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ZONE OF THE STRESS AND OF THE STRAINS WHEN BENDING LAMINARY COMPOSITES

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Abstract: Spreading stress–strain zone at bending or profiling of laminar composite is in function: layer material characteristic, geometric layer size, parameters at deformation layered composites and deformation degree. The mechanical properties of the layered material significantly affect the position and intensity of the voltage–deformation zone and the way of making the laminar composite. If the mechanical properties of the layers are significantly different, the stress zone deformation defines the material of the layer with higher mechanical properties. This paper deals with the case when the mechanical properties of the layers are very similar. Stress of the states can be simulated with program packages that are related to areas, ie possible of the stress–strain states area. One of these software is ANZIS. In this program, simulation of the position of the two–layer laminar composite with Cu–Al layers was performed. The simulation was performed by force bending in the middle of the work pieces

Keywords: laminated composites, bending, stress zone, deformation zone

INTRODUCTION

Composite materials are largely used in science and technology. The technologies of getting these materials are becoming more and more perfect. Known technologies for obtaining laminar composites are: rolling, explosive affixture and gluing. Their technological processing into semi–products and products requires reliable processes that will not lead to the appearance of micro–cracks at the layer boundary and in the layers themselves which can later propagate in realistic conditions of application due to dynamic loads, which can lead to destruction of the system in which they are applied. Prior to bending or profiling of composite layers it is very important to know the position of the layers in relation to the radius of bending and profiling and their mechanical and gepometric sizes. In order to gain access to product–making technology, which will not result in the emergence of crack in the composite layers, degradation of layer thickness and micro–crack formation [1,2]. The zones of the stress and of the strain intensity is exactly dependent on the above parameters and the degree of deformation [3].

STRESS–STRAIN ZONES AT BENDING OF THE LAMINAR COMPOSITES

When bending the composite laminar materials, report is triaxial stress and strain state, Figure 1.

Since of the bending non–monoton process is very important to know: the geometric prametri layers, the mechanical characteristics of the layer material, the position of the layers in relation to the bending radius and the degree of deformation [4]. These parameters affect the stretching and pressure zones at the cross section of the profile, their size and the degree of deformation at which the destruction will not occur.

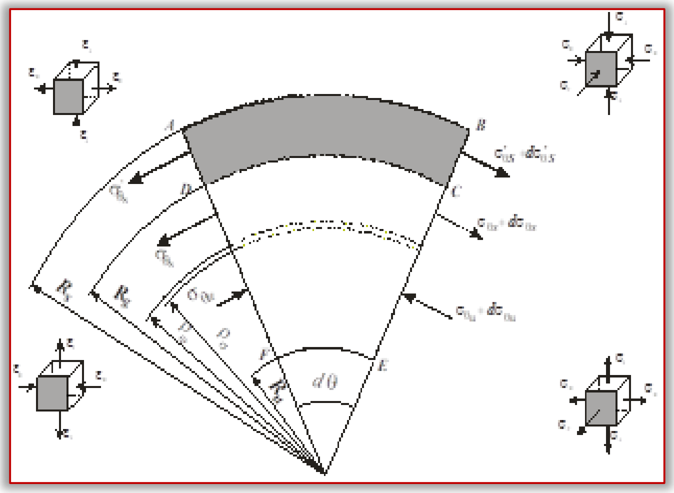

Figure 1. Scheme of stress and strain state at the bending of the two–layered composite, Rs – radius of bending the outer surface, Rg – radius of bending on the boundary of the layers, Ru – radius of bending of the inner surface,□□ – radius of neutral surface (lines) deformation, □σ – radius of the neutral surface (lines) of the stress, σ_θ – tangential of the stress, σ_r – radial of the stress, σ_s – longitudinal stress in the direction or radius of bending, ε_θ – tangential of the strain, ε_r – radials of the deformation and ε_s – longitudinals of the deformation

When bending single–layer or multilayer materials, the stress and deformation state in work piece can be brought in:

- elastic of the area
- elastic–plastic, and
- plastic of the area.

