CONTRIBUTION TO IDENTIFICATION OF CYCLIC DAMAGE DEVELOPMENT OF AlMg ALLOY

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Abstract

The paper describes some basic exposures of AlMg alloy (EN-AW-6082) behaviour change during high cycle fatigue loading which were detected using AE method and analysis of load frequency changes of the electromagnetic loading device. These procedures allow identification of different stages of fatigue process, however it is very difficult to exactly specify the reason of AE signal change or the loading frequency. That is why the X-ray diffraction analysis of the structure method was used. This method can further clarify some processes in the loaded material. First results of these observations are described in the basic article of prof. Fiala et al.: *Cycle induced micro-structural changes*, which is published on the page 73 of these proceedings.

Keywords: acoustic emission (AE); fatigue properties; loading frequency; burst signal characteristics;

INTRODUCTION

Al and Mg alloys present a very important group of construction materials, which are used thank to its specific properties in many different applications mostly in transportation – for example in aircraft and automobile industry. The requirements posed on these materials are constantly increasing and therefore it is necessary to explore their properties in more and more detail and consequently purposely change some these properties. Understanding the progression of degradation processes that can occur during exploitation of constructions made of AlMg alloys is very important. The reliability of machine parts in transportation often makes the difference not only when it comes to material losses but more importantly human lives.

An important group of degradation processes of construction parts is connected with mechanical and especially cyclic mechanical loading. The process of cyclic degradation of properties of AlMg alloys differs in some ways from standard principles relatively well known at iron alloys. For example damaging of AlMg alloys proceeds even with loading amplitudes that correspond to app. 10^7 load cycles (standard threshold of fatigue of common materials) and therefore reliable determination of fatigue threshold is very difficult.

A considerable problem of AlMg alloys (whose semi-products are fabricated by forcing -through method) is non-homogeneity of structure and its significant differences in different directions – so called structure directivity. This directive non-homogeneity can influence some mechanical properties and consequently the properties of individual real parts can differ. One of the projects that are currently being solved at Institute of Design of Faculty of Mechanical Engineering of BUT in cooperation with Institute of Material Science and Engineering of FME is identification and quantification of these changes and determination of their influence mainly on fatigue properties.

MATERIAL AND EXPERIMENTAL EQUIPMENT

The results described in this paper and the paper of prof. Fiala (pp.73-80) were obtained with alloy EN-AW-6082 whose composition is described in Table 1. The material was supplied heat treated to status T6.

Tab.1 Chemical composition of tested Al alloy

Chem. element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
	% (wt)							
EN-AW-6082	1,01	0,17	0,067	0,66	0,84	0,16	0,030	0,032

The fatigue tests were performed on fatigue testing machines Cracktronic 160 and 70 made by RUMUL AG company; these machines work on the principle of electromagnetic resonance. Samples were loaded by four point bending (Fig.1). Used test samples were flat blocks with dimensions 15 x 5 x 70 mm with two lateral notches 40 mm in diameter and 2,5 mm deep milled in the central part. Surface of samples was grinded and consequently the surface layer was chemically etched, so the area deformed by machining was removed. One of the samples can be seen on Fig.2 (type A). Loading frequency on this type of equipment depends on sample rigidity and used Cracktronic test machine; in our case it was somewhere between 80-90 Hz.

After fixed number of loading cycles the tests were stopped and samples were sent to West Bohemia University in Pilsen for X-ray diffraction analysis of structure of the surface.

Immediately after finishing of these „interrupted“ examinations, continual measurements of AE signal change during the fatigue load were carried out on another samples. The AE signal was read using glued sensors of Midi type made by Dakel firm (Fig. 2).

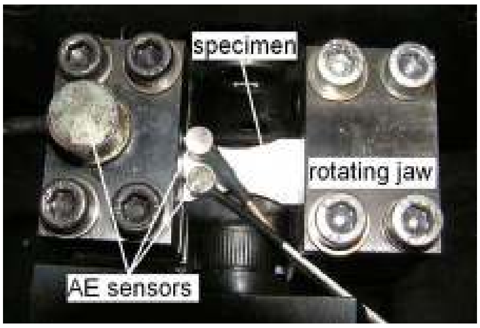

Fig. 1 The fatigue test arrangement with AE sensors

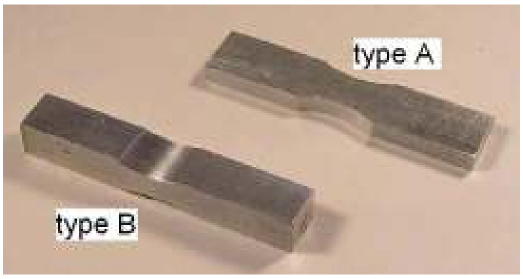

Fig. 2 The typical shapes of fatigue test specimen. The type A was used for discussed experiments

RESULTS

The electro-resonance fatigue test machine works with loading frequency corresponding with resonance of the whole loading system. In case that the rigidity of the tested sample is changed (cyclic hardening or softening in the initial part of loading, fatigue crack initiation and crack spreading etc.) this frequency is changed (see Fig.3). It means that it is possible to estimate approximately the length of these stages. From practical point of view the most important is the identification of the fatigue crack spreading phase of course, but in case of detailed analysis some changes of frequency can be detected in the stage of “stable” mode.

