RAPID PROTOTYPING OF WOOD-BASED MATERIAL

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ABSTRACT

This paper presents initial development of wood-based composites with the aim to develop an alternative material at low cost for rapid prototyping process. Powder blends containing wood powder (90-120μm) with commercial ZP102 as a plaster powder material from ZCorporation were mechanically blended to produce different composition of (vol.%) 25:70, 50:50 and 75:25 respectively. The blended material were successfully processed on 3D printers (Z406) which was used as a rapid prototyping machine to produce three-dimensional components and followed by post-treatment with ZMax solution to improve the mechanical properties. The mechanical properties, dimensional accuracy and surface quality of the build components were evaluated and the results were compared with the unfilled ZP102 material. The result shows that the mechanical properties were improved with the increasing of wood powder content up to 50 vol.%. However, dimensional accuracy and surface quality were decreased as the wood content increased. Further work on powder preparation is required in order to fully realize these performance benefits particularly for surface quality improvement.

KEYWORDS*: Rapid Prototyping, Rapid Manufacturing, Additive Manufacturing and Layer Manufacturing.*

1.0 INTRODUCTION

Rapid Prototyping (RP) technologies are also often referred to as Layer Manufacturing (LM) technologies (Debasish, 2001). Such technologies are also known as Freeform Fabrication (FFF), Solid Freeform Fabrication (SFF) and additive processes (Kruth *et.al*., 1998). A universally agreed terminology for these technologies still does not exist at this point, but the definitions for these technologies can be found in the SME published dictionary (Kruth *et.al*., 1998).

The techniques are all based on the principle of creating three-dimensional components directly from computer aided design (CAD) in two-dimensional profiles on layer-by-layer process without using moulds or tools as used in conventional manufacturing techniques (Kruth *et.al*., 1998; Palm, 2002). To date, the RP processes have been used to produce physical components for various purposes: patterns for prototyping, fit/assembly components and also functional models (Hopkinson, 2003). In fact, some of the rapid prototyping processes are already being used in rapid manufacturing to produce finished components (or at least near finished) for small volume production. Boeing and NASA are examples of industries using layer manufacturing processes for direct fabrication of aircraft and aerospace components (3D Systems, 2005a).

1.1 Rapid Prototyping techniques

There is a variety of RP techniques available today, for example streolithography (SLA), selective laser sintering (SLS), fused deposition modelling (FDM), three-dimensional printing (3DP), and others. The 3DP has an advantage to produce parts from any powder material including polymer-based, metal-based and ceramic-based. The production costs using 3DP also appear to be significantly less than for other RP techniques, particularly when compared with SLS, SLA and FDM process. This makes 3DP have a great future potential for production of prototype and components.

However, the currently available materials and the properties of the 3D printer components are still limited such as ZCast, Starch, Plaster etc. The overall aim of this research is therefore to examine whether wood powder can be used as an alternative raw material in 3DP.

1.2 3D Printing Process

The 3D Printing system, sometimes also called a concept modeller, is a less-costly and less-capable variation of RP technology (Wohlers, 1997). Similar to other RP system, 3D printing also builds parts in a layer by layer process using CAD solid model data. Each layer begins with a thin distribution of powder spread over the surface of a powder bed (Figure 1).

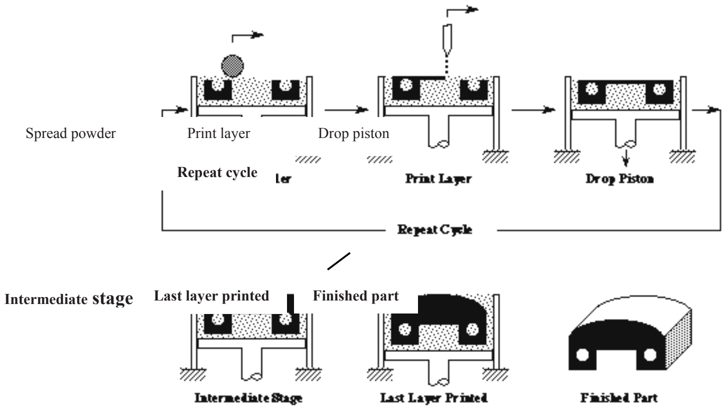


FIGURE 1
Schematic diagram of 3D printing process (WTEC, 1997)

