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FRICTION ASSISTED PRESSING OF PM COMPONENTS

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ABSTRACT: Present paper deals with a new technique for compaction of PM parts by use the friction force between pressing die (container) and PM preform as an active force in order to reduce the gradient density on the component length. By moving the container of the die to the punch direction according of a particularly speed, the friction force acts in the same sense as the pressing load with the results of improving pressing condition. The paper presents the experimental results of compaction parameters versus relative speed of container/punch, density distribution and friction force for 316 L stainless steel with different lubricants.

KEYWORDS: Mobile container, active friction force, compaction.

1. INTRODUCTION

Two main directions have emerged of recent research: the first one refers to continuation of the study on reducing friction forces to minimum values, the second is the aims at employing, these as active forces [1,2].

The compaction process of PM parts by use the friction force as an active force, join the advantages of the classical compaction with the extrusion process using the friction force as an active force.

The paper present results of researches concerning the friction force influence between powder and container, used as friction force in compaction process of preform with solid circular section. The advantages concern simultaneous moving of container with the die punch, concerning fall of deformation pressure on tools and favoring pressing [3].

It's known the disadvantageous influences of friction forces in deformation processes concretizing by increase deformation stress, by emphasize inhomogeneous density distribution, decrease edges strength and increase wear of tools. In pressing processes the friction force between powder and container have increase simultaneous with pressing stress. For decrease the friction forces it's use different lubricants, which decrease deformation, stress and attenuate negative effects of friction forces on process [4,5].

Using this method one can obtain compacts with better properties: increase density, higher edge strength and decrease wear of tools.

2. MATERIAL EQUIPMENT AND METHOD USED

2.1. Material and Specimens

Gas atomized 316L stainless -steel powder with an average grain size of 90 μm and iron powder DWP200 (<100 μm apparent grain size) were used in this paper. Specimens with a solid cylinder shape of 11,33 mm diameter with the height/diameter ratio h/d of 1.5, 1 and 0.5 have been compacted on a 200 kN hydraulic press at the room temperature. Lithium Stearate has been applied on the container active surface. The powder in the container was compacted by applying axial pressure of 300-500 MPa [3]. The chemical compositions for 316 L stainless-steel powder and chemical compositions for iron powder are preseted in Table 1 and Table 2.

Table 1. *Chemical compositions for 316 L stainless-steel powder*

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	N	B
0.028	0.24	1.70	0.018	0.008	17.2	12.2	2.50	0.12	0.07	0.078	0.001

Table 2. *Chemical compositions for iron powder*

C	Si	Mn	P	S	$O_2(H_2\uparrow)$
≤0,02 %	≤0,05 %	≤0,20 %	≤0,20 %	≤0,015 %	≤0,20 %

Compressibility for P= 600 MPa is ≥6,95 g/cm^3

2.2. Experimental apparatus and conditions

For friction assisted compaction with movable container a special device, built in two variants, has been used. Figure 1 represents the pressing principle with the movable container (3) and pressing punch (1). In the first variant the ratio of container/punch speed was c= $V_c/Vp > 0$ (0.33; 0.5). In this case the container has the same direction with the movement of the punch. For the second case, the ratio of speed was c= <0 (-0.5), - the container have been moved contrarily to the punch. The tooling system has been set on a 200 kN hydraulic press and was driven by a mechanical lever device shown in Figure 2. In Figure 2 it is presented the first variant of container/punch movement, where the container (4) is actuated by the lever (5) connected to the bottom plate through a joint (at the right end) and to the upper plate (1) by a vertical road. The compaction force was recorded by use a load cells (2) located between upper punch (3) and upper plate (1). The speed ratio container/punch was changed by the lever length to the joint.

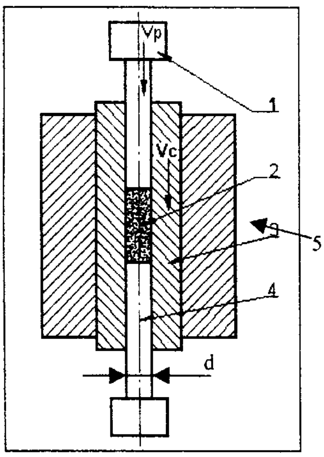


Figure 1. *Movable container tool.*

A resistive strain gauge applied to the lever (5) have been use in order to record the movement load of the container. Figure 2-b shows the second variant of the system where the joint of the lever is between the lever ends.

