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CHANGES OF MECHANICAL CHARACTERISTICS OF EXTRUDED ALUMINIUM ALLOYS EN-AW 6082 AND 7075

ZMĚNY MECHANICKÝCH VLASTNOSTÍ SLITIN HLINÍKU EN-AW 6082 A 7075 VYROBENÝCH PROTLAČOVÁNÍM

Abstract

In the article there are concentrated and partly commented the results of tensile and fatigue tests which were realised on the alloys EN-AW 6082/T6 and alloy EN-AW 7075/T6. Semi products of these materials were produced by extruding technology and their structure demonstrated visually inhomogeneity (directionality). In the frame of experimental tests they were evaluated and mutually compared the mechanical parameters obtained on the samples produced in different directions to the extrusion axis. The reached results indicate that the fatigue properties of tested materials are influenced by the structure orientation only gently.

Abstrakt

V článku jsou soustředěny a částečně komentovány výsledky tahových a únavových zkoušek, které byly realizovány na Al slitinách EN-AW 6082/T6 a EN-AW 7075/T6. Polotovary těchto materiálů byly vyrobeny technologií protlačování a jejich struktura vizuálně vykazuje významnou nehomogenitu (směrovost). V rámci experimentálních prací byly hodnoceny a vzájemně porovnány mechanické parametry získané na vzorcích, vyrobených v různých směrech vzhledem k ose protlačování. Dosažené výsledky naznačují, že únavové vlastnosti sledovaných materiálů jsou směrovostí struktury ovlivněny pouze mírně.

1 INTRODUCTION

The producers deliver often aluminum alloys as compression molded profiles. The extruding technology of semi-product production is accompanied with rise of direction oriented structure and therefore it is necessary to expose the materials to various ways of fatigue loading as well as to orientate experiments to various directions because the orientation to the direction of molding can have an impact to the properties of real parts [1,2,3,4,10]. The evaluation of mechanical properties is very important for practical application. Due to prevalence of cyclic type of mechanical loading of real parts, evaluation of fatigue properties is preferred among mechanical tests.

2 EXPERIMENTAL SET-UP AND RESULTS

As to experiment described in this contribution, were chosen two aluminum alloys applied to a great extent in production of transportation means. It is the alloy ***EN-AW 6082*** with Magnesium and Silica as main ingredient elements and alloy ***EN-AW 7075*** with Zinc. Their chemical composition is found in the Table 1.

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Tab.1. Chemical composition of used Al alloys (wt %)

element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
EN-AW 6082	1,01	0,17	0,067	0,66	0,84	0,16	0,030	0,032	rest
EN-AW 7075	0,4	0,5	1,6	0,3	2,4	0,2	5,7	0,2	rest

The material has been delivered in form of extruded rectangle strips with dimensions 20 x 80 mm and length 1000 mm. Both materials have been heat treated to the condition T6, i.e. by solution annealing up to the temperature 530^{o} C followed by cooling in warm water (over 20^{o}C). After one hour the material is age hardened under the temperature 160^{o}C lasting 10 minutes followed by cooling in water.

2.1 Tensile tests

The first step of the comparing study was to make the standard specimens for tensile tests with diameter 6 mm clamping into die heads M 11x1. Dimensions of semi products made possible to make samples with axis conform to longitudinal direction L and transversal direction T – see Fig. 1. The micro-structural outlook of EN-AW 7075/T6 alloy shows Fig. 2. These samples have undergone the tensile tests on the Tiratest facility. The graphics in the Fig. 3 show results of these measurements – the curves present a mean from 3 measurements.

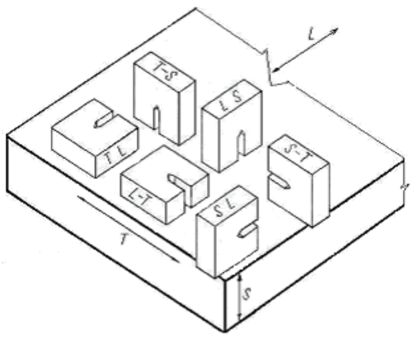


Fig. 1 Conventional direction signs used in this article

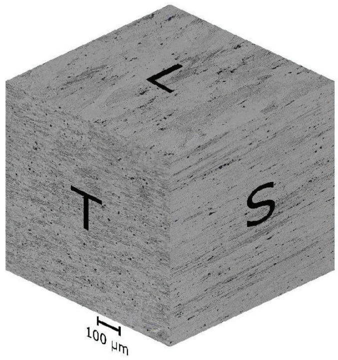


Fig. 2 Alloy EN-AW 7075/T6 micro-structure look in various directions of material

Material EN-AW 6082/T6 shows a little higher tensile characteristics in the L (longitudinal) direction as in the T (transversal) direction (with the comparable ductile behaviour). The samples of the other material EN-AW 7075/T6 show lower yield strength in the L (longitudinal) direction as in the T (transversal) direction with ductility value in the first direction (L) essentially higher then in the second (T). The structural orientation impact is here quite clear. The obtained experimental results on both cases prefer L (longitudinal) direction in both materials. Absolute values of measured parameters (yield strength) are in case of the first material by 250 MPa lower than in the second.

