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Structural Modifications in Materials Volumetric Formed with Floating Contact Surface

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ABSTRACT

In this paper there are presented results of researches concerning the identification of macro and micro structural modifications of the material volumetric formed in the conditions of a tool/workpiece contact surface much reduced relative to the classical uniaxial forming. The influence of the superior die motion relative to the workpiece, onto material flow and hardness curves distribution was studied. In the case of the volumetric forming with floating contact surface, the deformation stress and the process itself are concentrated, at a given moment, into a small volume if compared to the entire processed workpiece. The superior die realizes an incremental deformation of the workpiece's material. The deformation zone is mobile in space and time, covering the whole workpiece's frontal surface.

KEYWORDS: incremental forming, floating contact surface, hardness curves, micro and macro structural modifications.

1. Introduction

The volumetric forming with floating contact surface distinguishes from the classical uniaxial forming through the reduced processing force required, due to the diminished momentary contact area between the superior die and the workpiece, contact nature between them being also different (Fig. 1). Hence follow important advantages concerning the equipment price, tools reliability, the noise in the working space. Process dynamics enables a better participation to workpiece's crystals deformation, which further allows a maximum deformation degree increasing. The pieces are obtained after a single deformation stage, without intermediary heat treatments for reducing the peening degree.

2. The Process' Kinematics

As a result of researches done at the ITCM Research Center from "Dunărea de Jos" University of Galați, it was established that the forming process kinematics can be studied by using the equations of the trajectory described by the oscillatory die points.

The oscillatory bearing which supports the superior die 3 (Fig. 2) describes a plane trajectory, with its axis passing through O_1 point, due to the rotation motion of the bushes with eccentric holes, 1 and 2.

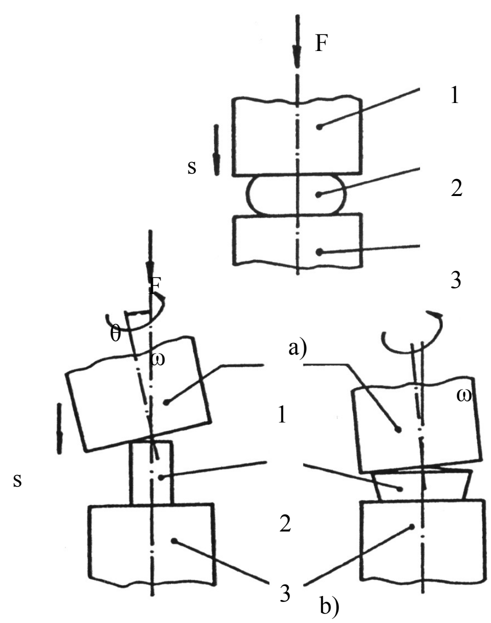

Fig. 1. *Working principle: a – volumetric uniaxial forming; b – floating contact surface forming.*

The analysis of the orbital forming process reveals the fact that tool / workpiece contact point trajectory, presented in the dedicated literature under four types of curves (Fig. 3) is, in fact, a closed cycloid curve with a variable (but always finite) number of lobes, depending on the ratio ω_2 / ω_1 (according to the data from Table 1). The trajectory does not cover workpiece's entire surface, this drawback being compensated for by the geometrical configuration of the superior die active zone.

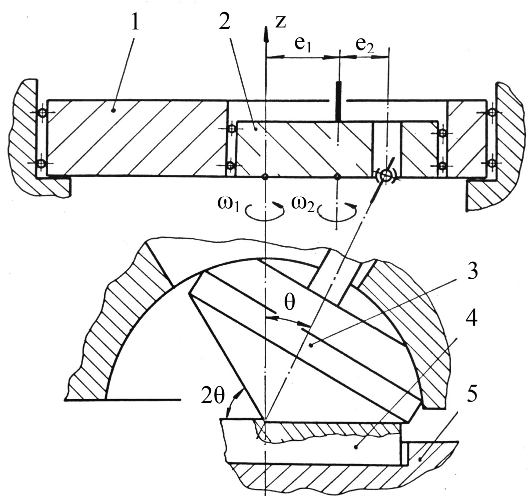

Fig. 2. *The constructive principle of superior die driving mechanism*

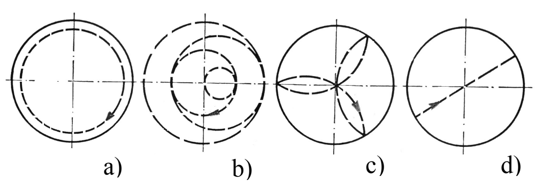

Fig. 3. *Types of trajectories for the tool / workpiece contact point:*
a – orbital; b – spiral; c – planetary; d – straight

