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THE APPLICATION OF AUTOMATED STRAIN ANALYSIS METHOD TO DETERMINE THE STRAIN DISTRIBUTION DURING EXTRUSION

The application of numerical image analysis for determining strain distribution in layered composites in the extrusion process was presented. Commercially available an ASAME (Automated Strain Analysis and Measurement Environment) computer code was used. Based on experimental study of layered composite extruded through different dies and use of the grid distortion method, strain distribution using ASAME code was presented.

Introduction

One of the important advantages of extrusion process is that the final shape of the product can be obtained in a single operation with large change of shape and there is possibility of changing the deformation zone by changing the shape of the die. Improvement in the production of metallic composites by extrusion depends on suitable designing of such types of material and its plastic deformation. Various approximate experimental and theoretical methods are used to estimate distribution of strain and stress in plastic deformation zone. Methods based on surface formulas, deserve special attention among many experimental methods. These methods consists of formulas plotted at the surface of analyzed component. These formulas in the form of lines, circles, lines, etc. inform the movements of individual points of the sample surface allowing the analysis of deformations. Depending on the nature of the research can be divided into imaging technique using optical circuits or digital circuits. Digital image processing involves the presentation of the selected image in the form of two-dimensional matrix of numbers, represented by the specified number of bytes. The resulting image is the result of the actual process of digitizing the image. Of the optoelectronic image sensors have gained a dominant role monolithic integrated CCD (Charge Coupled Device) [1]. In terms of forming techniques using digital image processing involves the use of image analysis. This method enables digital image recording the deformed surface of the sample during or after the process [2-5]. Among many experimental methods using image analysis during strain defining process, the most common method is grid analysis method and image analysis method using Fourier transformation. Grid method consists of two stages: first consists of defined grid nodes, second consists of calculations based on obtained measurement data. Using CCD cameras and scanners it is possible to record image during or after the test. Modeling processes of plastic processing, including extrusion process using incremental method of grid analysis permanently plotted at the surface of deformed material is based on theoretical analysis of experimental tests results and definition of kinematics and static at the plasticization area in select process stage. Research consists of measurement of deformed mesh in order to determine node displacement quantity. Coordinates measured for each strain stage enables defining components of displacement increment gradient for each node.

The paper presents the possibility of using numerical image analysis to determine the distribution of strain in layered composites extrusion process using the commercial program.

Experimental procedure

To determine mechanical behaviour of different metals under their simultaneous plastic deformation, the extrusion process with use of different types of the dies has been carried out. The experimental part of the study was carried out on a specially equipment, which allowed to apply direct extrusion process. A set of flat die and convex die (Fig. 1) leading to the extrusion ratio $\lambda = 3$ were used in forward extrusion without lubrication. The composite billets consisting of the following model materials: hard lead (PbSb3) – as a core and soft lead (99.98% Pb) – as a sleeve have been used for testing. The composite billets have been prepared in concentric layout: core with circular section – sleeve in hard core-soft sleeve with volume ratio of the core $V_{core}/V_{composite} = 0.31$, $V_{core}/V_{composite} = 0.08$. Basic parameters of performed extrusion tests are presented in Table 1.

Determination of strain distribution in layered composites during extrusion based on the grid deformation method (Fig. 2). Before extrusion each layer of the composite rods was firstly, split into two equal halves and square grids of 1.5x1.5 mm were inscribed onto the longitudinal symmetrical plane of the split half. Then two halves were fitted together and put into the container to implement the experiments of the extrusion of composite rods. In all cases, the process was stopped after 50% of the initial billet length was extruded.

In the second part of the study commercially available an ASAME (Automated Strain Analysis and Measurement Environment) program with automated measuring position equipment with CCD camera to determine strain distribution during composite sample extrusion process has been used. Design of such device with marked shift directions of particular elements is presented in Figure 3.