Stress of the states can be simulated with program packages that are related to areas, ie possible of the stress–strain states area. One of these software is ANZIS. In this program, simulation of the position of the two–layer laminar composite with Cu–Al layers was performed. The simulation was performed by force bending in the middle of the work pieces, which is resting be on two supports, Figure 2. Copper thickness 3.2 mm and Al 3.5 mm. When is the copper layer on the concave (upper) side, ie. to the defomated force, the neutral line stress distance is 2.9 mm from the concave surface. When in this position Al then is the neutral line spaced 3.75 mm.

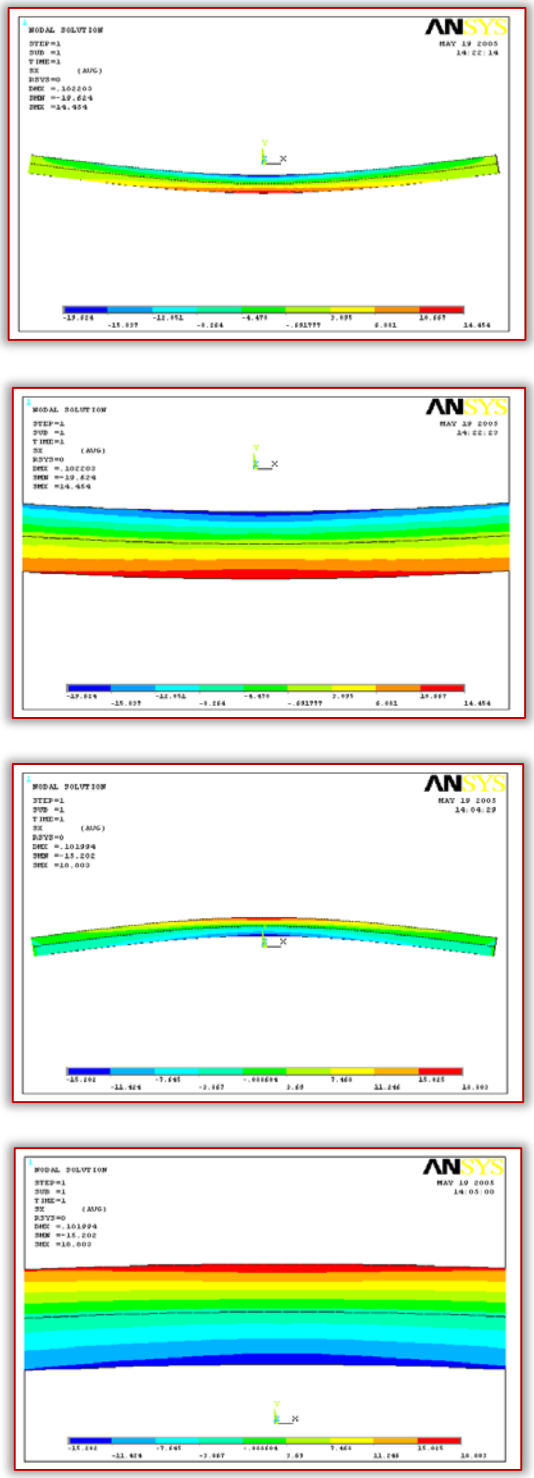

Figure 2. Double layer laminar composite, Cu–Al

For determine the radius of neutral deformation surface ρ_φ, it is necessary to know the size of the outer (R_s) and inner (R_u) radius of bending, on the basis of which the radius of the neutral layer (surface) of deformation can be determined by the expression

$$\rho_\varphi = \frac{R_s^2 - R_u^2}{2s_u} \qquad (1)$$

where: s_u–the thickness of the work pieces of the two–layer composite

The deformation state on the convex (outer) and concave (inner) surface is determined by expressions

$$\varphi_{is} = \frac{2}{\sqrt{3}} \ln \frac{R_s}{\rho_\varphi} \qquad (2)$$

$$\varphi_{iu} = \frac{2}{\sqrt{3}} \ln \frac{\rho_\varphi}{R_u} \qquad (3)$$

After determining the radius of the neutral layer of deformation, knowing the size flowing limits of the material can be determined the boundary between elastic and plastic zone. After that, the stress of the per troughout laminate composite can be determined.

