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MATHEMATICAL MODELLING OF THE FIXED-BED BIOMASS-COAL CO-GASIFICATION PROCESS

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Abstract. The paper considers mathematical modelling of downdraft fixed-bed gasification process of the mixtures of woody biomass and coal. Biomass/coal ratio, biomass moisture content and air equivalence ratio are varying parameters. Boundaries of the efficient gasification regimes are estimated.

1 Introduction

Biomass (at first as forest products and agricultural wastes) has significant potential as a source for energy production [1]. However, energy use of biomass faces some technical difficulties: biomass combustion is usually not enough efficient and reliable process. Concerning this, other approaches in biomass conversion are developed, including co-conversion of biomass and coal.

There are different ways of thermochemical conversion besides combustion. Gasification is one of possible alternative technologies: it is conversion of solid fuel into product gas containing CO and H_2. The gas has better combustion characteristics and could be used in heat and electricity production [2, 3]. Co-gasification may have following advantages: providing stable thermal regimes for moist biomass gasification, and increasing of fuel mixture reactivity by biomass addition.

Presented work is devoted to investigation of the fixed-bed woody biomass and coal co-gasification process efficiency under co-current fuel and air flows condition (downdraft gasification process).

2 Model input parameters

Reactor concerned in model is vertical cylinder tube with following sizes: bed height is 0.5 m; bed diameter is 8 cm. Mean particle sizes: 5 mm for coal and 10 mm for biomass. Fuel feed rate changes from 1 kg/h (for coal only) to 2 kg/h (for biomass only). Main model variables are biomass mass portion in feed (0-100 %), air equivalence ratio (0.25-0.8) and initial biomass moisture content (10-40 %). Efficiency criteria are cold gas efficiency (the

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degree of solid fuel heating value into gas heating value conversion) and fuel conversion degree (average for biomass-coal mixture).

Mathematical model developed in previous works [4, 5] was used, added by main features of co-gasification process (particles sizes difference and fuel reactivity). Mixtures of Azeysk brown coal and woody biomass are considered (fuels characteristics are listed in table). It is supposed that fuel reactivities in mixture do not change compared with individual fuel reactivities.

Table 1. Properties of coal and biomass.

% mass	W^r	A^d	C^{daf}	H^{daf}	O^{daf}	$(N+S)^{daf}$	V^{daf}
Coal	10	17	76.4	5.3	16.3	2.0	44
Biomass	10-40	1	47.2	5.7	47.0	0.1	85

3 Modelling results

Calculation results are presented at figs. 1 and 2. It is possible to estimate limits of biomass-coal mixture efficient conversion regimes area. In all cases maximum cold gas efficiency is reached at boundaries of parameters area. If initial biomass moisture content is 10 % or 20 %, efficient conversion of biomass without coal is possible. If moisture content is more than 20 %, it is necessary to maintain high air ratios to achieve high fuel conversion degree that leads to low cold gas efficiency.

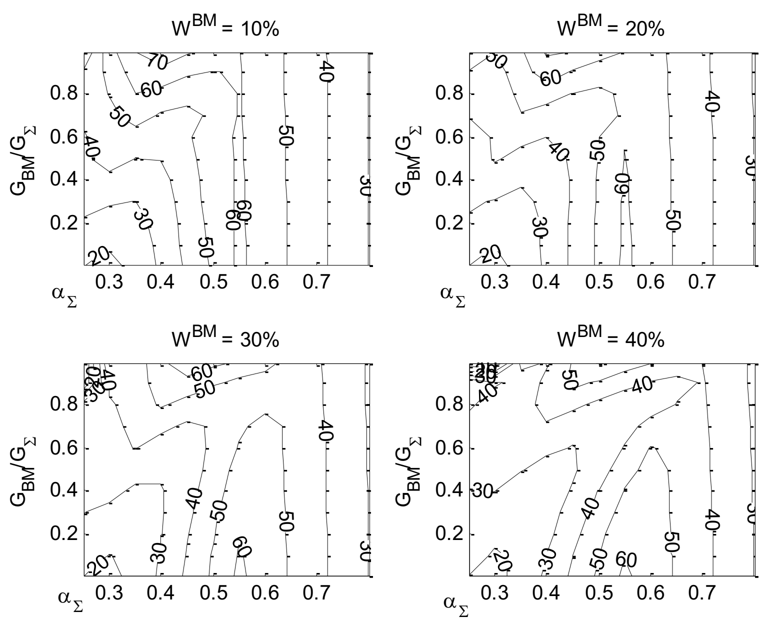

Fig. 1. Cold gas efficiency dependence on air ratio (α_Σ), biomass mass fraction (G_{BM}/G_Σ) and its initial moisture (W^{BM}).

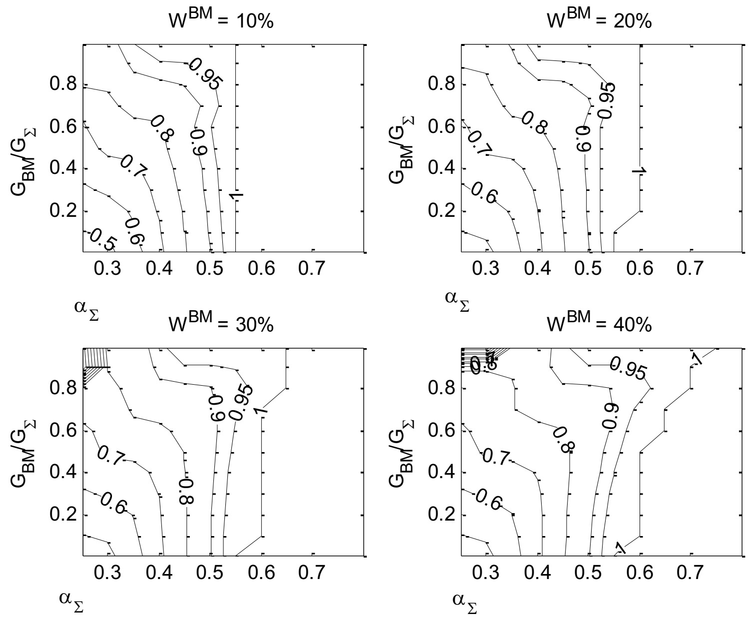

Fig. 2. Average fuel conversion degree dependence on air ratio (α_Σ), biomass mass fraction (G_{BM}/G_Σ) and its initial moisture (W^{BM}).

Lower limit of cold gas efficiency may be fixed at 60 % (allowable value in comparison with existing low-capacity gasifiers [6]). Then reasonable biomass fraction in fuels mixture will naturally decrease with moisture content: it is 50 % at 20 % of moisture in raw biomass; 15 % at 30 % moisture in raw biomass; and less than 5 % at 40 % of moisture in raw biomass.

Future work could be directed to investigation of efficient methods of heat recirculation for moist fuels gasification. Using this, it is possible to push boundaries of efficient biomass-coal co-gasification regimes.

This work considers thermal interaction of fuels in mixture only (e.g. by heat of chemical reactions). However, chemical interactions are possible that lead to changes in fuel reactivities. Development of mathematical models taking into account these features could be an object of future research.

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