The 3D printing is using a technology similar to ink-jet printing and uses a binder material to selectively join particles on the layer where the object is to be formed. A piston that supports the powder bed and the part-in-progress is lowered so that the next powder layer can be spread and selectively joined. This layer-by-layer process is repeated until the part is completed.

Z Corporation (2009) manufactures the Z series of three-dimensional printing systems, based upon technology originally developed by the Massachusetts Institute of Technology. This process uses a print head with 125 jets to selectively spray drops of binder onto successive layers of powder to create appearance models.

2.0 EXPERIMENTAL EQUIPMENTS AND PROCEDURE

2.1 Preparation of raw material

The 3D printing process uses powder as raw material. Therefore, powder preparation procedure for the process need to be established and must be suitable for the RP process. Different types of wood powders were collected from timber factory at Sindora Timber Sdn. Bhd., located at Bandar Tenggara, Johor, as shown in Figure 2.

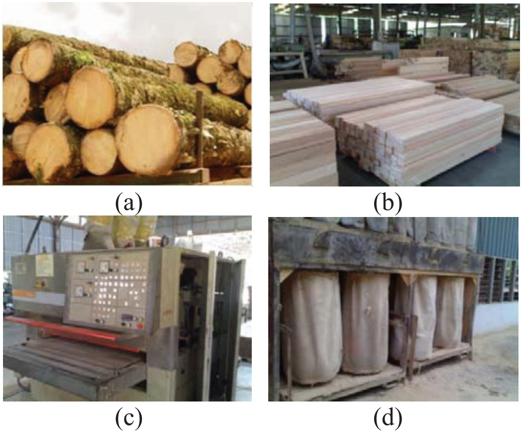
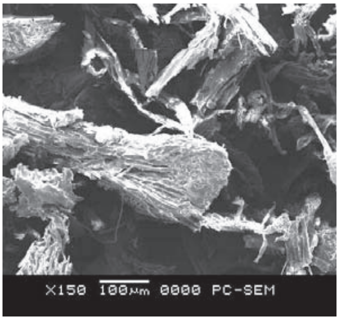


FIGURE 2
Photograph images of (a) Timber block (b) Processed wood (c) Sanding machine (d) Wood powder collector

The powders were taken from powder collector machine produced from sanding machine which is one of the finishing processes in the factory. In general, all wood material in the factory were chemically treated before it can be used for production such as furniture, doors, wood tile act., therefore, the resulting powder from the finishing process can be used directly for RP process.

The wood powders were dried in an oven at 70 °C for 8 hours to reduce moisture content in the powder and then sieved using different sizes of mesh starting from 150µm, 120 µm and finished with 90 µm. Figure 3(b) shows the photograph and SEM images of the final wood powder after sieving process. It can be seen that the powders were irregular in shape and having rough surfaces.

(a)



(b)

FIGURE 3
(a) Photograph images of WP (mean size: 90-120µm) (b) SEM image of WP at 150x magnification

The wood powders were mixed with a commercial ZP102 to make the material more suitable with the existing binder used in the current 3DP machine. Three different composition of wood powder and ZP102 at 25, 50 and 75 (vol.%) were studied. The WD and ZP102 materials were mechanically blended using V shell tumbler device, as shown in Figure 4.

