CYCLE INDUCED MICROSTRUCTURAL CHANGES

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ABSTRACT
X-ray diffraction analysis of the structure of an aluminium alloy EN-AW-6082 subjected to cyclic stress proved that the effect of cycling was first to transform an irregular dislocation distribution into cellular one. But later, after a certain number of cycles, the effect of cycling reversed and the cells gradually disintegrated. Such changes may be to advantage used for monitoring structural degradation and estimating residual life of fatigued components.

Keywords: fatigue, aluminium alloys, microstructure, x-ray diffraction

INTRODUCTION

Since 1850 it has been recognized that a metal subjected to repetitive or fluctuating stress will fail at a stress much lower than that required to cause fracture on a single application of load [1, 2]. Unfortunately, there is no obvious change in the structure of a metal that has failed in fatigue, as observed by an optical or electron microscope, which can serve as a clue to our understanding of the reasons for fatigue failure [3]. That is why we use a special x-ray diffraction technique to this purpose. The used fatigue test procedure and material are described in the other paper in these proceedings (*Mazal,P. et al.: Contribution to identification of cyclic damage development of AlMg alloy – p.169*).

X-RAY DIFFRACTION EXAMINATION

The technique is designated as "diffraction imaging" or "grain-by-grain" method [4]. This technique makes use of the fact that in case, that the size of the coherent scattering regions (CSR´s) is between 10µm and 100µm, the diffraction lines are split up into individual spots (reflections) – Figs.1b,2b,...,5b. These spots are diffraction images (topographs) of individual CSR´s which satisfy the Bragg conditions for a given experimental arrangement. The information on the size, shape, orientation and various structural defects of these CSR´s can be inferred from the size, shape, orientation and distribution of diffracted intensity through the corresponding spots (reflections) which forms the so-called azimuthal diffraction line profile (Figs.1a,2a,...,5a). The number of CSR´s (in the diffracting volume) which are smaller than 10µm is so large and the diffraction spots they produce so plentiful, that they overlap, producing continuous background of the diffraction line (and the corresponding azimuthal diffraction line profile) above which the resolved reflections from CSR´s that are larger than 10 µm, stand out [5,6]. The area P_1 under the solitary reflections is proportional to the share of the CSR´s which are larger than 10µm, while the area P_2 under the continuous background is a measure of the proportion of the CSR´s which are smaller than 10µm (Figs.1c,2c,...,5c). The value R of the ratio $R = P_1/(P_1 + P_2)$ then equals to the proportion of the large CSR´s in the test sample under consideration, characterizing in this way its structure [7].

