Thermal cycling of Pb/Sn eutectic alloy

S. Mostafa, Z. El-Baradie, H. El-Din, T. El-Bassuny

► To cite this version:

S. Mostafa, Z. El-Baradie, H. El-Din, T. El-Bassuny. Thermal cycling of Pb/Sn eutectic alloy. Journal de Physique IV Proceedings, 1993, 03 (C7), pp.C7-541-C7-544. 10.1051/jp4:1993788 . jpa-00252208

HAL Id: jpa-00252208

<https://hal.science/jpa-00252208>

Submitted on 1 Jan 1993

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Thermal cycling of Pb/Sn eutectic alloy

S.F. MOSTAFA, Z.M. EL-BARADIE, H.N. EL-DIN and T.A. EL-BASSUNY

CMRDI, P.O. 87, Helwan, Cairo, Egypt

ABSTRACT

Severe deformation, annealed and thermal cycling are employed on Pb/Sn eutectic alloy. The cycling was carried out between room temperature and 140°C, and the cycling number ranged from 0 to 1300 cycles. Microstructural studies revealed that grain size and volume fraction were increased by thermal cycling. The morphology of lamellar structure changed to spherical structure by severe deformation and annealing. No effect of thermal cycling on morphology was observed. The dimensional change after cycling was anisotropic; the length expanded, whereas the width and thickness shrank. These changes in dimensions are attributed to elastic and plastic strains, and / or creep strain. Preliminary tensile test measurements showed that "m"-value decreased by cycling. Also, total ductility decreased. These are due to the increase in both grain size and volume fraction.

INTRODUCTION

The phenomenon of superplasticity indicates the ability of certain ultrafine grained structure (<10 µm) alloys to undergo extremely high deformations; in a certain temperature-strain rate range without macroscopic failure^[1-3].

In common superplastic alloys (eutectic or eutectoid) the recrystallization and grain growth are restricted by the presence of small separate grains of the two phases^[4-6].

From an applied mechanics viewpoint, superplastic metallic alloys have higher strain rate sensitivity ("m"-value)^[1]. Value of "m" can be calculated from the relation :-

$$m = d \ln \dot{\epsilon} / d \ln \dot{\epsilon} \quad [4]$$

Two methods are available for achieving the high strain rate sensitivity "m", that is required for superplasticity namely, transformation cycling^[7,8] or thermal cycling^[9] and grain refinement^[1,10-14]. In the present work; both methods were used.

EXPERIMENTS

Eutectic Pb-62 Sn was prepared from high purity metals, melting them in a heat resistance electric furnace and then poured into steel mould, commonly having dimensions 300x40x200 mm³. The cast alloy was cold rolled to the final thickness of 3 mm. The tensile specimens, each having a gauge length of 6.2 mm, were cut from the rolled sheet parallel to the rolling direction. Then, they were annealed at 140°C for 1hr. Some of these specimens were thermally cycled at zero stress between room temperature and 140°C. Before and after each predetermined number of cycles, the dimensions of the specimen were accurately measured. Hot tensile testing at 100°C was carried out on the annealed and cycled specimens in an air furnace attached with a Shematzue tensile testing machine. Cross head

speed was changed from 0.5 to 1mm/min every 20% strain until fracture in order to measure the max strain rate sensitivity "m". Cross head speed was kept constant at the value which gave maximum "m", and then, maximum elongation was measured. The microstructure examinations by optical microscope were studied.

RESULTS AND DISCUSSIONS

Microstructure

Optical examinations are shown in Fig.(1). There are two - phase microduplex equiaxed grains; Sn rich in Pb "bright grains" and Pb rich in Sn "dark grains" as was previously reported^[15]. Superplastic behaviour requires that the material should be two - phase with a uniform distribution of particles to pin the grain boundaries. The aged specimen (0 cycle) which was subjected to severe deformation before aging have a very fine microstructure. The lamellar structure of casted alloy is changed under severe deformation and aging to spheroidal structure. As the cycling increased from 0 - 1300 cycle, grain size and volume fraction of dark grains were slightly increased. The results of grain size and volume fraction are listed in Table (1). The increase in grain size with thermal cycling is contrary to that reported in previous work^[16].

Dimensional stability

Measurable change of the dimensions of specimens which were subjected to 1300 cycles are observed, Fig.(2). It can be seen that the change in dimensions is anisotropic. The length of the specimen expands whereas the width and thickness shrink. The change in length is greater than those in either width and thickness. At the same time, the decrease in thickness is much higher than that of the width. These results agree with previous studies^[17-19]. Dimensional changes are due to the elastic, plastic strain; and / or creep strain. Normally, plastic strain at 140°C exceeds yield strain at room temperature^[16]. The precipitate yielded during each thermal cycling and leaving a permanent plastic strain in the matrix. The expansion along the length direction took place. This expansion caused the shrinkage along the thickness and width directions. When the creep became the predominant effect than plastic strain, during heating cycle, the matrix was subjected to compressive creep strain. While on cooling the creep strain was reversed^[19].

