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BIOMASS UTILIZATION FOR THE PROCESS OF GASIFICATION

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Abstract

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Biomass as one of the renewable resources of energy has bright future in utilization, especially in obtaining various forms of energy (heat, electrical energy, gas).
According to the conception of energy policy of the Czech Republic and according to the fulfillment of the indicators of renewable resources using until the year 2010, the research of thermophysical characteristics of biofuels was realized.
There were acquired considerable amount of results by combustion and gasification process on the basis of three-year project „Biomass energy parameters." By means of combustion and gasification tests of various (biomass) fuels were acquired the results which were not published so far.
Acquired results are published in the fuel sheets, which are divided into four parts. They consist of information on fuel composition, ash composition, testing conditions and measurand overview. Measurements were realized for the process of combustion, fluidized-bed gasification and fixed-bed gasification. Following fuels were tested: Acacia, Pine, Birch, Beech, Spruce, Poplar, Willow, Rape, Amaranth, Corn, Flax, Wheat, Safflower, Mallow, and Sorrel.

biomass, gasification, pyrolysis, renewable resources, gasifier tests, pellets, briquettes

At present, the concern about biomass utilization grows in order to acquire various kinds of energy. The aim at the development of the biomass processing technologies is to attain the high operational reliability, performance, low operating costs and low capital expenditure. It is still to solve the matter of reducing injurants wasting the atmosphere.

When solving these problems, it is not sufficient just to know only basic biomass parameters, such as heating value, which is dependent on the water content. It is important to know also other parameters, which affect the transformation process in a given machinery. However, no sufficient database of these parameters so far exists and also important is the fact that biofuels quality if affected by the area of their growing, too, i. e. soil type, fertilization, climatic effects, etc.

For the illustration, from the total quantity of the fuel samples I am introducing the values and results of one of the fuel sample – rape – from the three processes.

MATERIAL AND METHODS

Measurement methodology

In this methodology is described the measurement procedure and which objectives were to solve. The part of this methodology is the operation process while experimental method data mining while biomass gasification.

1.1 Measurement

For each measurement it is necessary to find out the following information:

- **fuel composition and characteristic** (in our case particular biomass types)
- **operating parameters** (temperature, pressure)
- **input and output materials flows** (fuel, air, gas, ash)
- **output gas composition**.

At first, each fuel type was analyzed; this analysis contained the following values:

- low heating value, high heating value

- proximate analysis (water content, ash content, flammable matters, volatile flammable matters)
- ultimate analysis (C, N, O, H, S, Cl)
- bio-chemical analysis (tannins, residuous compounds, lignin, holocellulose)
- characteristic ash temperatures (deformation temp., sphere temp., hemisphere temp., flow temp.)
- ash composition (P_2O_5, Al_2O_3, Na_2O, SO_3, SiO_2, CaO, K_2O, Fe_2O_3, MgO, TiO_2, MnO,Cl, Pb, Cd, Cu, Hg, Cr, Ni, V, Zn).

The spot fuel samples were analyzed in the accredited laboratories. Their brief characteristics and analysis methodology is mentioned in the text below.

Proximate and ultimate analysis of fuels and ash composition stated the accredited laboratory No. 1060 TÜV NORD Czech, Ltd., Analytical Chemistry Laboratory, characteristic temperatures of ashes stated partly already mentioned laboratory TÜV NORD Czech, Ltd., and the Brown Coal Research Institute, j. s. c., in Most. The bio-chemical analysis of fuel samples was done by the Department of Wood, Pulp and Paper at Faculty of Chemical Technology of University of Pardubice.

1.2 Measuring procedure

For the measurement is stated the methodology, by course of it is proceeded and by course of it the spot operations are being done.

- **Fuel sampling for physiochemical analysis**
  While fuel sampling the conventions according to Czech government standards ČSN 44 1301 and ČSN 44 1304 were followed. More sampling at various places of fuel storage was made; the sample consisted of sizes with various fractions.

- **Declaring the row material specific value**
  The evergreen tree species samples were during the fixed-bed gasification tests dosed in the form of lump wood at sizes lower than 20 cm and of maximum humidity 20 %. Culm plants, except of amaranth, mallow and safflower, were gasified in the form of pellets or briquettes. Amaranth was able to gasify in the form of shreddings and it was not need to modify it. It was unable to use mallow and safflower in the form of pellets, however the gasification of shreddings from these two products was not successful. As supposed, the shreddings are not suitable for this type of gasification generator.

