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RDF (50% SEWAGE SLUDGE, 50% PLASTICS) GASIFICATION PROCESS ANALYSIS

ANALÝZA PROCESU ZPLYŇOVÁNÍ ALTERNATIVNÍHO PALIVA (50% ODPAD, 50% PLASTY)

Abstract

The paper presents analysis of alternative fuel gasification with use of flue gas as a gasifying agent. As a result of a process syngas with combustible components (CO, H2, CH4, CnHm) was obtained. Laboratory tests were carried out to determine usability of selected alternative fuel to low-temperature gasification process. Tests were conducted in a laboratory reactor allowing to gasify a fuel sample of appx. 1 g. The experimental stand enables recording of a sample weight loss and syngas composition. The process takes place for fuel samples of a constant weight and different granulation and with a set composition of flue gas used as a gasifying agent. The aim of the laboratory research was to determine the usability of RDF fuel for indirect co-firing in power boilers and to build a knowledge base for industrial-size process by defining the process parameters: kinetics (time for fuel to remain in the reactor), recommended fuel granulation and process temperature.

Abstract

Článek prezentuje analýzu zplyňování alternativního paliva s využitím spalin jako zplyňovacího prostředku. Jako výsledek zplyńovacího procesu “syngas” byly definovány hořlavé složky (CO, H2, CH4, CnHm). Byly provedeny laboratorní testy pro určení použitelnosti vybraného alternativního paliva pro proces zplyňování při nízkých teplotách. Testy byly prováděny v laboratorním reaktoru, který umožnil zplyňovat vzorek paliva o hmotnosti cca. 1 g. Experimentální zařízení umožňuje zaznamenat úbytek hmotnosti vzorku a jeho složení. Proces probíhá u vzorků paliva s konstantní hmotností a s různou granulometrii a se stanoveným složením spalin použitým jako zplyňovací medium. Cílem laboratorního výzkumu bylo zjistit použitelnost paliva RDF pro nepřímé spolu-spalování v energetických kotlích a vytvořit znalostní základnu pro reálný průmyslový proces definováním parametrů procesu: kinetiky (doby setrvání paliva v reaktoru), doporučená granulometrie paliva a teploty procesu.

Keywords

alternative fuels, sewage sludge, gasification.

1 INTRODUCTION

Waste and alternative fuels can be characterized by an increased share of elements, such as S, Cl, K, Na, Hg and P and considerable non-homogeneity. Comparing with conventional feedstock their temperature characteristics for ash transformations are much lower. All this features make these

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fuels unattractive. Their direct co-firing in power boilers is related to numerous difficulties, from problems in stoking systems to the increased contamination of heated surfaces and their corrosion [1]. These problems may be avoided by running an installation for indirect co-firing of alternative fuels. Proposed in-direct combustion method assumes low-temperature gasification in an external reactor. As a gasifying agent flue gases from a power boiler can be used. Final combustible gas (syngas) is recirculated to the combustion chamber of the boiler. The idea of industrial-size rotary gasification unit is discussed with details in [2]. To the best of the author's knowledge there is very limited data referring to gasification with use of flue gases as a gasifying agent. Following paper presents a laboratory tests on low-temperature gasification of RDF fuel. Main aim of presented research is to assess the possibility of use of RDF fuel for this kind of in-direct co-firing in power boilers. This kind of syngas not only can be combusted in power boilers but can be also used for production of liquid or gaseous fuels by further processing [3].

2 FUEL CHARACTERISTIC

Alternative fuel with composition of 50% of sewage sludge and 50% of plastic waste was selected for gasification tests. Fuel characteristic is presented in Table 1.

Tab. 1 Fuel characteristic

	Symbol	Unit	Value
Moisture	M^{ar}	[%]	13,34 (+20% water addition)
Lower heating value	LHV	[MJ/kg]	19,85
Higher heating value	HHV	[MJ/kg]	21,67
Chlorine content	Cl^{ar}	[%]	0,28
Sulfur content	S^{ar}	[%]	0,80
Bulk density		[kg/m^3]	298
Ash	A^{ar}	[%]	23,50
Fixed carbon	FC^{ar}	[%]	76,50
Volatile matter	V^{ar}	[%]	10,30

Fig. 1 RDF fuel as received (left) and after grinding (right)

One of aims of presented study was to determine an influence of fuel granulation for the kinetics of gasification process. RDF fuel was tested in two granulation states: as received and ground (Fig. 1). Before and after grinding the sieve analysis was conducted to determine the particle size distribution.