Table 1

$\omega_2/\omega_1 = p/q$	1	1/4	-1/2	-1
N = ǀp-qǀ	0	3	3	2
Trajectory type (Fig. 3)	a	b	c	d

3. The Experimental Frame

The forming stress and the deformation itself are located, at a given moment during the orbital forming process, into a small volume, if the entire processed workpiece is referred to.

As a consequence of the facts upper exposed, it follows that the trajectory of the contact point between the superior die and the workpiece is a closed, cyclic curve, with a finite number of lobs. Their width depends on the relation between the kinematical parameters which define the forming process. We assumed the existence of a correlation between the trajectory type and the material state after the floating contact surface forming. Cylindrical specimens made from OLC 15, having the dimensions shown in Fig. 4, were used. The forming process was realized on a polish press PXW-100, which develops a maximum forming force of 160 kN. Four batches of workpieces were processed, in each case the press being set to follow one of the four trajectories (Fig. 3).

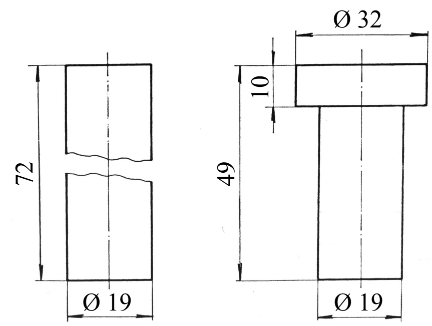

Fig. 4. *Piece dimensions before and after the floating contact surface forming process*

The pieces from each batch were longitudinally sectioned, into an axial plane, finished by grinding (with cooling) and polished. The Vickers micro hardness was measured by using a PMT-3 device, into 15 zones of the deformed material. Two measurements in neighbored points were made in each zone, the final value of the local micro hardness being considered their average.

The macroscopic metal structure analysis was carried out after attacking the surface with IATEVICI reactive (30 cm^3 HCl, 12 cm^3 H_2SO_4, 50 cm^3 distilled water, 30 minutes of attack time interval, at a temperature of 70 – 80 °C).

Photo pictures were taken for the microscopic metal structure analysis, in all the 15 zones where micro hardness measurements were done, after the samples were attacked with NITAL 3% reactive. The study was performed using of a NEOPHOT microscope (100 times magnifying).

4. Structural Modifications and Hardness Analysis

The workpiece material initial structure, ferito-perlitic type, was disposed in strips, due to its elaboration by rolling. This fact facilitated to draw conclusions concerning material flowing directions, when it was deformed in different zones.

The deformations were also inferior limited by a conic surface (Fig. 5), having at its peak an angle of

132° (a – batch, Fig. 3), 141° (b – batch), 130° (c – batch) and 123° (d – batch). At the cone base, which is coincident to the diameter step zone, a layer of strongly peened material is observed at the pieces from batches a, b and c but it is not present at the pieces of d batch. The existence of this layer is determined by the shearing stresses, which appear in the transition zone, due to the eccentric action of the oscillatory die, until the worked material fills the inferior die. This layer seems to be absent for the pieces from d – batch because, in this case, the sectioning plane did not coincide with the one where die’s axis oscillated.

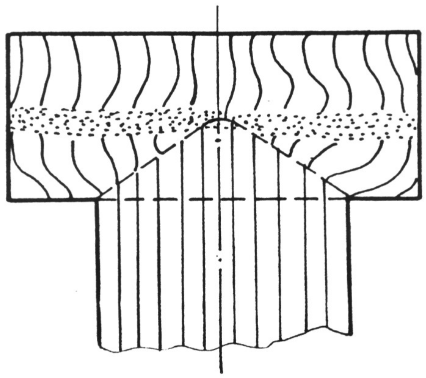

Fig. 5. *Scheme of piece’s material layers affected by deformations*

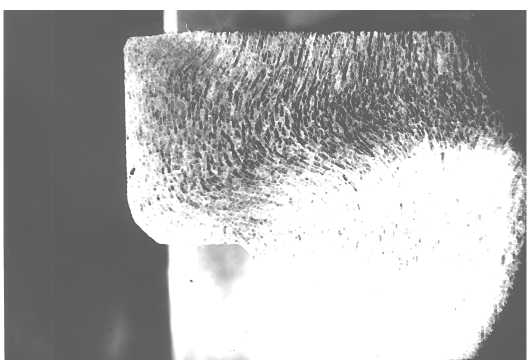

Fig. 6. *Macroscopic structure of the pieces processed by floating contact surface, with orbital trajectory (Fig. 3 – a)*

