GENERAL ENGINEERING PROBLEMS OF FOREST INDUSTRY COMPLEX

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EFFECT OF IRON CONTENT AND LASER HARDENING ON THE FRACTOGRAPHY OF HIGH-FREQUENCY FATIGUE FRACTURES IN AK8M3 ALLOY SAMPLES

The equipment and techniques of accelerated fatigue tests allowed to determine an optimum iron content in the secondary aluminium alloy AK8M3 strengthened by laser processing.

Introduction. At present aluminium-based alloys rank second in the production volume due to their good service qualities being inferior only to iron-based alloys. However, it should be noted that obtaining one ton of primary aluminium involves much more power consumption than obtaining the same amount of iron-based alloy. Therefore, the problem of increasing application of secondary aluminium is of great importance all over the world since it can reduce power consumption as much as twenty times and exerts weaker impact on the environment. In EU countries the production of secondary aluminium alloys is known to grow faster than that of primary alloys and there are about 200 plants dealing with processing of secondary raw materials [1].

To reduce labour input and time for making fatigue tests especially on large (up to 108 cycles) bases, it is highly promising to use high frequency of mechanical vibration that allows to have a considerable number of cycles over a reasonable period of time. So, to make tests at 50 Hz and on a 108 cycle base, 555 h (over 23 days) of continuous work of testing equipment are needed, while the same tests carried out at 20 kHz will take only 1.3 h. This investigation method is especially efficient when carrying out comparative tests [2].

Main part. The subject-matters of the research are 2-mm thick flat beam specimens from AK8M3 secondary aluminium alloy with different iron-content and surface condition (see Table). The reference sources [3] provide an overall view of non-laser-processed specimens revealing fatigue damage and of laser-processed ones without fatigue cracks.

The loading of specimens was carried out using specially designed research equipment at 18 kHz resonance vibration frequency.

The specimens were exposed to loading at their second mode of vibration. The selection of size and shape of the specimens was carried out so that fatigue damage occurred at the points of maximum cyclical stress, approximately in the centre of the straight-line portion. This enabled easy investigation of changes in material properties and fatigue crack development.

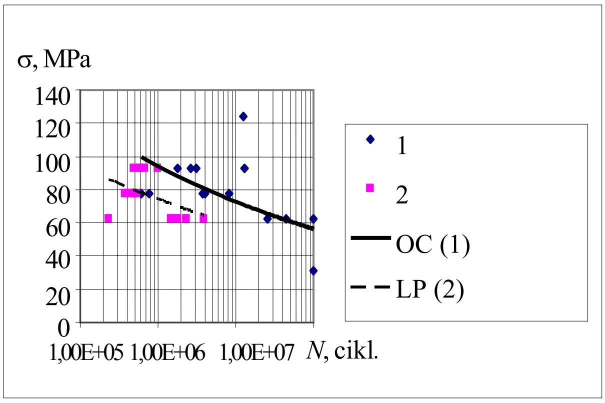
The kinetics of the specimen damage was assessed by the decrease of resonance vibration frequency coupled with fatigue crack development [4]. The tests stopped after the frequency had dropped to a certain value. The study of the obtained diagram showing the crack pattern on the specimen area made it possible to detect the coincidence between the fatigue cracks spots and the maximum estimated value of cyclical stress for the given vibration mode of a specimen.

Characteristics of the alloy under investigation

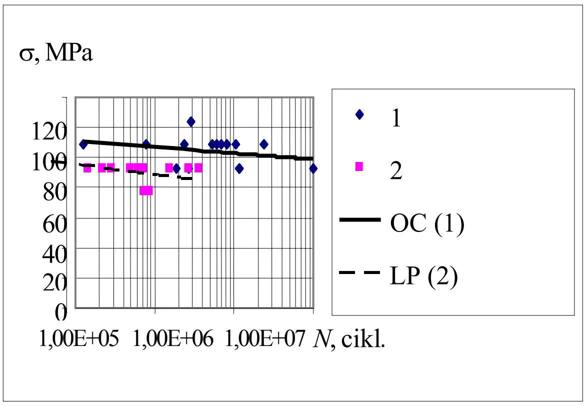
Alloy marking	Iron content, %	Technology of production and surface condition
11	0.40	Melting under cover-degassing flux (62% of NaCl, 13% of KCl, 25% of NaF) + modifying acc. to patent N 57584A, followed by casting and T6-mode thermal processing. Impulse laser processing with surface fusion at KBAHT-12 unit, impulse time – 4 msec, wave length – 0.6943 μm, stain covering – 30%. Laser impingement point – about 200 μm deep
33	0.92	
55	1.45	

Fig. 1, *a–c*, shows fatigue curves of alloys with different iron contents and surface conditions, Fig. 2 shows fractography of fatigue fractures.

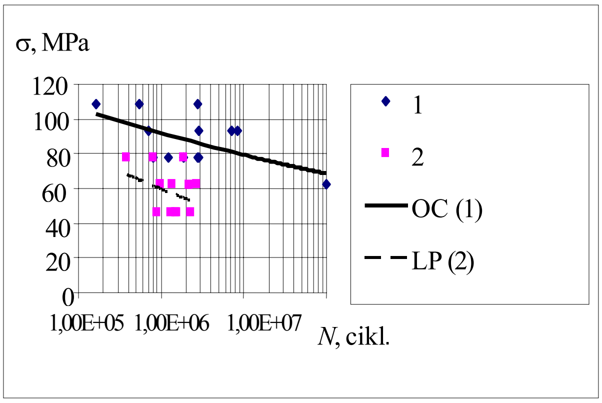
As it can be seen in the pictures, laser processing has a significant effect on the behaviour of original cast structure of all alloys and causes its considerable change. Thus, along with increased structure homogeneity, laser processing can also result in round-shaped gas bubbles in the heat-affected area.