Tab. 2 RDF fuel sieve analysis

Sieve mesh diameter [mm]	As received (before grinding)		Ground (after grinding)	
	Fuel residue [g]	Fuel resiue [%]	Fuel residue [g]	Fuel residue [%]
3mm	19,931	28,190	X	X
2mm	19,852	28,078	X	X
1mm	17,196	24,322	4,368	6,546
0,6mm	6,532	9,239	9,319	13,967
0,3mm	3,988	5,641	18,08	27,097
≤0,3mm	3,025	4,279	34,456	51,640
	$\sum 70{,}702$	$\sum 100$	$\sum 66{,}723$	$\sum 100$

3 MEASUREMENT

Alternative fuel witch characteristic presented in Table 1 was tested in 3 states:

- As received (fuel sieve analysis presented in Table 2)
- Ground (fuel sieve analysis presented in Table 2)
- As received with moisture addition (composition presented in Table 1 with 20% water addition)

As a gasifying agent a mixture of gases was used. Nitrogen and carbon dioxide from gas tanks were mixed together to imitate the composition of typical flue gases (dry, 0% O_{2}). The process occurred in 4 temperature levels: 550, 650, 750 and 850°C for fuel samples of 1 g.

Experimental stand presented in Figure 2 allows online measurements and recording trends of temperature , mass loss and composition of process gas.

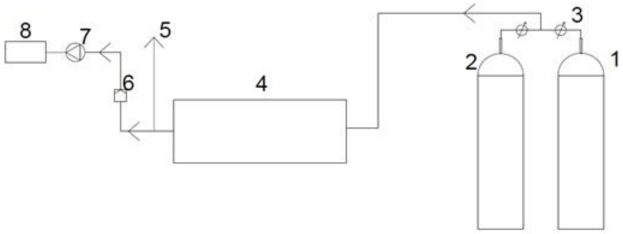


Fig. 2 Experimental setup scheme (1,2-nitrogen and carbon dioxide tanks, 3-gas flow meters, 4-horizontal tube furnance, 5-weight loss measurement, 6-set of filters, 7-gas pump, 8-gas analyzer)

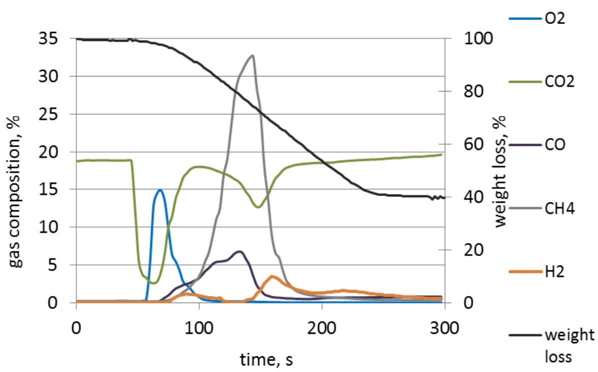
4 RESULTS

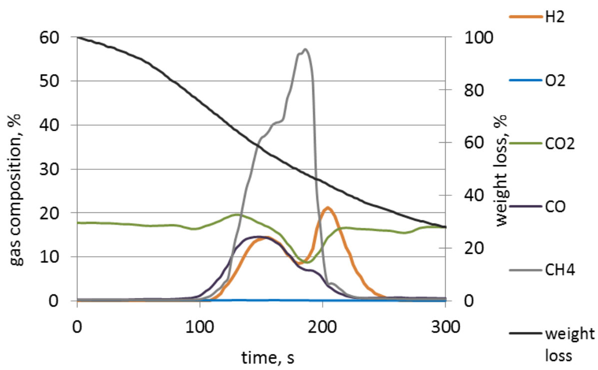
As a result of gasification process a syngas with combustible components was obtained. To determine the kinetics of the process a time constant value (T) was used. In field of process dynamics time constant is defined as a time of reaching 63% of conversion. 4T is defined as a time of full conversion (in inertial model process). 4T is assumed as a recommended time for gasification process in industrial-size reactor. Maximum concentrations of combustible components in syngas (max CO, max CH4. max H2, max CnHm) time constant (T) and recommended time of gasification process (4T) for 3 states of fuel: As received, ground and humid are presented in Table 3 and graphically (Fig 4-7). Gas composition and weight loss for RDF fuel gasification in 750°C are presented in Fig 3a-c.

Tab. 3 Maximum concentrations of combustible components in syngas (max CO, max CH4. max H2, max CnHm) time constant (T) and recommended time of gasification process (4T) for 3 states of fuel: As received, ground and humid

Temp [°C]	**max CO [%]**	**max CH_4 [%]**	**max H_2 [%]**	**max C_nH_m [ppm]**	**T [s]**	**4T [s]**
As received						

550	1,48	2,83	0,32	769	X	X
650	6,12	13,94	0,68	2281	300	1200
750	6,77	32,68	3,48	3852	218	872
850	8,06	22,55	4,97	2352	136	544
Ground						
550	0,97	1,07	0,44	116	X	X
650	3,95	23,34	5,32	879	282	1128
750	14,56	57,26	21,26	6429	188	752
850	13,84	52,77	17,79	5156	132	528
Humid						
550	1,31	1,62	0,1	169	X	X
650	1,14	4,28	2,45	394	308	1254
750	5,5	28,84	6,67	3321	230	990
850	8,15	29,94	8,67	4350	140	518