The macroscopic analysis (Fig. 6, 7, 8 and 9) shows a material radial flow, stronger in the workpiece / superior die contact zone, because of the reduced friction between the two elements. Into the maximum deformation zones, situated in the stem head median plane, the disappearing or the breaking of the initial material fibers can be observed; this shows a structural homogenization, more obvious to the pieces from b and c batches.

It may be considered that, for the pieces from c batch, at the same deformation degree concerning the entire piece scale, a greater part of the material was involved, with small local elementary deformations, which summed between them.

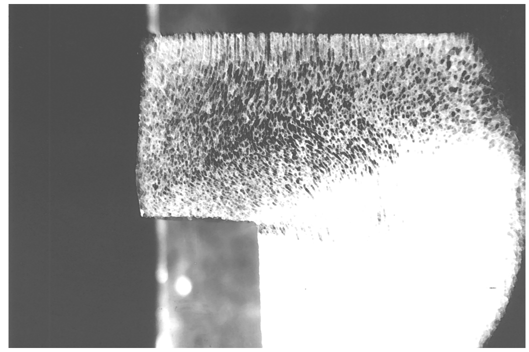

Fig. 7. *Macroscopic structure of the pieces processed by floating contact surface, with spiral trajectory (Fig. 3 – b)*

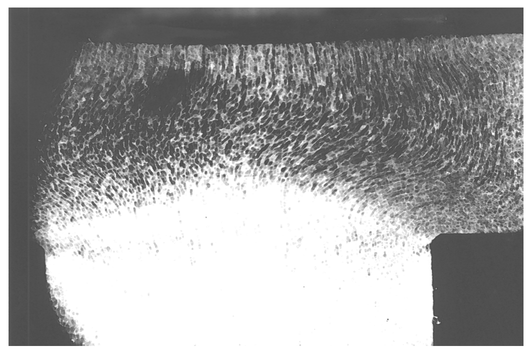

Fig. 8. *Macroscopic structure of the pieces processed by floating contact surface, with planetary trajectory (Fig. 3 – c)*

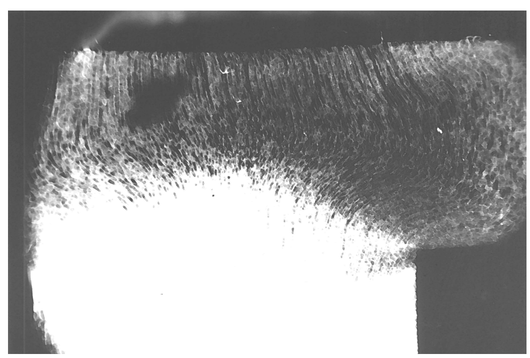

Fig. 9. *Macroscopic structure of the pieces processed by floating contact surface, with straight trajectory (Fig. 3 – d)*

In this case, a greater availability concerning the maximum deformation degree that is accessible for the entire piece may be accepted. Micro hardness measurements, presented under diagram form in Fig. 10, show the homogenization zone in median plane, especially for the pieces from batch c. The micro hardness variation in radial direction, due to the intersection between the measuring plane with zones with different plastic deformations, caused by the finite number of lobs presented by the die / workpiece contact point trajectory, was also noticed.

