

Consideration on stainless steel plate plastic deformed by pressured nitrogen blasting combined with impact substances

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Abstract: - The paper presents a plastic deformation method for thin plates made of stainless steel, plastic deformed by pressured nitrogen blasting combined with impact substances. There are presented experimental results for comparative values of deformation velocities obtained by different initial pressured nitrogen blasting, respectively by pressured nitrogen blasting combined with several quantities of water impact substances.

Key-Words: - pressured nitrogen blasting, plastic deformation, stainless steel thin plates

1 Introduction

In the present stage of technological development, a new method of metal sheet plastic deformation process by gazes blasting shock waves, combined with impact substances, has come to complete, but not to replace, the diversity of high velocity deformation procedures: explosive substances, exploding wires in gasses, electro-hydraulic or magneto-hydraulic impulses, Dynapac hammer [1, 2, 3].

At first, this new method was developed to make parts for medium and low voltage special electric motors. Some types of tight lid for bearings made from Carbon Steel plates were obtained. Due to the elastic proprieties of the circular edge of the part obtained using this deformation method, this tight lid is used in the same time as Seger safety ring for the bearings. In the last time, this new plastic deformation method was improved to obtain spherical segment shaped plates made from porous materials, specially designed to protect the molecular sieves in the air filtration and drying modules which are components of pressure swing adsorption oxygen generator systems [5,6,7].

In the main, the new plastic deformation process by pressured gazes blasting and impact substances, is based on the physical phenomenon of compressed gas discharged from a pressured vessel. A special convergent-divergent nozzle carries out 350÷660m/s discharge velocity. The pressured gaze's shock wave combines with the impact substances, which are accelerated to the circular plate embedded in the contour of an open die. A plastically deformed part is obtained *with no* punch die action [5,8].

In order to estimate the performance of this new plastic deformation process, an experimental research method was designed for simultaneous determination of the maximum transverse deformation, and of the deformation velocity of the thin plate deformed by gazes blasting shocks combined with different quantities of impact substances (quartz; water).

2 Experimental installation

In the main, the experimental installation for plastic deformation by gazes blasting and impact particles (Figure 1) is consisting in a compressed gaze's supply; a compressed gaze's stockage vessel with fast discharge device; impact particles dozing system; a modular die device with adjustable hydraulic action; a modular conical convergent-divergent nozzle. The experimental installation for plastic deformation is connected with a complex data acquisition and processing system composed of displacement transducer (W50 Hottinger); conditioning amplifier (2626 Bruel & Kjaer); measuring amplifier (KM 2314 IEMI); acquisition interface (PCL 718 Advantech) and computer [5,8].

In order to determine the maximum transverse displacement/deformation, the permanent transverse displacement/deformation respectively, the mobile part of 4 displacement transducers were mounted in the control node 1N, 11N and 21N of the circular plate part (Figure 2).

The deformation velocity was analytically calculated by means of the acquisition and processing data system for each value of initial representative pressure p_0 inlet the stockage vessel ($p_0 = 7,5; 8,0; 8,5; 9,0; 9,5; 10\text{bar}$).

For each parameter combinations between deformable circular plate / initial pressure p_0 in the stockage vessel / quantity of impact particles, at the acquisition start command, it was used a triggering signal, coming from the control coil of the electropneumatic valve (due to the controlled supersonic gazes discharge is obtained) [3; 4].

The maximum transverse deformation velocity in each control node was analytically calculated and graphically represented by means of the data acquisition and processing system, for each initial representative pressure p_0 for which the porous material has significant deformations.

Spherical segment shaped plates with circular punches achieved respecting the technologically

parameter described in this paper, are made for a filtration equipment to obtain concentrated fruit juice.

For the experiments described in this paper there were used circular discs made on AISI 316 stainless steel (1 mm thickness; $D_0 = 130$ mm; $\Phi 0,8$ punch; 40 punches/cm²). According to the filtration stage where is necessary to be mounted, the spherical segment shaped plates plastic deformed by this method, must have the final dimensions $D_p = 110$ mm, $w_{pl,max} = 9...15$ mm.