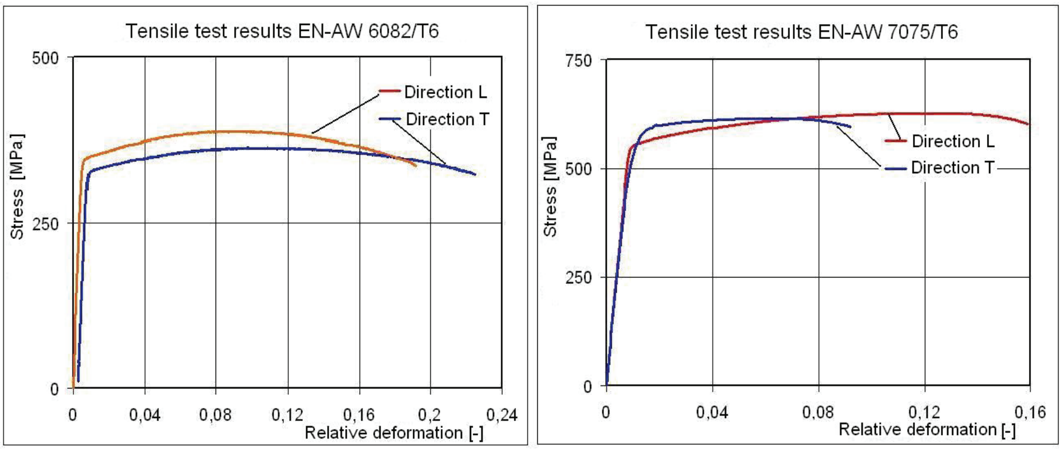


Fig. 3 Comparison of tensile test results of tested materials EN-AW 6082 and EN-AW 7075 in directions T and L

2.2 Fatigue tests

Two various types of test samples have been made from both materials for fatigue tests. The cylindrical samples (see Fig. 4) have been made for tension-pressure test made by servo-hydraulic system INSTRON 8801 and for 4-point bending tests made with high-frequency machine Rumul Cracktronic, the samples have been rectangular (see Fig. 5) and loading asymmetry was R = -1.

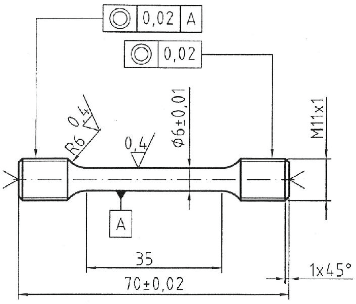


Fig. 4 Shape and dimensions of test samples for test machine Instron 8801 (axial tension-pressure loading)

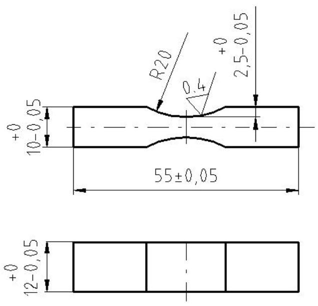


Fig. 5 Samples for fatigue tests on Cracktronic 160 testing machine (bending).

As in the case of tensile test samples, the cylindrical samples have been made with longitudinal (L) and transversal (T) orientation. The direction of main crack propagation is then normal to both mentioned directions. The rectangular samples for fatigue bending tests have been made also in mentioned directions and then even the direction of crack propagation can be defined vis-à-vis the stress type and shallow notch. Therefore these samples are marked as LS, TS, LT, TL, where first letter indicate the direction of sample (see Fig. 1) and the second gives the direction of main crack propagation. This direction is always normal to the direction of sample axis. With set tension amplitudes, the fatigue test samples have been cyclically stressed up to fracture. The test results have been evaluated with S-N curves (stress amplitude versus number of cycles to fracture).

