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CAPTURING OF WORKPIECE CHANGE SHAPE OF DEFORMATION IN OPEN DIES

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ABSTRACT
In this paper is described developed information measuring system and other equipment for recording workingpiece free contours and deformation force during process of bulk metal forming in open die. Measuring is done and given digital data processed in program which is written in MATLAB. For example, obtained curves of free workingpiece contour are given in the paper.
Keywords: Measuring System, Sensor, Contour, Bulk Metal Forming

1. INTRODUCTION
Bulk metal forming is for its complexity of a special importance within the field of metal working, this, above all, being conditioned by a fact that by such metal working, two criteria appear difficult to reconcile: solution correctness and simplicity. Though great efforts have been made on the part of many research workers, it may be said that there is neither a definitely adopted method nor a definite solution, not even of the most simple procedures in bulk metal working. [1]
This makes the field of investigating geometrical and mechanical parameters at die forging very actual and insufficiently researched one. The very complexity of the problems has made it necessary for the following interrelated approaches to be used: theoretical, experimental and numerical ones.
An axisymmetrical element free contour recording by the information measuring system has been done, and also computer modelling at bulk metal forging in open die. [2]

2. EXPERIMENT DEFINITION
Both geometrical and technological parameters were defined at the beginning of experimental procedures. A family of the degree axisymmetrical elements of two height degrees on one side and one height degree of the other side of a graded plane was adopted (Figure 1.) [3]. Lead was used as an experimental material.
A complete more factors first order orthogonal plan with factor varying at two levels is accepted for the experiment plan [4]. Input factor level variations are given in Table 1. where is basic die diameter: D=40 [mm].
The process factor is a reduced degree of deformation expressed as a relation between an instantaneous tool stroke and its total stroke, expressed by the formula

$$X_5 = \varepsilon^* = \frac{h_0 - h}{h_0 - h_1}, \qquad (1)$$

where,
h - current height ,
$h_1=H_0+H_1+h_v$ - final height,
h_v- flash height (Figure1).
Such a defined reduced degree of deformation ε* may take the values ranging only from interval: $\varepsilon^* \in [0,1]$. A relation between an relative degree of deformation and reduced degree of deformation ε* is expressed by:

$$\varepsilon = \varepsilon^* \left(1 - \frac{h_1}{h_0} \right). \quad (2)$$

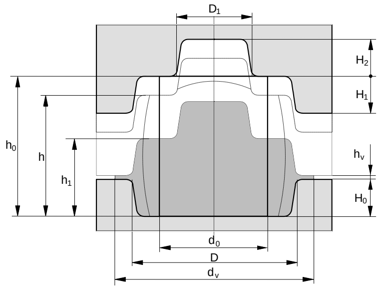

Figure 1. Workingpiece

Table 1. Input factor level variations

Input factors	Lover level	Basic level	Upper level
$X_1=H_2/D$	0.2	0.245	0.3
$X_2=H_1/D$	0.15	0.23	0.35
$X_3=D_1/D$	0.4	0.49	0.6
$X_4=d_0/D$	0.75	0.82	0.9

3. INFORMATION MEASURING SYSTEM
Measuring at the above mentioned the experimental procedures were done by a precise analog-digital measuring equipment connected with an information measuring system, consisting of sensor unit, measuring bridge, transitional unit, A/D card and computer, illustrated by a block diagram in Figure 2. [1].
Two inductance sensors placed on an universal grinding machine utilizing the possibility of a precise moving of the working table were used to make record of the workingpiece contours (Figure 3.).
On the movable grinding machine table (1) tightening head is mounted (3) with the grading device (2) within whose mouths a workingpiece is tightened (8), its axis being horizontal to the direction of the table moving.
A stroke inductance sensor (5) of HBM make, type W40K and measuring range ±40 [mm] is placed in workingpiece axial direction and makes measurements of the working table shifting and the value of y workingpiece contour coordinate.
Another stroke inductance sensor (6) is of HBM make, type W20K and measurement range of ±20 [mm], and is placed at the angle of β=10° in relation to the workingpiece radial direction. The sensor's body is fixed to a non-movable part of the grinding machine, whereas the movable armature is attached to a measurement needle specially made for that purpose (7) (Figure 4.).

