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THE REGRESION ANALYSIS OF DEFORMING STATE BY PHYSICAL DISCRETIZATION METHOD OF BULK FORMING IN OPEN DIE

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ABSTRACT
In this paper, the regression analysis of all deforming parameters of hot bulk forming in open die is given. Deforming elements are gradual, material is Al-alloy. The physical discretization method is used. The method is based on groove discretization of blank. Using the chemical treatment of element after deformation, the deforming picture of radial section is obtained.
The multifactor orthogonal plan with repetition at central point is used in the regression analysis. The best results are obtained using function of second power. A model has free, linear, mutual and power elements. The results are graphically presented and compared with experimental ones.
Keywords: Bulk Forming, Deforming State, Strain, Regression Alalysis, Point by Point, MPD

1. INTRODUCTION
To be successful and economical in projecting any technological procedure of deformation, it is important to know deformation parameters. The accepted bases of theoretical postulates and methods for their deformation are not in accordance in concrete deformation conditions, so, that in most cases there is the need of experimental parameter determination and their modelling. To meet this need, a Physical Discretization Method (PDM) has been developed [1,2].

2. PHISICAL DISCRETIZATION METHOD (PDM)
The base for determining deformation parameters in each point of treated piece volume is to know the displacement points. The determination of the bulk point displacement has been done by many authors in different ways, depending on the kind of deformation proces, stress state and other possibilities [3,4]. To determine displacements at PDM, segment preparation pieces of groove plates are used. Thus, preparation pieces are physically discreted, and the method is called after it. At such preparation pieces, plate grooves in meridial cross-section practically form a network of finite elements in physical sense, whose elements are determined by four nodes and three lines, so that it is possible to determine displacementsof node points both in radial and axial directions. Deformation state parameters are determined on the base of the known deformation theory [1,2].

3. EXPERIMENTAL INVESTIGATIONS

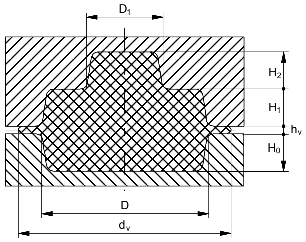


Figure 1. Treated piece

As an object of research, a finaly of step axi-symmetrical pieces is adopted (Figure 1.) [1,2].
As an experimental material, aluminium alloy AlMgSi0,5 is used, at temperature of hot treatment t=440 [°C]. Geometrical parameters of the treated piece are adopted (Figure 1.) [5]:
- Basic diameter: D=40 [mm];
- Wreath diameter: d_v=50 [mm];
- Wreath height: h_v= 1 [mm];

3.1. Experiment plan

To make as better plan of the experiment as possible, detailed preliminary investigations were done, based on which an experiment plan was chosen as well as input factors, on the base of which output quantities will be followed.

A complete multi-factor orthogonal plan with factor wariation on two levels is adopted as an experiment plan [6,7]. A repetition system in the central plan point n_0=4 times is adopted. A number of experimental points for the number of k factors with number of repetition in the central points n_0 is:

$$N=2^k+n_0. \tag{1}$$

Before measuring output points, the boundaries of variation intervals are adopted so that at an orthogonal plan, a condition must be satisfied:

$$X_{0i}^2 = X_{gi} \cdot X_{di},\ i = 1,2,...,k . \tag{2}$$

The levels of that factor are coded through transformation equation:

$$x_i = \frac{X_i - X_{0i}}{w_i},\ i = 1,2,...,k , \tag{3}$$

where:

X_i - natural value of i factor,

X_{0i} - value of i factor on the basic level, and

w_i - variation factor interval X_i, whose numerical value equals the difference of upper and basic levels, basic and lower levels respectively.

3.2. Input factors

As input independent variables (factors), geometrical factors of die are adopted (Figure 1.), as well as of a preparation piece, working temperature, friction factor and yield stress. Input factor taken into consideration are:

- *Geometrical die factors*, which for the generality of results, ere expressed by non-dimensional relations of characteristic dimensions of the die and basic D diameter:

$$X_1 = \frac{H_1}{D},\quad X_2 = \frac{H_2}{D},\quad X_3 = \frac{D_1}{D}, \tag{4}$$

- *Geometrey factor of a preparation piece* is a relation of an initial diameter of a preparation piece and basic diameter:

$$X_4 = \frac{d_0}{D}, \tag{5}$$

where, d_0 - preparation piece diameter.