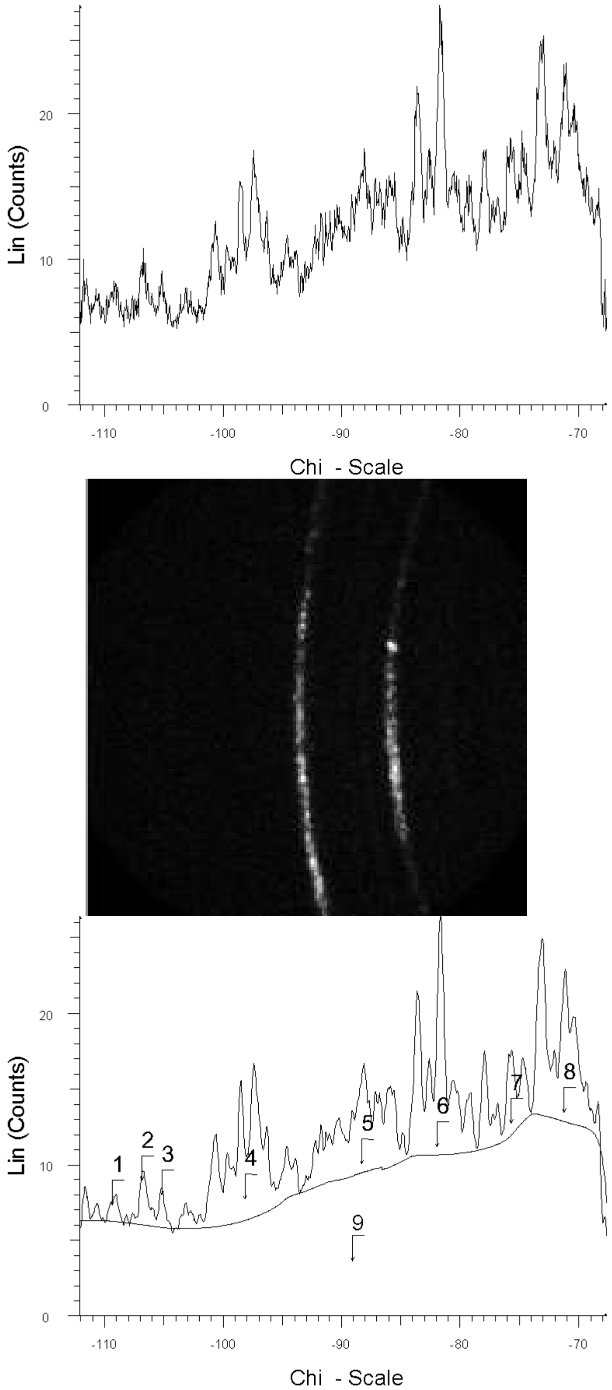


Fig.1. Test specimen in the initial state. Azimuthal profile (a) of the (200) aluminium diffraction line on the left side of the diffraction pattern (b). Areas under the peaks and background of the azimuthal profile for the determination of the value of R (c).

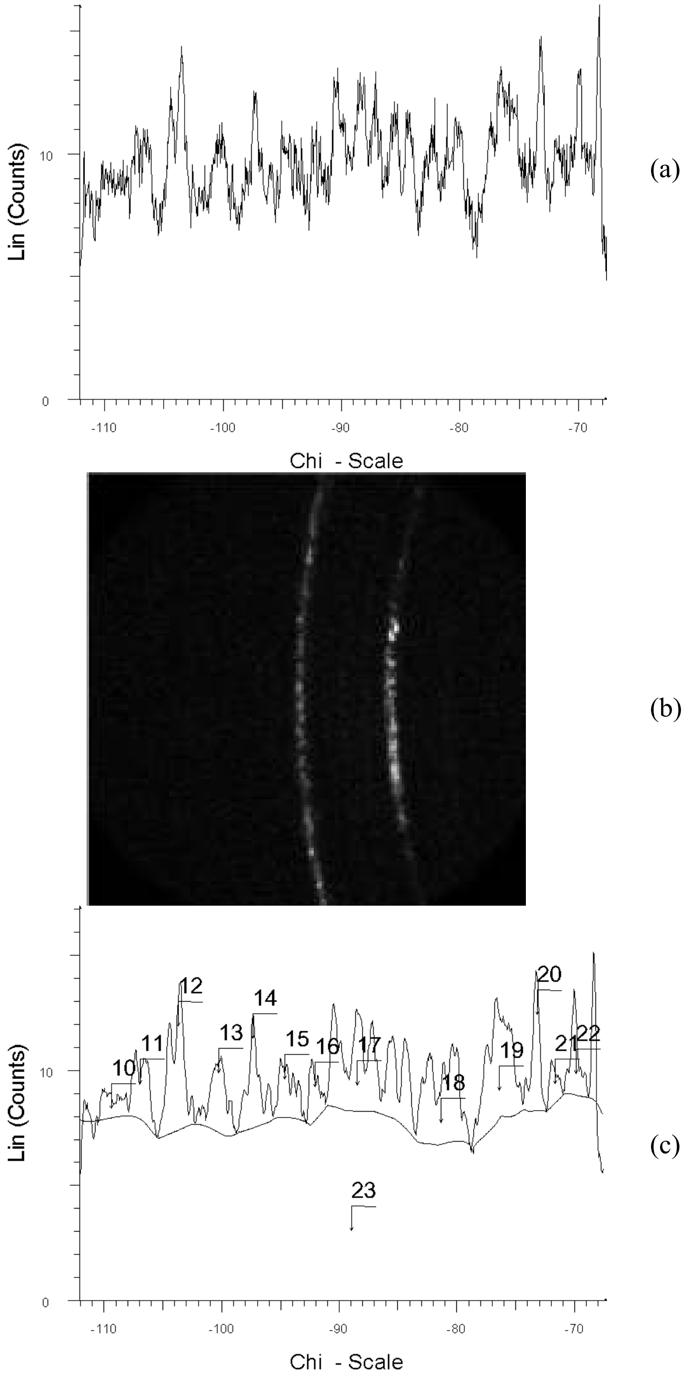


Fig.2. Test specimen loaded with 6000 cycles. Azimuthal profile (a) of the (200) aluminium diffraction line on the left side of the diffraction pattern (b). Areas under the peaks and background of the azimuthal profile for the determination of the value of R (c).