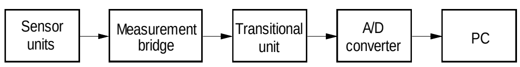

Figure 2. Information measurement system

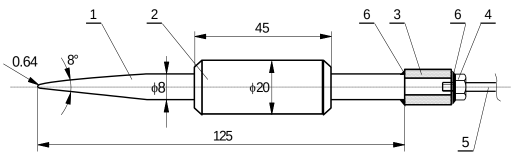

Figure 4. Measuring needle

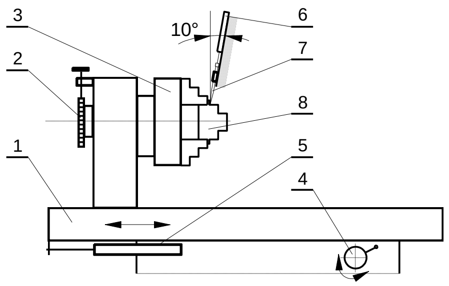

Figure 3. Device for registering recording workingpiece contours

Measuring needle (1) is made of a fine road machined out of the fast-cut steel and it slides by an action of its own weight within a tolerant container (2). By moving the movable part of the grinding machine table (1) it slides over an surface of the workingpiece (Figure 3.) and makes the measuring

inductance sensor armature move (5), this representing x coordinate of the workingpiece armature in the acute triangle system.
A signal from the sensor was amplified in the digital six-channel HBM measuring bridge, type KWS.637.D4. An output analog signal from the bridge was converted by AD/DA card of DT 2801-A type into a digital one and stored in the PC/AT/486 computer with the installed system for data activating GLOBAL-LAB.

4. EXPERIMENT CONDUCTION

The open die forging was conducted on a press and the process was discretized in the degree of deformation, namely pressing was done by stopping the process after a stroke step Δz. In an initial process stage, when the billet contour distortion is still insignificant, this step was higher Δz=5-6 [mm] for the higher samples (diameter d_0=30.3 [mm]) and Δz=2-3 [mm] for less high samples (diameter d_0=36.2 [mm]). In the final forging stage, when material fills the whole die engraving, and the material flows out into the flash, the stroke step is minimum Δz=0.5 [mm].
After each stop, the workingpiece was taken out of pressing tool and carried to the contour recording device (Figure 3.) being put into the tightening head (3). Testing of the working piece tightening co-axially was done by the indicator.
After the billet's tightening and bringing the movable table (1) to its initial position, the measuring needle (7) is going into contact with the workingpiece (8) and A/D measuring system is on. Moving the handle (4), the movable table is shifted to the left, the measuring needle follows the workingpiece contour starting the movable armature of the inductance sensor (5) (Figure 4.), registering a change.
To avoid the influences on the measurement correctness due to tightening non-axially and irregularities of the workingpiece deformation, contour is recorded along six radial directions by repeating the previously described measurement procedure after turning the tightening head for angle $\Delta\varphi$=60°, by graduated device (2).
A/D measuring equipment is switched of after taking 6 records of a contour in one tightening, and the signal obtained is stored in the computer hard disk.
The workingpiece is placed in the forging tool again in the same way as before being taken out of the tool, and a new stroke step Δz is realized on the press. The procedure described is repeated as long as a final shape of the workingpiece is reached.
An example of the signal from the inductance sensor in radial (6) and axial (5) direction of the device for contour recording (Figure 3.) is given in Figure 5. and Figure 6.

