Optimize Print Speed and Laser Power of the 3D Printing Technology Selective Laser Sintering (SLS) for Mixture of Powder Materials Green Bean and Polylactic Acid (GBP/PLA)

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Abstract. In this study, we performed the optimization study of selective laser sintering (SLS) 3D printing mode for the material is a mixture of Green Bean Powder and Polylactic acid powder (GBP/PLA) to created new biodegradable synthetic material (GBCP). The study was designed with 2 factors changing: print speed and laser power, fixed factor is the ratio of GBP/PLA is 20/80. Through Scanning Electron Microscope (SEM) to assess the structure of materials; tensile strength, flexural strength and impact strength evaluate the mechanical properties of materials. Experimental results show that with the printing speed of 2 m/s, the printing power of 21 W, the GBP/PLA material has the best quality with a tensile strength of 2.89 MPa, flexural strength of 5.91 MPa and impact strength is 0.57 KJ.m².

1. Introduction
Selective laser sintering (SLS) is an additive manufacturing process (AM) invented by Carl Deckard at the Department of Mechanical Engineering at the University of Texas at Austin [1]. Selective laser selection involves the use of high-power lasers (for example, carbon dioxide lasers) to merge small plastic powders into a desired three-dimensional shape and a solid structure [2, 3]. Selective laser consolidates the powdered material by scanning the sections created from a 3-dimensional digital description of the part (e.g. from a CAD file or scanning data) on the surface of the powder layer [4, 5]. After scanning each section, the dough layer is lowered by one segment, a new coat of material is applied on top, and the selective laser sintering process is repeated until that part is completed. Therefore, technology (SLS) can create complex shapes and designs; Own design has precision and durability high, prototype parts, Capable of being used directly in final production, or rapid prototyping dramatically shortens the launch time of new products [6-8].

Currently, the materials used for SLS mainly focus on metals, ceramics, polymers and their respective composites [2, 9]. However, material preparation technology is still protected commercially. It is costly because the material suitable for a specific AM application must meet some initial technical requirements and undergo some processing stage, compared to the raw material used in traditional manufacturing and therefore must be produced or specific adjustments. These requirements reduce the available materials and increase production costs, posing an obstacle for the broader adoption of SLS.
technology [7]. Meanwhile, the urgent need of SLS is to expand the diversity of available materials, especially sustainable and cheap materials with increasing concern about energy use and issues environment [6, 7, 8, 10].

The development of new powdery materials in line with the SLS process to expand its application area is currently one of the leading research topics and challenges [2, 4, 11]. Several research efforts have been conducted in recent years for the design of new SLS powders such as Co-PES resin powder combined with bamboo pulp, rice husk pulp, walnut pulp, pinewood pulp... succeeded [6, 7, 8, 10, 11, 12]. The characteristics and performance of laser sintering of different composites studied have shown diversity according to differences in composites components, method of material preparation, selection process parameters. In this direction, the use of mung bean flour and polylactic acid powder for low-cost AM technology, which is biodegradable and environmentally friendly, promises to create a new synthetic material. The primary purpose of this work is to present a new synthetic content containing green bean powder and Polylactic acid hot melt adhesive (PLA) as materials for SLS. This material system is abbreviated as GBCP.

Green bean powder is the product obtained after the grinding process of green beans seed. Currently, green beans are an essential crop in the agricultural economy; green beans have wide adaptability, fairly drought tolerant and can adapt to areas with extreme conditions. Green beans are used in everyday life as food for humans, animals and skincare cosmetics ... In 100g of edible green beans, containing about 62-63% carbohydrates and 16% fiber, 24% protein, 1% fat, and provides approximately 340kcal (Jyoti Chopra 1998, Earl E. Watt 1977), so when green beans are crushed, and the powder particles are small in size and smooth, consistent with the requirement to use for SLS technology.

Polylactic acid (PLA) powders are emerging as one of the most promising alternatives for petroleum-based polymers for various potential applications. The main advantages of PLA include its biodegradability and recyclability, as it is derived from plant resources, renewable and sustainable. Bio-polymers exhibit properties are similar to many petrochemical-based composites. They are being used in 3-D Printing industries and as renewable materials in packaging applications, bio-composites [2, 4, 14, 15, 16].

These two components are mechanically mixed for use in SLS. This study mainly focused on identifying, selecting parameters, processes, printing speed and print capacity affecting the new BGCP composites created after the testing process: Testing mechanical properties of GBCP material, Observe the cross-section structure, observe the surface of the content of the material. The results of testing and analyzing the structure of materials are the scientific basis for selecting the printing speed and capacity for a mixture of mung bean flour with polylactic acid powder with a weight ratio of 20/80 in GBCP composite material have the best quality.

2. Materials and methods

2.1. Material preparation

Green bean powder: A kind of food powder bought in the market, produced by KangHua Food Company, the company's products are certified product standard ISO9001 products No. NY / T906-2006 raw materials and green beans. The address of the company Wang Heng Economic Development Zone, Xinghua, Jiangsu, China. Cost was $3.5/Kg, is shown in Figure 1.a.

