НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ ТОМСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ

РОССИЙСКИЙ ФОНД ФУНДАМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ

ИНСТИТУТ ПРОБЛЕМ ХИМИКО-ЭНЕРГЕТИЧЕСКИХ ТЕХНОЛОГИЙ СО РАН

АО «ФЕДЕРАЛЬНЫЙ НАУЧНО-ПРОИЗВОДСТВЕННЫЙ ЦЕНТР «АЛТАЙ»

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КОМПАНИЯ MACH I, INC.

ВЫСОКОЭНЕРГЕТИЧЕСКИЕ И СПЕЦИАЛЬНЫЕ МАТЕРИАЛЫ: ДЕМИЛИТАРИЗАЦИЯ, АНТИТЕРРОРИЗМ И ГРАЖДАНСКОЕ ПРИМЕНЕНИЕ

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INVESTIGATION OF MICROSTRUCTURAL CHANGES AND MECHANICAL PROPERTIES OF ALUMINUM AND MAGNESIUM ALLOYS AFTER TREATMENT BY SEVERE PLASTIC DEFORMATION

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The major goal of this study is to define the effect of severe plastic deformation (SPD) on the microstructure and mechanical properties of the light structural alloys such as aluminum alloy of grade 1560 and magnesium alloy of grade Ma2-1, which are the closest analogues of the known alloys 5083 and AZ31, respectively. These alloys are widely used in aviation, automotive and space industries. By changing theirs physical and mechanical properties, it becomes possible to optimize structural elements and to increase the service efficiency under various operating conditions owing to the reduction in the weight of parts and structures.

Prismatic billets for processing and subsequent investigation were prepared from bars of hot rolled coarse-grained alloys 1560 (chemical composition: 91% Al – 6.12% Mg – 0.59 Mn – ~ 2.29% other impurities) and Ma2-1 (chemical composition: 93.65% Mg – 4.36% Al – 1.33% Zn – Mn – ~ 0.66% other impurities). The main billet axes coincided with the bar rolling direction. The billets were subjected to SPD by equal channel angular pressing (ECAP) to produce ultrafine-grained (UFG) structure using a collapsible steel die [1] with the channels intersecting at an angle of 90 degrees without fillets. The pressing was carried out using route B_c, in which the billet is rotated by 90 degrees about the longitudinal direction in every next pass. The quality of the processed billets was assessed by non-destructive testing using the microfocus X-ray system YXLON Y. Cheetah [2].

A series of tests were performed on the processed prismatic billets to examine the physical and mechanical properties of the studied materials, including microstructural analysis, microhardness measurements, and uniaxial tensile testing of flat specimens.

While selecting optimal pressing modes for the studied materials, some crucial governing parameters were experimentally revealed which must be taken into account. The first parameter is the temperature, which must be 473 K for aluminum alloy and 523 K for magnesium alloy. The second parameter is the pressing speed, which was equal to 15 mm/min. The third parameter is friction. Friction between the billets and the die channel walls was minimized using a high-temperature lubricant on the basis of mineral oil and molybdenum disulphide. With the above parameters, the processed material preserves its continuity without cracking.

Microstructural studies has shown that aluminum alloy 1560 in the as-received state exhibits a grain size distribution within a wide range from 2 to 400 μm, with the average grain sizes 50 μm. The grain size distribution in the as-received magnesium alloy Ma2-1 ranges from 2 to 60 μm, with the average grain sizes 18 μm. Since the billets were cut out from hot rolled bars, the grain structure has a well-defined direction. Coarse grains are elongated along the rolling direction and clusters of fine grains are adjacent to them, together forming bimodal structures. After treatments in the selected optimal mode, a more homogeneous UFG structure with an average grain size of 3 and 7 μm is formed in the central part of aluminum and magnesium alloy billets, respectively.

After four ECAP passes, the microhardness increases by on average 40–60 % as compared to its initial value for the both materials. The maximum microhardness reaches 1550 and 786 MPa, with the initial value not exceeding 1000 and 560 MPa for the aluminum and magnesium alloys, respectively.

It is seen that after four ECAP passes the yield strength of aluminum alloy 1560 increases from 150 to 270 MPa and its ultimate tensile strength increases from 320 to 460 MPa, while those of magnesium alloy increase from 150 to 200 MPa and from 250 to 290 MPa, respectively. The maximum elongation to failure under uniaxial tension increases from 0.17 to 0.24 for magnesium alloy and decreases from 0.24 to 0.17 for aluminum alloy. These data indicate that the strength characteristics in the bulk of the both studied alloys increase during SPD by ECAP. Uniaxial tensile test results are represented as stress-strain curves in [3].

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СИНТЕЗ, СТРУКТУРА И ФАЗОВЫЙ СОСТАВ АДДИТИВНЫХ МЕТАЛЛОКЕРАМИЧЕСКИХ МАТЕРИАЛОВ СИСТЕМЫ (TI-CR-NI)-TIN

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Материалы на основе Ti и Cr-Ni, в том числе упрочненные керамическими частицами, обладают повышенными параметрами жаропрочности [1] и могут использоваться при изготовлении ответственных частей газотурбинных двигателей (ГТД) [2]. Для получения деталей сложной формы, например, рабочего колеса ГТД, перспективными представляются методы аддитивного лазерного выращивания изделий, которые в свою очередь, могут существенно снижать стоимость и трудоемкость процесса получения деталей [3]. Реакция между Ti и N