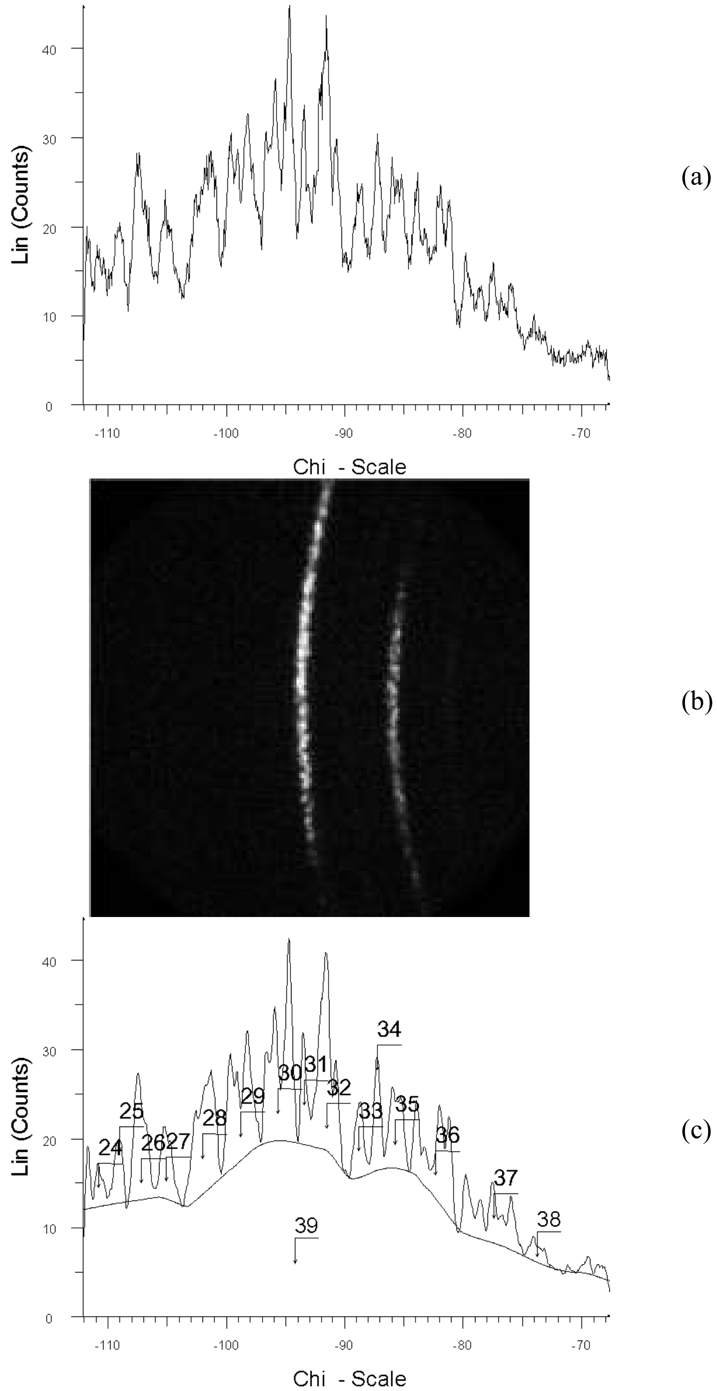
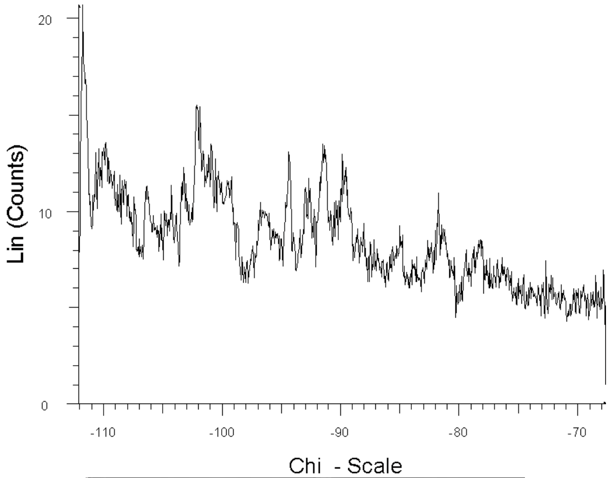
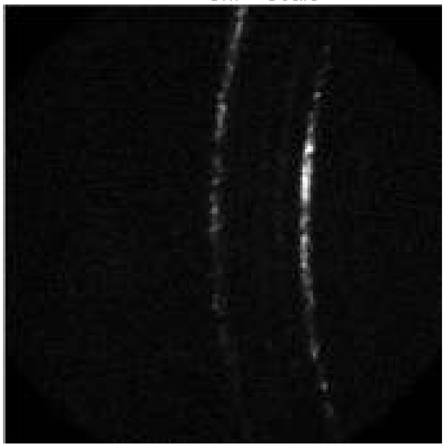