In order to avoid energy losses due to the round punches in the material, each circular part is covered on both sides with very thin plastic material (PVC).

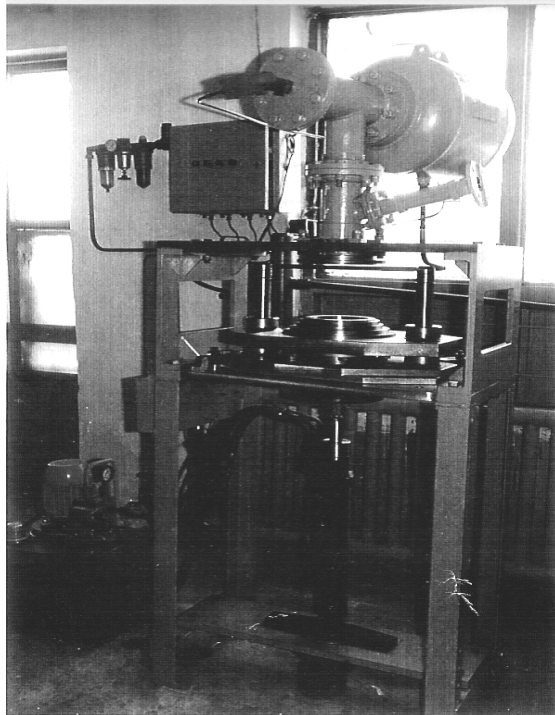


Fig. 1. Experimental installation for plastic deformation by gazes blasting and impact substances

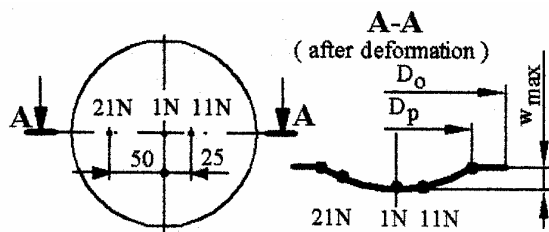


Fig. 2. Spherical segment plate dimensions after plastic deformation

3. Experimental results and discussions

In order to compare the experimental results, an analytical method based on the finite element method (FEM) was used. FEM takes into account the following hypothesis: the large specific deformations must consider the isotropic hardening of the material; the deformable thin plate is considered as PLANE 2D axial-symmetrical elements, with GAP contact element with no friction. In the dynamic nonlinear analysis, for a quick convergence, the Newton-Raphson method was used and, as an integration method, the NEWMARK method with RAYLEIGH amortization factor for maximum 0,5s time range, divided in an increment $DT_{min} = 1E-5$ and $DT_{max} = 5E-3$ [4].

The synthetic comparison between the maximum transverse deformation velocity values, on the plastically deformed stainless steel part obtained only by means of nitrogen blasting shock wave produced by initial pressure $p_0 = 10$ bar, experimentally determined with Hottinger transducers placed on three nodes of the round disc, and the analytically obtained values with FEM, is presented in Table 1.

Table 1

Maximum transverse deformation velocities in control nodes of the disc, [m/s] (control radius, [mm])				
1N (0)	11N (25)	21N (50)	31N (55)	41N (60)
Experimental Method (transducers)				
1,7	1,5	1,3	-	-
Analytical Method (FEM)				
1,62	1,41	1,22	1,16	1,02

In Table 1 can be observed that the values obtained using FEM are 6-8% smaller then the values determined by experimental method.

The synthetic comparison between the maximum transverse velocity values, on the plastic deformed disc, obtained using only nitrogen blasting shock wave produced by the consecutive increasing of the initial pressure p_0 from 7,5bar to 10bar, determined with three transducers placed on three control nodes of the disc, respectively analytically FEM values, is presented in Table 2. It can be observed that the values obtained using FEM are 5-10 % smaller then the values determined by experimental method.

The experimental data using nitrogen blasting with initial stocking pressure p_0 , to determine the maxi-mum elastic deformation $w_{el,max}$ and the transverse plastic deformation in control nodes of the disc are presented in table 3.

