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DEFORMATION ZONES AT TWO-LAYER BENDING COMPOSITES

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Abstract: Stress-strain zone at bending of single-materials has nemonoton character. On the intensity and impact zone propagation affect have: kinematic processes, the history of deformation, geometrical parameters of tool, geometrical parameters of the work piece and others. All these parameters affect the reliability of the process and make it complicated. However, if the process of bending with layered composite materials becomes complex, also the reliability of its policies must be defined trough the size limits of certain parameters. This paper gives an overview of the parameters that have a significant impact on the size of the stress-deformation zone and the reliability of the process.
Keywords: bending, layered composite, reliability

1. INTRODUCTION

Layered metal composite materials have applications in power systems and devices that require elevated security in the working and living environment, increasing the durability of the product for the purpose of lowering the cost of production. The technological development of composite laminates depends on the thickness of layers, the number and position of the layers and quantity. If the thickness is more than 0.1 mm, then the preparation is done with cladding and coating. In addition, the technological development of mechanical systems and components of the layered metal composites is desirable to know in advance to the final geometric shape of machine parts, the desired position of layers of materials, the necessary mechanical and chemical characteristics for the reliability of making and using same. In the process of making technological changes may occur bifurcation of layers and layers microcracks, which negatively affect the reliability of the product from which are they made. This paper treats the problem of propagation of deformation zones in function of the position of the layers with respect to the bending radius of two-layer metal composite. Deformation was conducted with a history of deformation and without it.

2. STRESS-STRAIN STATE AT BENDING DOUBLE-LAYER COMPOSITES

Bending is non-monotonic deformation process. Neutral surface stress and deformation continuously changes its position with increasing degree of deformation of the finite strain, or until a bifurcation at the border of layers or the appearance of microcracks in the surface layers of composites. Base layer can be defined by the thickness and mechanical characteristics of the material layer. From the position of the base layer, its mechanical and chemical properties, and its size depends on the geometric definition of a reliable technological process of making the product. Stress-deformation diagram is a function of the position of the primary and coating layer compared to the bending radius, ie. whether it is concave or convex.

The intensity of the stress state in the cylindrical coordinate system is determined trough equation

$$\sigma_i = \frac{\sqrt{2}}{2}\sqrt{(\sigma_\rho - \sigma_\theta)^2 + (\sigma_\theta - \sigma_z)^2 + (\sigma_z - \sigma_\rho)^2}\ , \qquad (1)$$

the intensity of logarithmic strain

$$\varphi_i = \frac{\sqrt{2}}{3}\sqrt{(\varphi_\rho - \varphi_\theta)^2 + (\varphi_\theta - \varphi_z)^2 + (\varphi_z - \varphi_\rho)^2}\ , \qquad (2)$$

where

- $\sigma_\rho,\ \sigma_\theta,\ \sigma_z -$ stress tensor components,
- $\varphi_\rho,\ \varphi_\theta,\ \varphi_z -$ logarithmic strain tensor components.

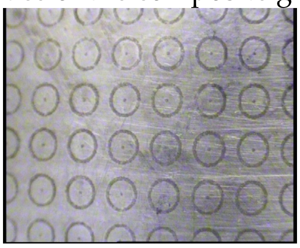
Logarithmic strain on the grid in the circular direction and radians are calculated according to the forms:

$$\varphi_\theta = \ln\frac{d_\theta}{d}\text{, that is } \varphi_z = \ln\frac{d_z}{d} \qquad (3)$$

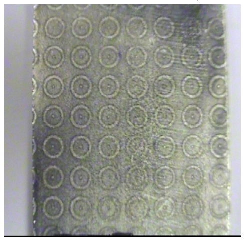
3. EXPERIMENTAL RESEARCH

Experiments were conducted on two-layer composite, steel layer of X5CrNi18.10, 1.5 mm thick and layer of Al99, 4 mm thick. The aim of the research is the analysis of the effective parameters on the propagation of the deformation zone, ie a function of material strength, the position of the layers relative to the bending radius and the size of the radius of bending. The patterns are applied:

- On the outer surface of the composite grid with circles of the same size, chemically, Figure 1



grid on surface
of layer X5CrNi18.10



grid on surface
of layerAl 99,0

Figure 1. Grid on the surface of the sample

- caused by the parallel lines using the tool on the lateral surface of a microscope sample, spacing 1 mm, Figure 2.