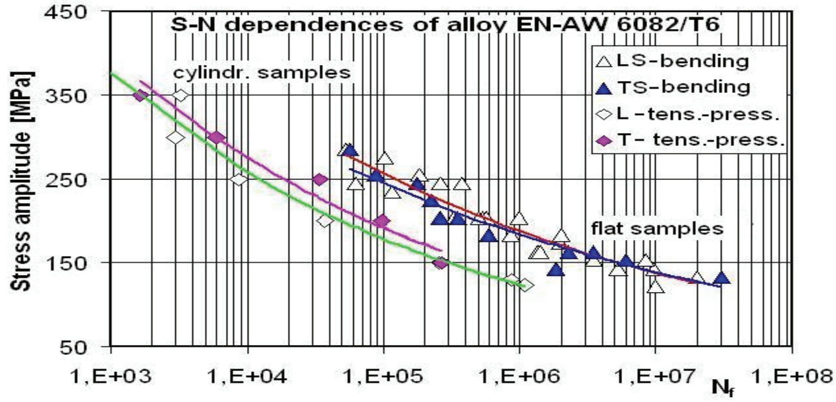


Fig. 6 Comparison of S-N dependencies for different directions and types of fatigue tests (material EN-AW6082/T6)

The diagram on the Fig. 6 summarises the fatigue test results with material EN-AW 6082/T6. The orientation of samples directed longitudinally and transversally has quite small impact that can be included into common dissipation zone. Some shift of experimental values can be noticed if both types of fatigue tests compared, where tension-pressure loading shows shorter fatigue lifetime.

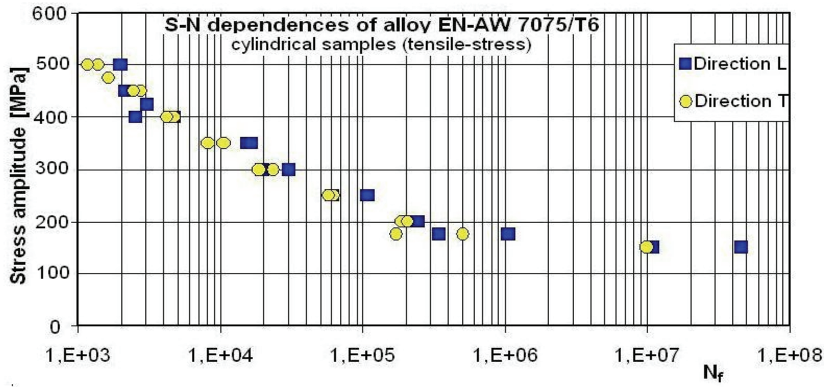


Fig. 7 S-N dependence of alloy EN-AW 7075/T6 – cylindrical samples and axial loading [6].

The stress amplitude/number of cycles to fracture relation as measured on the cylindrical samples made from alloy EN-AW 7075/T6 stressed by tension / pressure shows the same parameters for longitudinal as well as for transversal directions (Fig. 7). If compared with the position of experimental points obtained for bending stress (see Fig. 8) then the values show shift to the lower fatigue lifetime, similarly as in the case of the alloy EN-AW 6082.

Figure No. 8 gathers the results of sample tests from material EN-AW 7075/T6 loaded by flat bending. All directions available (for marking LS, LT, TS, TL see Fig.1) are shown here. Here it is also clear the dissipation of measured value grows noteworthy in the field of tensile stress amplitude equal approximately to 200 MPa. Moreover, it is obvious the samples having following longitudinal direction (L) with crack propagated in the transversal direction (T) [also marked LT] show higher lifetime and vice versa the samples made in transversal direction (T) with cracks growing in longitudinal direction (L) [i.e. marked TL] have shorter lifetime and are then in the left side of the band. The shift of LS samples from left side of the band (zone of high amplitudes) to the right band (zone of smaller amplitudes) is also interesting. The size of values dissipation in the zone of longer lifetime speaks however for material high sensitivity to various structural inhomogeneities and surface defects.

