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The Effect Machining Processes can have on the Fatigue Life and Surface Integrity of Critical Helicopter Components

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Abstract

The desire to reduce cost in helicopter components has meant that manufacturing/production engineering is always looking into novel machining processes. However, before these processes can be adopted by manufacturing, the effect that these machining techniques can have on fatigue performance will need to be assessed and characterized. The paper aims to present examples of three machining techniques which were identified by manufacturing/production engineering as offering distinct benefits over machining processes currently used in the manufacture of helicopter components for AgustaWestland Limited (AWL), namely:-

1. Thread Milling.
2. Hard Turning.
3. High Speed Machining.

The paper will present the results of the assessments that were carried out by the AWL Materials Technology Department, in order to characterize each process against the methods that are currently used by AWL in the manufacture of critical helicopter parts.

Keywords: Fatigue; Residual Stress; Surface Integrity

1. Main Rotor Head (Lynx)

1.1 Thread Milling Vs Machine Tapping

1.1.1 Introduction

In the mid 1990's the Lynx Semi Rigid Main Rotor Head was extensively redesigned in which the two main changes were:-

- The titanium alloy was changed from annealed Ti-6Al-4V to solution treated & aged Ti-10V-2Fe-3Al [1] in order to achieve a 20% improvement in fatigue life.
- The design was simplified resulting in a 50% reduction in manufacturing cost.

As part of the design simplification the cruciform (Disc) was bolted onto the drive shaft (Mast) using a series of 18 mm attachment bolts and dowels to resist torsional loading, see Figure 1. During the design phase Production Engineering requested a change to the manufacturing method used in the production of the threaded holes from machine tapping to thread milling. The reason for the requested change was that thread milling [2] offers distinct advantages in terms of superior surface finish, greater flexibility, lower inventory costs and greater usable thread depth when compared to tapping. A series of small 10 mm threaded holes to accommodate the lifting eye at the top of the Disc, as shown in Figure 1 was also part of the thread milling investigation. In both cases wire thread inserts were fitted to the holes to improve the load distribution and enhance durability.

1.1.2 Test Program and Specimen Design

The type of axial specimen used for the fatigue test program is shown schematically in Figure 2a for the 10 mm thread milled holes. The samples were first

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manufactured from four individual Rotor Head Sleeve forgings before being subdivided into two batches. In one batch the threads were machined into fatigue samples in accordance with the current Mast thread tapping standard while the other was machined using the proposed thread milling method. Details concerning the machining parameters and wire thread inserts used for the 10 mm holes are shown in Table 1. Fatigue testing was carried out on a 250 kN Mayes servo-hydraulic machine at a frequency of 50 Hz. The specimens were loaded via the 48 mm external thread and through the slave stud screwed into the wire threaded insert. The slave stud was attached to the test machine load cell by a series of locking nuts connected to an adaptor. The fatigue samples were tested using a load of P ± 4P at various alternating loads in order to generate a fatigue curve. Tensile and micro-hardness testing was carried out in accordance with BS EN10002-1 and ASTM E384 respectively.

1.1.3 Test Results

The results from the tensile and hardness testing are shown in Table 2. Although slight differences in the strength were observed between the two test groups both were fully compliant with regard to the drawing and material specification requirements. The fatigue results obtained are shown in Figure 3 in which a difference of approximately 60% in performance between thread milling and machine tapping was observed, as summarised in Table 2. A similar reduction in fatigue of 55% was observed in the larger 18 mm diameter holes. Examination of the failures confirmed the primary failure site was in the thread root.

Table 1 – Machining Parameters and Insert Description

Machining Process	Tool Type	Feed Rate (mm/rev)	Cutting Speed (m/min)	Wire Thread Insert Description
Machine Tapped	HSS	0.15	3	Cross Spiralock18349002 Silver plated
Thread Milled	HSS	0.20	40	

Table 2 - Property Comparison between Thread Milling & Machine Tapping

Machining Process	Fatigue Endurance (kN)	UTS (MPa)	Elongation (%)	Thread Root Hardness (HV)
Machine Tapped	13.3	1176	7.9	332
Thread Milled	6.1	1212	7.7	303

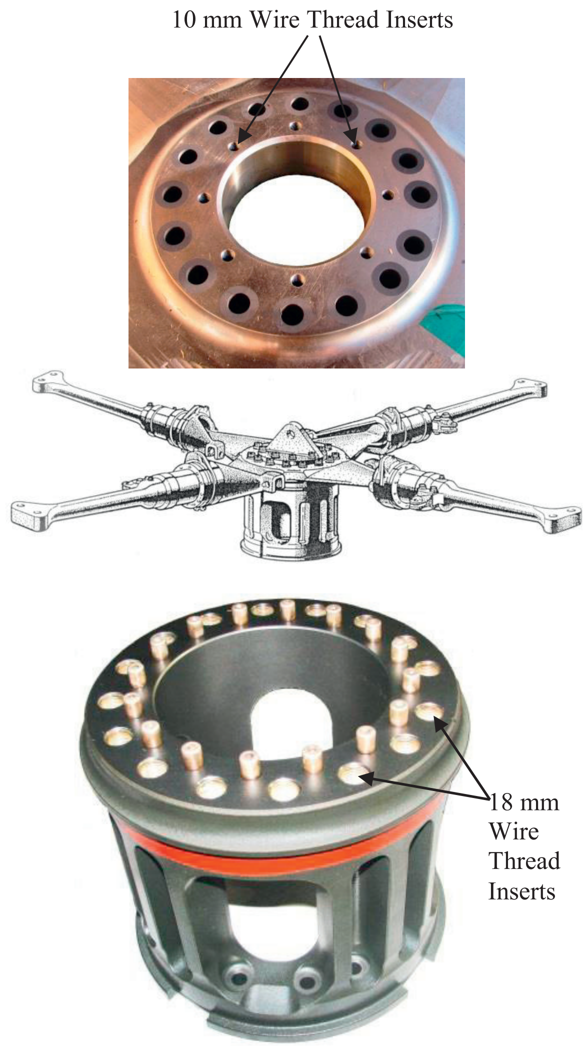

Figure 1 – Schematic Diagram Showing the Configuration of the Lynx BMRH and the Location of Threaded Holes in the Titanium Ti-10V-2Fe-3Al Mast and Disc

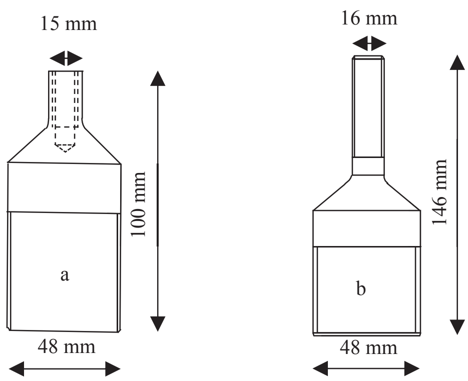

Figure 2 – Test Piece Configuration for (a) Thread Milling and (b) Thread Turning Trials