The tangential stresses in the compression zone are determined by the expression

$$\sigma_{\theta u} = -\frac{2}{\sqrt{3}}\left(\sigma_i + \frac{\sigma_{iu}\varphi_{\theta u} - \sigma_i \varphi_\theta}{n+1}\right) \qquad (3)$$

$$\sigma_i = A\left(\ln \frac{\rho_o}{r}\right)^n$$

Radial stress are determined by expression

$$\sigma_{ru} = -\frac{2}{\sqrt{3}} \frac{\sigma_{iu}\varepsilon_{\theta u} - \sigma_i \varepsilon_\theta}{n+1}. \qquad (4)$$

The intensity of deformation on the convex surface is determined by equality

$$\varphi_{is} = \frac{2}{\sqrt{3}} \ln \frac{R_s}{\rho_\varphi}. \qquad (5)$$

The intensity of deformation on concave surface is determined by equality

$$\varphi_{is} = \frac{2}{\sqrt{3}} \ln \frac{\rho_K}{R_u} \qquad (6)$$

EXPERIMENTAL DETERMINATION OF THE POSITION OF NEUTRAL SURFACE

Experimental determination of the neutral deformation surface position can be determined by the method of parallel lines, and the degree of deformation on the convex concave side by the application of the circles mesh or squares network

[5]. It is therefore necessary to apply the line to the side surfaces of the work pieces, and the circles on the surface of the deformation work pieces [6,7].

The optimal distance between the lines is about one millimeter, and can be less. Detection of line position change during deformation is possible by using a three–dimensional camera or after deformation by recording the geometric size of the lines and circles by means of a microscope. By processing the positions, comes position of the neutral deformation surface is reached in the multilayer composites and deformations on the convex and concave sides of the contour. The neutral deformation layer does not change its length during bending deformation but only changes the curvature, which is the result of the bending radius [8].

Depending on the change in the position of the applied lines at the sides, the comes is to the neutral deformation surface is reached. Mathematical dependency can be expressed through the following

$$s_{n\varphi} = \frac{(l - l')}{(l'' - l')} s \qquad (6)$$

where are:

$s_{n\varphi}$, mm – the distance of the neutral surface of deformation from the inner surface of the workpiece

l, mm – the initial spacing of the parallel lines applied to the workpiece ,

l', mm – the spacing of parallel lines on the inner side of the workpiece ,

l'', mm – the spacing of parallel lines on the outside side of the workpiece,

s, mm – workpiece thickness.

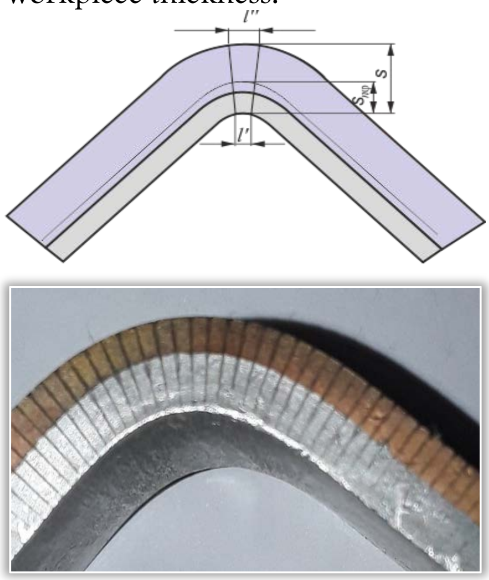

Figure 4. Geometrical size of the position and spacing of the parallel lines applied to the lateral surface and their position after the deformation of the Cu–Al

Line on the surface of the piece and the workpiece at the bending of the two – layer laminar composite (layered material), Figure 4.

In Table 2, given on the neutral position of the deformation surface of the two–layer composite Cu–Al is calculated, the radius on the tool r = 6 mm

Table 2. Position of neutral deformation surface

Workpiece	Angle of the bending in the first and second phase	Layer on the convex side of the workpiece	Distance of neutral surface from concave surface, mm
1	52° 10′	Al	2.00
	89° 03′		1.735
2	50° 14′	Cu	3.611
	89° 50′		3.204

After deformation, the thickness of the aluminum layer was increased when this layer was on the concave side and thinning when it was on the convex side, Figure 5.