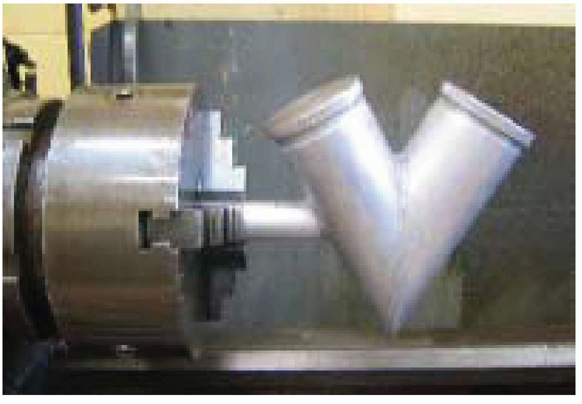
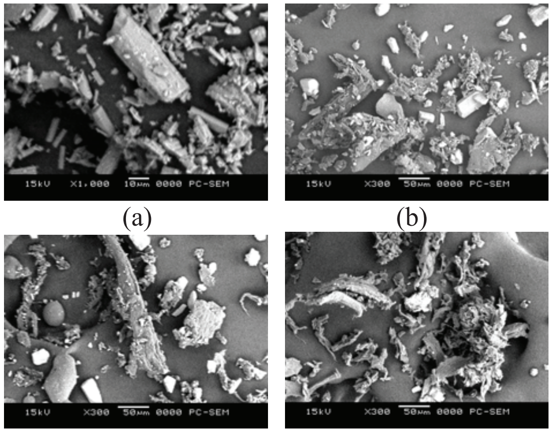


FIGURE 4
V shell tumble device

Figure 5 shows SEM images of the blended materials at different composition. Good dispersion of WD and ZP102 were seen on the blended materials. The ZP102 looks to be dispersed randomly, shown as white contrast in the images.



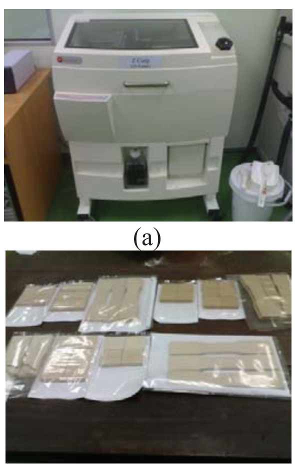
(a) (b)

(c) (d)

FIGURE 5
SEM images of (a) ZP102 (b) ZP102/WP25vol% (c) ZP102/WP50vol%
(c) ZP102/WP75vol%

2.2 3D Printing process

The Z406, a 3D printer machine (Figure 6a) from ZCorporation was used to produced test samples material. By using a default setting parameters, two different types of test samples were fabricated; tensile test specimen (ASTM D1037-72a) and hardness test (ASTM E18), as shown in Figure 6(b). The same samples were used for dimensional accuracy measurement.



(a)

(b)

FIGURE 6
(a) Commercial 3D printing machine (b) 3D components produced for mechanical properties test

3.0 RESULTS AND DISCUSSION

3.1 Mechanical Properties

Tensile testing was carried out using a UTM tensile testing machine to measure the tensile properties of the specimen. The test was carried out at room temperature using 10KN load cell. The loading rate was set at 1mmm/min and the test continued until fracture. Figure 6 shows one of the Force-Stroke graph from the tensile test produced from ZP102/WD (50vol.%) samples.

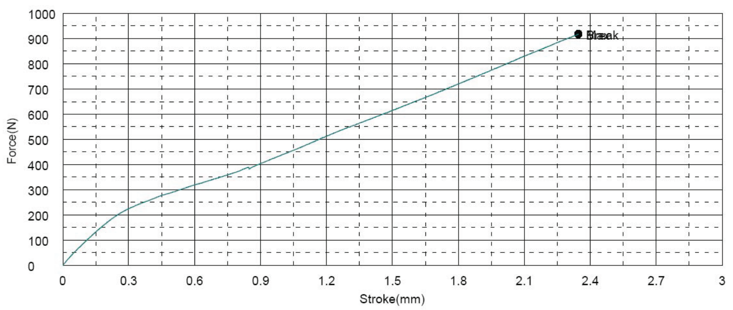


FIGURE 7
Force vs. stroke for ZP102/WP (50vol. %)

Figure 7 shows the maximum stress values for the material at different composition of WD and ZP102. The stress value found to be increased slightly with the increased of WD content. However, its starts decreased after 50vol%. Similar behavior was found to the maximum strain values, as shown in Figure 8.