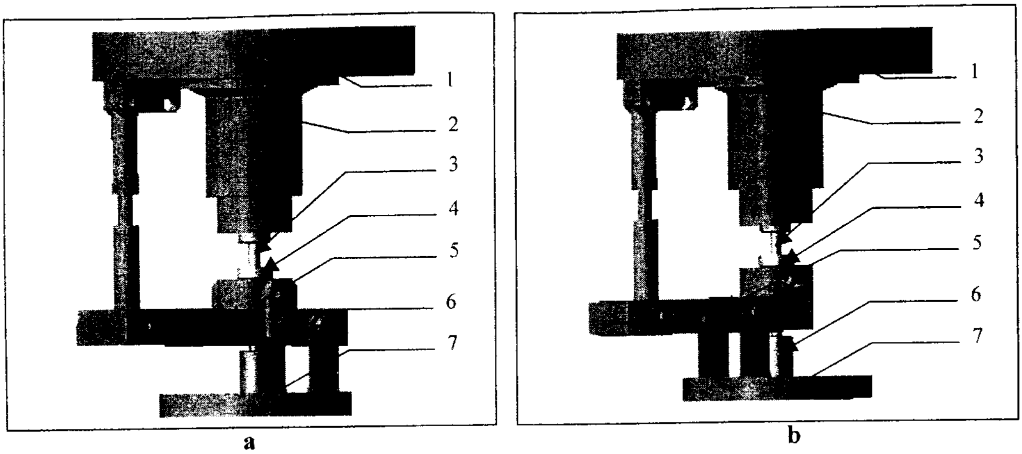
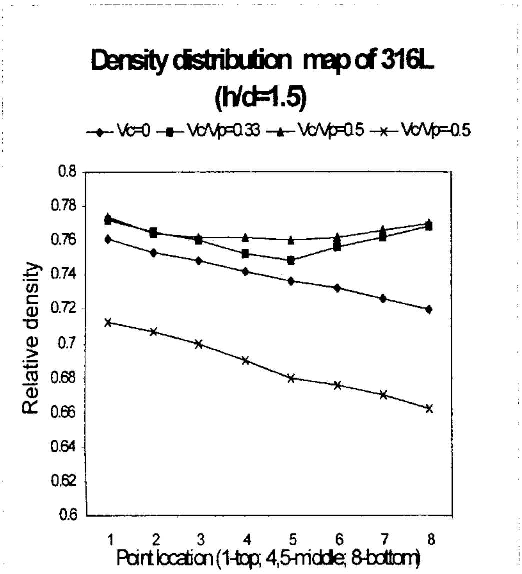


Figure.2. *Movable container tooling device: (a)-First variant for c=Vc/Vp>0 (0.33; 0.5); (b)-Second variant for c=* $V_c / V_p < 0$ *(-0.5).*

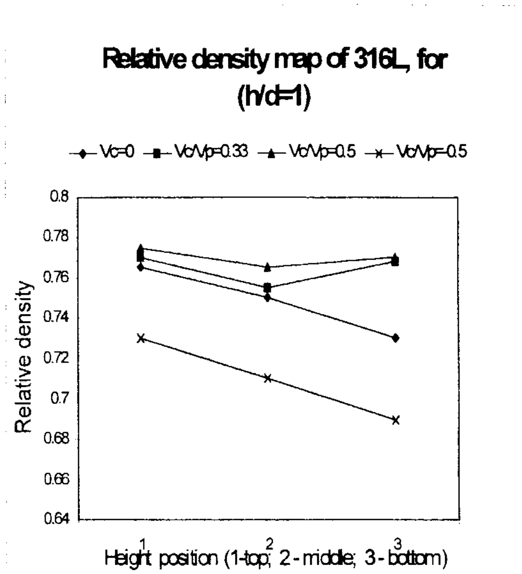
During compaction process there have been recorded on PC the evolution of axial force on the punch F_p, movement load on the container F_c, punch and container displacement versus pressing time. A proper UNIV1 –developed software have been used for up to 16 channels analogue inputs. All experimental compaction data have been saved in a text format file. Compact dimensions and mass were measured, after each test, in order to obtain relative density values. The partial machining method has been used to find local density along of each 2 mm to the height of the compact.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