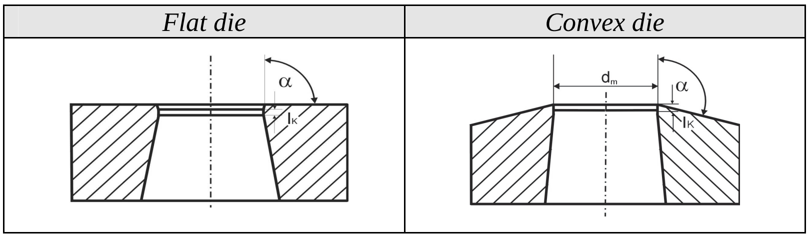


Fig. 1. The dies used in the extrusion process – the scheme of longitudinal section of the die: l_k – bearing length, α – die angle, d_m – die orifice diameter

Rys. 1. Matryce zastosowane w procesie wyciskania – przekrój wzdłużny matrycy: l_k – pasek kalibrujący, α – kąt stożka matrycy, d_m – średnica otworu matrycy

Table 1. Process parameters used in experimental work

Tabela 1. Parametry procesu zastosowane w badaniach

Parameter	**Unit**	**Value**
Temperature of extrusion	K	293
Die angle α	degree	90; 100
Billet diameter	mm	36
Billet height	mm	72
Extrusion ratio λ	-	3
Extrusion speed (ram speed)	mm/s	1

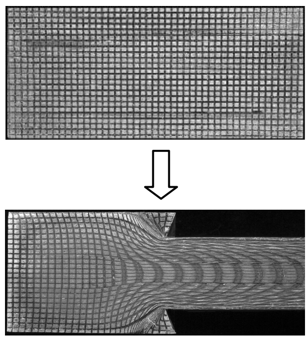


Fig. 2. Samples for experimental extrusion with use of the grid distortion method

Rys. 2. Próbki do badań eksperymentalnych z użyciem zdeformowanej siatki

Results and discussion

Grid distortion in the cross-section of the billet during extrusion of composite material has been presented in Figure 3.

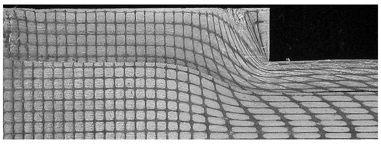
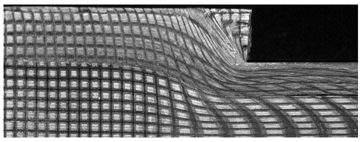
Flat die $\alpha=90^{o}$	Convex die $\alpha=95^{o}$
	

Fig. 3. Grid distortion on the longitudinal section of the billet during extrusion through flat and convex dies

Rys. 3. Deformacja siatki na przekroju wzdłużnym próbki podczas wyciskania przez matrycę płaską i wypukłą

Basing on the grid deformation, program has been used in order to determine strain distribution during composite sample extrusion process. To calculate the true thickness strain and true effective strains from the true major and true minor strains (Fig. 4), the following equations are used:

$$\varepsilon_{thickness} = -\varepsilon_{major} - \varepsilon_{\min or} \tag{1}$$

$$\varepsilon_{effective} = \frac{2}{\sqrt{3}}\sqrt{\varepsilon_{major}^2 + \varepsilon_{\min or}^2 + \varepsilon_{major}\varepsilon_{\min or}} \tag{2}$$

$$\varepsilon_{\min or} = \ln\sqrt{1+2E_{\min}} = \frac{1}{2}\ln(1+2E_{\min}) \tag{3}$$

$$\varepsilon_{major} = \ln\sqrt{1+2E_{\max}} = \frac{1}{2}\ln(1+2E_{\max}) \tag{4}$$

