CREEP AND FATIGUE OF COMPOSITES AND LIGHT MULTIFUNCTIONAL ALUMINIUM ALLOYS

Zbigniew L. Kowalewski[(1)], Agnieszka Rutecka[(1)], Tadeusz Szymczak[(2, 3)]

[(1)] Institute of Fundamental Technological Research
ul. Pawińskiego 5B, 02-106 Warsaw, Poland
zkowalew@ippt.gov.pl
[(2)] Motor Transport Institute, ul. Jagiellońska 80, 03-301 Warsaw, Poland
tadeusz.szymczak@its.waw.pl
[(3)] Bialystok University of Technology, ul. Wiejska 45c, 15-351 Białystok, Poland
szymczak@pb.edu.pl

ABSTRACT – An applicability of two light aluminium alloys (AlSi7MgCu0.5 and AlSi8Cu3) and A356+TiB_2 based MMC to work at room or elevated temperatures under constant long-term or cyclic loading was experimentally evaluated.

INTRODUCTION: A lot of industrial branches need novel materials which should guaranty higher strength and resistance to an impact than the commercial metals or their alloys. In this paper two light aluminium alloys (AlSi8Cu3 and AlSi7MgCu0.5) and A356+TiB_2 based MMC were selected for investigations under loading conditions leading to the creep or fatigue in order to check their applicability to work at carefully chosen temperatures under constant long-term or cyclic loading.

PROCEDURES, RESULTS AND DISCUSSION: Creep tests were performed on the plane specimens. During experiments the strains were measured under selected tensile stresses and temperatures. A single specimen was heated up to 20 hours at one of the following temperatures 180˚C, 200˚C, 220˚C or 240˚C, and then the stress equal to 25 MPa was applied. For each temperature considered a strain response of the material was observed for time intervals equal to 5 or 10 hours. For each specimen a level of stress was increased by a value of 25 MPa to obtain 25 MPa, 50 MPa, 75 MPa, 100 MPa and 125 MPa. Both aluminium alloys were investigated for low and high values of porosity, different heat treatment, ageing and DAS (Dendrite Arm Spacing). An influence of creep due to step increased loadings on the mechanical behaviour of the AlSi8Cu3 and AlSi7MgCu0.5 aluminium alloys was investigated for high and low porosity materials at different temperatures. The results of creep tests carried out at 220˚C are presented in Fig. 1a for both materials of low porosity. A higher durability of the AlSi7MgCu0.5 expressed by the time to rupture increase can be observed. The creep strain rates achieved for the same stress level are in the case of AlSi8Cu3 much higher than those for the AlSi7MgCu0.5. Therefore, the tertiary creep of the first alloy appeared earlier (after 15h) than for the second one obtained (after 25h). Creep curves in Fig. 1b identify weaker creep resistance and higher strain rates of the low porosity AlSi8Cu3 at 220˚C in comparison to the same material of high porosity. Therefore, the secondary and tertiary creep of the low porosity material appear after 15 hours at 220˚C (Fig. 1b). Moreover, at 200˚C it exhibits shorter lifetime in comparison to the high porosity material, while at 240˚C the strain rates and times to rupture of both materials are similar. In the case of aluminium alloys the LCF tests were carried out under strain control using cylindrical specimens. Three blocks of 100 cycles each with a constant strain amplitude were performed. The results of LCF tests were analysed with regard to chemical composition and porosity variations of the materials tested.

