Influence of a weak pulsed magnetic field on the recovery and recrystallization in aluminum

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Introduction

In recent years, interest has grown in processing with pulsed magnetic fields, as it is an easy and effective method for changing the properties of various materials, including non-magnetic ones. Of particular interest is the use of processing pulsed fields in the range of treatment with weak magnetic pulses (H<10^6 A/m) or the so-called "weak magnetic field processing" (MFP). The authors [1-2] of the first publications on weak pulsed fields overcame great skepticism on the part of other researchers about the effectiveness of the impact of such magnetic treatment on non-magnetic materials. But numerous subsequent studies [3-5] and publications speak in support of it. It is known that MFP changes the state of impurity–defect complexes on dislocations, and therefore affects materials that are in an unstable, transition state and can change properties that depend on the dislocation structure. MFP affects the processes of microplastic deformation, irreversible temper brittleness, and strain aging [6–7]. Aluminum is used as a substitute for more expensive metals, and the possibility of its use in various applications increases every year. A feature of aluminum is (as a metal with a high energy of stacking faults) and therefore a tendency to creep of dislocations, facilitated the formation of structural defect complexes and, as a result, a strong dependence of its plastic and strength properties on the dislocation structure. Therefore, it can be assumed that treatment with a weak pulsed magnetic field will be effective when exposed to aluminum under conditions of a change in the dislocation structure during the processes of recovery, polygonization, and recrystallization. The method of internal friction (IF) was used, as the most sensitive in the study of structure-dependent properties. Ke [8] observed a relaxation peak of internal friction on pure polycrystalline aluminum with a maximum temperature of 280C.

Experimental setup

The object of the study was polycrystalline aluminum with a purity (99.99%), deformed by tension by 10%. Samples 3x3x25 mm in size were obtained by machining from a deformed material.

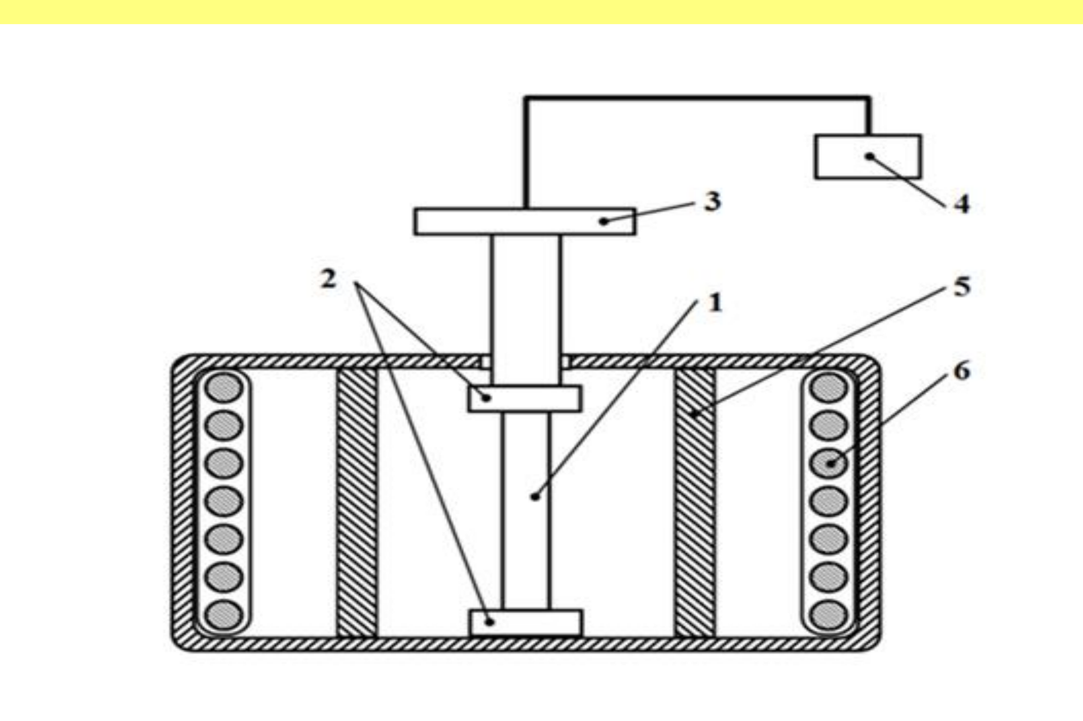

Fig. 1. Setup to study the effect of a pulsed magnetic field on a material with simultaneous heat treatment. 1 - sample; 2- clamps; 3- inertial detail; 4 – counterweight; 5- heating chamber; 6- magnetic solenoid.

Results

The temperature dependence of the internal friction of aluminum with and without magnetic field treatment during the recovery process is shown in Figure 2.