Taking into consideration condition (2), values of basic levels and variation intervals of single input factors are adopted, and their values on all the variation levels are given in Table 1.

Table 1. Input factor experimental plan variation levels

Input factors	Lower level	Basic level	Upper level
X_1	0.175	0.250	0.357
X_2	0.150	0.250	0.417
X_3	0.417	0.500	0.600
X_4	0.757	0.839	0.908

4. REGRESSION ANALYSIS

Regression analysis is carried out to obtain highly correlated mathematical models of strain deformation quantities of deformation process in open dies of an investigated family of step-like axi-symetrical elements, functioning as input factors. To carry out the regression analysis correctly, it is necessary to make a proper choice of a simple mathematical model. A lightly correlative mathematical model should satisfy two conditions:

1. to approximate output quantities along the cross-section of the working piece, i. e. in radial and axial directions, and

2. to approximate well output quantities in all the points of hyper-space of input factors within adopted limits.

The first out of the two listed conditions is very difficult to satisfy as it is practically impossible co choose a model to describe a very heterogeneous behavior of deformation parameters in the meridial working-piece plane. Another condition may be satisfied, due to the character of deformation parameter change, within the adopted input factor interval variation limits. The reasons mentioned show that it is not possible to adopt a unique mathematical model to describe all the changes of deformation parameters in hyper-space of the experiment plan matrix input factors in single points of meridial cross-section, thus the regression analysis will be done according to the "*Point by Point*" principle.

As the points of cross-section in which regression analysis is performed, points i=36 of cross-sections along horizontal, from the symmetry axis to the end of the working piece contour are adopted, as defined in Figure 2., this making a total of 756 cross-section points. The question is in a relatively great number of points this not being the problem for the use of computer.

To carry out the regression analisis, programmes were made in MATLAB v. 7.0.0., possesing statistical tools for *Nonlinear Estimation*, by using Gauss-Newton's method of the least squares. The input data for regression analysis are the matrix, the value of the input factors in points of experimental plan, vectors of the column of output values of an observed deformation parameter for all the combination values of input factors and single points of the working-piece cross-section, as well as the supposed of the model parameters.

As for the matematical model several different models were applied in this paper, but most of them gave unsatisfactory results[5,6]. The results with high correlation coefficient are obtained using so-colled model with square function response, consisting of linear members, interaction factor members and aquare members. Such a model for four input factors, being the case at deformation parameter modelling, has the form of:

$$\begin{aligned} y = {} & \beta_1 + \beta_2 x_1 + \beta_3 x_2 + \beta_4 x_3 + \beta_5 x_4 + \\ & + \beta_6 x_1 x_2 + \beta_7 x_1 x_3 + \beta_8 x_1 x_4 + \beta_9 x_2 x_3 + \beta_{10} x_2 x_4 + \beta_{11} x_3 x_4 + \\ & + \beta_{12} x_1^2 + \beta_{13} x_2^2 + \beta_{14} x_3^2 + \beta_{15} x_4^2. \end{aligned} \quad (7.14)$$

As there are five deformation parameters (three normal strains, shear strain and effective strain) and it is necessary for each to determine model parameters ($\beta_1,...,\beta_{15}$) in 756 cross-section points of meridial plane, we obtain datatoque which, due to abundance, is not possible to be shown in paper. Based on the obtained datoteque model parameters, it is possible to obtain model values of all deformed parameters along working-piece cross-section, which on 3D diagrams resemble very much the diagrams obtained by PDM, so the example is given for 3D diagrmas effective logarithm strain (Figure 3.) in one of the central plan points.