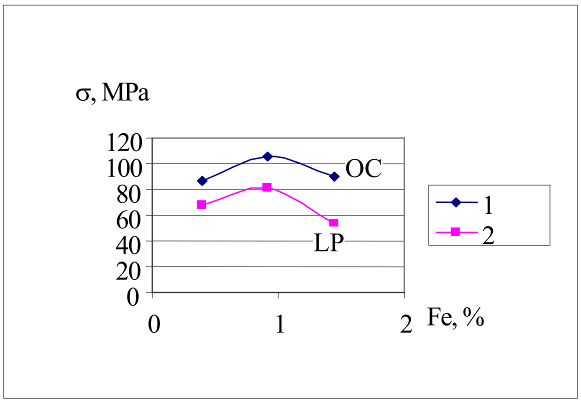
a



b



c



d

Fig. 1. Fatigue curves for specimens with different iron-content and relation of iron content in AK8M3 alloy (a, b, c) and surface laser processing to the fatigue limit on the basis of $N = 2 \cdot 10^6$ cycles (d):
a – 0.40% Fe, *b* – 0.92% Fe, *c* – 1.45% Fe;
OC – original condition; LP – laser processing

Alloy 0.40% Fe 0.92% Fe 1.45% Fe

OC

LP

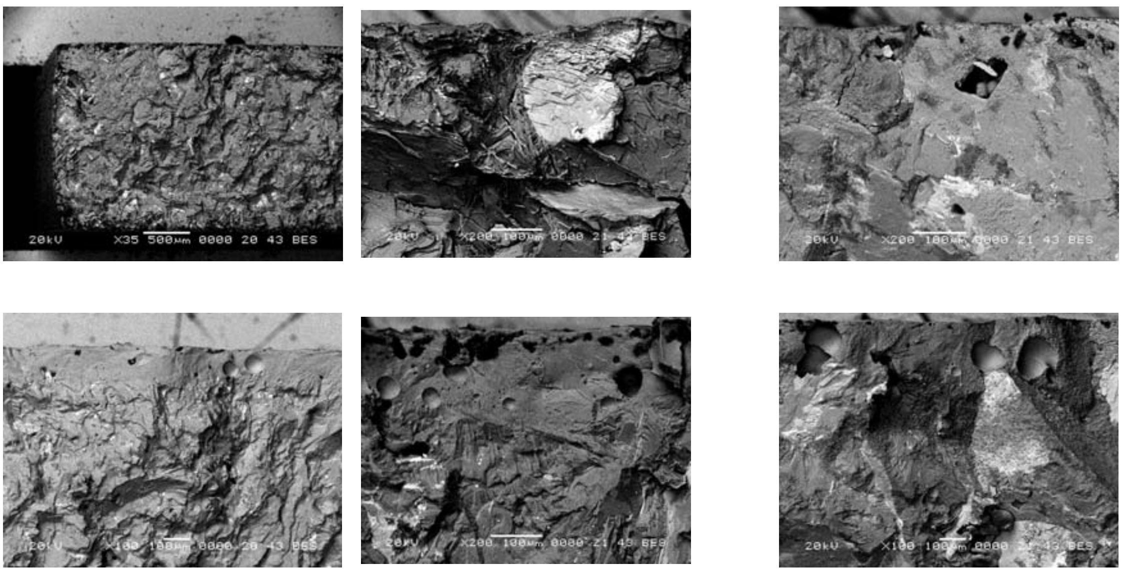


Fig. 2. Fractography of high-frequency fatigue fractures in specimens with different iron-content in AK8M3 alloy.
OC – original condition; LP – laser processing

Conclusion. 1. High-frequency loading makes it possible to carry out comparative tests of construction materials. This also intensifies the investigation process, improves the accuracy of results due to a greater number of materials under testing, saves labour and energy resources.

2. The optimum percentage of iron in the alloy under study has been found experimentally with regard to its increased fatigue properties. This value can be assumed to be within 1%, allowable variation being below 0.5% of Fe. This effect of iron can be supposed to appear at other processes of the alloy surface treatment as well.

3. Laser processing has been found to considerably affect both the visual appearance of the alloy surface (making it rougher) and structural components of the surface layers (making structure visually more homogeneous). At the same time it results in considerable gas inclusions which are mainly located in the fatigue fracture front.

4. These changes have a multiple effect on the behaviour of fatigue characteristics in all types of the alloy under investigation. On the one hand, laser processing can resist the crack development to a greater extent over the fatigue crack front than it is done by original structure parameters due to the absence of important volume irregularities which can contribute to the increased concentration of weak structure components. At the other hand, however, surface roughness and subsurface gas inclusions can generate the cracks and thus, greatly lower general fatigue characteristics. It is very probable that careful selection of parameters of laser processing will allow to obtain uniform structure of alloys without such defects as gas inclusions (bubbles) but with improved fatigue resistance properties.

5. Therefore, it has been found out that the characteristics of laser hardening technology discussed in this paper cannot be employed to improve the fatigue performance of the alloy under study. Further research into this issue is needed to select proper parameters of laser hardening.

6. The results obtained are a good example of the efficient application of high-frequency load technique [5] for quick detection of defects which result either from the technology itself or from the wrong employment of conventional hardening technology and can considerably affect the fatigue performance of construction metals.

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