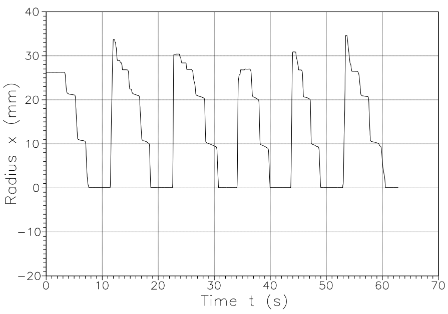

Figure 5. Signal from the radial sensor

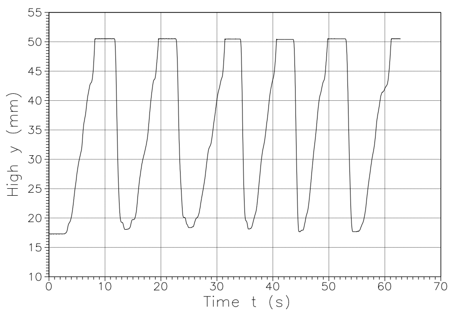

Figure 6. Signal from the axial sensor

5. RESULT MODELING

At modeling contour, only the free part of the contour is modeled, namely the part which is not in contact with die, as the part being in contact with die is defined geometrically based on the known die geometry. [5,6]

5.1. Side Contour Modeling

When all the values of the abscissa of all the points for all the reduced degree of deformation observed are determined, the diagrams of the radius change expressed by the relation 2x/D are obtained.

Model parameters are obtained by regression analysis, whereas their significance and the model adequacy of all the side contour points, for values of the reduced degree of deformation, are estimated by dispersion analysis.

5.2. Head Contour Modeling

Head contour modeling implies height change modeling expressed by y/D relation in the function of the input factors accepted by the experiment plan. This case is analogous to the side contour modeling except for the fact that side contour height is determined on the base of the volume constancy conditions, whereas 2x/D value interval of head contour is defined by the upper die geometry.

In all the accepted points of the upper head contour, for the values of the reduced degree of deformation in which the contours were recorded, y/D relation is determined..

6. OBTAINED RESULTS

Based on the obtained models of the parameter change defining the position of the contour points, it is possible to generate a workingpiece contour in any point for any reduced degree of deformation. This is achieved by interpolation of the values obtained on the discrete series of points ε^* in which the models of side contour point radius change are determined. In this way, model contour for the value of a reduced degree of deformation $\varepsilon^*=0.35$ is determined on the basic level of an input factor. The model contour obtained, along with a corresponding experimental contour is presented in Figure 7.

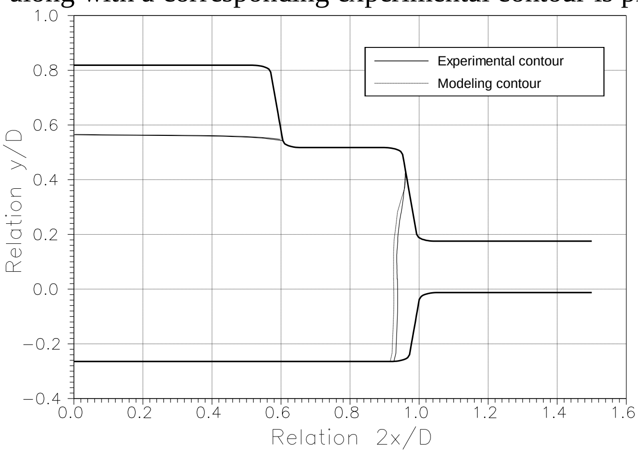

Figure 7. Experimental and model contours for basic level of input factors and $\varepsilon^*=0.35$

7. CONCLUSIONS

A good correspondence of the experimental and model contours being substantially analogous ones, is evident in Figure 7.

A complete modeling is done on the computer by using an advanced software written in MATLAB The model procedure used this research having been applied to the researched class of axisymmetric elements may also be applied to other cases of axisymetric open die forging.

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