

Dynamic Simulation of Disintegration of Wood Chips Caused by Impact and Collisions during the Steam Explosion Pre-Treatment

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Abstract : Wood material is extensively considered as a raw material for the production of bio-polymers, bio-fuels and value-added chemicals. However, the shortcoming in using wood as raw material is that the enzymatic hydrolysis of wood material is difficult because the accessibility of enzymes to hemicelluloses and cellulose is hindered by complex chemical and physical structure of the wood. The steam explosion (SE) pre-treatment improves the digestion of wood material by creating both chemical and physical modifications in wood. In this process, first, wood chips are treated with steam at high pressure and temperature for a certain time in a steam treatment vessel. During this time, the chemical linkages between lignin and polysaccharides are cleaved and stiffness of material decreases. Then the steam discharge valve is rapidly opened and the steam and wood chips exit the vessel at very high speed. These fast moving wood chips collide with each other and with walls of the equipment and disintegrate to small pieces. More damaged and disintegrated wood have larger surface area and increased accessibility to hemicelluloses and cellulose. The energy required for an increase in specific surface area by same value is 70 % more in conventional mechanical technique, i.e. attrition mill as compared to steam explosion process. The mechanism of wood disintegration during the SE pre-treatment is very little studied. In this study, we have simulated collision and impact of wood chips (dimension 20 mm x 20 mm x 4 mm) with each other and with walls of the vessel. The wood chips are simulated as a 3D orthotropic material. Damage and fracture in the wood material have been modelled using 3D Hashin's damage model. This has been accomplished by developing a user-defined subroutine and implementing it in the FE software ABAQUS. The elastic and strength properties used for simulation are of spruce wood at 12% and 30 % moisture content and at 20 and 160 OC because the impacted wood chips are pre-treated with steam at high temperature and pressure. We have simulated several cases to study the effects of elastic and strength properties of wood, velocity of moving chip and orientation of wood chip at the time of impact on the damage in the wood chips. The disintegration patterns captured by simulations are very similar to those observed in experimentally obtained steam exploded wood. Simulation results show that the wood chips moving with higher velocity disintegrate more. Moisture contents and temperature decreases elastic properties and increases damage. Impact and collision in specific directions cause easy disintegration. This model can be used to efficiently design the steam explosion equipment.

Keywords : dynamic simulation, disintegration of wood, impact, steam explosion pretreatment

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