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The Comparison of the Characteristics of Displacement Isolines in the Cylindrical Green Compact under Ultrasonic Vibration

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Abstract

This research is a comparison of the characteristics of the displacement isolines due to powder-die-wall friction that arise during the compaction of ceramic powders in conventional die. It has been done using the CosmosWorks software package of the SolidWorks simulation software. The results of comparative simulation with FEM showed that the comparison of the displacement isolines and distribution of deformation of the ceramic powders. In the case of conventional uniaxial dry compaction for long length cylindrical green compact, considerable bending of the layers in the form of a cone can be observed. It is symmetry along centerline of cylindrical green compact. The distributions of the deformation of the green compacts (diameter 14 mm, height 20 mm) as a result of conventional compaction under ultrasonic vibration with power 1 and 2 kW are reduced to 4% and 6.5% when compared with conventional compaction without ultrasonic vibration respectively. Thus, density distribution can be minimized by increasing the power of ultrasonic vibration.

Keywords*: conventional compaction, cylindrical green compact, displacement isolines, ultrasonic vibration*

1. INTRODUCTION

Currently there are many processes of moulding of ceramic powders. The favourite and simplify process is a compaction with cold and hot pressing which classify in a uniaxial single compaction or double compaction [1-3].

The main factor affect to ceramic powder compaction in microns and nano level is friction force between powder compact and die wall. This factor as a result, the volumetric density of the green compact is not uniform. The density is maximum at the top edge of green compact or under of upper punch and the next effect is shrinkage of product after sintering process is not uniform. The friction interaction between compact powder and die wall those has an important roles of powder compaction

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lead to density changes, increasing press, material removal force from die and die corrosion [4]. It is difficult to eliminate die wall friction in the process of conventional compaction and there are several study cases in article [5-9]. The nonuniform density is the major problem in creating compact bulk nanostructured materials from nanoparticles in conventional pressing. The new die of conventional pressing is developed and patented by E.S. Dvilis and his group [10-14]. A collector pressing is a new die pressing that is called “Collector die” to make the green compact goes higher and uniform density in the volume. E.S. Dvilis and his group also represented variety of research of ultrasonic vibrations in dry powder compaction [10-14].

In this research, software SolidWorks is used for die design and CosmosWorks is used for deformation simulation of ceramic powder. The report has presented the characteristics of displacement isolines and density distribution of cylindrical green compact of Al_2O_3 in three dimensional.

2. MODEL FOR CYLINDRICAL POWDER COMPACTION

The powder material can also be regarded as a continuum media. In the model compaction I.C. Sinka [8] described have to know 1) Constitutive law, explained volumetric powder deformation under compressive force. 2) friction interaction between powder and tooling 3) geometric shape of die and punch 4) compression pattern and compact axial movement sequence 5) original conditions in state of powder after filling into die. To compare the powder deformation under ultrasonic vibration and without ultrasonic vibration so that the research chose the finite element method with assumption of compact powder as an isotropic material and linear elastic deformation. The friction coefficient is defined into CosmosWorks with the friction coefficient from experiment [15]. Begins pressing the power in die until becomes green compact with height 20 mm.

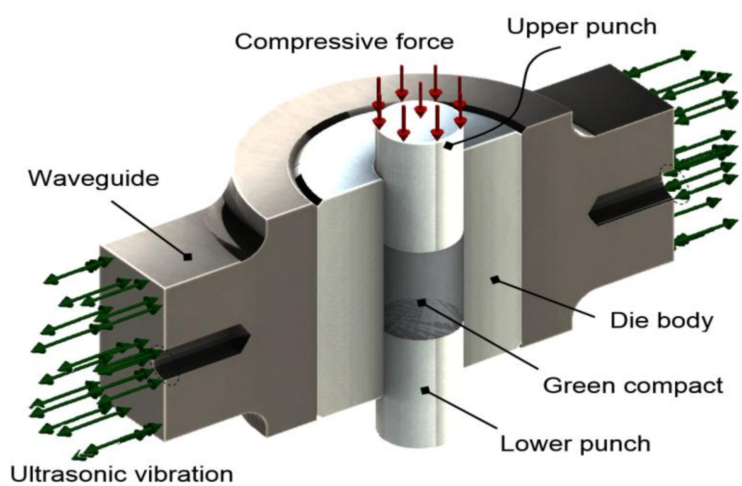

Figure 1. Conventional die under ultrasonic vibration.

Figure 1 shown conventional die of uniaxial compaction contained Al_2O_3 until complete the cylindrical shape under ultrasonic vibration at frequency f = 20 kHz. The conventional die consists of die body, upper punch, lower punch, and waveguide to connect to the ultrasonic transducer. Compressive force acts on the upper punch only and the lower punch places on press bar. The final size of green compact has diameter (D) of 14 mm and height (H) of 20 mm.