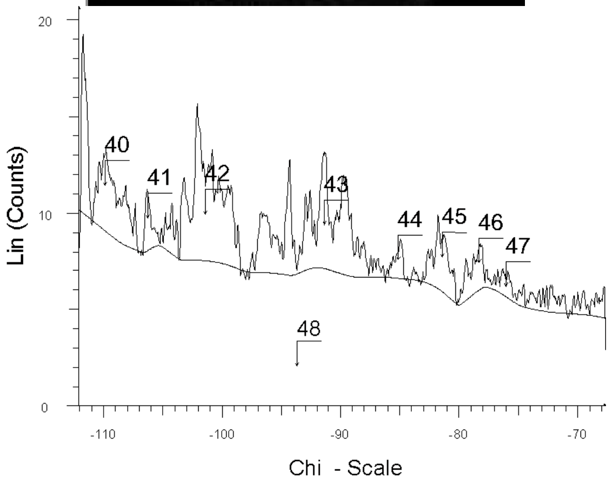
Fig.3. Test specimen loaded with 60000 cycles. Azimuthal profile (a) of the (200) aluminium diffraction line on the left side of the diffraction pattern (b). Areas under the peaks and background of the azimuthal profile for the determination of the value of R (c).



(a)

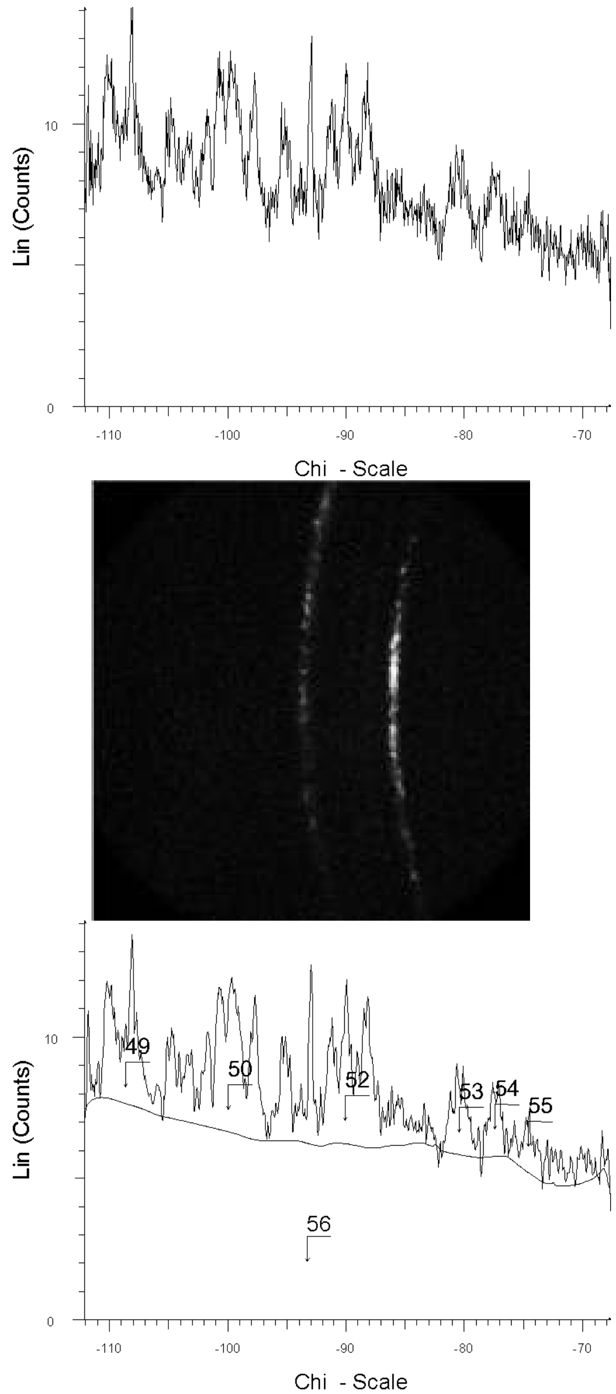


(b)



