Mechanism Bond Formation of Powder Multi Material Sintering: Polyethylene – Poly Vynil Chloride

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Abstract
The demands of the functional aspects and the economic value of manufactured products to encourage the development of multi-material sintering process. But in its realization, various problems emerging techniques, including the determination of the type of material that can be sintered, non-uniform shrinkage phenomenon, and the bonding mechanism between different grains of unknown material. This study was conducted to determine the mechanism of bonding between the grains and calculate the shrinkage that occurs based on the grain due to the implementation of the sintering process. In practice, this study pursued through two stages. The first stage in the form of observations of the two grains with similar material (the material used is polyethylene). While the second phase in the form of observation of grains of polyethylene (PE) with a grain sintered poly vinyl chloride (PVC). Observations were made at isothermal conditions and periodically done shooting so the bonding process can be visualized. Based on the image data that has been retrieved, the volume shrinkage analysis can be done by calculating the projected area of the particle. From the research that has been done, the volume shrinkage that occurs on sintering material (PE with PVC) at an isothermal temperature of 110^0C is equal to 20.42%
Key Word: mechanism bond, sintering, polyethylene, poly vinyl chloride

INTRODUCTION

The demands and needs of manufacturing products with high economic value, while meeting the functional aspect of encouraging the development of multi-material products. With multi-material products is the material of a component consists of a wide variety of materials. The use of materials with high strength is only used on the products that have high loadings. In this way, the price of a product can be reduced so that it becomes more economical to keep the functionality aspect. However, in practice many problems that arise in the realization of multi-material products through the sintering process. The problems that arise, among others, is the lack of uniformity shrinkage, sintering temperature difference of the two materials, and the bonding mechanism between the grains are not yet clear. By understanding the issues above, the product of a multi-material sintering can be set so as to produce a product that suits your needs. In the sintering process is mostly done modeling and simulation of sintering process to obtain predictions of the sintering characteristics of the product, including the prediction of shrinkage that occurs. A common modeling is modeling for similar materials with the same powder size. Modeling for multi-material sintering has not been done. Shimosaka et al. (2003) did modeling for two different powder materials of different sizes. In his research, Shimosaka et al. (2003) stated that in addition influenced by the sintering conditions, the sintering behavior of two different material types is also influenced by the solubility properties of the material with each other. The formation of solid solution occurs at the grain boundaries through a transport mechanism. Transport mechanisms include surface diffusion, volume diffusion, grain boundary diffusion, evaporation-condensation, and grain growth. To avoid the hassle of doing this then sintering modeling Maximenko and Olevsky (2004), proposed a scale parameter called the effective diffusion coefisien. This measurement is the grain boundary diffusion merger between the volume diffusion. By using this coefficient, the modeling can be done in 2 dimensions. In addition through complex modeling in general, the problem of non-uniform shrinkage phenomenon in multi-material sintering process can be studied experimentally. The initial step in this research is to perform sintering using the same material but with different treatments.

Hambir and Jog (2000) states that the result of sintering of the green parts with low density will result in a product with greater shrinkage than the result of sintering of the green parts with high density. his forms the basis of research Garino and Howard in conducting initial research on the variability from multi material shrinkage on sintering process. By doing sintering of two green parts that have different density variation on the phenomenon of shrinkage can be obtained. From the results of research conducted Garino and Howard found that the shrinkage that occurs depends on the thickness of each layer of the green part. The purpose of this first stage of research is to understand the mechanism of bonding between two points and calculate material shrinkage that occurs experimentally.

THEORY

The formation mechanism of bond

Sintering process can be divided into three phases, namely the initial stage (initial stage), middle stage (intermediate stage), and the final stage (final stage). There are no clear boundaries for each of these stages. The initial phase is characterized by the rapid increase in the diameter of the neck. Middle stages of the form marked porosity that has been narrowed by the cylindrical shape of the porosity associated with the other. At the end of this stage of grain growth can also occur to produce grains with larger size with a fewer number of grains. While in the final stage, the porosity has been isolated and has a spherical shape. At this stage of grain growth occurs with slow densification process. Modeling of the process can be seen in Figure 1.