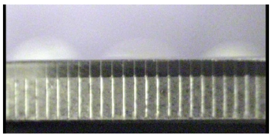


Figure 2. The parallel lines on the side panels

Bending radius is varied from 2 mm to 6 mm with 1 mm pitch. Bending is performed on the V-profile in two steps, the angle of 45° and 90°.

3.1. The survey results

Deformation is intense in the circular direction, the radial and axial are negligible. Displaying deformation zone are given in Figure 3.

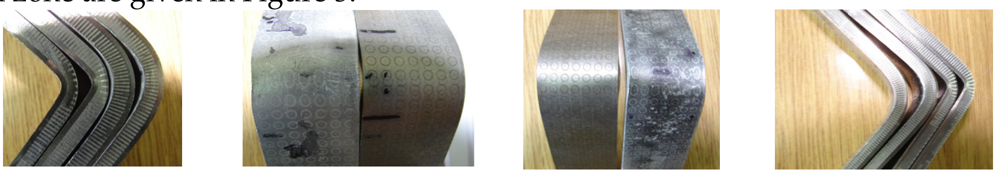


Figure 3. Flexural deformation zone of dual-layer composite on V-profile (90°)

Based on the strain deformation network circuits after bending angle of 45°, intensities were quantified by strain on the outer and inner surface layers, a diagrammatic representation of the results is given in Figure 3. A layer of material X5CrNi18.10 was on the outside, deformation was carried out at 45° angle, then the angle of 90°, the value of deformation shown in diagram 3 and 4.

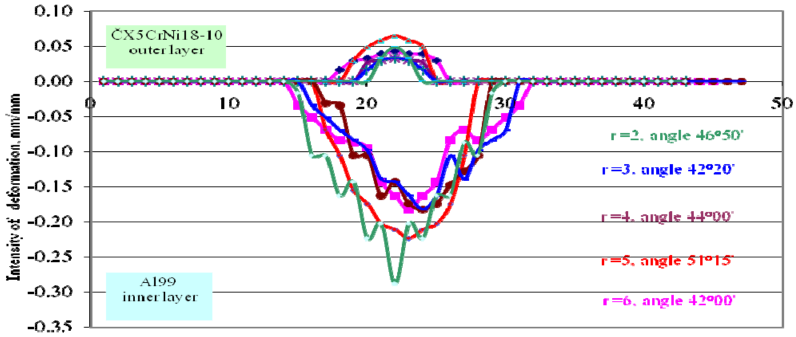


Figure 3. The intensity of the deformation of the outer and inner surface of the V-profile, bending angle of the tool 45° and different radii of the punch

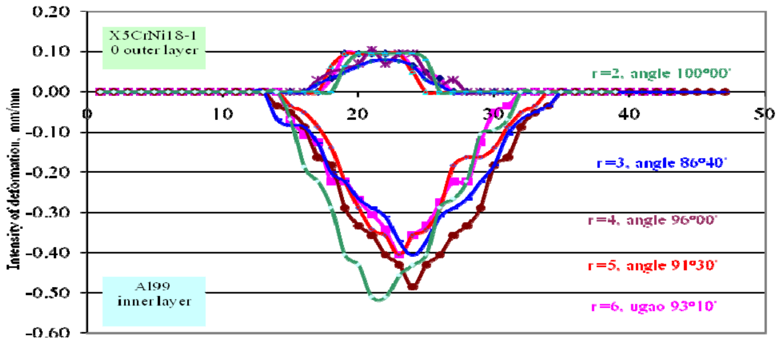


Figure 4. Intensity of the logarithmic strain on the outer and inner surface of V-profile, bending angle of the tool 90° and different radii of the punch

When folding a very important role in the assessment of relative deformation has the bending radius. On the basis of the relative bending radius is presented the intensity of deformation in function of the position of the layers with respect to the bending radius and bending angle. From this study, it can be given a conclusion how impact of increase in intensity of a previous strain has on the bending-layer composites. Figures 5 and 6 give the intensity of deformation diagrams percentage in function of the relative bending radius.

