STRUCTURE AND PROPERTIES OF THE BRONZE LASER ALLOYED WITH TITANIUM

S. Kač, J. Kusiński

AGH University of Science and Technology,
Faculty of Metallurgy and Materials Science, 30 Mickiewicza Ave.,
30-059 Cracow, Poland

The paper describes the microstructure and properties of the bronze laser alloyed with titanium. The laser alloying was done using a pulsed Nd:YAG laser with a generated beam energy of 25-35 J. The microstructure formed under rapid solidification conditions was investigated by scanning electron microscope and energy-dispersive X-ray spectroscopy. Microhardness was determined using a Hanemann microhardness tester. In order to evaluate wear resistance, the specimens were tested and their mass-loss was measured. The roughness of surface was measured by Surtronic 3+ tester. A very fine microstructure was formed under such rapid solidification conditions like laser treatment. The high chemical homogeneity and fine structure of the melted zone were attributed to high cooling rates due to the short interaction time with Nd:YAG pulsed laser radiation and relatively small volume of the melted material. The structure obtained in the surface layer after laser alloying permits to get a high level of hardness and an improved wear resistance.

The Cu-10%Al-4%Fe-2%Mn bronze is applied for the parts of the machines which work in the sea water (propellers, propeller shafts). This material is applied on the parts exposed to the wear. Wear, which may be caused by adhesion or abrasion processes, is a surface or sub-surface phenomenon and can be reduced by modification of materials surface layer. The principal aim of the application of laser alloying technique in the materials surface processing is to improve their properties due to formation of hard, homogenous and ultrafine structure of the surface layer, with changing its chemical composition.

The chemical composition of investigated bronze is listed in Table 1. The coatings (mixture of Ti powder with non-organic binder) of thickness 0,1 mm were deposited on the sample surfaces and dried. The laser treatment was performed on coated bronze coupons by a pulse Nd:YAG laser with the generated beam energy of 25 J, 30 J and 35 J. The scanning speed of 0,6 mm/s was applied during alloying. During laser treatment the frequencies of the pulse was 1,5 Hz and the duration time of the laser pulse was 25,5 ms.

The structure of the material before laser treatment consisted of α phase which is the solid solution of aluminum in copper and eutectoid $\alpha+\gamma_2$. γ_2 phase is the Cu_9Al_4 electron compound base solution. This phase is very hard and brittle. Very disperse (1-2 μm) oval-shaped precipitations enriched in iron are observed in the matrix.

The SEM investigations indicate, that the surface layer after laser alloying is composed of three zones: laser alloyed zone (enriched in titanium), the melted and rapid solidified zone and the heat affected zone (Fig. 1). The structure obtained in the melted and rapid solidified zone was very refined and no cracks and no porosity was observed. The β phase is over-cooled (similarly as the austenite in steel). This phase is the Cu_3Al electron compound base solution. The rapid cooling with the velocity higher than, critical velocity, causes diffusionless phase transformation β phase to the β' phase, which is similar to the martensite in the steels. The oval-shaped precipitations enriched in the titanium are also observed (Fig. 2). In the heat affected zone the partially dissolved particles of the α phase, around which the martensite structure was formed, and oval-shaped precipitates enriched with iron were present. The measurements of microhardness were executed in the crosssections of laser alloyed samples. The investigation shows, that the microhardness of material after laser alloying was higher than the microhardness of bulk material. The microhardness in the bronze before laser

treatment was on the level of 200-240 HV_{0,65}. The highest value of microhardness in the laser treated zone was obtained for the energy of laser beam of 25 J (about 467 HV_{0,65}) (Fig. 3). The wear resistance is very important characteristic of the bronze applied e.g. for the screw propeller, slide bearing. The investigation shows, that the surface layers obtained by laser alloying (with every parameters applied) have a better wear resistance, than the bulk material. The smallest mass-loss (the highest level of the wear resistance) was obtained for the surface layer treated with energy of 25 J (Fig. 4). The results of the roughness measurements show that for every surface layer obtained by laser treatment, the laser alloying caused the increase on roughness. The increase of energy of laser beam led to increasing of Ra parameters (Ra parameter is the arithmetic mean of the departures of the profile from the mean line).

Table 1. Chemical composition of Cu-10%Al-4%Fe-2%Mn bronze

Element	Cu	Al	Fe	Mn
Wt. %	83.60	9.76	4.45	1.84

Fig. 1. SEM image showing microstructure of bronze after laser alloying

Fig. 2. SEM image showing microstructure of melted and rapid solidified zone

Fig. 3. Microhardness profiles of the surface layers of bronze after laser alloying

Fig. 4. The diagram showing wear resistance of the surface layers after laser alloying

References

- 1) De Mol van Otterloo J. L., De Hosson J. Th. M.: Laser treatment of aluminium copper alloys: a mechanical enhancement, Scripta Metall. Mater. Vol. 30 (1994) 493-498.
- 2) Kusiński J., Lasery i ich zastosowanie w inżynierii materiałowej, WN Akapit, Kraków, 2000.
- 3) Kusiński J., Woldan A., Kac S.: Modification of the steel surface layer for its better wear resistance by means of laser melting and alloying Laser Technology VII: Applications of Lasers, Vol. 5229 (2003) 155-162.
- 4) De Mol van Otterloo J. L., Bagnoli D., De Hosson J. Th. M.: Enhanced mechanical properties of laser treated Al-Cu alloys: a microstructural analysis, Acta Metall. Mater. Vol. 43, No. 7 (1995) 2649-2656.