(c)

Fig.4. Test specimen loaded with 100000 cycles. Azimuthal profile (a) of the (200) aluminium diffraction line on the left side of the diffraction pattern (b). Areas under the peaks and background of the azimuthal profile for the determination of the value of R (c).



(a)

(b)

(c)

Fig.5. Test specimen loaded with 200000 cycles. Azimuthal profile (a) of the (200) aluminium diffraction line on the left side of the diffraction pattern (b). Areas under the peaks and background of the azimuthal profile for the determination of the value of R (c).

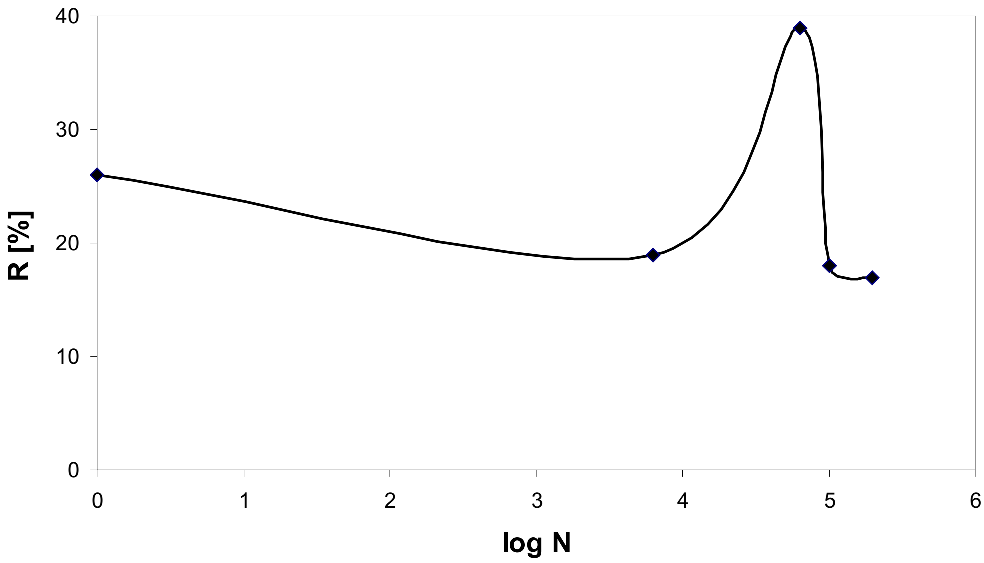


Fig.6. Fatigue response in the aluminium alloy under consideration. R = proportion of large structural cells, calculated from the azimuthal profiles of the aluminium (200) diffraction line for the respective test specimens.

RESULTS AND DISCUSSION

By x-ray examination of the aluminium alloy under study we have found that its microstructure, as characterized by the proportion R of the large CSR´s (mosaic blocks, structural cells) greater than 10 µm, does change much under repeated stress (Fig.6). In the first stage of loading (up to 6000 cycles), the CSR´s due to the introduced plastic strain disintegrate. As a result of this, the boundary surface of the cell aggregate extends, and, consequently, its energy finally increases enough to initiate its coarsening. The energy necessary to activate the growing of the larger blocks at the expense of the smaller ones is supplied by further cycling (over 6000 cycles). But, during this growth, paracrystalline distortions emerge, which gradually accumulate in the interior of the widening cells, raising thus their volume energy. After 60000 cycles, the energy increases to such degree that the blocks begin disintegrate anew. Due to this disintegration, the paracrystalline distortions relax and the alloy energy drops.

FUTURE DEVELOPMENTS

First, our study, limited so far essentially to low-cycle fatigue, will be extended to a higher-cycle domain. Second, the test samples will be unified concerning their initial structure. Third, the mosaic block size of the test samples in the virgin, non-cycled state will be adjusted to some 50 μm in order to make proper use of the efficiency of the x-ray diffraction technique applied which is maximum in this range.

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