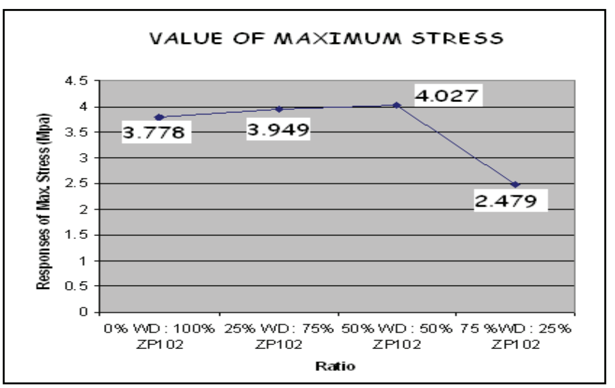


FIGURE 8
Maximum stress at different composition of ZP102/WD materials

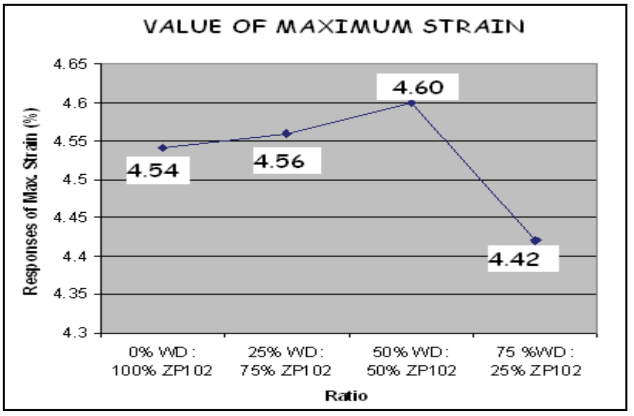


FIGURE 9
Maximum strain at different composition of ZP102/WD materials

3.2 Surface quality

Figure 10 shows the result from the roughness measurement on the top surface of the specimen. The result shows that the addition of WD to the ZP102 was increased the roughness (Ra) value. This was thought to be the result of rough surfaces found in WD powder as compared to ZP102. By increasing the WD powder contents will make the part surfaces mainly dominated by WD powder and therefore will increase the roughness. Slightly reduce in the Ra at 50 and 75wt% were assumed from the effect of post-treatment process.

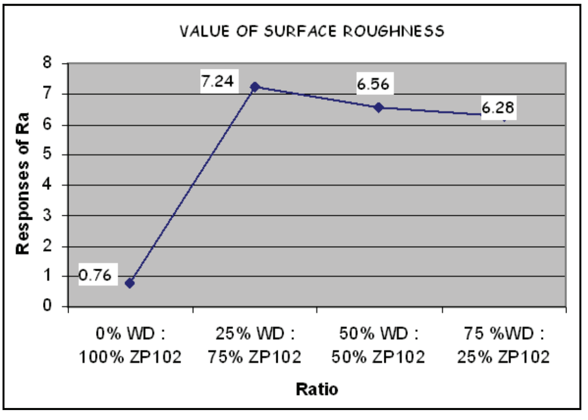


FIGURE 10
Roughness (Ra) at different composition of ZP102/WD materials

3.3 Dimensional accuracy

Figures 11 and 12 have shown the result from the dimensional accuracy measurement of the specimen measured for x (length) and y (width) direction.

