Direct Fluidized Bed Gasification

In fluidized bed gasifiers the reaction space contains a sand-like bed material that is fluidized (the sand is lifted by the gas stream and gets a liquid appearance) or entrained by the oxidant gas (air or oxygen), steam, or mixtures thereof being added in the bottom. Autothermal (i.e., direct) gasifiers use an oxidant, and allothermal (i.e., indirect) gasifiers use steam without an oxidant being fed to the gasifier section.

The feedstock for fluidized bed gasifiers can be very broad, but it is undesirable to have too many small fuel particles. In the case of a stationary (or bubbling) fluidized bed, the bed material is kept suspended by the gas in a defined bed volume through which gas in the form of interstitial gas and bubbles pass. Above the bed there is a freeboard section used for disengagement of particles, mainly ejected by bubbles erupting on the bed surface.

In a circulating fluidized bed, the gas velocity is higher than for a stationary (bubbling) bed and the bed material is carried up in the gasifier shaft by the gas. Some of this material moves radially to the wall and is transported back to the bottom by gravity as part of a wall layer sliding down. The remainder of the solid-gas suspension is carried out by the gas to an external primary particulate separator, typically a cyclone, from which it is returned to the bottom of the gasifier by means of a recycle line with a moving bed of solids. The effect is a huge net circulation rate between the bottom and top of the reactor.

The vigorous movement of the bed material in combination with the large circulation of bed materials gives a high internal heat transfer rate that assists in maintaining an even temperature in the entire bed. This avoids hot spots, thereby avoiding or restricting agglomeration. The temperature is in the range of 750°–950°C and is limited by ash melting properties.

Even if the feedstock is fed into a hot environment, the temperature is not enough to completely decompose tars. The raw product gas typically contains tar in a magnitude of 5–20 g/Nm^3.

Direct fluidized beds can be built at large scale. The largest biomass gasifier in operation at atmospheric pressure in Vaasa, Finland, has a capacity of 140 MW$_t$. They can also be pressurized up to 1–3 MPa to further increase the single-vessel capacity.

Indirect Fluidized Bed Gasification

Allothermal, or indirect fluidized beds (i.e., that use a gasifier-combustor combination) can have different combinations of fluidization types in the two beds, such as two stationary fluidized bed reactors, one stationary fluidized bed gasifier and one circulating bed combustor, one circulating fluidized bed gasifier and one stationary bed combustor, or two circulating fluidized beds. Indirect double fluidized beds function in the same way as a fluidized bed. The main difference is that there is no oxidant; instead, steam is typically added to the gasifier. The energy required is provided by hot sand bed material being transferred at a high rate from the second combustor bed.

After releasing heat in the gasifier, the sand is returned to the combustor from the bottom of the gasifier, where entrained carbonaceous char material from the gasifier and other fuels are combusted with air to generate the temperature required to reheat the massive flow of sand. Since the combustor is subjected to the same limitations on operating temperature as other fluidized beds to avoid agglomeration, the gasifier is operated at slightly lower temperature compared to when air or oxygen is used directly, to have a temperature difference that matches the sand flow. Therefore, the tar content is of the same magnitude or slightly higher than for a direct fluidized bed. The heated sand is returned to the gasifier via a bed overflow in the case of a stationary fluidized bed combustor, or via the primary separator for circulating fluidized beds.

The need for a close-coupled circulation loop in practice restricts the capacity of such reactors from layout limitations to somewhere above 50 MW_t. Due to the small pressure differential between the two reactors, pressurizing such units becomes very challenging. The main advantage of these systems is that a medium calorific value gas can be produced without recourse to the use of oxygen.

Other forms of indirect fluidized bed gasifiers use indirect heat transfer into the bed via heat exchanger tube bundles immersed in the bed using flue gases from combustion of part of the product gas outside of the gasifier section, or so-called heat pipes immersed in the bed that work as an intermediate heat transfer unit.

The advantages of indirect gasifiers relate to those for synthesis gas—i.e., a medium calorific heating value gas can be produced without the use of pure oxygen, and total conversion of the fuel can be achieved for some designs.