The fuel was supplied mainly in the form of pellets and briquettes – see Fig. 1 and Fig. 2 – as well as in the form of piece material. The illustration of waste – ash – is at the Fig. 7.

1: *Fuel – pellets*

2: *Fuel – briquettes*

3: *NH_3 and Cl gas-meter*

4: *Computer output*

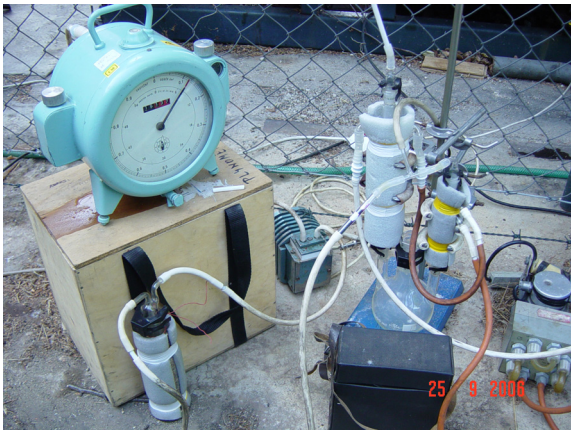
5: *The detail of analog instrument*

6: *Analog emissions instrument*

7: *Ash*

8: *FID – flame-ionization detection*

9: *Heated take-off filter for solid parts > 2ηm*



10: *Apparatus for measurement and BTX*

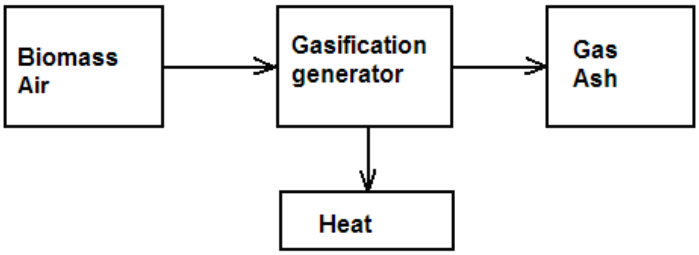
11: *Group of washing for tarry substances*

1.3 The course of the measurement while gasification process

For the defined period of time was the sample of a gas taken-off after setting the Energoblok E 30 machine to the stable state. After setting the right value is necessary to make a correction of measured values.

1.4 Input and output parameters of generator

Input parameters for gasification generator are biomass and air, output parameters are gas, ash and heat (Fig. 12).



12: *Input and output parameters of generator*

1.5 Fuel analysis

Carbon monoxide (CO), Carbon dioxide (CO_2) and Nitrogen oxides (NO_x)

The measurement appeared from procedures mentioned in ČSN ISO 10396, ČSN ISO 10849, ČSN 83 4711 part 7 and ČSN 83 4740. The concentrations of CO, CO_2 and NO_x were measured with the continual analyzer (computer output at Fig. 4) Advance OPTIMA, URAS 14 from Hartmann & Braun Comp., working on the principle of infra-red absorption (Fig. 6). Gas sampling was realized by the help of sonde with heated ceramic filter for solid parts separation, behind which was connected heated Teflon hose (PTFE), which should prevent from water condensation in the gas sample when being transported. At the end of the heated hose was integrated convertor (converting NO_2 to NO) and behind him was gas chillroom, in which was separated the humidity from the gas. This way modified sample was installed to the analyzer, which was before the measurement calibrated by calibration mixture.

Oxygen (O_2)

The concentration of O_2 in gas was measured by continual analyzer PMA 30 from AFRISO, Ltd., which makes use of paramagnetic feature of oxygen. The gas sampling was the same as in case of CO, CO_2 and NO_x measurement. The instrument was before the measurement calibrated by pure nitrogen for the zero calibration (0 % of O_2) and by ambient air (21 % of O_2) and the instrument measured within the range 0–30 %.