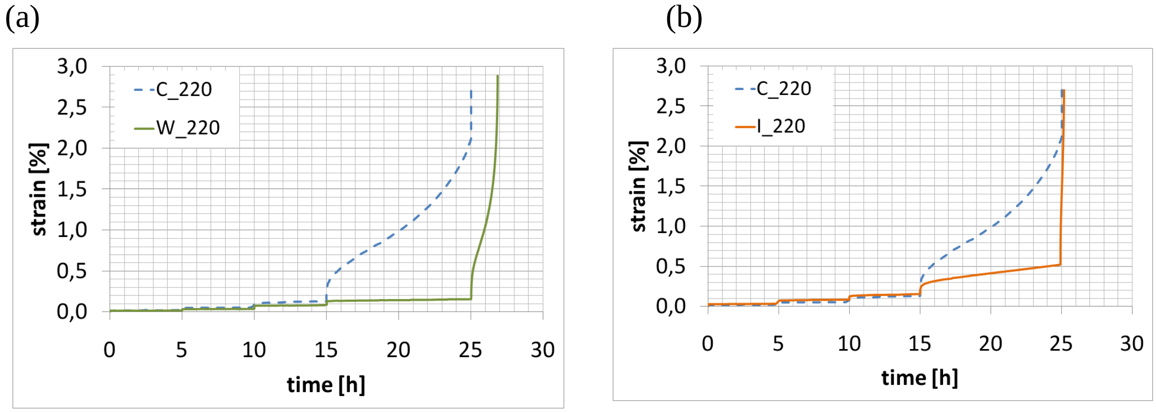

Fig. 1. Comparison of the creep curves for the materials of low and high porosity tested at different temperatures: (a) – AlSi8Cu3 (C_220) and AlSi7MgCu0.5 (W_220), low porosity, temperature 220˚C; (b) – AlSi8Cu3, low porosity (C_220) and high porosity (I_220), temperature 220˚C

A comparison of the hysteresis loops for the first two cycles carried out on aluminium alloys in the as-received state and subjected to the 312 sequence of strain amplitudes at all temperatures considered indicates stronger stress response of the AlSi7MgCu0.5, Fig. 2a,b.

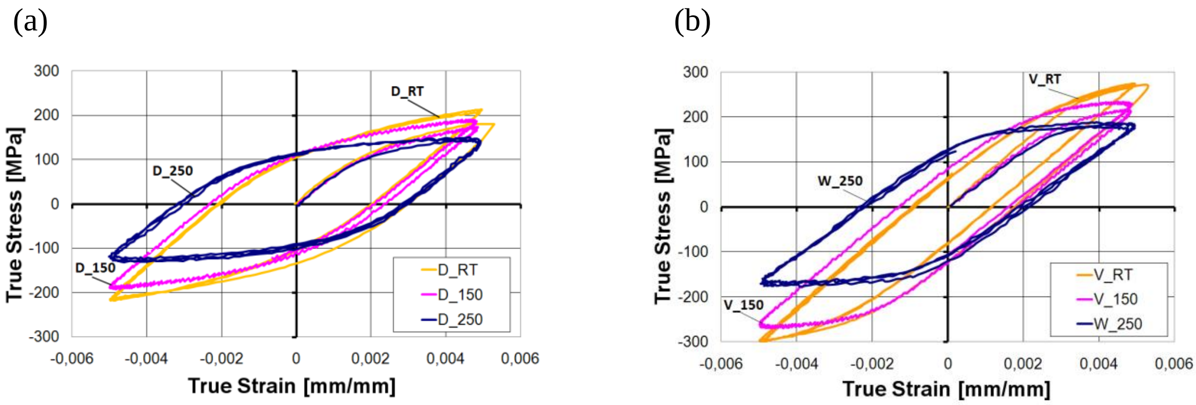

Fig. 2. First two cycles of hysteresis loops for both materials in the as-received state, tested with the 312 sequence of cycle blocks and 0,001 [1/s] strain rate at room and elevated (150˚C and 250˚C) temperatures: (a) – AlSi8Cu3; (b) – AlSi7MgCu0.5

