have been applied in variations and combinations to determine their individual effect on the fatigue strength of the ALM components.

Keywords: Additive Layer Manufacturing (ALM), Ti-6Al-4V, Fatigue Testing, Shot Peening, Superfinishing, Residual Stress, Roughness; Topographical Features

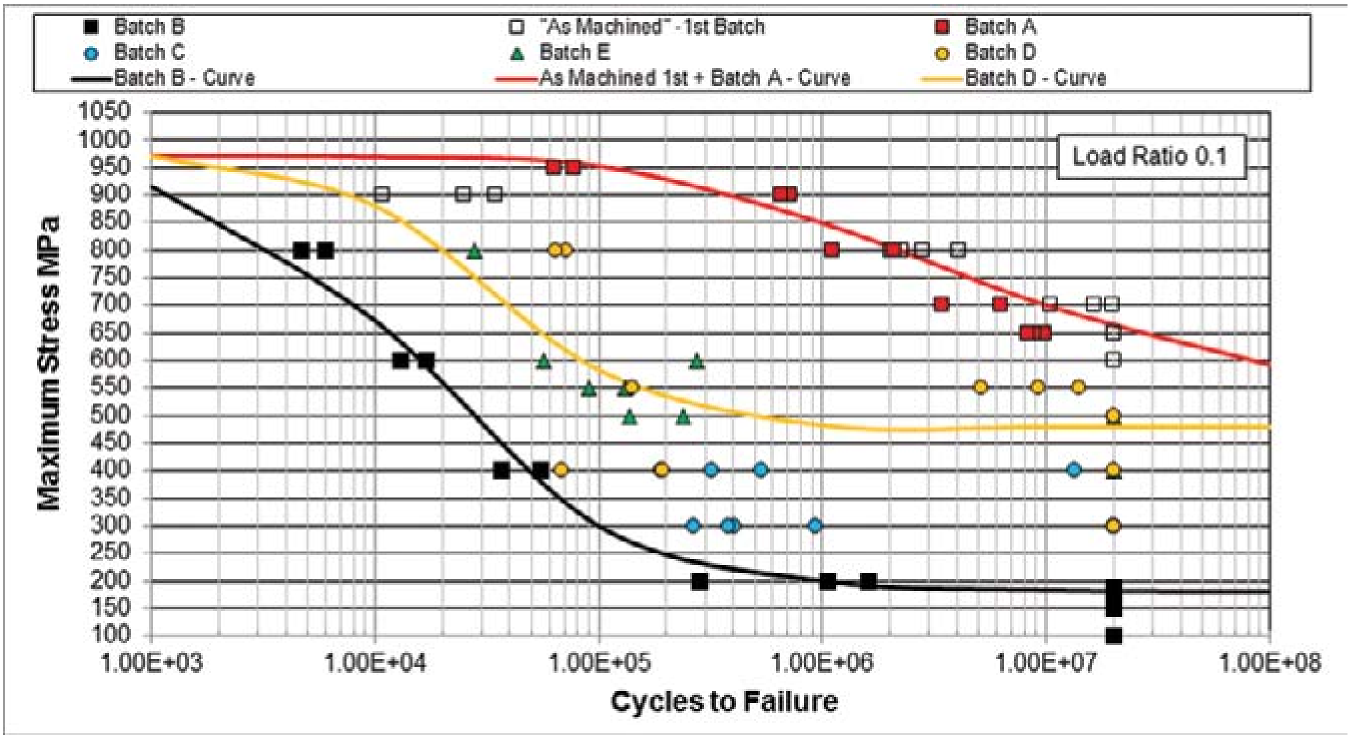
INTRODUCTION

Based on the initial characterisation trials carried out by the Leonardo Materials Laboratory, on the static and fatigue property data for ALM produced Ti-6Al-4V, Design Engineers have used this data to model and stress two ALM parts. As one of these parts was a flight critical part, Design and Stress Engineers required additional fatigue test data on both "As Printed" ALM and the effect post-processing techniques, e.g., shot peening and/or superfinishing, had on the fatigue properties of "As Printed" ALM. Consequently, this paper summarises the main topics results of the evaluation carried out by the Leonardo Materials Laboratory on "As Printed", machined and post processed ALM produced Ti-6Al-4V especially in terms of fatigue performance.

CONCLUSIONS

When compared to the "As Machined" ALM produced fatigue samples the "As Printed" ALM fatigue samples exhibited a substantial loss in fatigue life. The reason for this substantial loss in fatigue was due to four main factors, i.e., a rough surface, presence of surface contamination, evidence of tensile residual stresses in the surface and the creation of surface flaws/notches caused by partially remelted powder particles resulting in cold shuts/oxide films.

The fatigue life of the "As Printed" ALM can be increased by using shot peening, super-finishing or a combination of both post-processing techniques, in which the greatest improvement in fatigue was achieved by the use of shot peening combined with super-finishing. However, although substantial improvements in fatigue endurance are possible, fatigue endurance cannot be restored to the "As Machined" condition largely due to the fact that surface flaws/notches caused by partially remelted powder particles resulting in cold shuts/oxide films are still present.



S/N Curve of "As Printed" [Batch B], "As Machined" [Batch A], Shot Peened [Batch C], Shot Peened/Superfinished/Shot Peened and Superfinished [Batch D] or Superfinished alone [Batch E]. Note: Samples tested to 20 million cycles are defined as "run outs" (i.e., un-failed samples)