where: $E_{\min} = E_{average} - r,$

$E_{\max} = E_{average} + r,$

$E_{average} = \dfrac{E_{11}+E_{22}}{2},$

$r = \dfrac{1}{2}\sqrt{(E_{11}-E_{22})^2 + (2E_{12})^2}.$

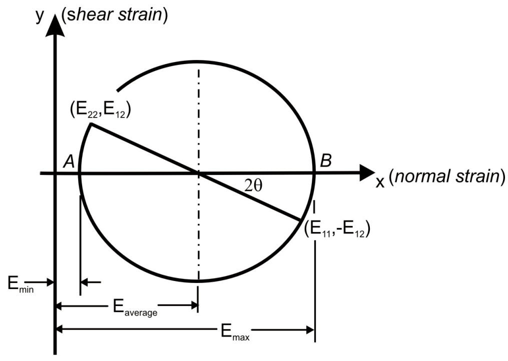


Fig. 4. Mohr's Circle

Rys. 4. Koło Mohra

FLAT DIE

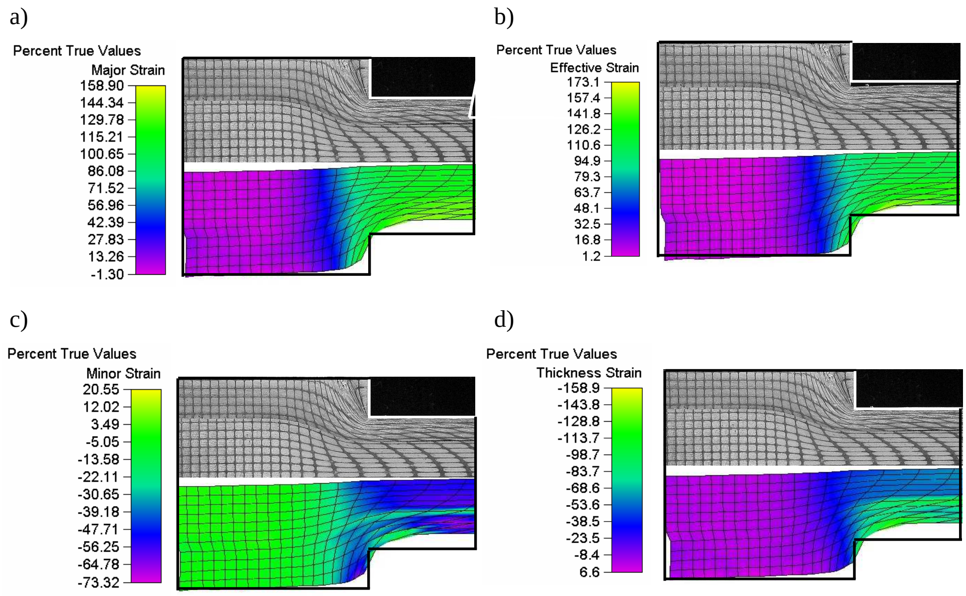


Fig. 5. Strain distribution in composite sample extruded through flat die ($\alpha = 90^o$), $V_{core}/V_{composite} =$ $= 0.31$: a) major strain, b) effective strain c) minor strain, d) thickness strain

Rys. 5. Rozkład odkształceń w próbce kompozytowej wyciskanej przez matrycę płaską ($\alpha = 90^o$), $V_{rdz.}/V_{komp.} = 0.31$: a) największe odkształcenie główne, b) odkształcenie zastępcze, c) najmniejsze odkształcenia główne, d) odkształcenie obwodowe

Strain distribution in composite sample extruded through different dies received with using ASAME program is presented in Figures 5 and 6.