Polylactic acid powder (PLA) is a kind of white plastic powder (density 1.24g/cm3; melt-flow index (MFR) 14 g per 10 min at 210o C) was supplied by Nature-Works (Minnetonka, Minnesota) as a semi-crystalline grade. Bio-max (Strong 120) was supplied by Dupont while (Shanghai, China). Cost was $4/Kg. is shown in Figure 1.b.
Before preparing GBCP synthetic material, green bean powder and PLA powders were screened through standard mesh sieve 70 with a mesh size of 0.212 mm. The flour obtained after the sieving process is dehydrated at 55°C for 8 hours in an incubator to lower the moisture content of green bean powder to below 2%. Green bean powder and PLA powder are put into a high-speed mixer with a weight ratio of 20/80 (wt/wt) and mechanically mixed for 15 minutes initially incorporated at low speed 750 rpm and then mix for 5 minutes at high speed 1500 rpm. Finally, GBCP composites with a component weight ratio of 20/80 (wt/wt) were prepared. The GBCP is shown in Figure 1 (c).

2.2. Selective laser sintering experiments
SLS experiment: The process of sintering of GBCP components with a weight ratio of 20/80 (wt/wt) was made on rapid prototyping equipment AFS-360 by the Technology Co., Ltd. Beijing, China produced. Contains CO₂ laser source and has a wavelength of 10.6 mm, the laser beam diameter of 0.4 mm and maximum output power of 55 W. Diagram of the processing system of the AFS360 rapid prototyping machine is shown as Figure 2. The main process parameters are as follows: laser power 10-14 W; scanning speed of 1.8-2.2 m/s; scanning distance of 0.2 mm; and layer thickness of 0.1 mm, preheating temperature of 105°C. Laser power and scanning speed are two factors to analyze the importance of them to the laser-sintered parts.

![Figure 1. Components of GBCP composites and their microstructures.](image)

![Figure 2. Schematic of process system of AFS360 rapid prototyping machine.](image)
2.3. Characterization

DSC: Green bean powder, PLA powder, BGCP powder with weight composition ratio of 20/80 were analyzed by US Pyris Diamond differential scanning calorimeter (PerkinElmer, Waltham, MA, USA). The test parameters are as follows: the mass of each sample of material to be analyzed is 5 mg; heating rate is 10°C/minute; The test temperature range is 40 to 200°C. The DSC curves of green bean powder, PLA powder, BGCP flour with a composition ratio of 20/80 were obtained.

SEM: Cross-sectional profiles of sintered GBCP structure samples were analyzed by scanning electron microscope (SEM). Because the samples were non-conductive, they were sprayed with a thin layer of gold to remove the charge before observing the SEM. GBCP parts with a weight ratio of 20/80 wt/wt, analyzed under the scanning electron microscope (SEM; FEI QUANTA 200) at a working distance of about 25mm, a voltage of 12.5kV and 6 × 10−10A transducer line (High vacuum degree, detector size ETD and 6.5 points). Scanning electron microscopes made by the Dutch company were used to observe and obtain images of the microstructures of the cross-section in GBCP composites.

Density: The weight and dimensions of GBCP parts are measured through electronic equalizer and Size calipers. Here, the density is calculated through equation (1).

\[ \rho = \frac{W}{l \cdot b \cdot h} \]  

Where \( W \) is the mass of parts (g); \( l \) is the length of parts (mm); \( b \) is the width of parts (mm); and \( h \) is the thickness of parts (mm).

Mechanical testing: Mechanical performances of the GBCP parts with different parameters was tested by TMS System Ltd.’s CMT5504 tensile testing machine and the Jilin Province Taihe Ltd. TCJ-4 impact testing machine. (Changchun, China). The test standards are as follows:

Tensile strength is determined according to ISO527-2. The cross speed is 5 mm/min and the gauge length is 50mm.

Three-point flexural strength is determined according to ISO178. The cross speed is 5 mm/minute and the span length is 64mm.

The intensity of the U-collision is determined according to ISO179-2. The impact strength of the pendulum is 4 J and the span length is 60mm.

3. Results and Discussion

3.1. Thermal Analysis

Before the SLS of GBCP powder with a weight ratio of 20/80 (wt/wt), the sintering window called the SLS processing temperature range of materials was determined through a differential scanning calorimeter (DSC). Because the process of forming the primary polymer of SLS involves heating the powder from the solid phase to partially or entirely molten state, then cooling back to solidification. For amorphous polymers, \( T_g \) is the glass transition temperature, \( T_c \) is the crystallization temperature \[7\] To prevent them from warping, hardening and improving the sintering efficiency of parts and the utilization rate of powders, ensuring optimal component formation. Therefore, the determination of sintered windows for polymers Amorphous without a melting point is essential.