3. FINITE ELEMENT RESULTS

Simulation of the deformation process of powder compact by uniaxial compaction and ultrasonic vibration conditions of die wall friction was carried out using the finite element method (FEM).

3.1 Comparison of Result of Displacement Isolines

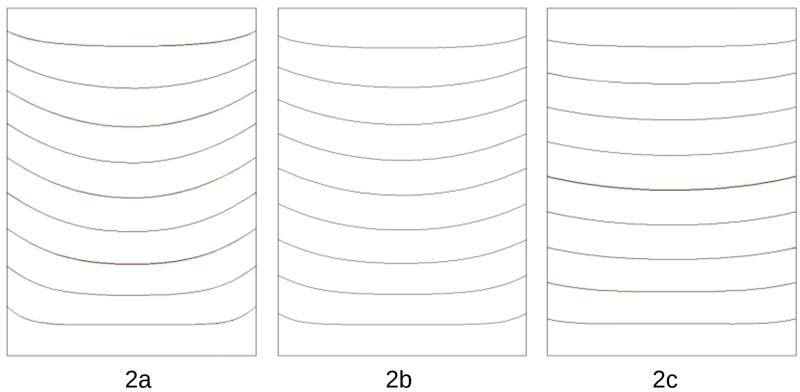

Figure 2. Displacement isolines of green compact under die-wall friction force.

Before pressing, the powder Al_2O_3 in die is divided as 10 layers of height which each layer's height is same and pressed until the green compact has height of 20 mm. Figure 2 shown displacement isolines characteristics of green compact after compaction process which was cut in half along the height.

Due to friction force between powder compact and die wall, the characteristics of displacement isolines are curved that is curve of displacement isolines depend on the friction force. The loss of the compaction force for overcoming the wall friction forces inside of powder body the minimal densification degree is observed in the most distant from the top pressing punch. The distributions of the wall friction forces and the density in a height of powder body are axisymmetric and non-uniform.

Figure 2b and 2c shown displacement isolines from the case of pressing under ultrasonic vibration with power 1 kW and 2 kW respectively.

Figure 2c shown that the displacement isolines, it has less curvature than the figure 2b due to the ultrasonic vibration is a cause to decrease the friction force between powder compact and die wall. The satisfied results are lower density distribution, higher uniform volumetric density than condition out of ultrasonic vibration.

From the figure 2, create vertical grid lines by divided as 10 columns with the same width. So the cross section area of half green compact has been divided to 100 sections and calculates every area using program ImageJ. After that must also determine radial volume of green compact and using Archimedes methods to determine density of each cross section. All calculated density can be generated the model of density distribution in three dimensions.

3.2 Comparison of Result of Density Distribution

There are two methods to eliminate or reduce die wall friction forces for dry powder pressing process which allow pressing into complex shape compacts, with uniform density distribution in the bulk: pressing under a powerful ultrasonic action pressing and the collector pressing [10-14]. The former research presented density distribution for two dimensions, but this research shown density distribution of green compact in three dimensions of cross section to angle 150 degrees as show in figure 3-5. The density has been represented as a contour line in an equal density scale.

Figure 3 shown density distribution due to pressing without ultrasonic vibration, found that the maximum density occurs at the upper edge of green compact of 0.007-0.0085 g/cm^3 because it has higher friction force on the edges, the minimum density occurs in the middle portion at the bottom of green compact of 0.00255 g/cm^3. Considering on the lower edge of green compact found that low density of 0.00255 g/cm^3 but rather higher in the middle at the bottom of green compact of 0.0032 g/cm^3. If compare the maximum density at the top and the bottom of green compact found that the maximum density at the top is greater than the maximum density at the bottom of green compact.

Figure 4 and 5 shown density distribution due to pressing with ultrasonic vibration powers are 1 and 2 kW respectively. The contour line pattern of density is like in case of without ultrasonic vibration, the density distribution is substantially less if considers the color gradient closely. Figure 5 shown the quality green compact with maximum density of 0.00315 g/cm^3 and minimum density of 0.00265 g/cm^3.

