Simulating particle–wall micromechanical interaction in entrained-flow slagging gasifiers by cold impact experiments

M. Troiano[1], L. Pirro[1], R. Solimene[2], F. Montagnaro[3] and P. Salatino[1]

1. Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione Industriale, Università degli Studi di Napoli Federico II, Piazzale Vincenzo Tecchio 80, 80125 Napoli (Italy)
2. Istituto di Ricerche sulla Combustione, Consiglio Nazionale delle Ricerche, Piazzale Vincenzo Tecchio 80, 80125 Napoli (Italy)
3. Dipartimento di Scienze Chimiche, Università degli Studi di Napoli Federico II, Complesso Universitario di Monte Sant'Angelo, 80126 Napoli (Italy)

Abstract:

This paper deals with particle–wall interaction phenomena in entrained-flow slagging coal gasifiers. Different micromechanical char–slag interaction patterns may establish, depending on the stickiness of the wall layer and of the impinging char particle. Micromechanical interaction patterns were studied by means of an appropriate experimental apparatus which permitted to record a single particle/droplet impact on a flat surface. Montan wax was used to simulate, at nearly ambient temperature, the char–slag rebound characteristics upon colliding the wall. Particle–wall collision was described in terms of the particle restitution coefficient. In particular, the influence of the particle temperature and the impact angle as well as the impact velocity and the target surface on the rebound characteristics was studied. Results highlighted that the particle restitution coefficient decreased when enhancing operating conditions (temperature and impact velocity) able to promote plastic deformation upon particle impact.

1. Introduction:

Understanding the phenomenology and proper design of slagging entrained-flow gasifiers requires the assessment of the fate of char particles as they impinge on the wall slag layer. The relative importance of coal conversion associated with the entrained-flow of carbon particles in a lean-dispersed phase and the segregated flow of char particles in a near-wall dense-dispersed phase has been recently studied [1–8]. Troiano et al. [9] designed and set up a lab-scale cold entrained-flow reactor where wax was air-atomized into an air mainstream to investigate the interaction of droplets/particles with the near-wall layer. Montan wax was used to simulate, at nearly ambient temperature, the char–slag rebound characteristics upon colliding the wall.

2. Concept and methodology:

This study aims at improving the mechanistic understanding of near-wall phenomenology in particle-laden flows, crucial in CFD models to simulate entrained-flow gasifiers. Collisions of wax droplets/particles on a target are studied by an ad hoc designed experimental rig (Fig.1) simulating near-wall particle micromechanical interactions in entrained-flow gasifiers. Rebound characteristics are evaluated by a restitution coefficient ε, i.e. the ratio between the rebound and the impact velocities, or by a capture efficiency. The particle capture efficiency results reported as a function of temperature in Fig.2 and compared with the experimental results by Li et al. [10] in coal gasification tests show that the solid/liquid wax transition well simulates the char/slag transition. Figures 3 and 4 report the restitution coefficients as a function of temperature and of impact velocity, respectively. The normal coefficient of restitution shown in Fig.4 is in good agreement with theoretical results obtained by Thornton and Ning [11] for adhesive plastic particle impacts: plastic deformations occur and, as a consequence, the restitution coefficient is less than unity.

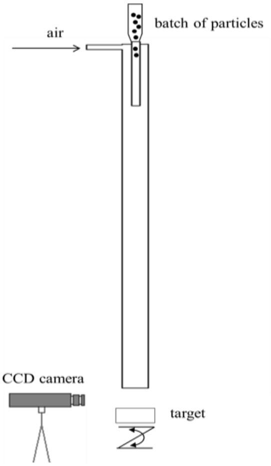

Fig.1: Experimental apparatus.

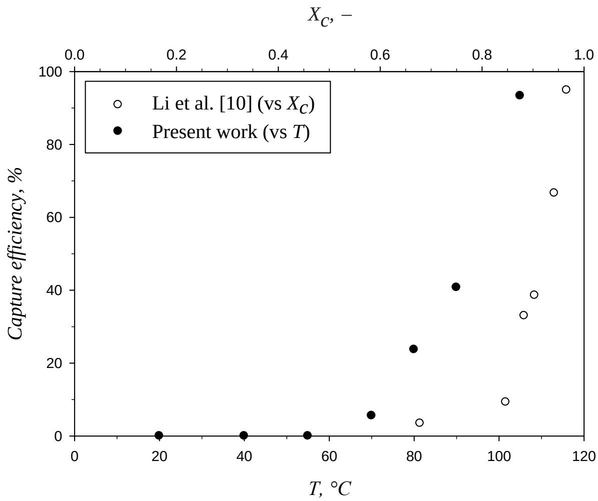

Fig.2: Effect of particle temperature (present work) and coal conversion (Li et al. [10]) on the capture efficiency.

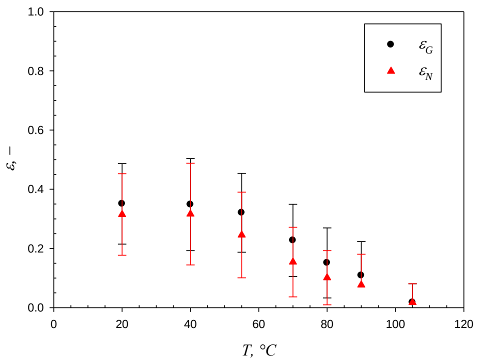

Fig.4: Effect of particle temperature on global and normal restitution coefficients.

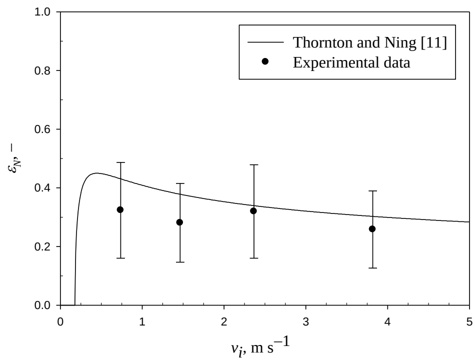

Fig.3: Effect of impact velocity on the normal restitution coefficient.

3. References

[1] T. Shimizu and H. Tominaga, Fuel. **85** (2006) p170
[2] J. Ni et al., Energy Fuels. **25** (2011) p1004
[3] G.N. Shannon et al., Fuel Process. Technol. **89** (2008) p1379
[4] L. Chen et al., Fuel. **113** (2013) p357
[5] F. Montagnaro and P. Salatino, Combust. Flame. **157** (2010) p874
[6] F. Montagnaro et al., Energy Fuels. **25** (2011) p3671
[7] F. Ambrosino et al., Combust. Sci. Technol. **184** (2012) p871
[8] F. Ambrosino et al., Fuel. **114** (2013) p44
[9] M. Troiano et al., Fuel. **117** (2014) p1267
[10] S. Li et al., Energy Fuels. **24** (2010) p1868
[11] C. Thornton and Z. Ning, Powder Technol. **99** (1998) p154