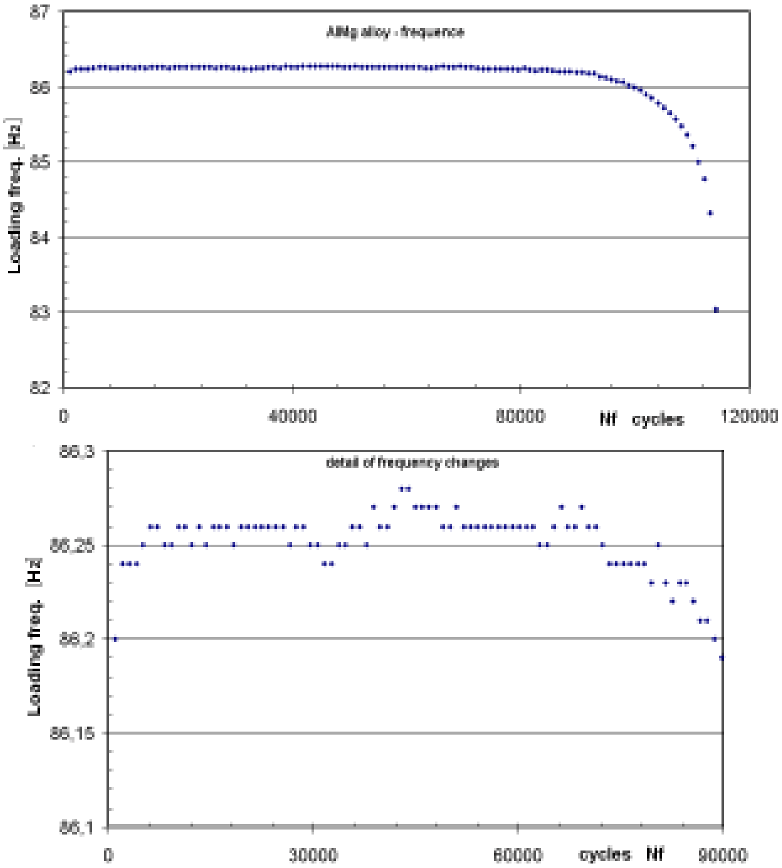

Fig.3 The plot of loading frequency changes during fatigue test on Cracktronic 160 test machine – overview and detail of the same plot

Much more detailed information about changes of mechanism of cyclic damage is provided by AE method application, which identifies plenty of damage mechanisms. An example of the simplest record of AE activity can be seen of Fig. 4.

In this case the count of oversight of AE over predefined thresholds is captured. It is again possible to relatively reliably determine the length of initial changes phase from the record – here stabilization and the phase of fatigue crack propagation. It is however evident that the AE signal changes also in the period between these basic phases. Notably the relatively important activity rise in the phase of app. 30-40.10^3 loading cycles (app. 30% of this sample lifetime). Exemples of more detailed treatment of AE signal from this first period of fatigue loading is presented in Figures 5 and 6.

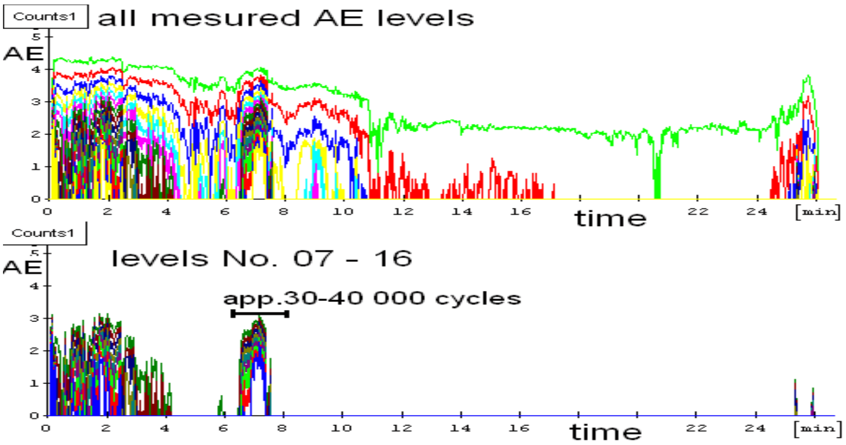

Fig.4 AE activity during fatigue test of AlMg alloy on Cractronic 160 test machine: in all measured AE signal levels and after elimination of lower levels No.1-6 (below).