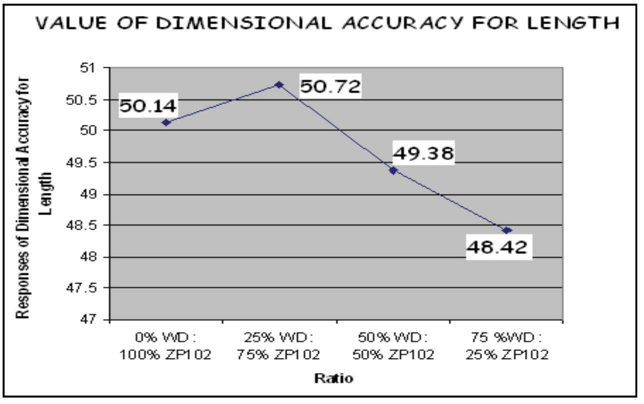


FIGURE 11
Dimensional accuracy (length) at different composition of ZP102/WD materials

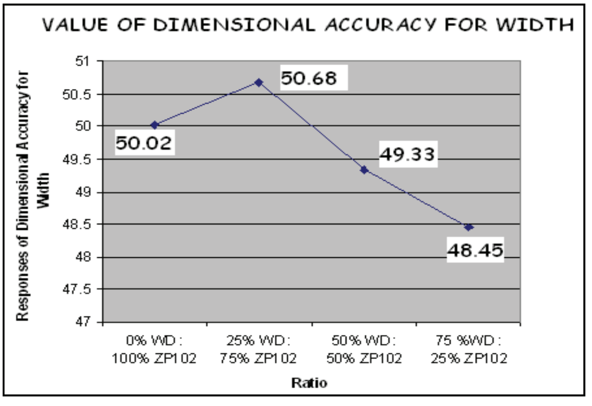


FIGURE 12
Dimensional accuracy (width) at different composition of ZP102/WD materials

The result shows that by increasing the WD powder contents, it reduced the dimension of the specimen up to 4.5%. It was believed from the effect of physical properties of the WD powders where some powders were in the form of fibers instead of solid. After the post-treatment, the samples were reduced in size as the fibers were shrinking during post-treatment process by the resin.

3.4 Hardness

Figure 13 shows the result from the hardness test of the specimen. The addition of WD to the ZP102 were increased the hardness value.

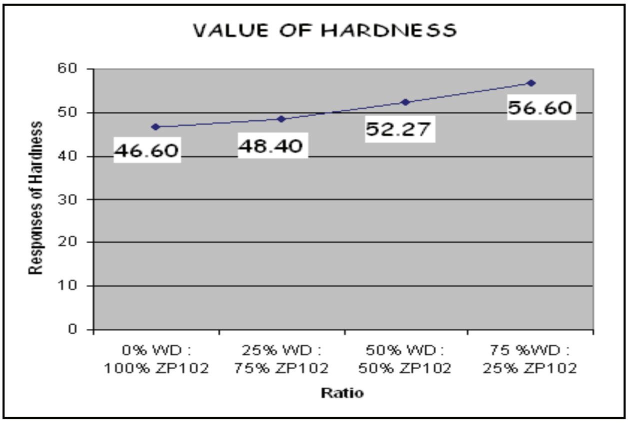


FIGURE 13
Hardness (Shore-D) at different composition of ZP102/WD materials

4.0 CONCLUSION AND RECOMMENDATION FOR FUTURE WORK

The following conclusions were drawn from this study:

1. Wood powders with addition of ZP102 can be successfully processed on 3D printer machine.
2. Composition of WD/ZP102 at 50wt% was found to be the optimum results for strength and elongation.
3. Addition of wood powder in ZP102 will reduce the dimensional accuracy up to 4.5%.
4. Wood powder can improve hardness properties of 3D printer material.

The quality of RP component produced from WD material can be improved by the following recommendation:

1. Surface quality can be improved by having more smooth powder.
2. Dimensional accuracy of the part produced by WD powder can be improved by reducing fibers contents in the powder.
3. The strength and elongation of the component can be changed by changing the post-treatment resin material.

5.0 ACKNOWLEDGEMENT

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