CONVEX DIE

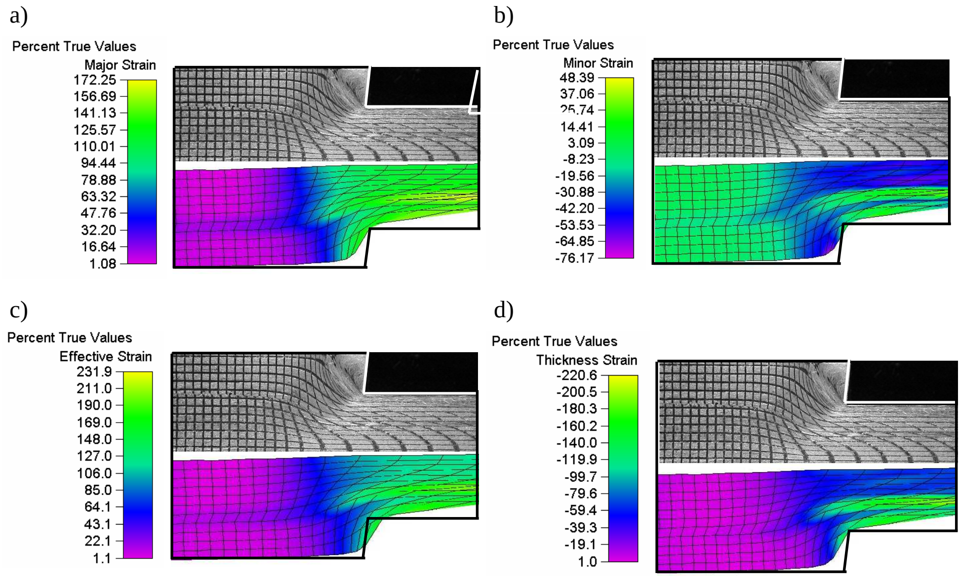


Fig. 6. Strain distribution in composite sample extruded through convex die (α = 95°), $V_{core}/V_{composite}$ = 0.31: a) major strain, b) minor strain c) effective strain, d) thickness strain

Rys. 6. Rozkład odkształceń w próbce kompozytowej wyciskanej przez matrycę wypukłą (α = 95°), $V_{rdz.}/V_{komp.}$ = 0.31: a) największe odkształcenie główne, b) odkształcenie zastępcze, c) najmniejsze odkształcenia główne, d) odkształcenie obwodowe

The results obtained show differences between the strain distribution for the composite layer in case of use of both types of matrices (Figures 5 and 6). The resulting distributions of the intensity of deformation obtained from the use of numerical image analysis, determine the degree of nonuniformity in the cross section deformation of the sample. In the case of layered composites by extrusion dies convex regions can be identified from short-changing the intensity of deformation by a certain minimum until it reaches again higher values along the radius of the billet. In the case of a flat die deformation intensity values are greater than for die convex. A limitation is the accuracy of the method of grids, which largely depends on the number of points taken in the analysis of movements.

Distributions of strain in the sample composite extruded through a flat and convex dies in the form of isolines shown in Figure 7.