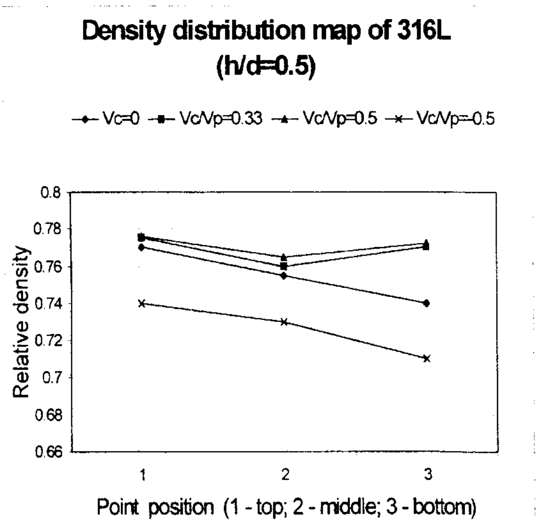
After each compaction the relative density distribution on the height of specimens have been plotted versus point location for all variants: fixed container (Vc = 0); movable container with c = 0.33; 0.5 and –0.5, respectively. For specimens with h/d =1.5, eight location points at each 2 mm along the specimen height have been used in order to plot density map. For components with h/d =1 and h/d=0.5, location points in the top (movable punch side), middle of height and bottom were used. Figure 3 - a, b, c presents the density distribution of 316 L stainless steel compacted at 300-500 MPa by use all variants of relative speed of the experiments. As it is shown in Figure 3 - a, for h/d =1.5, the distribution of the relative density on the surface contact to the container is more uniform for c=0.5 with small difference between top, middle and bottom. The shape of density plot for movable container (Vc/Vp>0) is similar with that of the bilateral pressing [4], but with a small gradient on the height of the compact. By decreasing speed ratio coefficient, c =Vc/Vp, at value of 0.33, results an increasing of density gradient. For the second variant, by moving container in the opposite direction to pressing punch, a sharp decrease of relative density on the specimen height is noticed. A similar density distribution is shown for h/d =1 (Figure 3 - b) and h/d =0.5 (Figure 3 - c), but the density differences are reduced by decreasing h/d, due to reducing of the container friction area.



(a)



(b)



(c)

Figure 3 a, b, c. Relative green density distribution of 316 L at 400 MPa, h/d=1,5; 1; 0.

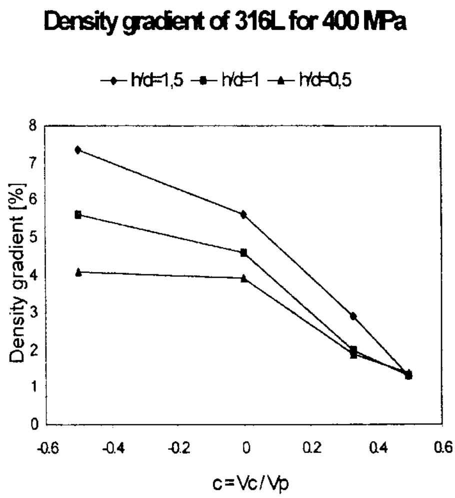


Figure 4. Relative density gradient versus relative speed coefficient, for 316-L stainless steel green compacts.

By moving the mobile container decrease the values of friction and pressing forces (Figure 5.) were used and increase service life of tools.