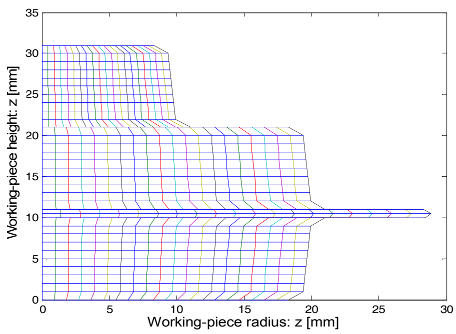


Figure 2. Distribution of observed points according to working-piece cross-section

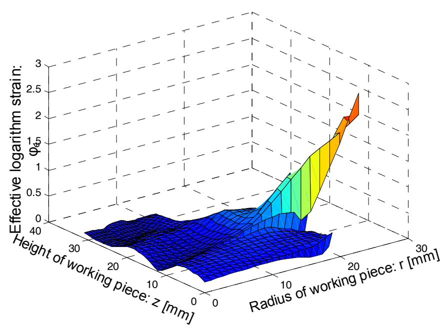
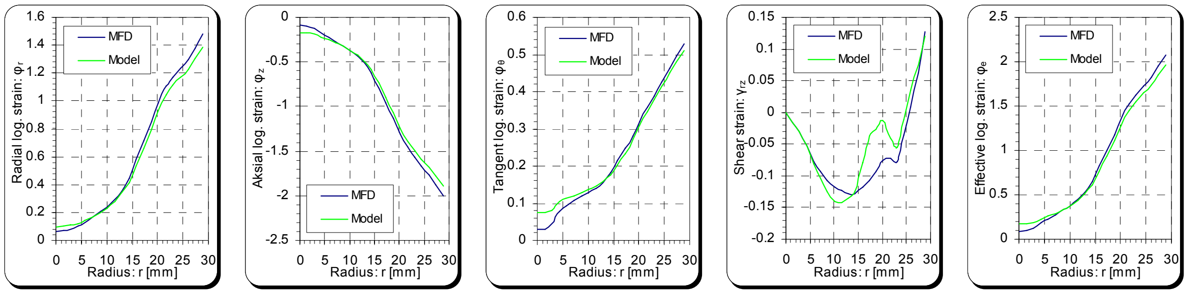


Figure 3. Effective logarithm strain: φ_e

5. STRAIN COMPARISON

3D diagrams of a deformation change are good for visual insight into character of quality changes, but they are not suitable for a quantitative result analysis. To that scope, more suitable are 2D diagrams in single characteristic cross-section of meridial working-piece plane. For example, in the paper will be given a comparison of deformation quantities obtained by PDM and regression analysis in cross-section corresponding to the parting plane of a working piece, in the central plan point (Figure 4.).



a) b) c) d) e)

Figure 4. Comparing deformation parameters obtained by PDM and regression analisis i cross-section of wreath plane of working-piece: a) Radial logarithm strain; b) Aksial logarithm strain; c) Tangent logarithm strain; d) Shear strain; e) Effective logarithm strain

By analyzing the diagrams, it may be concluded that there are some diferences in deformation parameters values.

6. CONCLUSION

The regression analisys of deformation state parameters obtained by phisical discretization method, according to the "*Point by Point*" principle is given in this paper. The model parameters with square response function are obtained and the results are compared.

It may be noticed that there are some deviations in values. These deviations are due to the repetition in the central plan point at which the obtained results differ mutually, for the same deformation conditions, this representing result dispersion due to a unique procedure caused by deformation anizothropy and process non-homogeneity. As four times greater repetition in the central plan point was made in the axperiment plan, the obtained values collide by modelling with arithmetic mean values obtained by PDM.

Due to result dispersion, there is a need of a statistical approach to data processing. It means that for the same conditions, deformation process is carried out on a definite number of samples. By a statistical preocessing, using one of the famous methods, it would be possible to reach the parameter values of the greates probability, thus contributing to increasing modelling accuracy.

The method of phisicaly discretization and the shown regression analisys are possible to be applied on other families of the part of the same or similar shape with geometrical parameter variation, taken into consideration by a suitable experiment planning, thus solvingpractical industrial problems.

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