Table 2

Initial pressure inlet stockage vessel, [bar]					
7,5	8,0	8,5	9,0	9,5	10,0
Maximum deformation velocity in the center of the disc, [m/s] Experimental Method (transducers)					
1,12	1,25	1,37	1,49	1,61	1,74
Maximum deformation velocity in the center of the disc, [m/s] Analytical Method (FEM)					
1,43	1,54	1,65	1,76	1,85	1,97

Table 3

p_0 [bar]	$w_{el,max}$ [mm]	Transverse plastic deformation in control nodes of the disc, (control radius, [mm])		
		1N (0)	11N (25)	21N (50)
7,5	8,3	6,2	5,8	5,5
8	9,2	7,3	6,8	6,4
8,5	10,1	8,1	7,7	7,2
9	10,8	8,9	8,6	8,2
9,5	11,7	9,8	9,5	9,2
10	12,2	10,2	9,9	9,5

In figure 3 is presented the FEM for maximum elastic deformation $w_{el,max}$ and for the transverse plastic deformation in control nodes of the disc, using initial nitrogen pressure 9,5 bar.

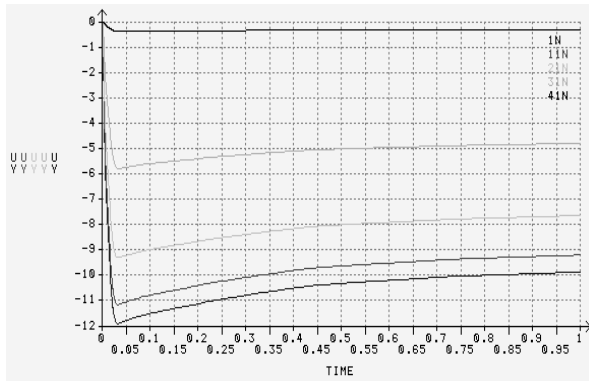


Fig. 3. FEM values for plastic deformation using initial nitrogen pressure 9,5 bar

The representative data for transverse plastic deformation in 1N, 11N and 21N control nodes of the disc, obtained using initial nitrogen pressure 9,5 bar are presented in figure 4.

In order to increase the depth of the plastic deformed part, it was necessary to increase the kinetically energy of the shock wave by introducing impact substance in combination with the nitrogen blasting shock wave.

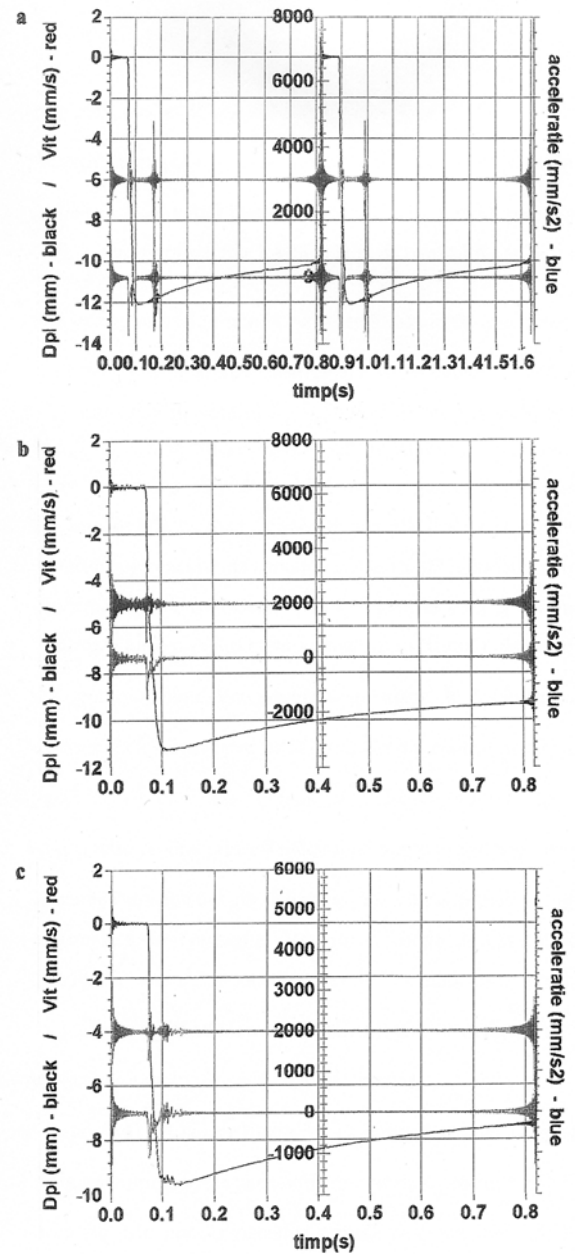


Fig. 4. Plastic deformation in control nodes, using initial nitrogen pressure 9,5 bar

