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CRACKING OF AN AIRCRAFT WHEEL RIM MADE FROM AL-ALLOY 2014-T6

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Generally failures of different aircraft components and parts are revealed and examined by the use of non-destructive examination methods. In further detailed explanation and interpretation of failures optical and scanning electron microscopy are used. This paper deals with a problem of a crack on aircraft wheel rim made from aluminium alloy 2014-T6.The crack was observed during regular control by the maintenance unit for non-destructive examination of the Slovenian air carrier Adria Airways. The crack on the rim of an aircraft wheel investigated was a typical fatigue crack. At same time a numerous pits were found which served as stress concentrations on the rim surface.

Key words: Al-alloy, aircraft wheel, rim, cracks, fatigue

Pucanje naplatka avionskog kotača izrađenog od Al-slitine 2014-T6. Oštećenja različitih dijelova i komponenti aviona otkrivena su i ispitivana primjenom nedestruktivnih metoda ispitivanja. Za detaljnja objašnjavanja i interpretaciju oštećenja korištene su metode optičke i pretražne elektronske mikroskopije. Ovaj se članak bavi problemom pukotine na naplatku avionskog kotača izrađenog od aluminijeve slitine 2014-T6. Pukotina je zapažena za vrijeme redovite kontrole od strane slovenskog zračnog prijevoznika Adria Airways. Ispitivanja su pokazala, da je zapažena pukotina na naplatku avionskog kotača bila tipična umorna pukotina. Također je utvrđeno, da brojna oštećenja u obliku rupica pronađena na površini naplatka djeluju kao koncentratori naprezanja.

Ključne riječi: aluminijeva legura, avionski kotač, naplatak, pukotine, umor

INTRODUCTION

Numerous cases of failures of different aircraft components and parts with abundant data and in-depth analysis of causes, development and manifestation of failures can be found in the literature [1-4]. The check-up of the integrity of aircraft components is carried out by trained and competent personnel. The regular inspection of particular components is scheduled depending on the number of flying hours, lifetime and priority as specified by strict international regulations.

The inspection is carried out by the use of verified testing methods. The most frequently used methods applied are the non-destructive testing methods: penetrants, replicas, ultrasound, magnetic powders, eddy currents, and radiographic examination [5-7]. If a failure is detected, the corresponding part or component must be repaired or replaced immediately. This paper deals with a crack in the rim of an aircraft wheel made from well known aluminium alloy 2014-T6 [8-10] revealed during routine inspection.

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EXPERIMENTAL WORK

The crack (Figure 1) was revealed in a regular check up by the method of eddy currents. The crack was approximately 38 mm long and had propagated trough the rim wall. Small pots over the entire rim/tire contact surface were revealed. A small number of corrosion pits were also observed by the naked eye. In the manufacture of tires a strong textile fabric net is incorporated. In worn-out tires the net is in direct contact with the rim surface. Therefore, high pressures result in pits on the rim surface.

The examination of the rim surface in the vicinity of the crack was carried out with a portable optical micro-

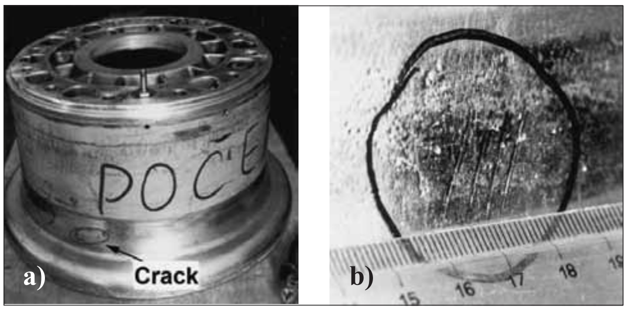

Figure 1 An investigated aircraft wheel with a crack (a), and the detail of crack in the rim (b).

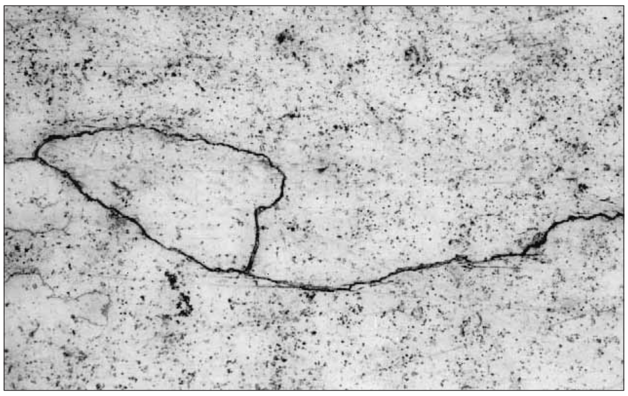

Figure 2 A branched crack (replica; OM) magnification 100x.