The DSC curves of PLA flour, green bean powder and GBCP powder are shown in Figure 3, showing the glass transition temperature of PLA flour; GBCP powder was 69.57°C, respectively; 66.14°C. To determine the sintered window, a laser sinter test is needed. From experiments, it can be seen that the GBCP powder with a weight ratio of 20/80 has completely hardened at 104.64°C. Therefore, the window for sintering is (66.14°C; 104.64°C). There is a phenomenon of heat accumulation in the powder during sintering; Therefore, preheating temperature and treatment temperature of GBCP powder layer is 105°C.
Figure 3. Differential scanning calorimeter (DSC) curves of the three different powders.

3.2. Laser Sintering Experiments
In the SLS process, the accuracy of sintered parts is a significant indicator of Sintering material and sintering process. The GBCP sections with different print speeds and print capacities are shown in Figure 5. Figure 5a, b shows the warping deformation of GBCP parts is most significant when printing capacity is smaller 19w and larger than 23w along with the influence of printing speed. The temperature has a more substantial impact on PLA powders. Because when the printing capacity is smaller than 19w and more significant than 23w and the printing speed changes. A higher laser sintering temperature causes is higher or lower than the crystalline temperature of GBCP, making the internal forming temperature of the rapid prototyping machine unstable, which causes warping distortion of the PLA parts. With print capacity is 19w and 23w PLA powders ensure crystallization temperature, and the temperature has little effect on PBCP powders, so the warping deformation of GBCP parts is reduced. On the other hand, an increase in friction between green bean flour, PLA flour and rollers is spread during the spreading of the dough, causing the shape size deviations of the GBCP parts to appear and increase with increasing pea flour content green bean. Therefore, the content of green bean flour does not need to be excessive when the size of the sintered parts is within a suitable range.

Figure 4. GBCP parts: bending parts with different print speed and print capacity.
3.3. Density of Parts

In SLS process, the density of sintered parts is one of the performance evaluation criteria. The change in density of GBCP parts with print speed and print capacity is shown in Figure 5. The observation in Figure 5 shows that, with the shift in print capacity, the density of GBCP parts also changes the conversion and has the most substantial value at 21W printing capacity, printing speed is 2.0m/s. Density is 0.827g/cm$^3$. The main reason is that, with the increase in laser power, the PLA powder content increases at the best melting and it can cover and bind green bean powder, resulting in the smaller the inner hole of WSPC parts, therefore, the increase of green bean powder, the highest density of the material.

![Figure 5. Density bar chart of density change of GBCP parts.](image)

3.4. Microstructure

The mechanism of association between green bean powder and amorphous PLA matrix, as well as the dispersion of flour particles, are important factors affecting the mechanical properties of GBCP parts. Print speed and laser power are the primary inputs of green bean powder and PLA powder, which affect the energy absorption capacity of GBCP powder. Therefore, according to SEM, the microstructure of the cross-section of GBCP parts is shown in Figure 6. It can be seen in Figure 6 that the green bean powder is evenly distributed in the PLA Matrix, and there is no phenomenon synthetic. The size and number of internal pores of GBCP parts are small, the sintered neck is large, and the sintering area is continuous. Due to the little content of green bean powder, PLA powder can fully absorb the power of laser radiation and completely melt, and its liquidity is improved. After that, the green bean paste bonded and wrapped caused many continuous sintering areas. Therefore, the size and number of pores inside GBCP are small.

![Figure 6. The scanning electron microscope (SEM) of the cross section of the GBCP parts.](image)
3.5. Mechanical Properties

![Mechanical Properties Graphs]

**Figure 7.** Mechanical properties of GBCP sintering parts. (a) Tensile strength; (b) bending strength; (c) impact strength.

In the SLS process, mechanical properties are one of the criteria for evaluating the quality of sintered materials and determining the performance and application scope of sintered parts. The changing mechanical properties of the WSPC parts are shown in Figure 7. In Figure 7 shows tensile strength; intensity curling; tensile impact strength, always changes when we change the factors of print speed and print capacity. GBCP materials have the best parameters as follows: tensile strength...
2.98 MPa; bending strength 5.91 MPa; tensile impact intensity 0.57 kJ/m². When printing at 21 w print power and print speed is 2 m/s.

4. Conclusion
In this study, we studied the optimize print speed and laser power of the 3D printing technology selective laser sintering (SLS) for mixture of powder materials green bean and polylactic acid (GBP/PLA) with a ratio of 20/80. The results show that:

✓ Print speed and laser power of the 3D printing technology selective laser sintering has a significant influence on the density and physical properties of materials.
✓ In the same laser power, and the same weight ratio. The different printing speed, the density, the mechanical properties of the material are also different.
✓ Experiments have proven that GBCP composites are sintered by AFS-36. With the weight ratio of green bean powder and PLA 20/80 powder, print speed 2 m/s, laser power 21 W. GBCP composites have the best qualities with tensile strength of 2.89 MPa, flexural strength of 5.91 MPa and impact strength is 0.57 KJ.m².
✓ GBCP synthetic materials are sustainable, environmentally friendly, non-toxic and biodegradable materials at low cost.

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