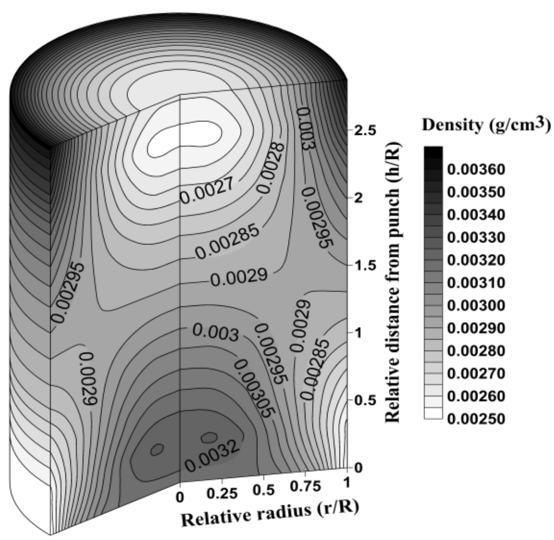

Figure 3. Density distribution in the volume of green compact without ultrasonic vibration.

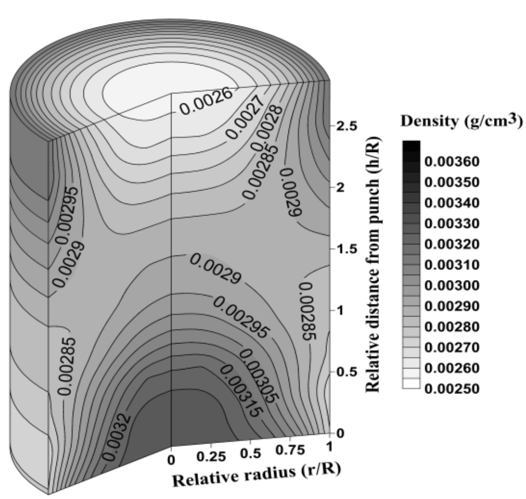

Figure 4. Density distribution in the volume of green compact under ultrasonic vibration 1 kW

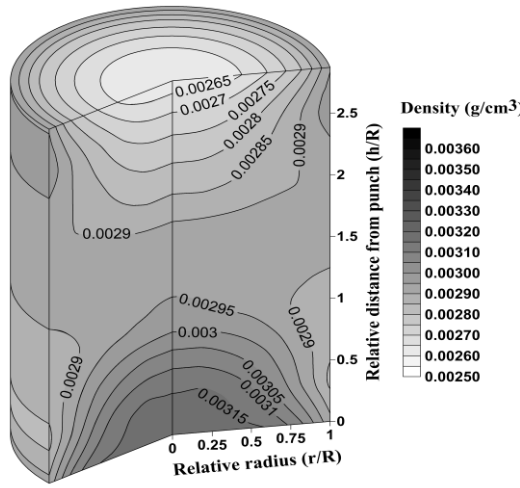

Figure 5. Density distribution in the volume of green compact under ultrasonic vibration 2 kW

Table 1. The comparison of density of green compact under ultrasonic vibration.

Power of ultrasonic generator (*P*)	0 kW	1 kW	2 kW
Dispersion of density in the volume	0.004317	0.0026406	0.0012534
Relative difference of density in height, ($\Delta\rho/\Delta H$)	0.0000026	0.00000191	0.00000191
Deformation distributions of the green compacts	0.0000351	0.0000337	0.0000328
Relative density	0.75	0.75	0.75

Density dispersion can be measured using statistics principal (variance) from the following formula.

$$\text{Dispersion of density in the volume} = \left(\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2\right) / \left(n-1\right)$$

where x is the sample mean AVERAGE(number1,number2,…) and n is the sample size.

As analyse of volumetric density distribution, in case of power of ultrasonic vibration is 2 kW, the density distribution less than in the case of ultrasonic vibration with power of 0 kW. This means the ultrasonic vibration affect to density distribution definitely. In the uniaxial single compaction, the deformation dispersion of green compact under ultrasonic vibration with power of 1 and 2 kW are reduced 4% and 6.5% if compares with in the case out of the ultrasonic vibration respectively.

In the table I shows the relative difference of density is to compare with height. If power of ultrasonic vibration increasing, the density distribution has been reducing.

After the green compact had been sintering, the shrinkage of cylindrical product under ultrasonic vibration 2 kW must be uniformly than in the case of without ultrasonic vibration and effect to reduce internal porous as well. For relative density of green compact is not significantly different.

4. CONCLUSION

A numerical analysis of deformation character for dry powder pressing was performed using the finite element method. The displacement contour line has been considered under high die wall friction force. The main factor affect to density distribution is friction between die and powder compact. There are two ways to reduce friction in compaction without using lubricants: powerful ultrasonic pressing and collector pressing. For the case of conventional pressing by means of the long length cylindrical green compact, considerable bending of the layers in the form of a cone can be observed. As analyse with finite element method found that when the friction reduced that caused by using ultrasonic vibration, the density dispersion will be decreased as well. Therefore the ultrasonic vibration should be used in powder forming compaction to support to complete the quality products.

ACKNOWLEDGEMENT

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