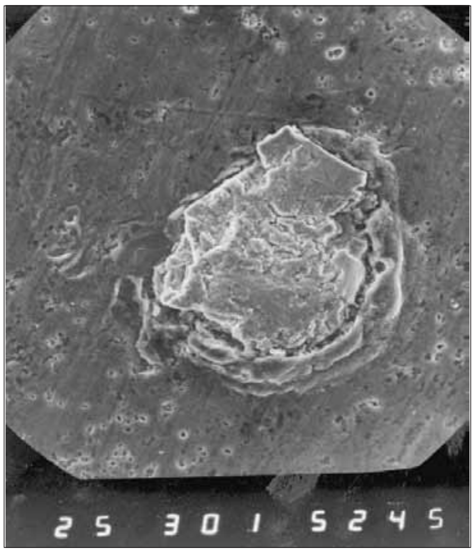

Figure 3 A corrosion pit on the rim surface (SEM); magnification 300x.

Figure 4 Parallel cracks (OM); magnification 100x.

scope (OM). In some places of a branched crack, corrosion spots as seen in Figure 2 were also observed. A number of cracks were found, some of them merged into a bigger one. Small corrosion pits visible only by the microscope were found all over the rim surface. The morphology of corrosion pits was examined by scanning electron microscopy (SEM) (Figure 3).

First of all the ends of cracks were examined. Parallel cracks were also found in one of the metallographic samples investigated, as seen in Figure 4.

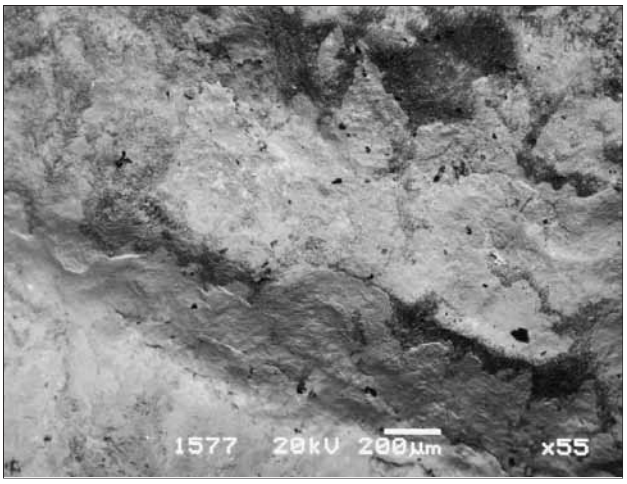

Figure 5 Fracture surface (SEM) analyzed by EDS; magnification 55x.

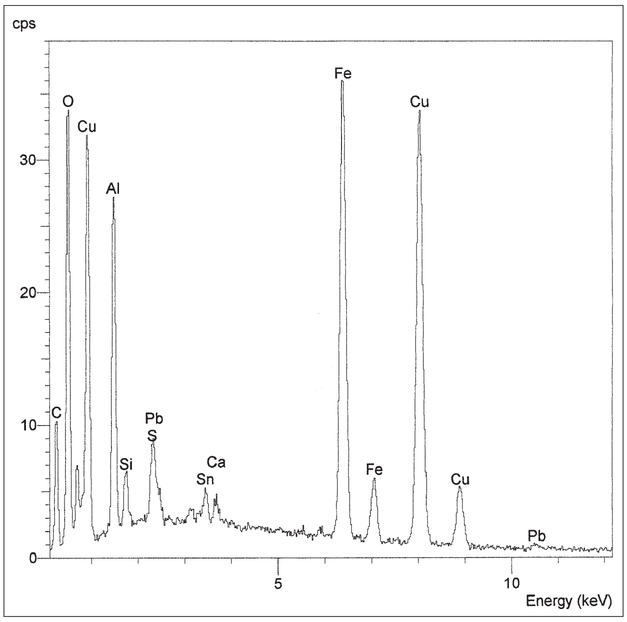

Figure 6 Qualitative chemical analysis of rim fracture surface (gray area in Figure 5) (EDS).

The material on the fracture surface of the sample presented in Figure 5 was chemically analyzed by energy dispersive spectrometry (EDS). The results obtained in different spots were different. The dark area in Figure 5 contains C, O, Cu, Al, Si, S, Ca, Mn and Fe, the gray area: C, O, Cu, Al, Si, S, Pb, Sn and Ca as seen in Figure 6, while the white area contains C, O, Fe, Cu, Al, Si, S and Mn. Typical elements in the fracture surface were sulphur and carbon originating most probably from tires.