Total organic carbon (TOC)

The flame-ionization detection method (FID) was used to determine the concentration of hydrocarbon gross content in the gas (Fig. 8). The gas was continually taken off by heated conducting (heated head with ceramic filter and heated hose from PTFE) attached to the input of heated filter unit, from which the gas was conducted to the Signal 3000 M analyzer from Signal Instrument Co. Ltd. This analyzer works on the principle of FID. The gas sample is conducted to the hydrogenous flame burning between two electrodes, where the hydrocarbon molecules ioni-

zation happens and where the electric charge comes up. The ion charges enable the creation of the current between FID electrodes, which bears a proportion to hydrocarbons concentration. Hydrocarbons concentration is expressed summarily as C_xH_y without qualitative resolution. As a calibration standard acted methane in a nitrogen. Obtained results were converted to the total organic carbon content (TOC).

Hydrogen fluoride (HF), Hydrogen chloride (HCl)

Gas sampling for the determination of fluorine gas adducts expressed as HF and chlorine gas adducts expressed as HCl started from the procedures mentioned in the ČSN 83 4752 part 2 and ČSN EN 1911-1. The gas had been sucked off proportionally through the take-off sonde with heated ceramic filter for solid parts separation (Fig. 9) to the two tandem washing apparatuses filled with the absorption solution (NaOH water solution, concentration of 0,1 $mol.l^{-1}$). Take-off route further continued by the silicone hose to the drying tower filled with silica gel, to the gas pump, in front of which was placed the flow controller, and to the precision liquid gas-meter (Fig. 3). After finishing the sampling the sample from both washing apparatuses as mixed, the demineralized water was filled up to the known capacity and the sample was transported to the laboratory to be analyzed.

Ammonia (NH_3)

The gas sampling for ammonia concentration determination was made according to the ČSN 83 4728 part 2. The gas was sucked off proportionally through the take-off sonde with heated ceramic filter for solid parts separation to the two tandem washing apparatuses filled with the absorption solution (H_2SO_4 water solution, concentration of 0,05 $mol.l^{-1}$). Take-off route further continued by the silicone hose to the drying tower filled with silica gel, to the gas pump, in front of which was placed the flow controller, and to the precision liquid gas-meter (Fig. 3). After finishing the sampling the sample from both washing apparatuses as mixed, the demineralized water was filled up to the known capacity and the sample was transported to the laboratory to be analyzed.

Water (H_2O)

The gas moisture was determined gravimetrically with the help of the condensation methodology. The gas sample was sucked off proportionally through the take-off sonde with heated ceramic filter for solid parts separation to the condenser, where mainly amount of water vapour contained in the gas in the form of condensed fluid was caught. The condensed fluid weight can be determined as a distinction between condensation bulb weight with the condensed fluid and empty condensation bulb. From the condenser outputs the gas with the water vapour content at the level of saturation (so-called satiated gas, whose temperature and pressure are measured). Take-off route further continued by the silicone hose to the drying tower filled with silica gel, to the gas pump, in front of which was placed the flow controller, and to the precision liquid gas-meter. The resultant gas moisture is determined as a sum of moisture caught in a condenser and residual moisture of satiated gas.

Benzene, Toluene, Xylene, Ethylbenzene, Styrene (BTXES), Benzofurane, Indene, Naphta-lene, Methylnaphtalenes

The measurement was done according to the procedures mentioned in the ČSN EN 13649. The gas sample was sucked off proportionally through the take-off sonde with heated ceramic filter for solid parts separation and through PTFE hose to the sorptive pipe ORBO 32 from Supelco Comp. consisting of the two sections with active carbon (400 and 200 mg). Take-off route further continued by the silicone hose to the drying tower filled with silica gel, to the gas pump, in front of which was placed the flow controller, and to the precision liquid gas-meter. The sorption pipes were after the analysis hermetically closed and transported to the laboratory to be analyzed.

Gravimetric tar, Polycyclic aromatic hydrocarbons (PAH), Dibenzofurane, Biphenyl and Phenols

The measurement methodology resulted from the "Direction for Measurement and Analysis of Tar and Elements in Gases from the Biomass Gasification." The gas sample was isokinetically taken using the sonde after which was inserted heated gripper with fiberglass filter, on which were caught solid parts (filter temperature was hold at temperature of 200 °C). Gas further passed through seven washing apparatuses filled with isopropanol, in which were caught tarry substances. The last three washing apparatuses were located in freezing box cooled by the mixture of ice and salt at the temperature of –20 °C. In this part of take-off apparatus were caught prospective residues of tarry substances from the gas. All the non-heated parts of the take-off apparatus to the last washing apparatus were created from glass or PTFE in order to except the sorption of tarry substances on the apparatus surface.

