DAMAGE CHARACTERISTICS OF LASER-MATERIAL INTERACTION IN AlLiCuMg ALLOYS

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ABSTRACT

The hardening of two-component alloys of AlLi type is achieved by thermal precipitation, and of much practical importance are the three-component alloy group AlMgLi and multi-component AlLiCuSiMg. They possess lower values for specific weight and higher values for Young's modulus compared to conventional aluminum alloys. Therefore, owing to their widely extended application in aircraft industry, an attempt for investigating and improving their characteristics is reasonable. In this paper an AlLiCuSiMg alloy was exposed to ruby laser radiation $\lambda = 0.694$ m, with 2×10^{-6} s and 3×10^{-8} s pulsing, and energy variations from 0.14 to 2.6 J. Scanning electron microscopy analysis of the structure has shown defined damages in the tested material. Shallow and deep craters have been observed and crater diameters have been determined. The main purpose of this investigation is to determine the differences of micro-damages in the material as a function of thermomechanical treatment. The influence of time dependent power densities (energies) was also studied.

INTRODUCTION

AlMgLi and AlLiCuMg alloys belong to a new group of materials that possess smaller values for density and larger values for Young's modulus compared to conventional aluminum alloys. Hence, poor weldability and strongly manifested anisotropy of mechanical characteristics require further developing and exploring of these alloys. The influence of thermomechanical treatment on the weldability of AlMgLi alloy, Lukin et al (1991), showed that a most convinient alloy microstructure developes when the disperse precipitate Al_2MgLi is uniformly distributed in the aluminum matrix. During welding with increasing temperature, redistribution and dissolvement of the Al_2MgLi precipitate and enrichment of grain boundary with lithium and manganese takes place, which, owing to additional stressing and a high deformation temperature leads to microcrack forming and intercrystal fracture. Study of deformation rates and their influences on fracture resistance in welded high-strengthened aluminum alloys, Labur et al (1991), are also of great interest. Tests on AlCuLi alloys, Sunwoo et al (1989), have showed separation of undissolved precipitates of the type: $CuAl_2$, AlLi, $Cu_8Li_2Al_{15}$, Al_2CuLi and Al_6CuLi in the aluminum matrix after quenching and artificial aging. Analysis of results for welding AlCuLi alloys, Bondarew et al, also pointed out a rising inclination to porosity in welds, caused by the presence of evaporable lithium and dissolved hydrogen. Taking into consideration the weldability of new aluminum alloys, Pyazantsew (1991), it shows that the welding method influences the crystalization mechanism and causes tendency for forming warm cracks.

As already stated besides problems in weldability of multicomponent aluminum alloys, with lithium alloy, there are problems concerning anisotropy. Materials incompletely recrystalized or with the absence of recrystalization exhibit emphasized anisotropy of their characteristics in comparance to completely recrystalized materials. Institute of metals London (1986) and Aluminium Alloys, Warley UK (1986).

Based on experiments, Romhanji et al (1991), accumulated knowledge indicates that AlLiCu Mg demonstrates large scale anisotropy of tensile properties, namely, maximum elongation and minimum strength are achieved in a direction 45 - 60° to the rolling direction of rolling.

Wide use of aluminum alloys, having in mind poor weldability and strong anisotropy of characteristics, requires application of laser welding, cutting and boring fine craters. Physical laws characterizing laser treatment processes of materials, and physical/technological parameters for processes in laser welding are given in Wedenow et al (1985), Bashenko et al (1987), Lopota et al (1987).

The complexity of laser radiation and material interaction in case of boring, e.g., forming fine craters, can be discussed from several viewpoints, like energy levels, power densities and laser regimes. Interaction with material enhances structural and phase transformations making temperature a parameter that should be monitored. Temperature monitoring during heating from interaction is also in connection with thermodynamical constants, and with conditions that change by cooling in inert gas, and also with ejected material in the process.

EXPERIMENTAL RESULTS

Experiments were done with AlLiCuMg alloy that, in addition to aluminium, is composed of: 2.5% Li, 1.6% Cu, 1.3% Mg, 0.25% Zn, 0.3% Te, 0.2% Si, 0.1% Cr and 0.1% Ti. After annealing and quenching in water the first group of samples were subjected to spontaneous aging at room temperature, the second one included artificial aging, while the third group was deformed immediately after quenching and afterwards aged artificially. After completing operations the materials were exposed to laser radiation. Obtained damages in the material are the result of a range of powers and impulse durations from a monoimpulse laser. Metal damages in tested materials were monitored via scanning electron microscope.

RESULTS AND DISCUSSION

Mechanical tests show a minimum yield point and tensile strength, and maximum ductility for the as-quenched state. Natural aging did not have greater influence on characteristics. Scanning electron microscopy analysis of damages for this alloy state showed that craters produced under laser interaction, impulse energy level E = 0.14 J, period $t = 30\times10^{-9}$ s, had circular shape. Approximate crater diameter was $d \approx 0.27$ mm. Crater edgings showing joining of material (light surface), that is broadened (upper right corner) and a continued deformation is dipicted in Fig.1.

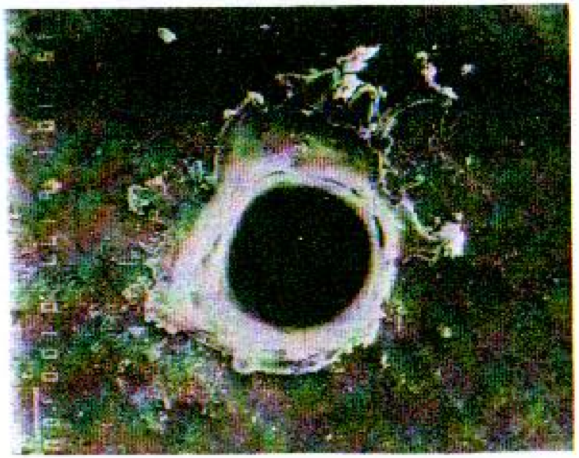

Figure 1.- SEM micrograph of damaged alloy (quenching + natural aging, E = 0.14 J).