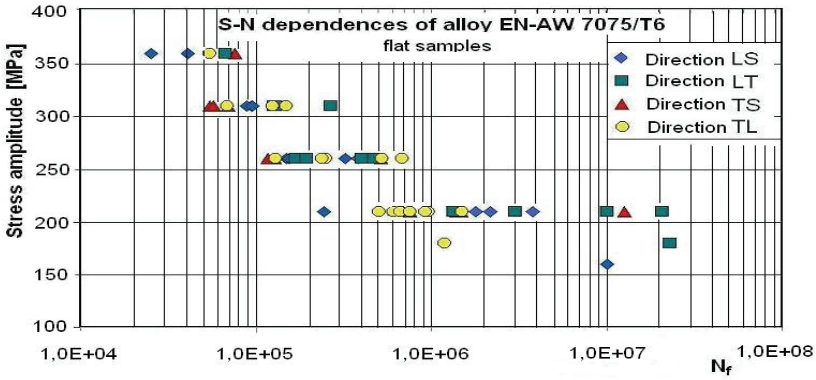
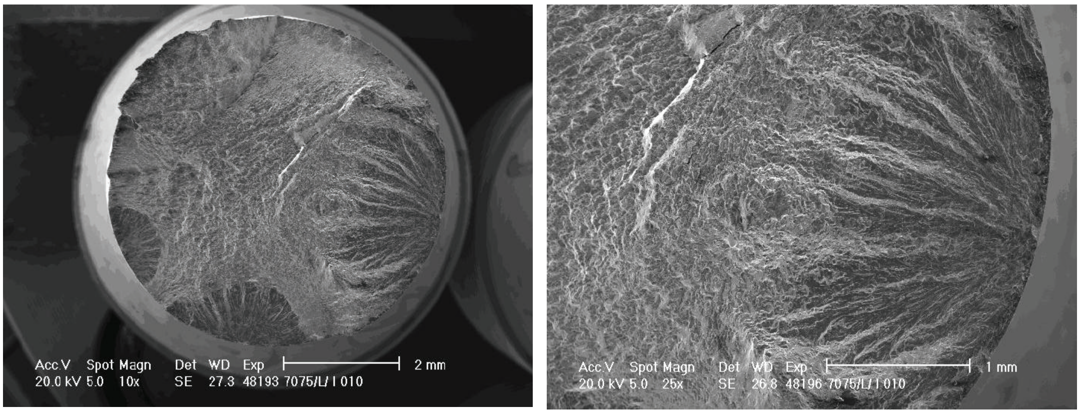


Fig. 8 S-N dependence of alloy EN-AW 7075/T6
(all measured directions, flat samples and four point bending).

2.3 Fractography of fatigue fractures

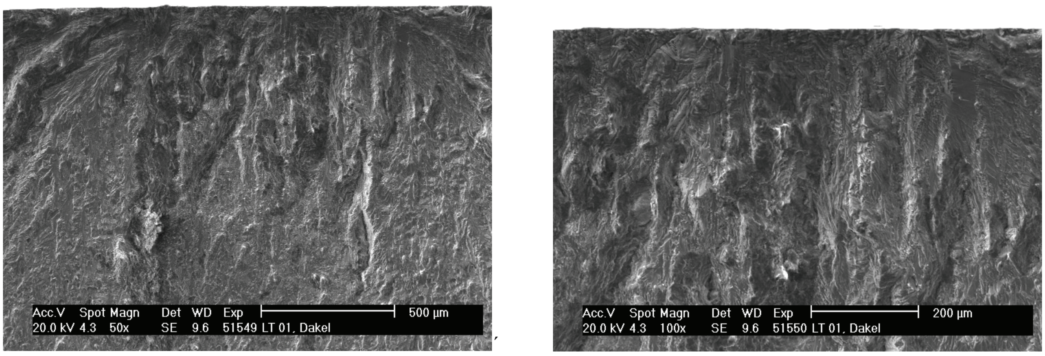
In the next you find a selection of figures showing features of the fractures of materials investigated.



a) b)

Fig. 9 Fatigue crack propagation on cylindrical sample (sample axis is perpendicular with direction L, axial loading σ_a = 300MPa, mater. EN-AW 7075/T6),
a) overview of the fractured surface, b) detail of crack initiation place.

Photos (Fig. 9) show the typical look of fracture surface of the cylindrical sample stressed by axial loading. We can see a great number of initiation places on the perimeter of the sample and so it is impossible to state whether cracks prefer a direction of their possible propagation (LS, LT, possibly TS, TL).



a) b)

Fig. 10 Fatigue fracture surface in the material EN-AW 6082 (flat sample, direction LT):
a) overview of the fatigue crack, b) detail view of crack initiation place

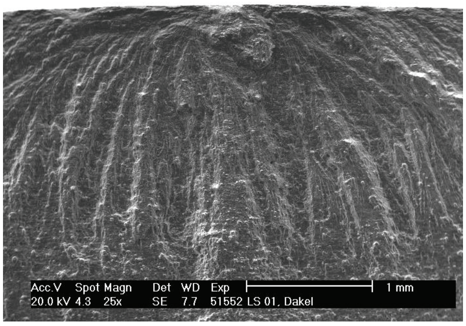


Fig. 11 Detail of initiation point and beginning of crack propagation (flat sample, material EN-AW 7075, bending stress, direction LS).