The filter with caught dust particles was after finishing the take-off taken to the sample case and created the first part of the sample being transported to the laboratory. Glass and teflon part of apparatus was several times washed with pure isopropanol and all liquid parts were transported to the laboratory in the glass closed vessel as the second part of the sample. Take-off route further continued by the silicone hose to the drying tower filled with silica gel, to the gas pump, in front of which was placed the flow controller, and to the diaphragm gas-meter.

The filter with caught dust particles was after finishing the take-off taken to the sample case and created the first part of the sample being transported to

the laboratory. Glass and teflon part of apparatus was several times washed with pure isopropanol and all liquid parts were transported to the laboratory in the glass closed vessel as the second part of the sample.

Hydrogen (H_2), Methane (CH_4), hydrocarbons (C_2-C_6), Sulfan (H_2S), Carbon monoxid (CO), Carbon dioxide (CO_2)

The gas samples for selective analysis of gas components were taken by a single application to the glass sample case. Glass sample case (filled with water in advance) was attached to the output part of take-off sonde with heated ceramic filter. By opening of ground-joint valve was the water emptied and the glass sample case was filled with the gas; sample gas was then immediately hermetically closed and consequently transported to the laboratory to be analyzed.

1.6 Used fuels and their characteristics

I mention only culm plants, which can by obtained in the form of shreddings, bulk straw or bales. They can be eventually treated in the form of pellets (Fig. 1) and briquettes (Fig. 2). In Tab. I are mentioned the eight most used samples of shreddings, which were intended for detailed analysis of energy parameters. Among these samples are waste samples as well as intently grown biomass.

Proximate fuel analysis was done for each sample at first, and then the ultimate analysis was done (Tab. I), as well as ash fusibility determination (Tab. III) and ash chemical analysis (Tab. IV). Mentioned samples, except of amaranth, mallow and safflower, were gasified in the form of pellets and briquettes. Amaranth was gasified in the form of shreddings and was not necessary to be modified. For fuel using in the form of shreddings it is necessary to make the appropriate technical adjustments of the machine. Energy parameters of these fuels are mentioned in Tab. II. The values of produced gas are mentioned in the Tab. V and tar contents in the Tab. VI.

I: *Ultimate analysis (% wt.)*

Plant	C	H	O	N	Cl	Sulphur content	
						Volatile	Sulphat. ash
Rape	45.2	5.81	41.9	0.63	0.3	0.08	0.3
Amaranth	42.5	5.77	44.9	0.8	0.01	0.01	0.03
Corn	40.2	5.52	37.9	1.01	0.26	0.01	0.02
Flax	47.4	5.91	40.4	0.44	0.01	0.01	0.02
Wheat	46	5.97	42.3	0.59	0.08	0.03	0.05
Safflower	47.1	5.99	41.8	0.73	0.49	0.03	0.03
Mallow	43.8	5.73	41.3	1.13	0.8	0.05	0.16
Sorrel	47	5.77	41.3	1.15	0.02	0.06	0.04

Note: mentioned values are in water-free state

II: *Energy parameters*

Plant	High heating value ($MJ.kg^{-1}$)	Low heating value ($MJ.kg^{-1}$)
Rape	4.41	4.05
Amaranth	4.4	4.03
Corn	5.26	4.83
Flax	4.07	3.82
Wheat	3.89	3.59
Safflower	ND	ND
Mallow	ND	ND
Sorrel	4.57	4.24

Note: ND – not determined

RESULTS

During the gasification tests were acquired several tens parameters, which for the first time brought coherent conception of biomass utilization possibilities for this process. A large number of analyses were acquired not only about the fuel, but also about

III: *Ash fusibility temperatures determination*

Plant	Temperature (°C)			
	deformation	sphere	hemisphere	solidification
Rape	1054	1062	1273	1279
Amaranth	1078	1088	1496	1499
Corn	1044	1052	1257	1264
Flax	1120	1200	1320	1460
Wheat	979	987	1128	1138
Safflower	1052	1057	1147	1153
Mallow	1045	1050	1454	1459
Sorrel	1086	1093	>1500	>1500