Figure 5. The layers of the laminar double–compozites after bending force and their deformation after the experiment was performed in two bending cycles

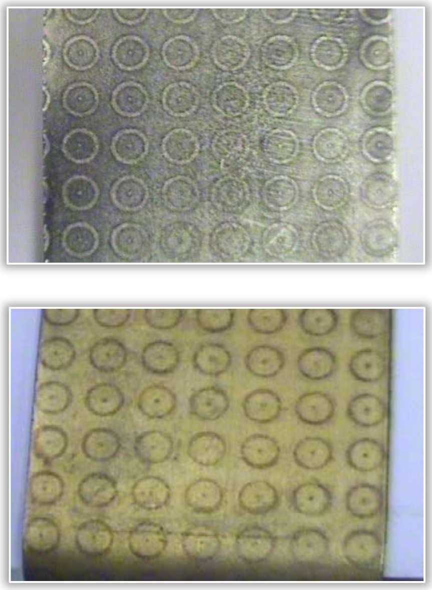

Figure 6. Circles on Layer Al surface 99.0 (left image) and on the surface of the Cu 99.9 layer (right)

On the surface of the two – layer laminated composite, a network of circles was introduced to determine the intensity of deformation on these surfaces, Figure 6. The intensity of deformation on the convex and concave sides is given in Figures 7 and 8.

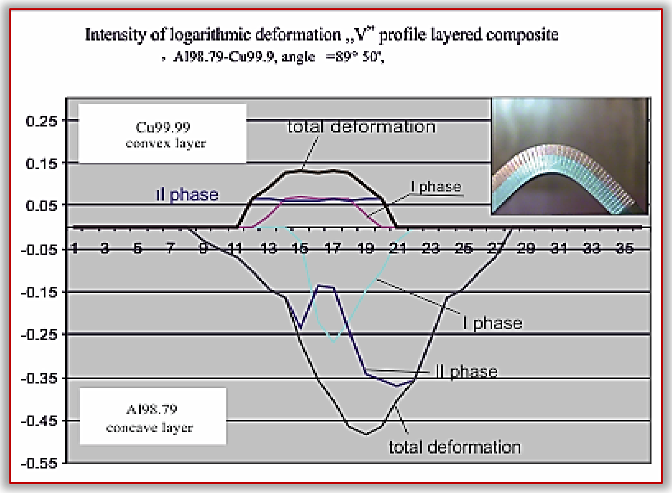

Figure 7. Intensity of deformation on the concave and convex surface of the two–layer laminar composite Cu–Al at bending of the radius tool r = 6 mm (Cu convex zone)

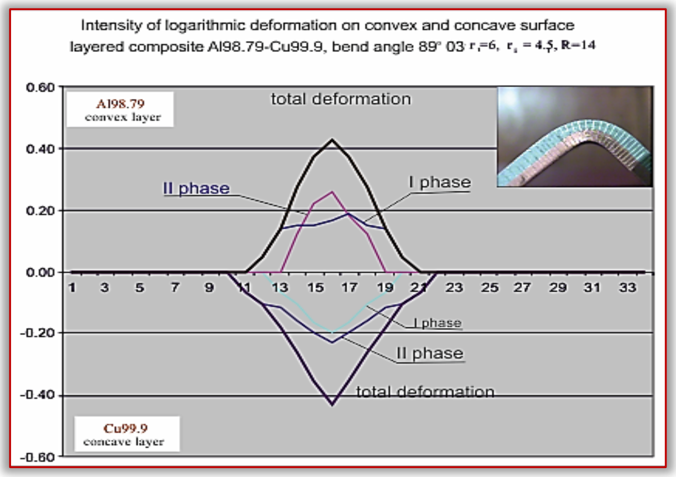

Figure 8. Intensity of deformation on the concave and convex surface of the two–layer laminar composite Cu–Al at bending of the radius tool r = 6 mm (Al convex zone)

CONCLUSION

Theoretical and experimental research of the deformation intensity when the bending of the two–layer composite, where he is aluminum layer (thickness 3.5 mm) and copper (thickness 3.2 mm) show that very important mechanical and geometric sizes are essential on the concave side. They directly affect boundary deformability if they are approximately the same. The study shows that the aluminum layer determines the maximum deformability limit, regardless of whether it is on a concave or convex side, an intense thickening or thinning of this layer is present.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

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ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

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