EXPERIMENTAL IDENTIFICATION OF ELASTOPLASTIC PROPERTIES OF Al/Cu BIMETALLIC SHEET OBTAINED BY COLD ROLLING

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1. Introduction

The design process of plastic forming the machine parts requires the knowledge about elastoplastic properties of used material. The identification of the mechanical properties by experimental tests is relatively easy in the case of isotropic and homogeneous structures. In the case of modern constructional materials, which are characterised by the complex internal structure, determination of physical properties by tests is difficult operation and need special approach. An example of such material may be a bimetallic sheet manufactured by hot or cold rolling by joining of two or more metal sheets with different physical properties. Experimental tests of these materials for determination their mechanical properties were conducted by Lee and Kim [1], Semiatin and Piehler [2], Choi et al.[3] and Uścinowicz [4].

The aim of the study was determination the directional values of the mechanical parameters, which were described the elastic and plastic properties of the Al/Cu bimetal in the form of a metal sheet taking into account the varying thickness of the copper layer.

2. Materials, specimens and methods

In experimental tests three types of specimens were used, i.e.:1) flat specimens with a "dog-bone" shape and made from Al/Cu bimetal, 2) bimetallic Al/Cu specimens in the shape of rectangular prisms, 3) aluminium specimens obtained from bimetallic sheet, but completely devoid of the copper layer. Specimens were cut from Al/Cu sheet in two directions, i.e. in the rolling direction (RD) and the transversal direction (TD). The mean share of metal components in the as-delivered Al/Cu bimetal was: Cu - 49% and Al - 51%. The essential group of bimetallic Al/Cu specimens were machined by milling to reduce the thickness of the copper layer in comparison to the aluminium layer. This involved reducing the thickness of the Cu layer by approx. 0.6 mm. The share of copper in Al/Cu bimetallic specimens amounted, as a percentage, respectively was: 0%, 25%, 40%, 45%, 50%. For the as-rolled Al/Cu sheet, no cracks and no intermetallic layer on the interface was observed.

In order to obtain information about the mechanical properties of the tested Al/Cu bimetal two experimental methods were used: 1) uniaxial quasi-static monotonic tensile test realised on flat specimens, 2) dynamic method of determination of elastic properties using impulse excitation technique in which an acoustic resonance frequency analyser for rectangular prisms specimens was applied. Basic elastic and plastic properties of the tested materials were determined for the selected RD, TD directions and in the direction perpendicular to the plane of sheet - ND (normal direction), i.e.: elastic limit ($R_{p0.05}$), yield point ($R_{p0.2}$), tensile strength (R_m), Young's (E) and Kirchhoff's (G) moduli, internal friction parameters (Q^{-1}), maximum uniform plastic strain (ε_u) and hardening curve coefficients (n, K, ε_o), specific energy of uniform elastic and plastic strains (L_e, L_p) as well as Lankford's coefficient (r) describing the normal anisotropy.

3. Results

The hybrid approach to mechanical tests, with the use of two methods, gave the possibility to determine the elastic constants in the plane of Al/Cu sheet and in perpendicular direction to it taking into account varying thickness of the copper layer (parameter f_{Cu}).

Figure 1 presents changes the values of elasticity moduli E_{ND}, E_{RD}, E_{TD} in three orthotropic directions. The values of moduli E_{RD}, E_{TD} change non-linearly as the share of copper in the Al/Cu bimetal increased and charts have progressions of similar shape. They achieve an extreme value for the share of copper as 38-39% in the Al/Cu bimetal. In the case of E_{ND} modulus a non-linear increase of the values of moduli E_{ND} is also observed.

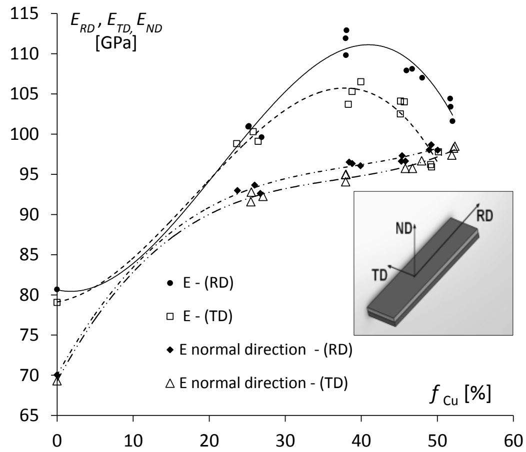

Fig. 1. The effect of increase the percentage fraction of copper in Al/Cu bimetal on values of E_{ND}, E_{RD}, E_{TD}.

Another interesting parameter obtained from measurements by using impulse excitation technique was internal friction (Q^{-1}). Non-linear changes of Q^{-1} accompanying the growth of f_{Cu} in two modes (flexural and torsional) are illustrated in fig. 2. It seems the rolling process caused greater hardening of Al/Cu specimens in TD direction, which had a more plasticized structure (texture). Charts of Q^{-1} in flexural and torsional modes have different progressions with increasing Cu content in the Al/Cu.

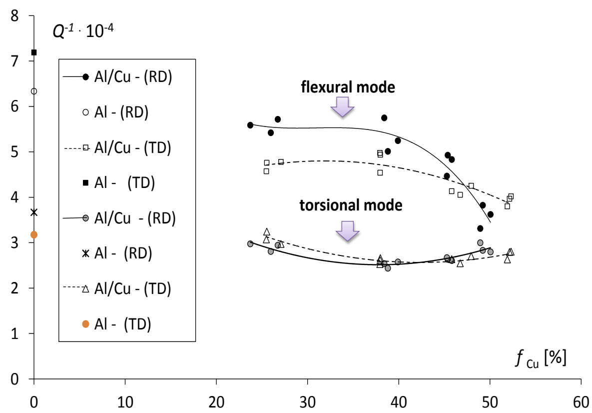

Fig. 2. Variability of internal friction Q^{-1} during the increase of Cu fraction in Al/Cu bimetal.

The changes of the normal anisotropy, which was connected with plastic deformation of the bimetallic sheet, was recorded by the Lankford's coefficient *r*. The variability of the value of coefficient *r* for aluminium and Al/Cu bimetal accompanying the growth of parameter f_{Cu} is shown in fig.2. It should be highlighted that values of Lankford's ratio for Al/Cu bimetal decrease more quickly in RD direction than TD accompanying growth of parameter f_{Cu}.

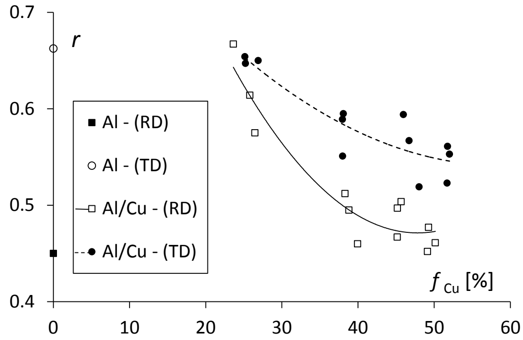

Fig. 3. Variation of values of Lankford's coefficients with increase of the copper content in Al/Cu bimetal.

4. Conclusions

- The quasi-static tensile tests and impulse excitation technique allowed to determine the values of the Young's modulus in the directions of orthotropy.
- The law of mixtures incorrectly describe the changes of elastic constants (E_{ND}, E_{RD}, E_{TD}) accompanying the growth of parameter f_{Cu}, i.e. percentage shares of Cu component in Al/Cu bimetal.

Acknowledgements

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