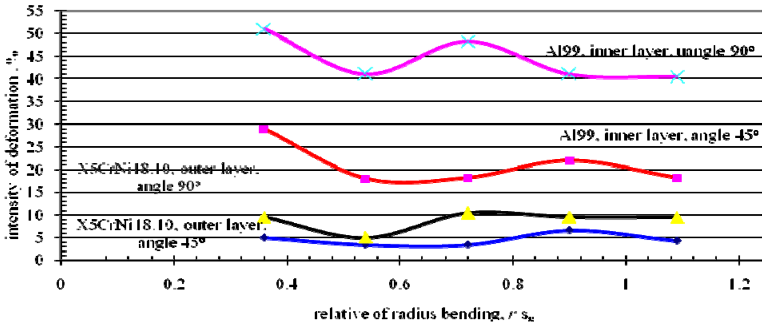


Figure 5. The intensity of deformation of the outer and inner surface in function of the relative bending radius

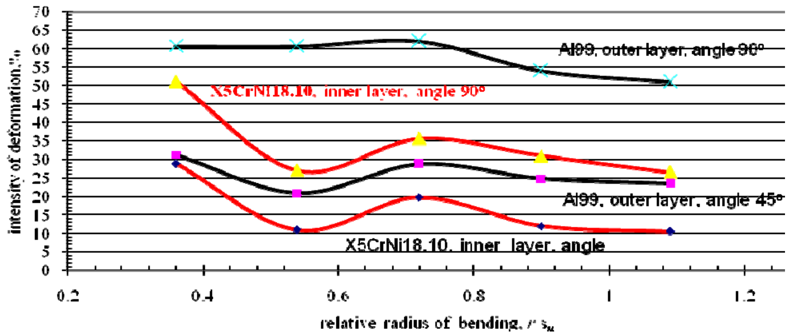


Figure 6. The intensity of deformation of the external and internal surface in function of the relative bending radius

3.2. Analysis of the results of research

The intensity of deformation of the outer surface layers are the highest in the circular direction and have sign plus or minus, while in the radial and axial direction are negligible. Deformation is more pronounced on the surfaces of materials with lower mechanical properties. With increasing degree of deformation: neutral layer strain and stress are moving towards the center of curvature. In materials with higher mechanical properties of the initial position of the neutral layer is the layer in the area or close to it, provided that its thickness is much smaller than the thickness of the second layer. The process can be no thinning or thickening of the layer with lower mehanical properties if the level of deformation has a greater value. The total thickness of the workpiece can be reduced or increased, figure 3. At the onset of process deformation φ_{is} is greater than the deformation φ_{iu}, when on the convex surface of a layer is material with lower mechanical properties, but with the increase of the curve this difference grows more intense. If the clad layer is on the inside of the workpiece and has a higher strength then: neutral layer strain and stress shifts to the side clad layer on the inner surface, deformation φ_{iu} is smaller than the outer surface φ_{is}, φ_{is} due to the growing movement of the neutral layer rises in the concave side of the surface. The relative thickness of clad layer is reduced, thinning of the base layer increases. If the clad layer is on outer side of the workpiece and has a higher strength then: neutral layer strain and stress are located in the zone of clad layer and slightly moves toward the center of the bending strain, on the concave surface φ_{iu} is greater than on the convex surface φ_{is}, φ_{is} slightly increase due to the shift of neutral layer in the inner surface side. Deformation zone on the outer surface is larger and broader in the circular direction, figure 3 and 4. Bending radius has less influence on the increase of deformation of bending angle profiles.

4. CONCLUSION

At banding layerd composites is very important position of layers in relation to the bending radius. The extension of the deformation zone depends on the position of layers, layer thickness, mechanical properties of material thickness, bending radius and angle. If you can not, from necessary reason, change the position of the layers with respect to the bending radius, then care must be taken to limit of the value of the radius and bending angle. If the layer of material with lower mechanical properties is located on the outside then strain limit values must be lower, because there is a possibility of a bifurcation in the boundary layer and microcracks. In this layer, they can not be visually noticed, which may lead to undesirable consequences in the working and living environment. If a layer of material with higher mechanical properties is on the outside it is harder to form the required bending radius because there is increasing thickness of material on the inside. Deformation zone takes up most of the space in the lower layer of the material mechanical properties.

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