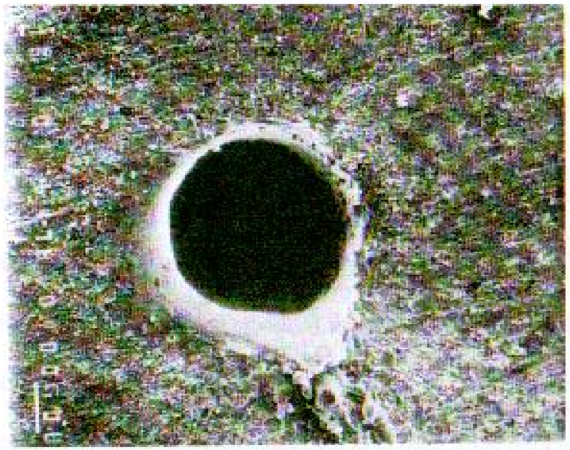

Figure 2.- SEM micrograph of damaged alloy (quenching + natural aging, E = 0.7 J).

Figure 2 shows damage in the material under pulse energy E = 0.7 J with the same interaction period $t = 30\times10^{-9}$ s, Impression diameter being $d \approx 0.275$ mm, and lighter surrounding surface area is mostly ≈ 0.07 mm. Joining occurred as well as the forming of new structural layers on crater edges. SEM micrograph in Fig.3 shows traces of low energy level ductile fracture.

The optimum mechanical characteristics of alloy are attained when the alloy (before artificial aging) is deformed by yielding up to 2.5%. Figure 4 shows damages in the material for pulse energy value E = 0.7 J; and in Fig.5 are damages for pulse energy value E = 0.14 J, with unchanged pulse durations $t = 30\times10^{-9}$ s.

Figure 3.- SEM micrograph - fracture (quenching + artificial aging).

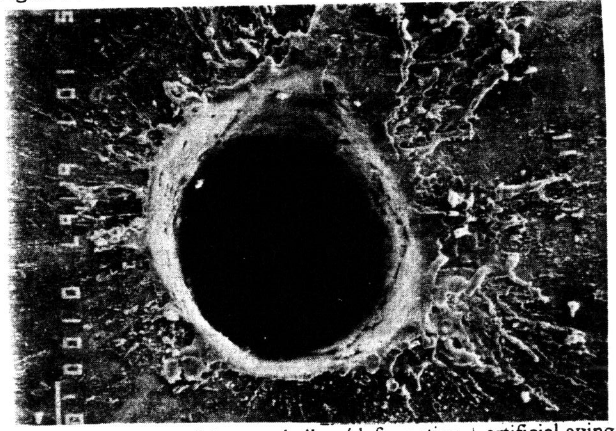

Figure 4.- SEM micrograph of damaged alloy (deformation + artificial aging, E = 0.7 J).

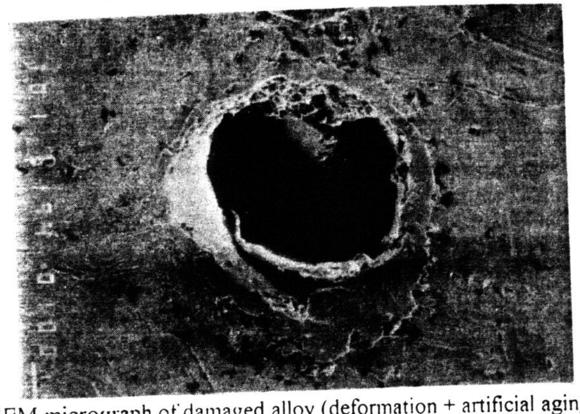

Figure 5.- SEM micrograph of damaged alloy (deformation + artificial aging, E = 0.14 J).

Fracture appearance is shown in Fig.6 for tensile testing, with cold plastic deformation followed by artificial aging. SEM micrograph depicts the fracture caused under shearing, planary state of stress, and longitudinal lines represent striping.

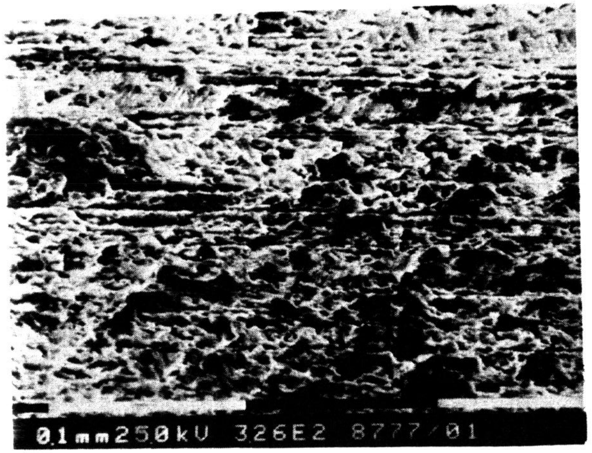

Figure 6. Fracture appearance.

CONCLUSIONS

Based on tested mechanical characteristics, optical and scanning electron microscope analysis the following conclusions can be drawn:

1. Results of optical and SEM analysis can be used for determining the degree of interaction.
2. Damages are of crater type and edges covered with gathered and ejected material, which corresponds to free generated regime.
3. Some alloys show noticeable presence of cracks in craters because of compound stresses induced under beam propagation.
4. In future investigations, in the sense of temperature distribution, temperature gradient and phase diagram assessment, multicomponent materials are of special interest because of their complexity.

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