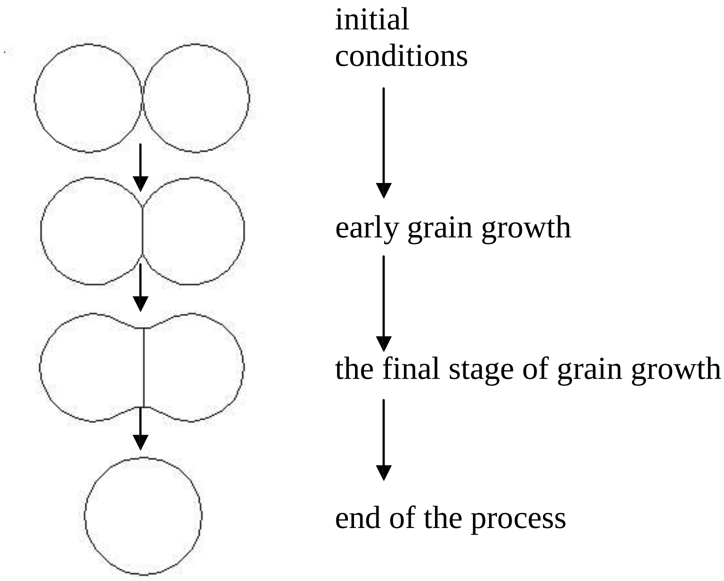

Figure 1 Modeling of bond between the grains in the sintering process of two spherical particles of the same size and similar material.

In the above process, the bonds between the particles occurs via the transport mechanism. This transport mechanism can be classified into two surface transport and bulk transport. Surface transport include surface and evaporation-condensation Difusion. While the bulk transport include volume diffusion, grain boundary diffusion, plastic flow, and viscous flow. Surface transport resulted in the growth of the neck without shrinkage, while the bulk transport resulting in shrinkage. Sources of energy (driving force) of sintering process is the surface energy. Surface energy per unit volume is inversely proportional to the particle diameter. So small particles have more energy than particles with large sizes. Occurs during the sintering process of mass transfer from the particle to the neck. The mass transfer occurs to reduce the surface energy of the particles by means of expanding the particle surface. So during the sintering process occurs elimination or reduction of surface energy. Due to the elimination of a surface energy that occurs during the sintering process, the parameters that can be used to measure the level of sintering (degree of sintering) is the surface area. Another parameter that can be used in measuring the sintering rate is the ratio between the size of the neck (X) with a particle diameter (D), for more details see Figure 2.

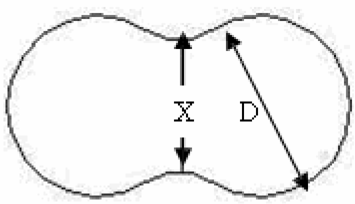

Figure 2 Modeling particle

Depreciation Equivalent Diameter and Volume

Powder particles have a variety of shapes. For powders with irregular shapes like a ball that has the volume of the powder can be calculated easily. For powders with irregular shapes, the other methods are needed. The method is usually used to calculate the volume of this powder is to use the equivalent diameter. Equivalent

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diameter can be calculated based on the projected area, surface area, and volume.
The method used to calculate the equivalent diameter dimilliki selected based on the data. If the data held is widely projected area equivalent diameter can then be calculated from the following equation.

$$D_A = (4A/\pi)^{1/2} \tag{1}$$

For the data in the form of powder volume (V), then the equivalent diameter (DV) are :

$$D_V = (6V/\pi)^{1/3} \tag{2}$$

For the data in the form of particle surface area (S), then the equivalent diameter (DS) :

$$D_S = (S/\pi)^{1/2} \tag{3}$$

The volume of the particles is calculated using the equation volume of a sphere:

$$V = \frac{4}{3}\pi D^3 \tag{4}$$

The amount of volume shrinkage ($\frac{\Delta V}{V_0}$) calculated by the equation:

$$\frac{\Delta V}{V_0} = \frac{V_i - V_0}{V_0} \tag{5}$$

with V0: initial volume of particles
Vi: volume of the particle at the moment

(5)**METHODS TESTING AND MATERIALS**
Material: Polyethylene (PE) and Poly Vinyl Chloride (PVC) 0.297 mm (mesh size)
Tool: Testing Sieving, Micro Structure Testing Powder, Powder Testing with EDX, Mechanism of bond
Observations
At first preheated heating plate at a temperature below the sintering temperature to a constant temperature heating plate placed under the microscope so that the particles become easier setting. After that PE particles placed on a heating plate and heating plate temperature is raised to the sintering temperature. Observations sintering process carried out under isothermal (110^0C) with periodic shooting. Volume measurement is done by measuring the projected area of the particle images were taken. Of the area can be calculated equivalent diameter (DA) which is used to measure the volume of the particle.