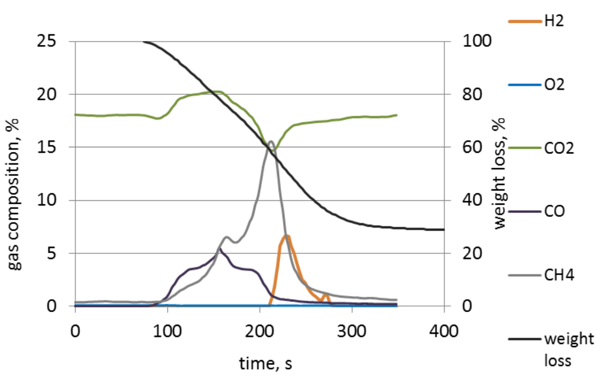


Fig. 3a-c. Gas composition and weight loss for RDF fuel gasification in 750°C for fuel in 3 states: As received (a), ground (b) and with water addition (c)

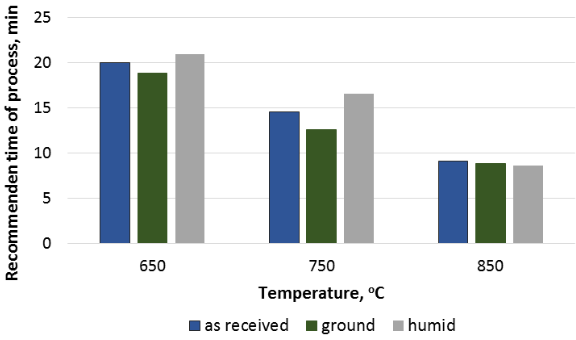


Fig. 4 Recommended time of process duration for 3 states of fuel: as received, ground and humid.

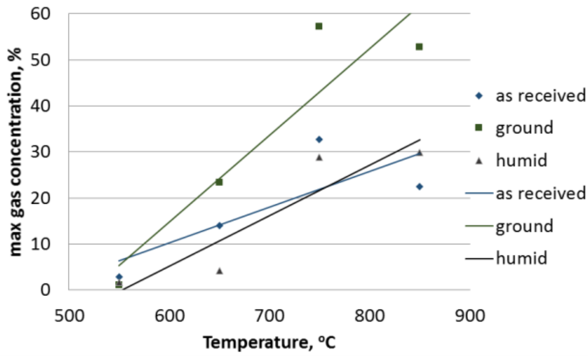


Fig. 5 Maximum CH4 concentration in syngas for 3 states of fuel: as received, ground and humid.

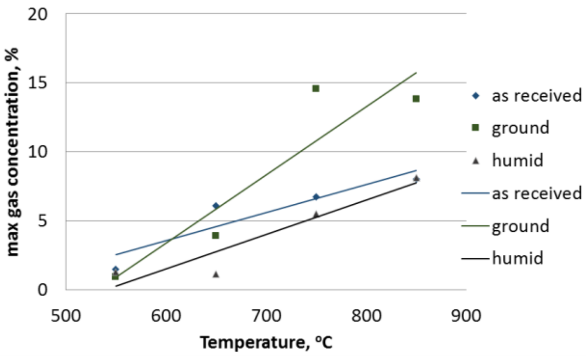


Fig. 6 Maximum CO concentration in syngas for 3 states of fuel: as received, ground and humid.

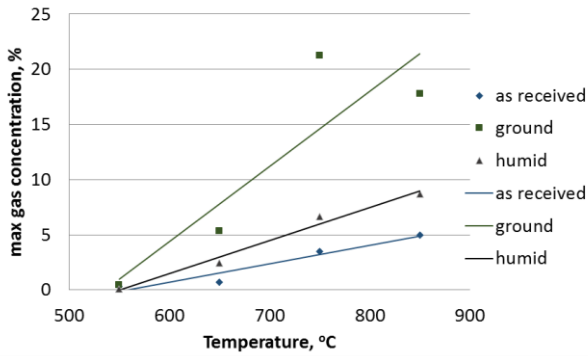


Fig. 7 Maximum H2 concentration in syngas for 3 states of fuel: as received, ground and humid.

Recommended time of process duration varies from ~20 to 8 minutes depending on the process temperature. Temperature 550°C has been proven to be clearly to low for this kind of fuel, hovewer in previous studies the authors have tested some biomass and plastic-based feedstock in temperature ranging from 350°C [2, 4]. Maximum concentration of combustible components (CH_4, CO and H_2) strongly increases with temperature rise and is visibly higher for ground fuel.

5 SUMMARY

Presented tests confirm the usability of RDF fuel for low-temperature gasification. As a result of the process a syngas with combustible components was obtained. Maximum concentration of CO, CH4, H2, and CnHm in syngas was significantly higher for ground fuel. Grinding increases the surface of fuel-agent contact and prevents formation of sintered layer on the bigger particles surface. Water addition did not increase hydrocarbons concentration, however it elevated hydrogen formation.

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