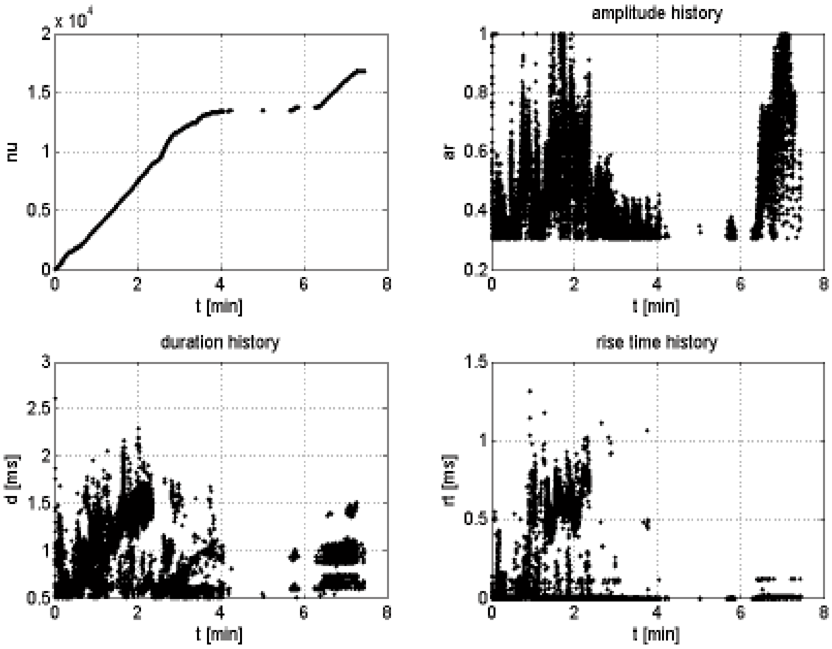

Fig.5 Detail of AE signal parameters changes in the first 8 minutes of loading (cumulative number, relative aplitude history, events duration and rise time history.

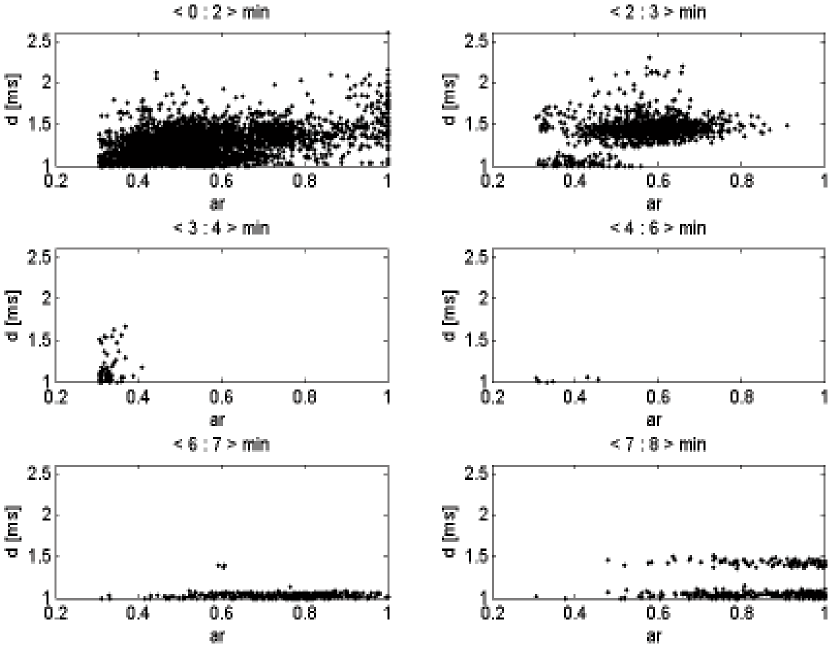

Fig.6 Correlation AE amplitude graphs in differents time periods for AlMg alloy in first period of loading.

Classical techniques of optical observation of surface do not provide any obvious reason for this phenomenon. On the basis of analogy with other observations it is possible to expect that the reason of emission activity can be for example accumulation of energy sufficient for loosening of dislocations captured in structural obstacles, occurrence of micro-cracks and eventual connecting of existing micro-cracks. The reason of increased emission activity during the so called stable mode can be also the changes of material substructure – emphasizing of sub-seeds, mutual rotation of suitable areas in frame of individual seeds of material etc. can appear. The already noted paper of prof. Fiala focuses on these observations.

CONCLUSIONS

The AE method application proved a possibility of basic identification of individual stages of fatigue processes in tested AlMg alloy. This method can further enrich knowledge about individual stages of fatigue damage. It is however not possible to expect from AE method the exact identification of AE sources. That is possible only by connecting AE with further laboratory procedures capable of identification of processes in material substructure. These commonly gained experiences will contribute to identification of processes, which take place in AlMg alloys even in loads which correspond to very high lifetimes and which are very difficult to identify by common material testing procedures.

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