BIOCHAR GASIFICATION WITH STEAM AND CARBON DIOXIDE: A REVIEW

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Abstract: The review systematizes experimental and theoretical studies on low- (below 1000 °C) and high-temperature (above 1200 °C) allothermal noncatalytic gasification of biomass-derived chars (biochars) in an atmosphere of superheated steam and/or carbon dioxide at atmospheric pressure. The paper addresses key laboratory research methods, including thermogravimetric analysis and the use of an innovative pulse-detonation steam superheater as well as core kinetic and spatial models of the process. It is shown that low-temperature gasification is rate-limited by chemical reactions, resulting in a low off-gas (OG) yield, high tar formation, and elevated CO_2 content. Conversely, high-temperature steam–carbon dioxide gasification ensures a high yield of high-quality OG, high carbon conversion efficiency (CCE), and simplified control over the gas composition without harmful environmental emissions. A comparison with pyrolysis under identical conditions confirms that gasification yields significantly higher CCE and OG output.

Keywords: biochar; pyrolysis; low-temperature gasification; high-temperature gasification; gasification agent; steam; carbon dioxide; carbon conversion efficiency; producer gas

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Figure Captions

Figure 1 Calculated changes in biochar particle morphology during carbon dioxide gasification obtained using a three-dimensional model with spatially resolved pores [38]: first row — initial porosity and pore size distribution, $\varepsilon_0 = 0.7$ (monodisperse); second row — $\varepsilon_0 = 0.3$ (polydisperse); third row — scanning electron microscopy images of wood biochar obtained at different carbon dioxide gasification temperatures [39]; and fourth row — calculated time evolution of the porosity field within a biochar particle during gasification in a steam–nitrogen mixture flow (gas moves from left to right) [40])

Figure 2 Schematic of a low-temperature allothermal gasifier reactor (GR) with an electrical heater for biochar gasification.

Figure 3 Schematic of a high-temperature GR with a plasma gun [64]

Figure 4 Calculated biochar conversion rate (*a*) and temperature (*b*) fields obtained using two gasification models: volumetric and surface models [69]

Figure 5 Dynamics of OG composition and average gasification temperature for three consecutive wood pellet injections [73]

Figure 6 Schematic (*a*) and demonstrator (*b*) of a high-temperature GR with a Y-shaped pulsed detonation gun (PDG)

Figure 7 Consecutive photographs of coal-water slurry (CWS) jet breakup in a shock wave emerging from the PDG, accompanied by rapid water evaporation and fragmentation of coal particle agglomerates (*a*) and self-luminescence of detonation products and coal particles formed after the CWS jet breakup in the PDG (*b*)

Table Caption

Main overall heterogeneous and homogeneous chemical reactions in the biochar gasification process

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