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Simulation of a novel reactor for plasma pyrolysis of hydrocarbons to prepare nano-carbon materials

Jianqiao Li, Xianhui Chen@, Weidong Xia@
Department of Thermal Science and Energy Engineering, University of Science and Technology
e-mail: lijq6@mail.ustc.edu.cn;
Corresponding author: chenxian@mail.ustc.edu.cn;xiawd@ustc.edu.cn

Abstract:

In this paper, a novel plasma reactor for pyrolysis of hydrocarbons to prepare carbon nanomaterials is designed. In order to build a large-area uniform high-temperature reaction zone, four-corner and six-corner tangential circle structures are adopted to enhance heat and mass transfer between high-temperature plasma gas and hydrocarbon gas. It also can improve the uniformity of product. Computational fluid dynamics (CFD) is applied to simulate the internal temperature, flow and concentration field of the reactor. Meanwhile, the chemical reaction process is neglected. For evaluating mixing efficiency of reactor, the effects of tangential circle diameter, inlet diameter of raw material jet and horizontal angle of plasma torch were studied. We define the swirl number (Sg), i.e., the ratio of the tangential momentum moment of the swirl to the axial momentum moment, to characterize the flow state. The mixing inhomogeneity is used to characterize mixing efficiency which is the difference of plasma gas mass fraction mixing between ideal and actual.

Results of the simulation show that the mixing efficiency of the four-corner and six-corner tangential circle structure has the same tendency for the dependence of different parameters. It was found that ,increasing the diameter of tangential circle leads to the increase of cross-section Sg. Meanwhile the increase of Sg indicates that the ability of the central jet to entrain the lateral fluid becomes stronger, which leads to stronger heat transfer and mass transfer. For the inlet diameter of the raw material jet (diameter 20-80 mm), the penetration depth of jet is directly affected. The low momentum flux of the raw material jet under the large diameter of the jet inlet makes the jet penetration depth not deep enough to mix with the high temperature region of the plasma. The high momentum flux of raw material jet with too small jet inlet diameter cause the jet penetrate deep through the high temperature region of plasma, which lead to short contact time and insufficient mixing between raw materials and plasma gas. We gets the optimized inlet diameter is 40mm, the momentum flux ratio of raw material jet to plasma gas is exactly 1, and the mixing effect is the best. As the angle between the torch and the horizontal plane increases, the axial momentum moment raises and the tangential momentum moment decreases. The tangential circle cross-section Sg abates, and the ability of the hot fluid to entrain the cold fluid gets weak, resulting in worse heat transfer and mass transfer effect. Under the same conditions, the six-corner tangential structure has greater Sg than the four-corner tangential structure, and the hot fluid entrainment is strengthened, and the mixing effect is superior, which can provide a more uniform high temperature reaction zone.

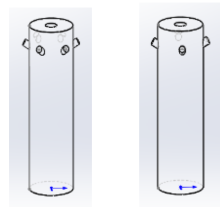

Figure1 Geometric structure of tangential circle mixing plasma reactor
(a) Four-corner tangential circle mixing plasma reactor
(b) Six-corner tangential circle mixing plasma reactor

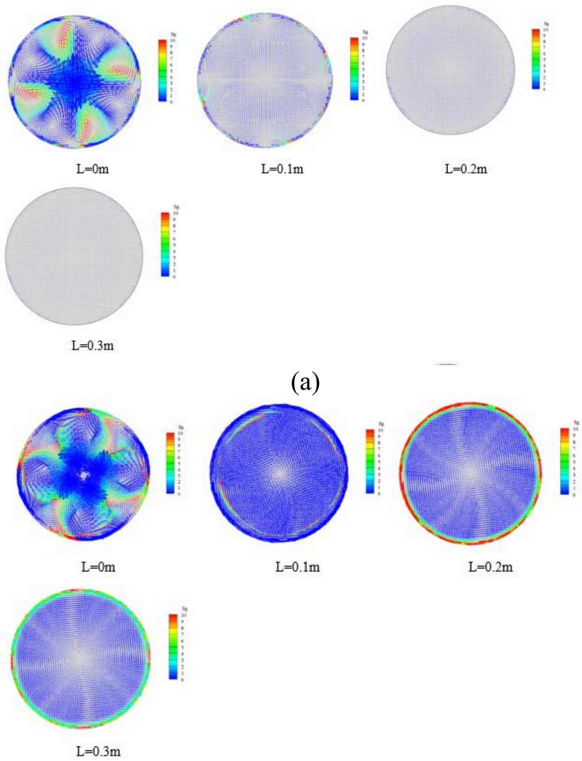

Figure2 Swirl vector on different mixing distance cross-sections
a) Tangential circle diameter 0mm
b) Tangential circle diameter 20mm

References

[1] Schuhbauer C , Angerer M , Spliethoff H , et al. Coupled simulation of a tangentially hard coal fired 700° C boiler[J]. Fuel, 2014, 122:149-163.

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Note: Abstract should be in 1 page