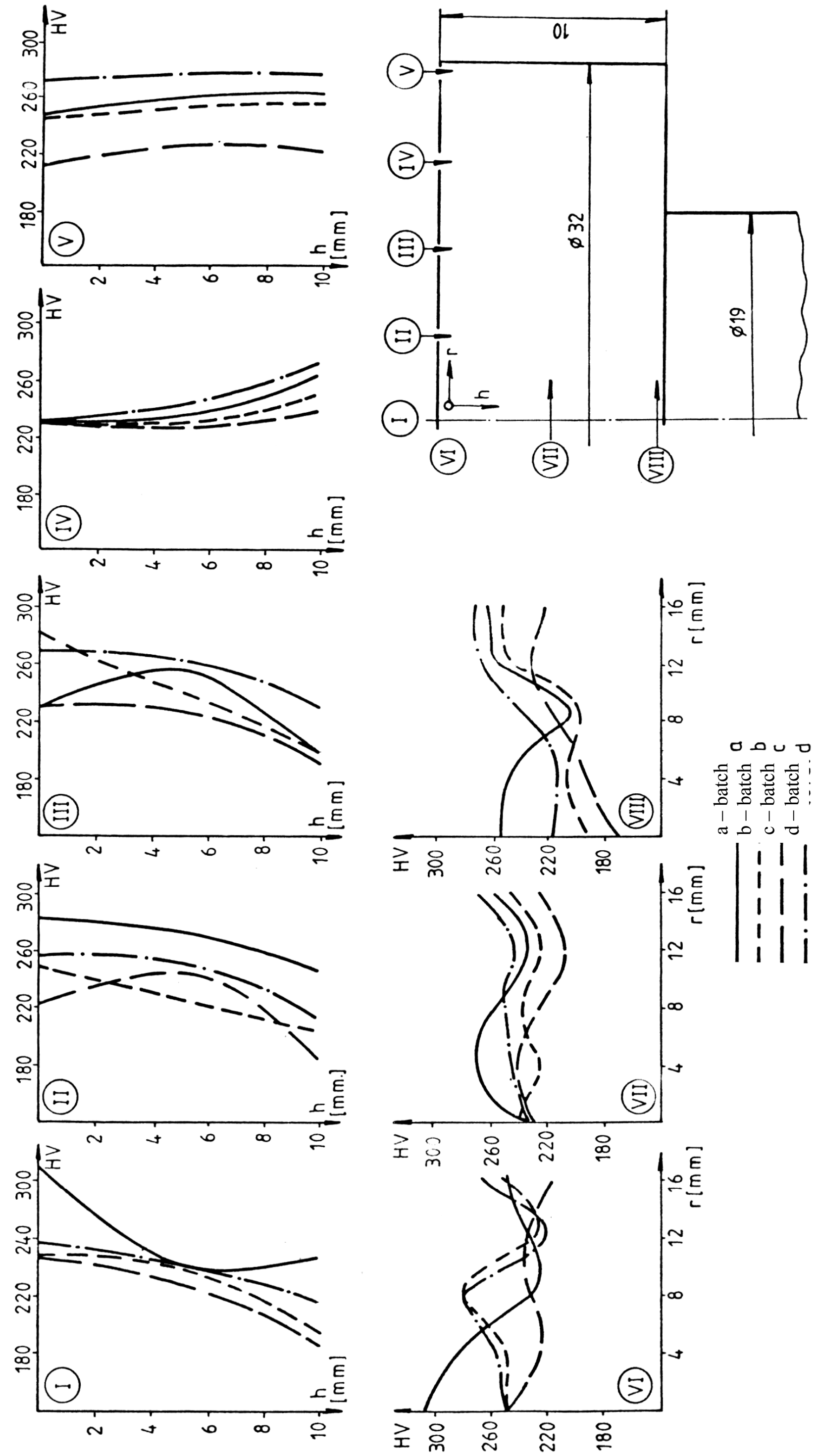

Fig. 10. *Micro hardness variation of the pieces obtained by floating contact surface forming*

In conclusion, we may appreciate that the orbital cold formed pieces structural homogenization is increasing when the number of material elementary elements which are involved in the deformation process is greater, meaning that the used trajectory has more lobs. In this case, because of the participation to the deformation process of an obvious greater number of elementary volumes, it is possible to reach, at entire piece's scale, increased deformation degrees without intermediary heat treatments.

5. Conclusions

As results of the experiments concerning the workability by volumetric cold forming, with floating contact surface, the following conclusions arise:

- Processed workpieces macroscopic analysis highlights a material radial flow, more intense into the workpiece / oscillatory die contact point zone, explained by the reduced friction between the two elements;
- The zones having a maximum deformation, placed in the median plane of the processed workpiece, show a more significant structural homogenization when the oscillatory die trajectory is spiral or planetary;
- The hardness variation in a radial plane indicates a maximum value at about (0.5...0.6)R, which suggests the existence of an extreme value of the forming pressure in that zone.

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