IV: *Ash composition – chemical analysis (% wt.)*

Element	Plant							
	Rape	Amaranth	Corn	Flax	Wheat	Safflower	Mallow	Sorrel
P_2O_5	3.93	5.29	1.74	3.26	5.92	9.86	3.73	8.71
Al_2O_3	0.23	0.55	6.14	5.18	3.21	0.95	1.97	0.53
Na_2O	2.09	4.53	0.52	0.67	0.38	2.4	3.47	0.49
SO_3	10.1	1.35	0.91	1.65	1.35	2.38	5.56	2.72
SiO_2	1.63	4.6	69.3	62	57.4	6.45	19.1	4.49
CaO	31.1	51.9	4.43	9.64	6.17	30	25.4	30.4
K_2O	33.8	18.9	10.7	9.58	9.55	26.7	23.8	27.8
Fe_2O_3	0.21	0.47	2.61	2.06	1.49	0.59	0.91	0.66
MgO	5.04	8.14	1.89	2.02	4.25	3.42	5.91	9.19
TiO_1	0.02	0.05	0.62	0.27	0.2	0.08	0.15	0.04
MnO	0.06	0.01	0.1	0.12	0.07	0.08	0.08	0.3
Cl	0.2	3.93	0.95	0.47	0.53	17.2	9.93	1.63
Pb	0.002	0.12	0.001	0.002	0.003	0.005	0.003	0.002
Cd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CU	0.03	0.067	0.022	0.041	0.08	0.043	0.04	0.01
Hg	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	0.009	<0.001	0.006	0.003	0.007	0.001	0.004	<0.001
Ni	0.11	0.04	0.01	0.009	0.08	0.009	0.007	0.16
V	ND	ND	ND	ND	ND	ND	ND	ND
Zn	0.001	<0.001	0.024	0.016	0.027	0.024	0.006	0.001

the whole gasification process. Not only results of flue gases components were acquired, but also energy parameters and produced gas composition.

Observed parameters are necessary to be commented. We have to realize that locality and conditions of its production have the effect on biomass composition – and hence on the whole gasification process. That's why the samples of the same type of biomass do not need to reach the same results.

While gasification tests of fuels were observed sulfur contents as well. Since gasification proceeds in the reducing atmosphere, sulfur merges especially into H_2S.

That's why measured values of sulphur oxide content in the gas are below the detection limit (<10 ppm).

While tests were stated hydrogen fluoride (HF) and hydrogen chloride concentrations, too. Organic adducts in the sorption solution made difficult to determine the precise concentration in formulas and the filtration was necessary for the precise analysis.

V: *Gas composition (% vol.)*

Element	Plant							
	Rape	Amaranth	Corn	Flax	Wheat	Safflower	Mallow	Sorrel
CO	11.9	13.4	11.2	14.5	9.85	ND	ND	12.3
CO2	12	16.2	12.9	15	14.7	ND	ND	19.7
N2	ND	ND	ND	ND	ND	ND	ND	ND
O2	ND	ND	ND	ND	ND	ND	ND	ND
H2	11.5	16	9.93	6.5	8.83	ND	ND	8.24
CH4	2.34	1.09	3.15	1.4	1.66	ND	ND	2.13
C2-C6	0.43	0.16	1.22	0.78	0.71	ND	ND	0.99
H2S	<0.001	<0.001	<0.001	<0.001	<0.001	ND	ND	0.01
Benzen	0.033	0.04	0.04	0.03	0.07	ND	ND	0.04
Toluen	0.009	0.008	0.14	0.013	0.016	ND	ND	0.025

VI: *Tars content (mg.m^{-3})*

Plant	Group					Total
	1	2	3	4	5	
Rape	1 077	28	570	411	26.4	2 112.4
Amaranth	5 086	69.05	671	416	36.9	6 278.9
Corn	1 993	41.9	928	347	26.2	3 336.1
Flax	3 312	51.3	920	352	29	4 664.3
Wheat	2 566	66.2	1 087	649	71.8	4 440
Safflower	ND	ND	ND	ND	ND	ND
Mallow	ND	ND	ND	ND	ND	ND
Sorrel	13 723	125	1 947	452	20	16 267