Superplasticity

The change of strain rate sensitivity "m" with total elongation is represented in Table (1). The maximum "m" -value (0.6) and maximum elongation (2500 %) are obtained in zero cycled or aged specimen. Although, the same "m" - value previously recorded^[20,21], the maximum elongation was much higher than that arrived at in this work. This may be due to high aging temperature and strain rate (1.34×10^{-3}) used in this investigation. Both "m" - value and elongation decrease with number of cycles. This seems to be contrary to the previous results^[16,19]. It can be attributed to the increase in grain size and volume fraction with cycling. On the other hand, the experimental conditions (aging temperature, and strain rate) have also a higher effect on "m" and consequently maximum elongation.

CONCLUSIONS

In sammary, this study demonstrated that:-

- 1-Severe deformation and aging give a higher value of "m" and elongation together with more fine structure.
- 2- Thermal cycling together with previous condition decreases the "m"- value and consequently, the total elongation.
- 3- Thermal cycling causes a dimensional change. The length expands while the thickness and width shrink.
- 4- An increase in grain size and volume fraction resulted from thermal cycling.

REFERENCES

- 1- J.Wadsworth, I.G.Palmer, D.D.Crooks, and R.E.Lewis; Al-Li alloys II, TMS-AIME, April, 1983, 53
- 2- K.P.Chaudhury, V. Sivaramakrishnan, and F.A.Mohamed; Met. Trans. A, november, 1988, 2741
- 3- V.N.Perevezentsev, V.V.Rybin, and V.N.Chuvil'Deev; Acta Met., May, 1992, 887
- 4- R.H.Johnson; Metall. Rev., January, 1970,15
- 5- G.J.Davies, J.W.Edington, C.P.Cutler, and K.A.Panmonabhan; J.Mat.Sci., May, 1950, 1091
- 6- K.Matsuki, Y.Uetani, M.Yamada, and Y.Murakani; Metal Sci, July, 1976,235
- 7- B.P.Kashyap, and A.K.Mukherjee; Mat. Sci. and Tech., April, 1985, 291
- 8- R.Kot, and V.Weiss; Trans. ASM, Septemper, 1967, 566
- 9- R.H.Jonson, and E.C.Sykes; Nature, March, 1966, 192
- 10- A.Dutta, and N.C.Birla; Mat. Sci. and Tech., April, 1988, 341
- 11- N.E.Paton, C.H.Hamilton, J.Wert, and M.Mahoney; J.of Met., August, 1982, 21
- 12- K.A.Padmanabhan, and G.J.Davies; Met. Sci., May, 1977, 177
- 13- G.Gordon, L.Snarsky, A.Chen, and A.Rosen; Mat. Sci.and Tech., June, 1985, 466
- 14- A.J.Wert, N.E.Paton, C.H.Hamilton, and M.W.Mahoney, Met. Trans.A, July, 1981, 1267
- 15- J.W.Edington; Metal Tech., March, 1976, 138
- 16- B.H.Chapman, M.A.Cooke, and S.W.Thompson; Scripta Met., February, 1992, 1547
- 17- M.Taya, and T.Mori; ICOM VI of ECCM 2, July, 1987, 2
- 18- M.Taya, and T.Mori; Proc.IUTAM Symp., June, 1987
- 19- S.F.Moustafa, and A.N.Abel-Azim; PEDAC Univ. of Alex.Egypt, December, 1989, 27
- 20- M.M.I.Ahmed, and T.G.Langton; Met. Trans. A, November, 1977, 1832
- 21- F.A. Mohamed, M.M.I.Ahmed, and T.G.Langton; Met. Trans. A, November, 1977, 933

Table (1): Properties variations with thermal cycling

No. cycling Property	0	100	300	500	700	900	1100	1300
Grain Size (um)	6.25	6.9	7.4	8.1	8.9	9.2	10.1	11
Volume Fraction %	30	31	36	38	42	48	53	58
"m"- Value	0.6	0.56	0.54	0.48	0.45	0.4	0.345	0.32
Total Elongation%	2500	1850	1800	1750	1690	1300	1270	1248

Fig. (1) : Optical micrographs of Pb/Sn after :-
a) 0 cycle b) 300 cycle
c) 700 cycle d) 1300 cycle

Fig. (2) :- Dimensional change vs. number of thermal cycling