Torrefaction in a pulsed fluidized bed with heat recovery

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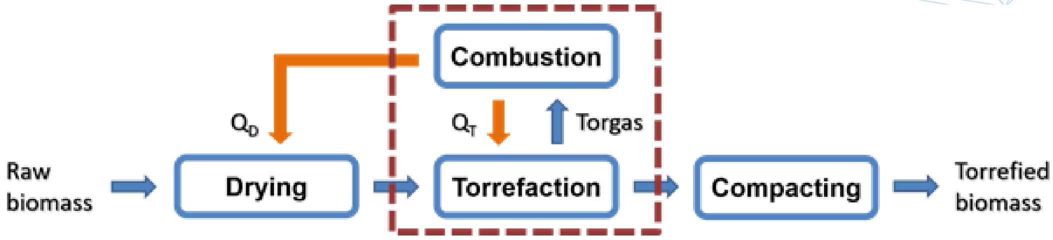

Biomass densification has been used effectively to deliver bulk and widespread biomass to conversion plants. A typical pellet plant consists of biomass drying, grinding, preconditioning, pelleting and pellet cooling operations. The regular biomass pellets suffers the problems of low energy density, emissions of toxic offgases during storage, short shelf life and poor water-resistance, limiting their wide applications in power and metallurgical industries.

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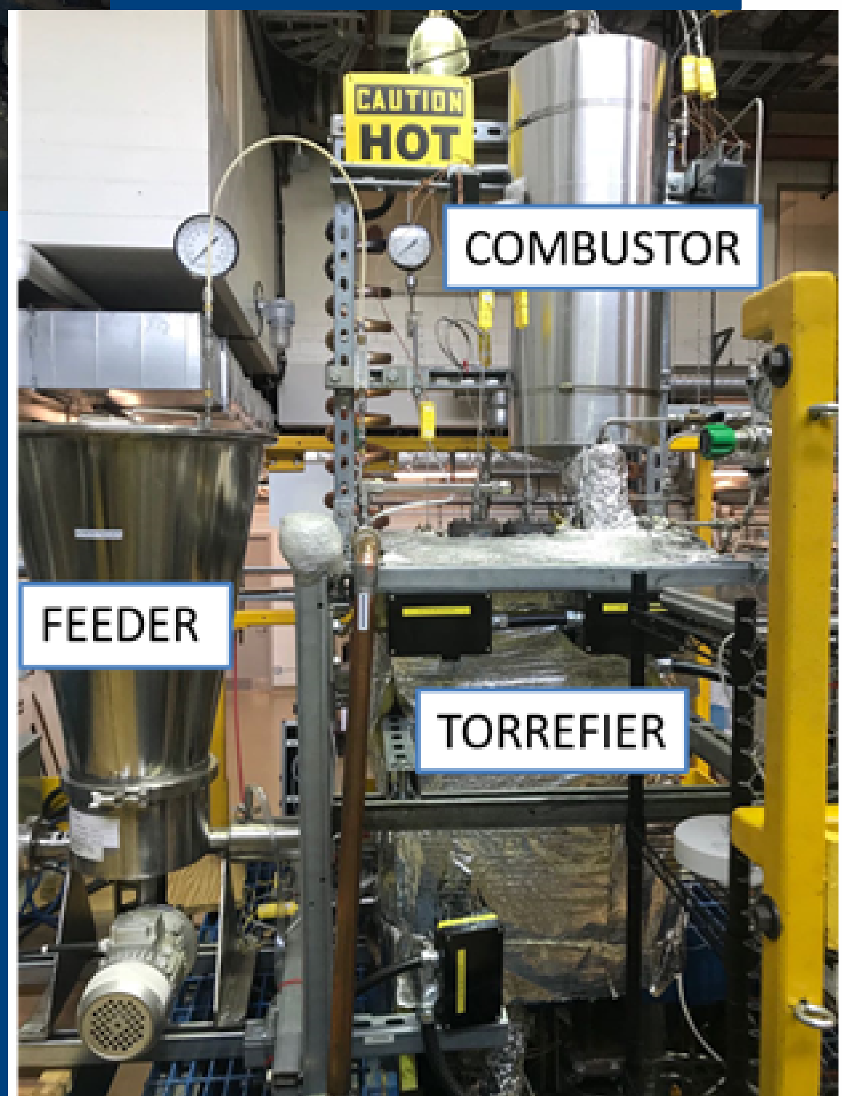
Torrefaction is a very promising approach to make the 2nd generation high quality biomass pellets, called torrefied pellets which are produced by thermally treating the raw biomass at 250 to 300 oC to remove 20 to 30% mass as volatiles before densification. Torrefaction of biomass improves grindability, prolongs durability, increases hydrophobicity and slows biological and thermal degradation, which can improve the shelf life, storage and transportation. Due to its high heating value and hydrophobicity, torrefied pellets have been considered as a premium substitute fuel for existing coal-fired power plants to meet the greenhouse emission reduction targets. As a result, interest in biomass torrefaction has been growing in recent years, especially in Canada where coal use for power generation is to be phased out in the near future.

Most researches have based on using fixed bed, moving bed or rotary type reactors, which are commonly used for drying of solids samples, for torrefaction. Dedicated high-efficiency reactors tailored for torrefaction are still not available. Fluidized beds have been widely used for small particles in the energy conversion field due to their excellent gas-solids heat and mass transfer performance. To take the advantage of fast heat and mass transfer rate of fluidized beds using fine particles, we propose to torrefy biomass in a fluidized bed reactor so as to shorten the reaction time, thus reduce reactor volume, and improve the heating efficiency. However, fluidization of biomass is often complicated by the unconventional nature of biomass particles. In light of the poor flowability and high cohesiveness, phenomena such as channeling, bypassing and defluidization frequently occur in fluidized beds with biomass. Over the past years, we have developed a novel fluidized bed with a pulsed gas flow. Hydrodynamics and biomass drying tests have been conducted in a square fluidized bed to evaluation and optimize the pulsation feature. The results clearly demonstrated the effectiveness of gas pulsation in achieving good fluidization quality of irregular sawdust particles.

The quality of torrefied or pyrolyzed biomass product is also determined by the uniformity of the product, which calls for uniform treatment. In conventional fluidized beds, particles are vigorously mixed, showing a broad distribution of residence time of particles when raw particles are continuously fed into the reactor and continuously discharged out. This will lead to non-uniform quality of product, with some over-reacted and some under-reacted. The uniformity issue is addressed by the design of a horizontal shallow fluidized bed to make particles moving horizontally from the feed side to the discharge side, with low horizontal backmixing.



A small pilot horizontal pulsed fluidized bed reactor has been developed for continuous sawdust torrefaction at a biomass feed rate of 2-5 kg/hr. A fixed bed catalytic reactor was included to combust the volatiles released from the torrefaction reaction. Effects of operating conditions on solid mixing and torrefied sawdust properties were also investigated.