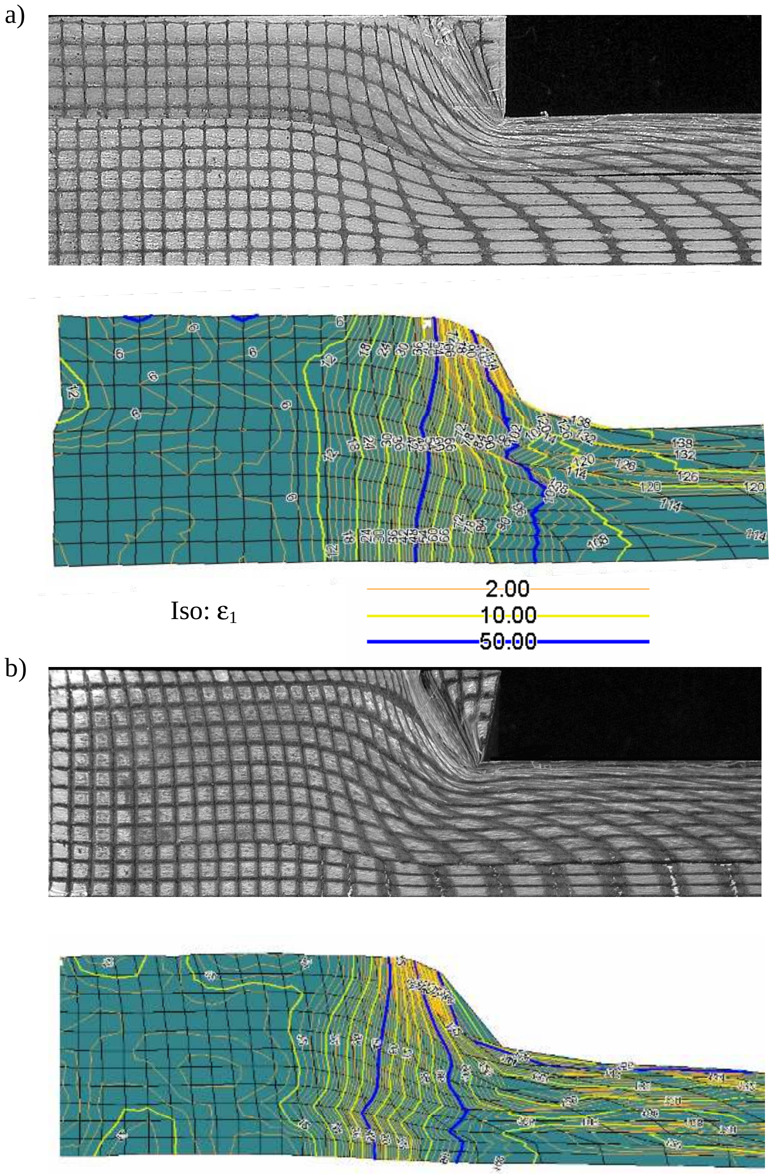


Fig. 7. Strain distribution in composite sample extruded through: a) flat die ($\alpha = 90^o$), $V_{core}/V_{composite} = 0.31$, major strain (isolines), b) convex die ($\alpha = 100^o$), $V_{core}/V_{composite} = 0.08$, major strain (isolines); values are given in %

Rys. 7. Rozkład odkształceń w próbce kompozytowej wyciskanej przez: a) matrycę płaską ($\alpha = 90^o$), $V_{rdz.}/V_{komp.} = 0,31$, na kierunku osiowym (izolinie), b) matrycę wypukłą ($\alpha = 100^o$), $V_{rdz.}/V_{komp.} = 0,08$ na kierunku osiowym ε_1 (izolinie); wartości podano w %

The observation of images obtained shows that the results obtained in certain areas are not precise. This is especially visible in the area of contact with the sample die. The program recognized the error grid, neglecting a significant part of the details. The calculations based on the displacement field may be subject to errors. ASAME code converts the movement as a homogeneous whole, without differentiation on the material properties, causing the results become less certain. In addition, the grid requires retouching to remove errors that may interfere with correct results in the numerical analysis.

Conclusions

The program used in the research enables to determine the distribution of deformation in layered composites during extrusion. Strain distributions determined during a numerical image analysis showed their differentiation depending on the die chosen. Nevertheless, the results indicate some limitations in the use of this program. In the case of a distorted grid in the area of the opening die interference it is impossible to improve the course of numerical analysis.

References

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ZASTOSOWANIE AUTOMATYCZNEJ ANALIZY OBRAZU DO OKREŚLENIA ROZKŁADU ODKSZTAŁCENIA PODCZAS WYCISKANIA

Streszczenie

W artykule zaprezentowano możliwość zastosowania numerycznej analizy obrazu do określenia rozkładu odkształcenia w kompozytach warstwowych w procesie wyciskania. Zastosowano komercyjny program ASAME (Automated Strain Analysis and Measurement Environment).

Opierając się na wynikach badań eksperymentalnych z procesu wyciskania kompozytów warstwowych z wykorzystaniem różnych matryc oraz z metody zniekształconej siatki, przedstawiono rozkład odkształcenia z użyciem programu ASAME.

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