For example, during the LCF tests carried out at room temperature, a stress corresponding to the 0,005 strain was equal to 205 MPa for the AlSi8Cu3 (Fig. 2a), whereas in the case of the AlSi7MgCu0.5 it was around 275 MPa (Fig. 2b). Moreover, the AlSi7MgCu0.5 exhibits anisotropy, what is expressed by a stress shift towards the negative stress direction for the tests carried out at room temperature and 150˚C. The effect disappears at 250˚C (Fig. 2b). Such phenomenon identifies existence of the residual stresses in the material. The tests show that they can be eliminated at temperature equal to 250˚C. In the case of AlSi7MgCu0.5 tested at all temperatures the strain hardening effect is larger, and the width of hysteresis loops in much smaller in comparison to these parameters achieved for the AlSi8Cu3. Thus, it exhibits better

strength of this material under the fatigue conditions. An essential cyclic hardening effect can be observed for the AlSi8Cu3 tested at room temperature, Fig. 2a. The effect is considerably weaker for the material tested at 150˚C. In the case of experiment at 250˚C it can be practically neglected. The effect can be also observed during tests at 150˚C for the AlSi7MgCu0.5. An interesting feature was observed in analysis of the LCF results concerning the elastic modulus represented by a tangential to the stress-strain characteristic at zero stress level. The elastic modulus was independent on the loading history, what indicates that it should not be used as a parameter sensitive to damage development in the materials investigated.
In the case of A356+TiB_2 based MMC hourglass specimens were manufactured and force controlled high cycle fatigue (HCF) tests were carried out on the servo-hydraulic testing machine to verify its applicability in the automotive industry. All HCF tests were performed at room temperature with the frequency of 20 Hz. During the tests, oscillating tension-compression load was applied to keep constant stress amplitude in the narrowest cross-section of hourglass specimen were a gage was located. Transversal strain was measured in the gauge length of each specimen and basing on it the axial strain was calculated using the Poisson’s ratio (Socha [2003]).

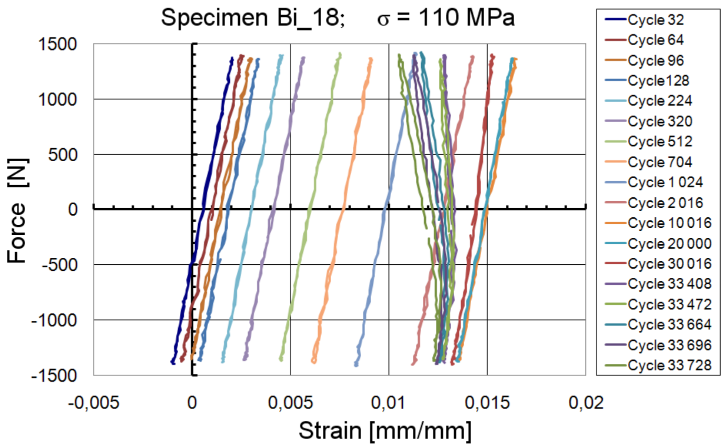

Fig. 3. Hysteresis loops of the A356+TiB_2 based MMC for selected cycles

The hysteresis loops determined during the HCF tests do not enlarge their width, but they move along strain axis and the ratcheting effect can be observed, Fig. 3. It is easy to see that from the first cycle until 10 016 one, the subsequent hysteresis loops move towards the positive strain values, while after 20 000 cycle they move back. The hysteresis loops width remains constant in subsequent cycles. Only the width of hysteresis loops registered as final increases (cycle 33 664 to 33 728).

CONCLUSIONS: During creep tests a shorter lifetimes and smaller resistance were observed for the low porosity materials. The results of LCF tests exhibited better strength of the AlSi7MgCu0.5 in comparison to the AlSi8Cu3 expressed by the smaller size of hysteresis loop width and greater stress amplitudes. It is shown for the A356+TiB_2 that the mean strain can be the most suitable variable describing damage development.

ACKNOWLEDGEMENT: The investigations were partly carried out within the framework of the project New Automotive Components Designed for and Manufactured by Intelligent Processing of Light Alloys (NADIA), 2006-2010.

REFERENCES:

Socha, G. 2003, “Experimental investigations of fatigue cracks nucleation, growth and coalescence in structural steel”, International Journal of Fatigue **25**, 139.