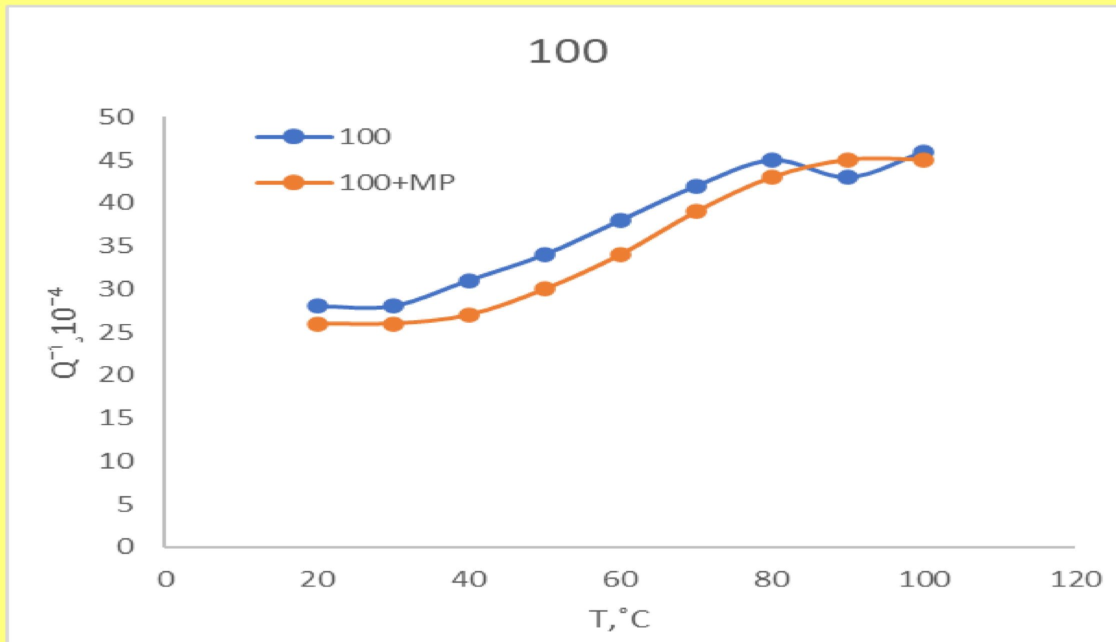

Fig 2. Temperature dependence of internal friction in aluminum (purity 99.99%) during annealing at a temperature of 100 C: 1- without a pulsed magnetic field; 2- in a pulsed magnetic field.

The effect of MFP on recrystallization and polygonization processes was studied on samples that were annealed as described previously. Then the samples were mounted in a setup and heated to a temperature of 500°C at a rate of 25 °/h. IT was measured without MFP treatment and with treatment with heating at intervals of 10°C to a temperature of 110°C, at intervals of 20°C to a temperature of 400°C, and at intervals of 50°C to a temperature of 500°C.

The temperature dependences of BT during further annealing at higher temperatures were shown Peak Ke (270°C) is clearly observed after annealing at 400°C and gradually increases as the annealing temperature increases and increases strongly at annealing at 600°C. However, the height of the main peak does not restore its original value before deformation. The peak at 150°C, which appeared after annealing at 300°C, increases slightly with increasing annealing temperature. The results of the study of the aftereffect effect are presented in Fig.3.