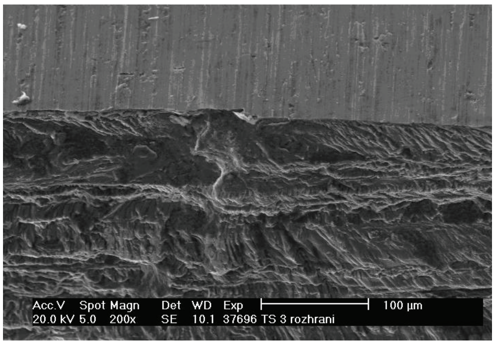
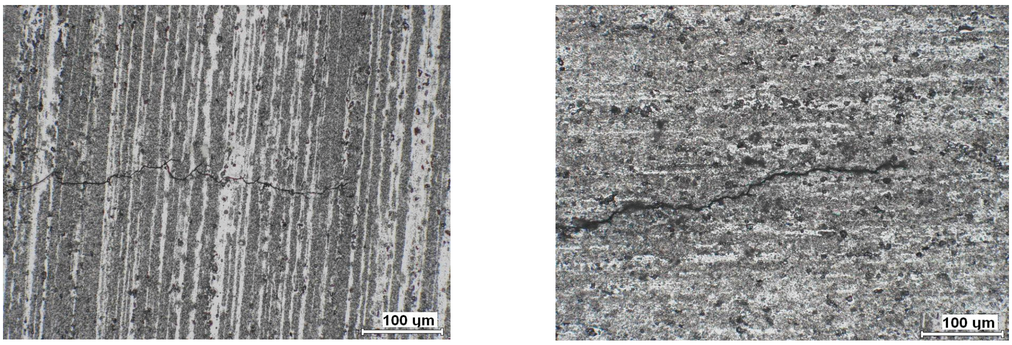


Fig. 12. Detail of the interface of fracture and sample surfaces (mat. EN-AW 6082, sample direction TS).

Photos on Fig. 10 show the look of fracture spots of the flat samples stressed by bending mode. Fig. 11 and 12 show initiation points and look of the fracture face of plane samples under bending stress. Photos (Fig. 13) compare look of main crack on the surface of flat etched sample in two normal directions.



a) b)

Fig. 13 Look of a growing crack on the etched surface of flat sample (material EN-AW 7075,
a) direction LS, b) direction TS).

3 DISCUSSION

Presented results of the fatigue tests show the impact of structural orientation is for tested materials less distinctive as expected after the study of microstructure look. This finding has many reasons. It concerns e.g. the way of material extrusion i.e. the technology of semi-product manufacturing. The chemical composition of alloys also damps essentially the structure orientation as it influences directly the rise of structural particles in materials. This concerns the quantity, positioning and shape of particles, their dimensions and hardness. These particles further influences with regard to their character the material matrix composed with multi-shaped and variously oriented grains. Also the quality of surface plays its role including impact of surface unevenness as well as the surface finishing operations. An unsuitable finish influences negatively the rise, character and distribution of residual tensions in subsurface layer [5, 6, 7]. These tensions can essentially influence the fatigue life of materials. As demonstrated by other [e.g. 8, 9], both materials are very sensitive as notch concerned. As defined, the surface is for initiation deciding.

Combination of mentioned factors affects first of all the initiation phase and possibly also the beginning growth of short fatigue cracks, the fatigue lifetime similarly in all tested directions. The effect of orientation appears more in the next phase of growing main crack. This time interval is shorter and therefore the orientation impact of the shaped structure on the fatigue resistance is small.

4 CONCLUSION

The results of experiments and observations we have done lead to conclusion the material inhomogeneities support the initiation of cracks in both tested inhomogeneous materials. Therefore the structure orientation impact on fatigue resistance during tension-pressure loading and bending loading is small and the orientation factor does not play the main role. Only the other material EN-AW 7075/T6 shows better stress resistance in longitudinal direction (L) then in transversal (T) at bending (flat samples) - in the area near to the fatigue limit. The impact of structural particles (their quantity, dimensions, distribution, hardness and shape) is essentially higher.

A great number of obtained results must be completed with next research concentrated to the dimension, shape and number of particles and perhaps to more detailed structural identification of particles. Of course, it will be also useful to precise the already made measurements by means of more experiments namely concerning the material fatigue. Bigger attention has to be paid to more accurate identification of fatigue damages during several stages using suitable methods of e.g. non destructive testing.

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