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Influence of casting defects on fatigue strength of an investment cast Ti-6Al-4V alloy

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Abstract. The influence of casting defects on fatigue strength of an investment cast Ti-6Al-4V alloy is investigated. The most common of these defects are: pinhole, linear defect and inclusion. Each of them is currently defined by its size, morphology and position from the surface but is different from each other for a same type. An experimental campaign is defined with different types of defect. The first part of the campaign is focused on the influence of an artificial and spherical defect, considering two different surface conditions. It is shown that fatigue behaviour of this alloy is very sensitive to the surface condition of this artificial defect despite stress concentrations at the tip of the defect. The second part of the campaign is focused on casting defects: reduction of fatigue life is quantified and it is shown that an electro-discharge machined defect cannot be representative of pinhole.

1. Introduction

Casting defects are metallurgical heterogeneities creating during the casting process. Their influence on fatigue strength is widely studied for aluminium [1] and steels [2]. However, fewer results can be found for titanium alloys [3]. The aim of this paper is to analyze the influence of casting defects by both quantifying reduction of the fatigue strength because of these defects and determining the critical defect size under which fatigue strength is not affected.

2. Material data, defects and fatigue tests

Flat castings were manufactured with a thickness of 5 mm. They are used for both determining reference fatigue properties and quantifying the reduction of fatigue strength due to defects.

In this study, defects are artificial or natural. Influence of artificial defects, which are electro-discharge machined (EDM), is studied according to two different surface conditions: an EDM surface which is characteristic of the machining method and a chemically milled (CM) surface which is characteristic of the chemical milling used to remove the scoured layer created during machining of defect by EDM. Natural defects are pinholes which were observed at the surface of flat castings.

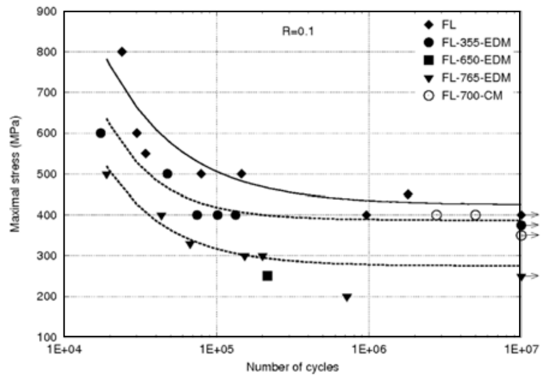

Figure 1. Influence of artificial defect.

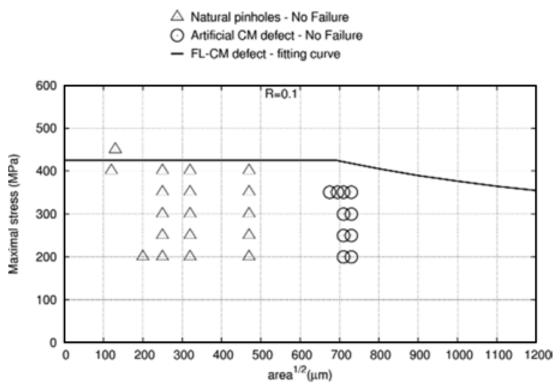

Figure 2. Kitagawa diagram at 10^7 cycles with natural pinholes.

Fatigue tests are performed on flat specimens designed to be representative of aircraft components. Stress ratio is equal to 0.1 and fatigue limit is estimated thanks to a step loading procedure.

3. Influence of artificial and natural defects

Figure 1 presents SN curves for both types of artificial defects. Fatigue strength is reduced for all specimens containing EDM defects: there is a reduction of 40% for the EDM defect of 765 μm at 10^7 cycles. Considering a CM defect with a similar size, fatigue strength is not reduced.

Figure 2 presents Kitagawa diagram at 10^7 cycles with natural pinholes and artificial CM defect. Pinholes observed at the specimen surface are not harmful because failure does not occur from these defects. This diagram shows that the critical defect size of pinhole is greater than or equal to 470 μm. Or, a 355 μm EDM defect reduces fatigue strength of this material (Fig. 1).

4. Conclusions

The experimental campaign performed on the investment cast Ti-6Al-4V alloy shows that this material is very sensitive to the surface condition of artificial surface defects. Considering stress concentrations introduced by a surface defect is not sufficient to take account of its influence on fatigue strength of the investment cast Ti-6Al-4V alloy. And so, an electro-discharge machined defect cannot be representative of pinholes.

References

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