RESULTS AND ANALYSIS
Of shots taken (see Figure 3) it can be seen that the lapse of time between 7-9 minutes is the initial stage of sintering. At this stage neck growth occurs without a shift in the grain boundary. An interval of 9-13 minutes is the stage where grain growth occurs, it can be seen from the particle diameter that is greater than the initial diameter of the particle.

(a) (b) (c)

(d) (e) (f)

(g) (h)

Figure 3. The process of formation of bonds between PE-PVC grains at 110^{o}C temperature during the sintering process a. 0 min, b. 7 minutes, c. 8 min, d. 9 minutes, e. 10 minutes, f. 11 minutes, g. 12 minutes, h. 13 minutes

From the image observations, measurements can be made to obtain the projection area equivalent diameter. Measurement of the area of the projection is done directly without regard to the magnification scale. The scale is not taken into account because it does not affect the calculation of volume shrinkage results. Of the equivalent diameter of the particle volume can be calculated. The results of the calculations are presented in Table 1.

Table 1: Results of the calculation of the volume shrinkage during the sintering process at a temperature of 110oC PE.

Time (Minute)	Area (mm)	Diameter Equivalent, D_S (mm)	Volume (mm)	$\Delta V/Vo$ (%)
0	1853.23	48.59	480239.50	0.00
7	1804.77	47.95	461526.56	3.90
8	1743.15	47.12	438092.72	8.78
9	1614.00	45.34	390318.55	18.72
10	1605.66	45.23	387297.13	19.35
11	1600.50	45.15	385431.69	19.74
12	1597.00	45.10	384168.08	20.00
13	1590.74	45.02	381911.47	20.47

From the above calculation is known that the shrinkage volume reached 20.47%, to determine the rate of volume shrinkage versus time graphs then made between the time the volume shrinkage (see Figure 4).

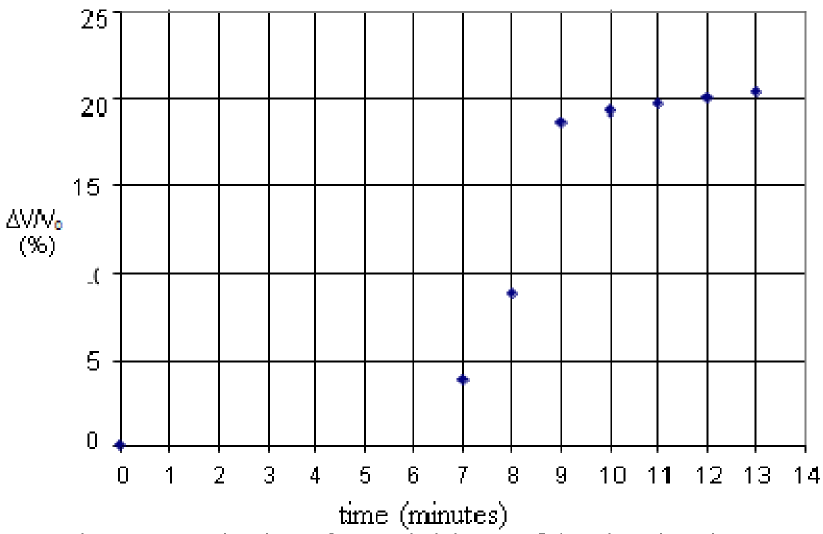

Figure 4 graphs the volume shrinkage of the sintering time

From Figure 4 it can be seen that initially the volume shrinkage occurs rapidly (7-9 min) which then slows down. At an interval of 7-9 minutes of neck size is still small so that the neck is an area with great energy. This energy is the source of energy for the sintering process. With increasing time, the larger the size of the neck so that the energy per unit volume of the smaller neck. The result is a marked slowdown in the sintering process by slowing the process of volume shrinkage at an interval of 9-13 minutes. At 9-13 minutes, can be seen from Figure 2 that the magnitude of the neck is almost equal to the amount of particles. It shows that the slowing volume shrinkage occurs when the diameter of the neck is almost the same as the diameter of the particle.

CONCLUSION

- Comparison between the neck diameter of the particle diameter can be used to determine the limits of the initial stage of the sintering process.
- The initial stage of the sintering process ends when the diameter of the neck is almost the same as the diameter of the particle.
- The results of the two powder sintering at temperatures of 110oC PE resulted in shrinkage of the volume of 20.47%.

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