Evaluating the Use of Ball-milling on the Douglas-fir Particles

Xiaxing zhou [a,b], Jinwu Wang [b], and Michael Wolcott [b]

[a] College of Material Engineering, Fujian Agriculture and Forestry University, China [b] Composite Material and Engineering Center, Washington State University, USA

Introduction

Using fine or very fine wood flours to improve processes & enhance product performance have received considerable research attentions in recent years. Size reduction can increase the bulk density of wood flour and influence particle size, distribution, aspect ratio, and morphology. The particle size distribution and the aspect ratio of wood flour are very important property in all applications, such as wood-plastic composites. In addition, vibration milling has been reported to be effective reducing particle size and cellulose crystallinity. For these reasons, milling can also be used as pretreatment for chemical and enzymatic conversion of lignocellulosic materials. In this research, the size reduction of wood flour was obtained by planetary ball milling and Ro-tap screening and the effect of these two methods on the properties of wood flours was comparatively analyzed.

Objective

The objective of the present study is to investigate the influence different ball mill time effects on size, distribution, aspect ratio, thermal stability, crystallinity, and surface morphology of micronized wood flours. These effects are specially evaluated by comparing screened fractions of material ball milled for different time.

Methods

- The Douglas-fir (Pseudotsuga menziesii), (1/32 inch from hammer-milled) was used and sieved using Tyler Ro-tap Test Sieve Shaker with US standard test sieves for 10 min.
- A fractionated 40-50 mesh WP (below 40 and above 50 mesh) with moisture content of 5%, was ball milled for 10, 20, 30, 60 and 90 min.
- 100 small stainless steel ball (diameter of 6 mm), 16 big ball (diameter of 8 mm). 2 jars, with 5 g feed material per jar, at a speed of 600 rpm, and a frequency of 50 Hz.
- Particle size and distribution: (i) sieve analysis (ii) Marlvern Mastersizer 3000 (Median size D50, and the width of particle size distribution $\triangle^*$, $\triangle^* = \frac{D_{90} - D_{10}}{10\mu m}$)
- Aspect ratio analysis: light microscopy & image analysis.
- TG analysis: at a heating rate of 10 ℃/min in a nitrogen atmosphere.
- SEM analysis (FEI Quanta 200F, USA)
- XRD analysis: (Minifex 600,Rigako, Japan) The crystallinity index (CrI) was calculated with Segal method.

FIGURE 1-1 Photo of PQ-N04 planetary ball mill

FIGURE 1-2 Photo of Marlvern Mastersizer 3000

Particle size and distribution

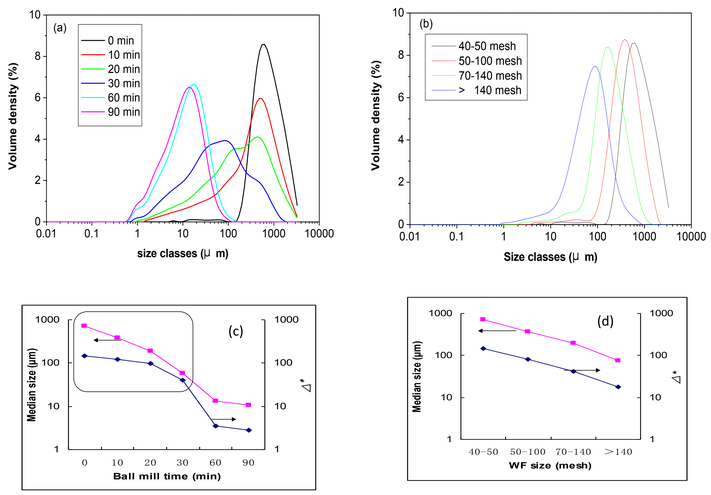

FIGURE 2-1 Effect of ball milling (a, c) and Ro-tap screening (b, d) on the particle size and the width of particle size distribution

