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EXPERIMENTAL STUDY OF HEAT EFFECT ON THE DEFORMATIONS OF AL/CU BIMETAL IN 3-POINT BENDING

Robert UŚCINOWICZ

0000-0003-4599-2632, Department of Mechanics and Applied Computer Science, Faculty of Mechanical Engineering, Bialystok University of Technology, 45C Wiejska, 15-351 Bialystok, Poland;
E-mail: r.uscinowicz@pb.edu.pl

1. Introduction

With the growing energy crisis and difficulties in obtaining new metals, layered composites are becoming more widely used, with aluminium-copper bimetal playing the dominant role. It is characterised by high electrical and thermal conductivity, high corrosion resistance, and relatively low density. The production costs of bimetal using rolling technology are low, and its use in a technical solution allows 30% to 50% savings compared to monolithic copper [1]. The composite is used in radiators, cables, cooling fins, heat exchangers, and other electronic and electrical components. However, the number of applications of Al/Cu bimetal is limited by the quite significant effect of heat on its elastic-plastic properties and structure. The purpose of the research conducted was to determine the effect of heat through growth and short-term withstanding of Al/Cu bimetal in the temperature range of up to 250 – 500 °C on its springback effect and the beginning of plasticity in its extreme layers under bending conditions.

2. Material and specimens

The experimental tests were carried out on aluminium-copper bimetallic samples in the shape of a cuboid strip with dimensions of 4 x 20 x 67 mm. They were cut from Al / Cu sheets produced by hot rolling by permanent deformational connection of sheets of electrolytic copper (CW004A) and pure aluminium (AW-1050A). The average percentage share of components in the Al/Cu bimetal is Cu - 51% and Al - 49%.

The samples were divided into two groups. Some samples were tested without thermal effects (T = 22 °C); the rest were annealed at temperatures of 250, 350, 450, 500 °C for 40 and 90 min.

The experimental studies included three-point bending tests of Al/Cu samples and microscopic analysis of the layer connection zone before and after plastic deformation of the samples.

3. Experimental setup

In the first stage of the investigation, three-point bending tests were performed. They were carried out on a hydraulic MTS Mini Bionix 858 machine, loading the samples perpendicularly to the lamination in a special device. Measurement of deformations and displacements (deflections) was performed using the Aramis 4M digital image correlation system from GOM. After mechanical tests, the bimetal structure was observed microscopically, which included a chemical analysis of the composition and measurement of the thickness of the diffusion layer formed on the Al/Cu interface because of thermal interactions. Observations were carried out on a Phenom XL electron microscope (SEM). The measurement of the thickness of the diffusion layer was performed by graphic analysis of SEM photographs, validating the results by linear analysis of the chemical composition.

4. Study of the springback of bimetal

As a result of heat exposure, irreversible changes occur in the mechanical properties of the Al/Cu bimetal. This is manifested by the effect of disturbed springback, i.e. loss of elastic properties after elastic-plastic deformation. This is treated as an operational defect, especially in the case of bending.

Springback in the tested Al/Cu bimetal was assessed and analysed by measuring the difference in angles $\Delta\phi$ during three-point bending in two states of sample deformation, i.e. before and immediately after unloading (Fig. 1).

It was found that with the increase in temperature in the range of 250 – 450°C, the values of angles $\Delta\phi$ increased significantly for the tested soaking times, and for the annealing time t = 40 min. the increase was linear. After soaking at 500°C, there was a slight decrease in the value of phi, which can be attributed to the developed brittle diffusion zone. The highest value of angle $\Delta\phi$ (springback)

obtained from the experiment for the Al/Cu bimetal was 3.2 deg.

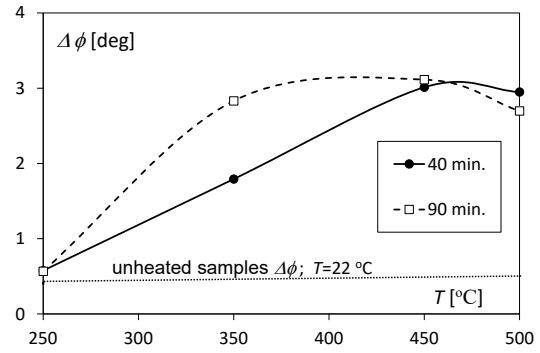

Fig. 1. Thermal effects of springback of bimetallic samples.

5. Identification of the composite plasticisation process

Experimentally, the bending curves did not reveal the beginning of plastic (physical) flow. To determine the actual values of the yield moments of the extreme bimetal layers, an analytical solution based on the experimental data was used. The changes in the yield moment M_p, depending on the temperature are shown in Fig. 2.

At 250 °C the M_p torque values for the annealing time of 40, 90 min were similar and amounted to approx. 12.8 Nm. They were slightly lower than the M_p value for the unannealed samples (13.6 Nm). In the temperature range of 350 – 500 °C the M_p values were similar (approx. 4 Nm), however, in relation to the temperature T = 250 °C a more than twofold decrease in the M_p value was observed.

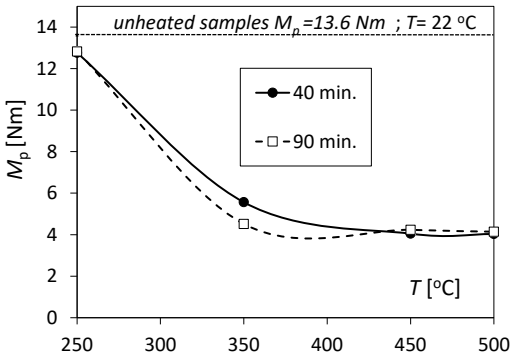

Fig.2. Changes in the bending moment M_p value under the influence of temperature.

6. Microscopic observations of the Al/Cu interface

SEM photographic observations allowed to measure of the diffusion zone thickness depending on the temperature for the tested annealing times (Fig. 3). It was found that in the case of unannealed samples (T = 22 °C) and annealed at 250°C for 40, 90 minutes, no copper diffusion into aluminium was observed. With increasing annealing temperature in the 350 – 500 °C range, the diffusion layer thickness increased exponential from 4.6 µm to 15.4 and 26.8 µm for times t = 40 and 90 min, respectively. Three intermetallic layers of different shades characterised by significant brittleness were distinguished at the interface.

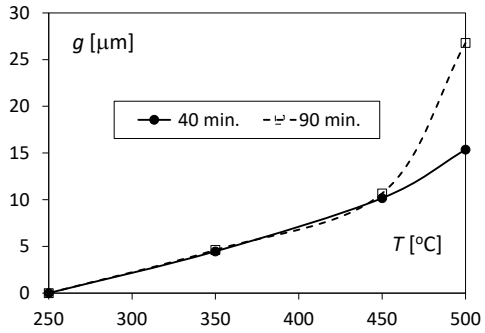

Fig. 3. Change in the diffusion's thickness zone under the influence of temperature.

7. Conclusions

- For samples heated at 450–500 °C, a six-fold increase in the springback angle was observed compared to the temperature of 250 °C.
- Heating at temperatures of 350–500 °C caused over two-fold decrease in the yield's value moment of the extreme layers of the Al/Cu bimetal compared to the lower temperatures tested.
- A strong exponential increase in the brittle's thickness diffusion zone was observed, causing a weakening of the Al/Cu joint.

Acknowledgements

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References

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