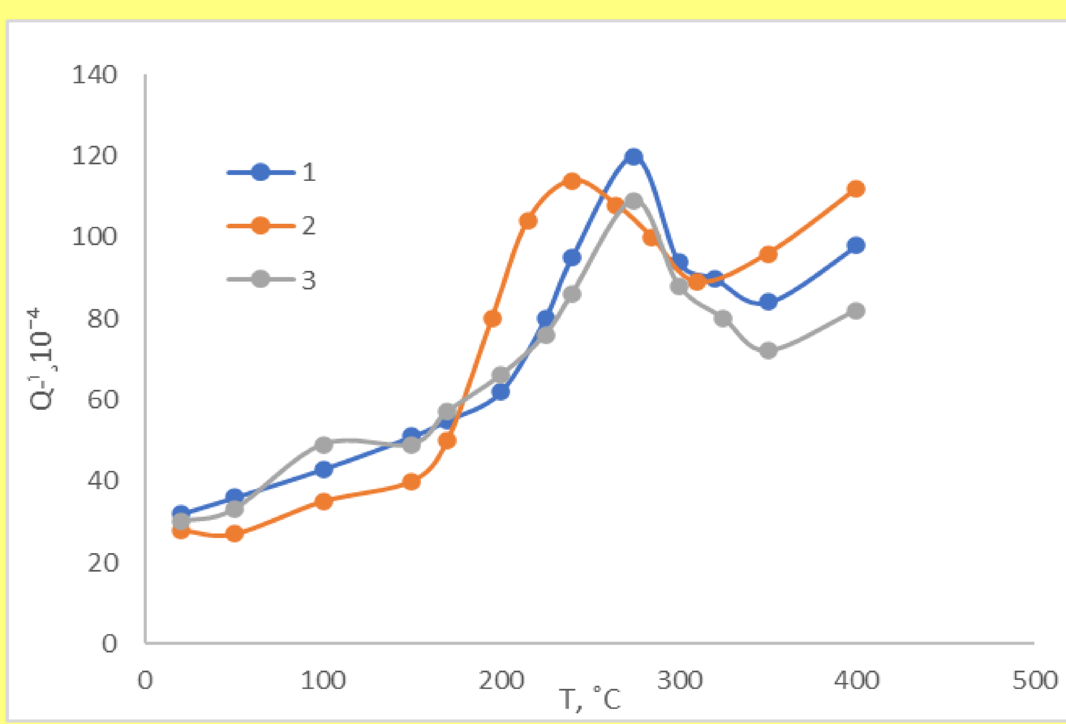

Fig.3. Temperature dependence of the internal friction in deformed aluminum with a purity (99.99%): *1*—without a pulsed magnetic field; *2*—in a pulsed magnetic field; 3- aftereffect of the magnetic field.

On the curve with MFP aftereffect (Fig. 3, curve 3), a slight decrease in the IT peak is observed, but in general this curve coincides with the curve without MFP. The decrease in the level of internal friction on the aftereffect curve at temperatures of 350°–400°C occurs more intensively than on the other two curves. The data obtained confirm the possibility of the influence of a weak pulsed magnetic field on the processes of structural rearrangement during the processes of polygonization and recrystallization of deformed polycrystalline aluminum with a purity of 99.99 (annealing at 200°-600°C).

Conclusions

1. Exposure to a weak pulsed magnetic field simultaneously with heating and annealing leads to a shift of the grain boundary peak of BT by 20-30°C lower, that is, it accelerates the processes of structural rearrangement occurring during polygonization and recrystallization, which begin at lower temperatures.
2. The aftereffect of the MFP (the effect of magnetic treatment on the material before heating and tempering) is manifested in a decrease in the height of the peak of internal friction and a more intense decrease in the BT level at temperatures of 350°- 400°C.
3. MFP affects low-temperature IT peaks (150°C), which are caused by lattice dislocations. This means that the magnetic field affects not only the grain boundary relaxation but also the dislocation relaxation, while the dislocation relaxation behaves similarly to the grain boundary relaxation.

References

1. Alshits V.I., Darinskaya E.V., Kazakova O.L, Mikhina E.Yu., and Petrzhik E.A. Magnetoplastic effect in non-magnetic crystals and internal friction // Journal of Alloys and Compaunds. 1994. v. 211, l212, p. 548-553.
2. Pavlov V.A., Pereturina I.A., and Pecherkina I.L. The effect of constant magnetic field on mechanical properties and dislocation structure of Nb and Mo // Physic State Solidy (a) 1980, v. 57, c. 449-456.
3. Akram, S.; Babutskyi, A.; Chrysanthou, A.; Montalvão, D.; Whiting, M.J.; Pizurova, N. Improvement of the wear resistance of nickel-aluminum bronze and 2014-T6 aluminum alloy by application of alternating magnetic field treatment. Wear 2021, 480, 203940.
4. Liao, C.Z.; Qin, Y.; Yang, Y.; Xu, G.L.; Yang, G.; Gao, H.J.; Wu, M.X. Enhanced service life of nickel-based alloy die for copper extrusion by pulsed magnetic field. J. Manuf. Processes 2022, 81, 798–806.
5. Yan, M.; Wang, C.; Luo, T.; Li, Y.; Feng, X.; Huang, Q.; Yang, Y. Effect of Pulsed Magnetic Field on the Residual Stress of Rolled Magnium Alloy AZ31 Sheet. Acta Metall. Sin. 2021, 34, 45–53
6. O. I. Datsko and V. I. Alekseenko and A.L.Brusova, Effect of magnetic field pulses on the anelastic properties of nitrogen - containing steel. Zh.Tekh.Fiz.Zh. Tekh.Fiz.69,122-123(1999).
7. O. I. Datsko, V. I. Alekseenko, and A.D.Shakhova, Fiz. Tverd. Tela 38,1799 [Phys. Solid State 38, 992(1996).
8. T.S.Ke.Phys.Rev.71, 533(1947).