In order to make spherical segment plates with circular punches up to 15mm maximum depth, as impact substance there were used several quantities of water (1dm^3 ; $1,5\text{dm}^3$; 2dm^3) which were accelerated by initial nitrogen pressure $p_0 = 7,5 \dots 10\text{bar}$.

In table 4 is presented the maximum deformation depth in the center of the plastic deformed disc using 1dm^3 ; $1,5\text{dm}^3$; 2dm^3 water impact substance.

In Table 4 it can be observed that using an increasing quantity of water impact substance, it is possible to obtain larger values for the maximum

depth (25% for 1,0 dm³ water impact substance; 39% for 1,5 dm³ water impact substance; 51% for 2,0 dm³ water impact substance) compared with the results obtained using only nitrogen blasting shock wave.

Table 4

Initial pressure inlet stockage vessel, [bar]					
7,5	8,0	8,5	9,0	9,5	10,0
Maximum deformation depth in the center of the plastic deformed disc, [m/s]					
Nitrogen blasting shock wave combined with 1,0 dm ³ water impact substance					
8,8	9,7	10,6	11,5	12,3	12,8
Nitrogen blasting shock wave combined with 1,5 dm ³ water impact substance					
9,4	10,5	11,4	12,4	13,0	13,9
Nitrogen blasting shock wave combined with 2,0 dm ³ water impact substance					
10,3	11,1	12,2	13,3	14,1	15,2

Figure 5 presents the FEM results obtained for nitrogen initial pressure $p_o=10\text{bar}$ shock wave combined with 2,0 dm³ water impact substance. The FEM values are 7-11 % smaller then the values determined by experimental method.

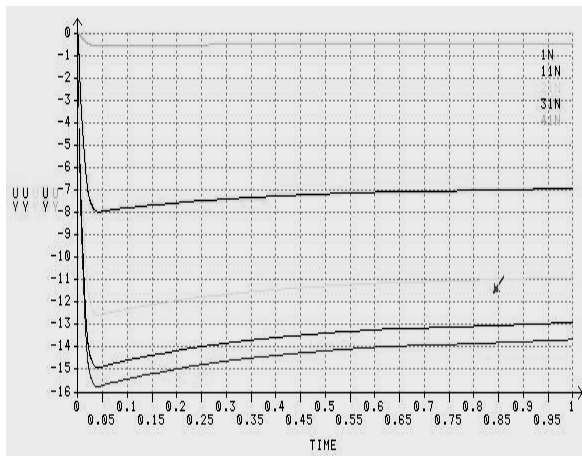


Fig. 5. FEM values for plastic deformation using initial nitrogen pressure 10bar, combined with 2,0 dm³ water impact substance

4 Conclusion

In the new high velocity deformation method presented in the paper, the contribution of the impact substances energy can be found both in the kinetic energy of the deformable plate, joined at a given moment (for the quantum time) with the mass of the impact substance, and in the same time, in the maximum dynamic pressure which interacts with the plate in the same quantum time.

The experimental research works show that the elastic maximal deformation is achieved in $0,03\div0,06\text{sec}$ and the permanent plastically deformation is achieved in $0,2\div0,4\text{ sec}$.

Due to the velocity values is confirmed that the new method is a high velocity deformation method.

The deformation energy which characterizes this new plastic deformation method shows that the efficiency of the plastic deformation process by air blasting shock wave and impact substances is comparable with the efficiency of the classical high velocity deformation methods, such as deformation by explosive powders, deformation by electro-magnetic impulses, exploding wires in gas.

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