FLOWFORMING TO IMPROVE THE FATIGUE LIFE OF IMPLANTS?

Mohamed Akram Mechter[1], Mina Gadour[1], Léa Romain[1], Myriam Brochu[1]

[1]*Polytechnique Montréal, Montréal, QC, CANADA*
** Presenting Author email: mohamed-akram.mechter@polymtl.ca*

Abstract

Fatigue failure of 316L femoral implants is reported in the literature with a crack initiation mostly located at fixation holes. This research project aims at improving the fatigue resistance of the material surrounding the holes using flow forming processes. A comparative analysis of the microstructure, the fatigue life and the fractured surfaces of 316L stainless steel bars drilled and tapped with two different processes is presented.

1. Introduction

Flow drilling is a thermal process that uses the axial force of a rotating tool to heat and penetrate the material to create a hole. Flow tapping is a cold thread forming method involving the plastic deformation Both forming processes have an impact on the microstructure and the hardness of the plastically deformed material.

The purpose of this research is to improve the fatigue life of threaded holes with a specific application to locking compression plates (LCP). Case studies and experimental research conducted on LCP revealed that fatigue failure initiation at threaded holes is common. B. Gervais et al. [1] studied the in situ premature failure of a LCP installed on a femur and concluded that the fatal crack initiated from a threaded hole. S. Mohajerzadeh [2] and C. Kanchanomai et al. [3] who tested LCP in laboratories revealed that all cracks initiated from the tapped hole. This paper investigates the use of the flow process as a means to enhance the fatigue resistance of implants with tapped holes. Microhardness measurements and microstructural observation are conducted to understand the impact of the flow processes on the material. Four-points bending fatigue tests are carried out at three stress amplitudes with a stress ratio of 0.1 following the ASTM F382-17. Results and conclusions are presented in this extended abstract.

2. Results

2.1. Metallographic observations

The plastic deformation induced by the flow processes increased the material microhardness by nearly 100 HV just beneath the surface in contact with the tool. The layer of hardened material is approximately 300 um deep. In the affected layer, grain refinements and material flow lines are revealed by metallographic observation as shown in Figure 1. At the peak of the threads, discontinuities such as folds (Fig.1 d) or craters are observed. Microhardness and metallographic observations performed around the holes conventionally cut and threaded revealed no features different from the bulk material characteristics.

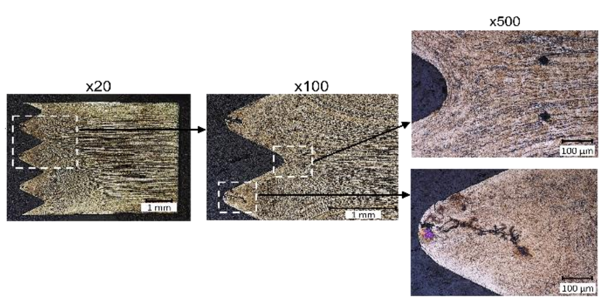

Figure 1. Flow processed hole metallographic observation. a) x20 magnification b) x100 magnification c) x500 magnification, bottom of the thread d) x500 magnification, discontinuity at the peak of the thread

2.2. Fatigue tests

The results of the fatigue tests are provided in Fig.2. No significant differences in fatigue life for tests performed bending moment is equal to 75% and 60% of the yield bending moment. Nevertheless, when the maximum bending moment applied was limited to 50% of the yield bending moment, the specimens containing holes manufactured by the cutting endure more cycles.

Scanning Electron Microscope (SEM) observations reveal that in the Conventional specimens (Fig.3), the crack always initiates at the peak of the first threads, just beneath the surface under maximum tensile stress. No material discontinuities were identified in the region of crack initiation. As for the flow specimens, the discontinuities revealed by metallographic observations are present at crack initiation sites. These act as pre-existing cracks most probably reduced the fatigue life and alleviating the possible beneficial effect of

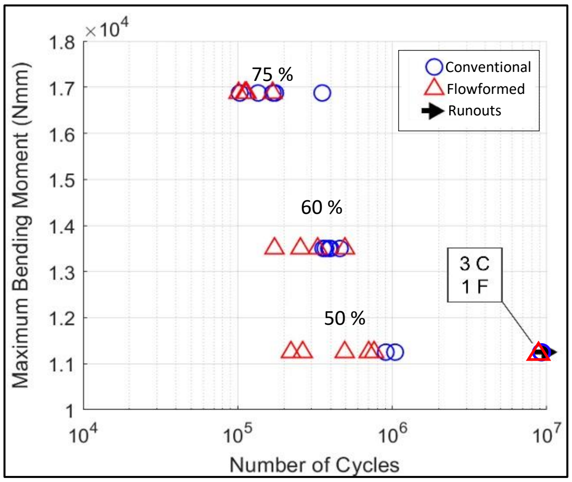

Fig.2 – Fatigue tests results

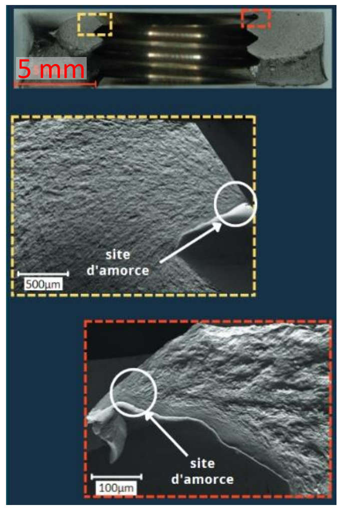

Fig.3 – Conventional specimen SEM observations

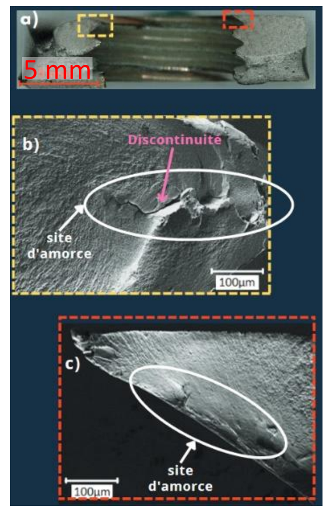

Fig.4 – Flowformed specimen SEM observations

the plastic deformation. In addition, secondary cracks were observed in the plastically deformed layer which may indicate that it was over hardened (Fig.4 c).

Increasing the number of tests will allow a more robust analysis of the difference in fatigue life.

3. Conclusions

Under the studied conditions, flow forming combined with flow tapping did not increase the average fatigue life of the 316L alloy. The presence of discontinuities created during flow tapping resulted in premature initiation of cracks.

In the future, the research team will attempt to optimize the flow forming processes to limit these discontinuities. If such is achieved, it is expected that the flow forming of holes will result in an improved fatigue life compared to that measured with conventionally drilled bars.

References

[1] B. Gervais, A. Vadean, M. Raison, and M. Brochu, "Failure analysis of a 316l stainless steel femoral orthopedic implant," Case Studies in engineering Failure Analysis, vol. 5-6, pp. 30–38, 2016.

[2] S. Mohajerzadeh, K. Farhangdoost, P. Zamani, and K. Kolasangiani, "Experimental investigation on fatigue evaluation of orthopaedic locking compression plate," International Journal of Advanced Design and Manufacturing Technology, vol. 11, pp. 47–52, 2018.

[3] C. Kanchanomai, V. Phiphobmongkol, and P. Muanjani, "Fatigue failure of an orthopedic implant – a locking compression plate," Engineering Failure Analysis, vol. 15, pp. 521–530, 2008.