Aspect ratio

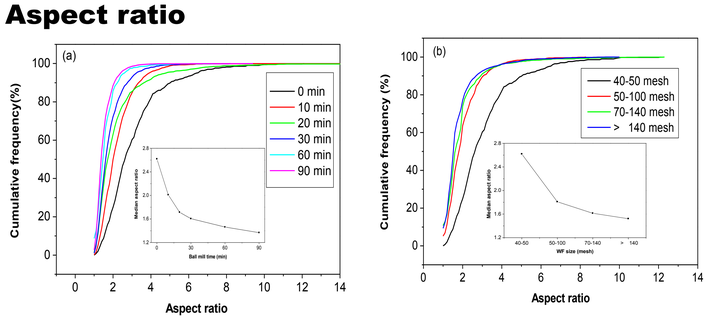

FIGURE 2-2 Effect of ball milling (a) and Ro-tap screening (b) on the cumulative frequency distribution of aspect ratio and median aspect ratio

TG Analysis

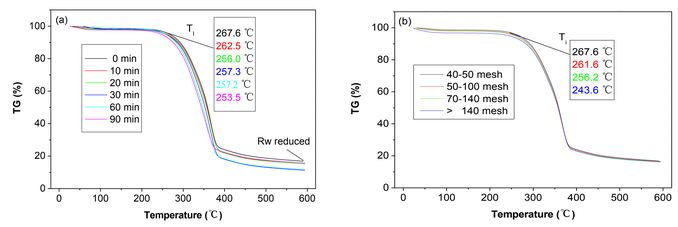

FIGURE 2-3 Effect of ball milling (a) and Ro-tap screening (b) on the thermal stability of Douglas fir particles

XRD Analysis

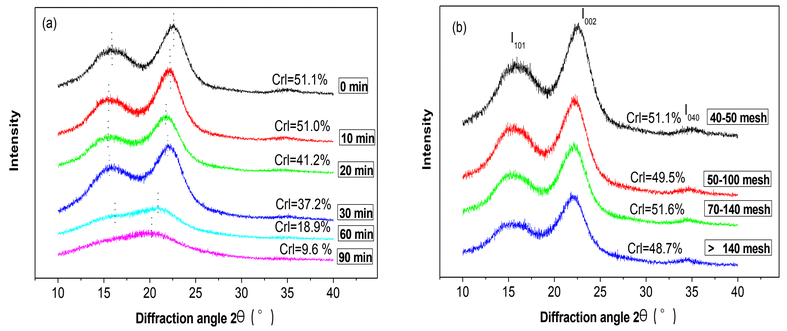

FIGURE 2-4 XRD profiles of wood powders produced from ball milling with different time (a) and Ro-tap screening with different meshes (b)

SEM Analysis

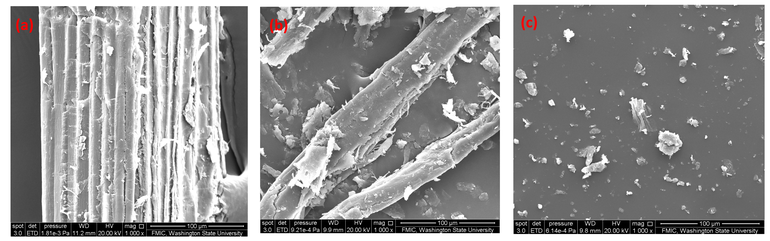

FIGURE 2-5 SEM photos of ball-milled wood particles with different time: (a) 0 min, (b)10 min, and (c) 90 min

Conclusions

- The particle size and aspect ratio of Douglas-fir powders (40-50 mesh) decreased significantly with the increased ball milling time, particularly from 30 to 60 min, and then slightly decreased with further milling time. Longer milling time produced wood powders with a narrower size distribution and a rounder particle shape. The attainable minimum median size was 10.5μm and the median aspect ratio (AR) was 1.368 after 90 min milling. The thermal stability of the fined wood powders reduced. The crystallinity declined obviously after milling for more than 20 min. SEM showed less change of surface morphology in 10 min-milled wood flour and clear destruction of cell structure after 90 min milling.
- The ball-milled wood powders (10, 20, and 30 min) with similar median size were obtained by Ro-tap screening (50-100, 70-140, and ＞140 mesh). Compared to the ball milling, the screening had narrower size distribution, smaller AR, and less influence on crystallinity.

Acknowledge

The authors thank China Scholarship Council sponsor. The authors also thank the LP Wood Materials and Engineering Research Fund. Materials were partially supported by NARA.

NARA
Northwest Advanced Renewables Alliance

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.