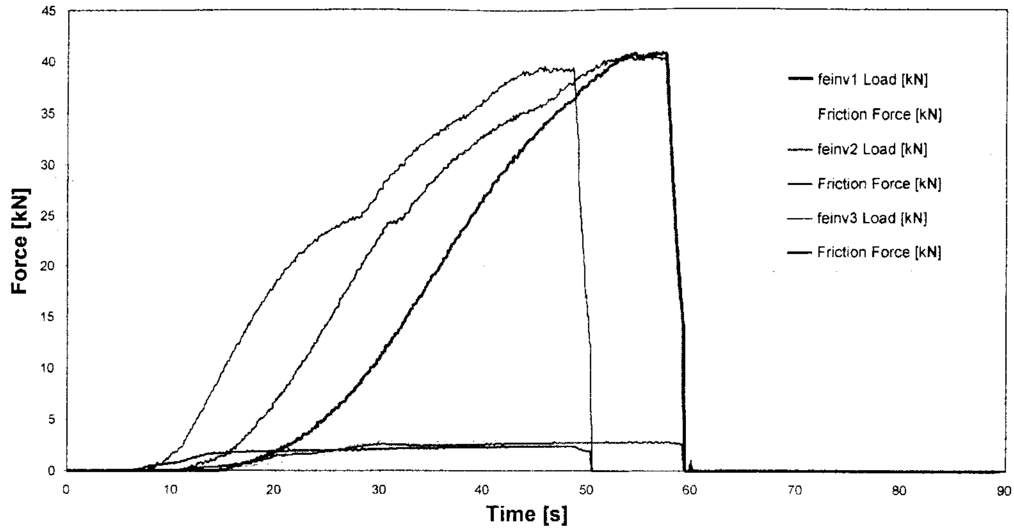


Figure 5. *The variation of pressing and friction forces by compacting of iron powder DWP 200*

Table 3. *The values of packing density for powder compacts (316 L and iron powder DWP 200)*

Material	h/d	Pressure [MPa]	Green density [g/cm^3]	Average of green density [g/cm^3]	Pressing manner
316lO1	1.5	400	5.82		Unilateral pressing
316lO2	1.5	400	5.83	5.822	Unilateral pressing
316lO3	1.5	400	5.817		Unilateral pressing
316l11	1.5	400	5.67		By moving container
316l12	1.5	400	5.57	5.62	By moving container
316l13	1.5	400	5.63		By moving container
316l21	1	400	5.75		By moving container
316l22	1	400	5.73	5.74	By moving container
316l23	1	400	5.76		By moving container
316l31	0.5	400	5.73		By moving container
316l32	0.5	400	5.805	5.79	By moving container
316l33	0.5	400	5.834		By moving container
316l4	1	300	5.398	5.398	By moving container
316l5	1	500	6.091	6.091	By moving container
316lc1	1.5	400	5.8	5.8	Container reverse moving
316lc2	1	400	5.81	5.81	Container reverse moving
316lc3	0.5	400	5.84	5.84	Container reverse moving
Feinv1	1.5	400	6.277	6.277	Container reverse moving
Feinv2	1	400	6.44	6.44	Container reverse moving
Feinv3	0.5	400	6.44	6.44	Container reverse moving

In order to underline the influence of the relative speed coefficient on the density distribution, relative density gradient has been calculated as:

$$\varepsilon = (\rho_{max} - \rho_{min}) / \rho \qquad (1)$$

Where: ρ_{max} represents local relative density at the topside of the compact (maximum value)
ρ_{min}- minimum value of local relative density across the height of the compact (Table 3.)
ρ – relative density –as global value.

As is shown in Figure 4, relative density gradient, for 316L, decreases with increasing the relative speed coefficient c, a minimum value of 1.3 % has been obtained for all of h/d geometrical factor. By decreasing relative speed coefficient, a higher difference of density gradient versus h/d is noticed.

Due to the different friction coefficient values of two materials, the shape of density gradient is different, but the influence of relative speed coefficient acts on the same manner. By reducing geometrical factor h/d from 1.5 to 0.5, density gradient decreases.

CONCLUSIONS

Densification behavior of stainless-steel powder 316 L and iron powder during compaction by use the friction force between pressing die (container) were investigated.

By replacing the fixed active container of pressing powder by a mobil container, the friction force of the part to be pressed can be actively used in processing. When using an exterior force for moving the mobile container, improvement of green density and tool service life can be expected. As pressing process efficiency depends on the ratio of deformation force and that of the friction force (friction force is opposing to material flowing).

Experimental data for four values of relative speed of container to punch movement have demonstrated a more uniform distribution of density across the height of the compact by moving the container in the same direction with the punch. The gradient of density distribution along the compact height is strongly dependent of relative speed coefficient. The effect of new proposed technique is similar of bilateral pressing. By using a proper relative speed, a particular density distribution on the compact is obtained. A negative value of relative speed coefficient, a sharp gradient of density will result. Further work is necessary in order to control the density distribution versus relative container to punch movement, for complex shape of the parts, compacted in different pressing conditions.

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