A sample of quadratic shape for Crackronix was cut from the rim wall to measure parameters of Parisžs equation (1) [11,12] as well as to calculate the propagation rate (da/dN) of the fatigue crack. The propagation rate can be calculated utilizing the equation (1):

$$\frac{\mathrm{d}a}{\mathrm{d}N} = C(\Delta K)^m, \qquad (1)$$

where:

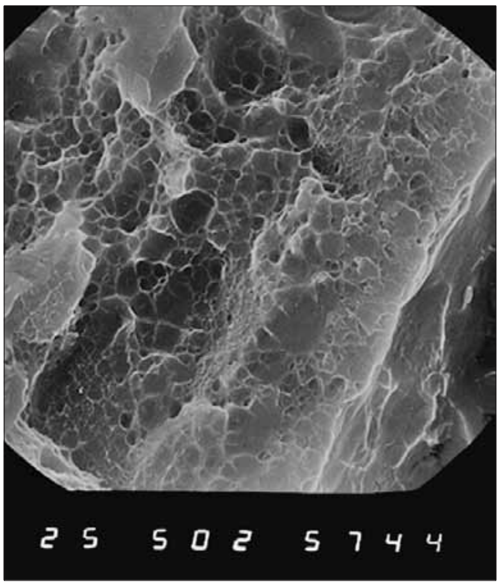

Figure 7 Boundary between ductile and fatigue fracture (SEM); magnification 500x.

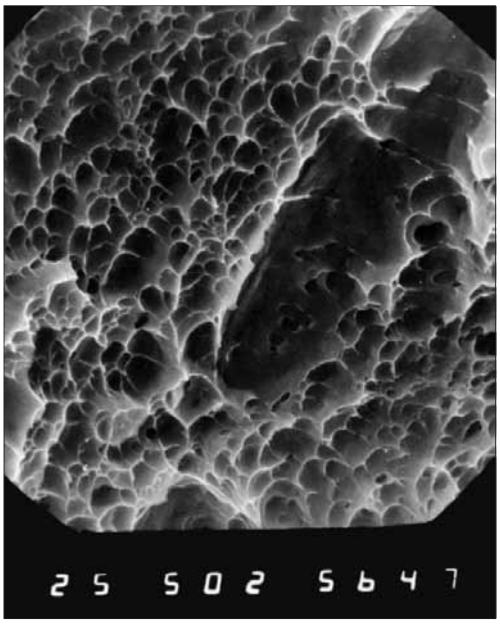

Figure 8 Ductile facture of rim over surface pits (SEM) magnification 5000x.

a = crack length (mm)
N = number of cycles (-)
m =3,345 (-), and
C = 2,17 · 10^{-8} (ΔK in MPa$\sqrt{\text{m}}$) [13].

The ratio between the lowest and the highest stress applied in testing was constant and equal 0,1. A diagram of fracture toughness (K_{IC}) vs. the exponent m can be used to estimate the fracture toughness at known value of the exponent (K_{IC} = 52 MPa$\sqrt{\text{m}}$) [13]. At given crack length (a = 38 mm) the critical stress (σ_I) resulting in immediate fracture can be calculated [14,15] from the equation:

$$\sigma_I = \frac{K_{IC}}{\sqrt{\pi \cdot a}} = 149{,}7 \text{ MPa}. \qquad (2)$$

An investigated sample was broken to observe the boundary between ductile and fatigue fracture (Figure 7). Only immediate i.e. ductile fracture is seen in Figure 8.

It was determined that the crack of the rim investigated was a typical fatigue crack [16]. The crack was branched, and its size was lower than the critical which could cause immediate failure. It was not possible to determine the site of crack initiation. The presence of carbon and sulphur in the crack represents strong evidence that the crack was a fatigue crack. Carbon and sulphur deposited on the surfaces of the crack and the surroundings. Probably during landing and slowing down when the temperature of wheel rim and tire was sharply increased, resulting in partial dissociation of the tire.

Consequently, carbon and sulphur gradually accumulated in and around the crack. Numerous pits on the rim surface were clearly seen. They were caused by the influence of mechanical factors, surroundings and increased temperature. The fatigue crack investigated most probably started from on these pits.

CONCLUSIONS

Failures of aircraft components and parts have mostly been detected by the use of non-destructive methods. The result obtained can be supplemented with metallographic examination which supplies additional information on the condition of material and the nature and origin of failures.

During landing and take off rims of aircraft wheels are subjected to high mechanical stresses and atmospheric influences. The crack in the rim investigated was a typical fatigue crack. It was ramified. Its size was lower than the critical size which at a sufficient load could cause immediate collapse.

Numerous pits were found on the rim surface, and the crack propagated over them. Therefore, it can be concluded that pits served as stress concentrators on the rim surface until one of them finally initiated the fatigue crack.

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Note: The responsible translator for English language is Tanja Goršič, University of Ljubljana.