VII: *Single fuel samples results*

Plant name	Form	Result	Note
1. Feeding sorrel	granule	satisfactory	1)
2. Amaranth	shreddings	satisfactory	2)
3. Wheat straw	briquettes	satisfactory	3)
4. Rape straw	granule	satisfactory	4)
5. Corn straw	granule	satisfactory	1)
6. Hemp (Cannabis sativa) - chaff	briquettes	satisfactory	5)
7. Mallow	shreddings	unsatisfactory	6)
8. Safflower	shreddings	unsatisfactory	6)

Notes:
1) The gas composition shows little CH_4, it is necessary do add the water to the gas generator.
2) Shreddings might be in the form of bigger pieces.
3) It is necessary to dose in less quantity and to know down to the firing zone.
4) Very heating, to dose in fewer parts, according to the instantaneous performance.
5) It is necessary to dry to moisture less or equal to 20 % of water content.
6) Shreddings for a given plant is unsatisfactory – unhatched.

The results of single measurements of gas components concentrations were also influenced by the gasification process instability, especially when using culm plants. Taking of this samples proceeds in very short time intervals.

While on-line measurements of nitrogen oxides contents was recorded very low value, which was in order in tens of ppm. Produced gas is not yet the final product and NO_x content is not hence for the subsequent use essential.

In Tab. VII are mentioned the results of single fuel samples in term of suitability for the gasification.

The gasification machine EB 30 proved its ability to gasify a given type of biomass. However, the process of particular parts of the procedure confirmed the necessity of modifications for the gasification of given commodities, in the sequel in case of mallow and safflower samples. For the better process stability is necessary to integrate automatic components to the system. Thereby may be relieved the shortages on the entering of the fuel to the generator, while clotted ashes liquidation and the better gasification stability may be achieved.

CONCLUSION

Energetic utilization of biomass is at present of big concern, especially because of it is renewable energy resource. Type of energetic product is determined by many factors: soil type, kind of usage and purpose, harvest and transport possibilities, species composition round about. Growing costs and costs production (power consumption) and energy revenues (earnings) must be compared in advance.

Among herbs are interesting are sugar-, amyl- and oil producing plants. For example sunflower and especially rape (colza-oil is made into diesel and lubricants, rape straw is used for gasification). Rape straw has higher low heating value 15–17.5 GJ/t in comparison with grain straw, which has low heating value 14.0–14.4 GJ/t.

Among perennial plants is known Reynoutria sachalinensis Nakai), which make high yields 30–40 t solids/ha. Very discussed energy plant is Miscanthus sinensis. Profitable is growing of *Cannabis sativa* L. because it does not require any treatment during growth.

From biomass may be through various processes gained all kinds of energy, which people need to meet their needs. These kinds of energy are warm, electric energy and energy for driving of vehicles.

From the state point of view is biomass one of the few possibilities, how to gain the energy in the future for next ten years. This plan is clearly formulated in the state energy conception until the year 2030.

The gasification is one of possible methods how to utilize a biomass for gaining these types of energy. Improving the performance of these machines is possible by using the gas separators or micro-turbines in the given machine. Big advantage is that these machines may be constructed as a small machine with output of 30 kW after as much as a configuration with total output of units of MW.

Obtained results are then very sympathetic to biomass utilization by this way, namely because they may solve the problems in a given region, i. e. self-sufficiency in a warm production, solving the employment in a given area and a contributing to atmosphere pollution control.

The results of measurement show that countercurrent gasifier may be used for energy generation from mentioned fuels. These results show also the approach to municipal waste disposal as well as the machine for sewerage plant, especially while using plasm.

DISCUSSION

The results of single measurements of gas components concentrations were also influenced by the instability of the gasification process, namely while using the culm plants.

There was complied uniform methodology of machine operation and measurements in the course of testing process. While testing the rape (Brassica napus) were discovered that it has high LHW, but it is necessary to dose it in fewer portions, namely according to immediate output in the gasification process.

Detailed results are very important especially for the future development and research in the field of gasification. They also serve as the basis for modernization of machine for generating the biomass energy. The tests showed the necessity to add the automatic components important for maintaining the stability of the whole process. The gasification process thus may solve also the questions in the field of reduction and disposal of the emission gases escaping to the atmosphere.

The tests being done confirmed the right way of biomass utilization – namely in the two phases. It means to produce the warm and the gas, and the produced gas then further use for given purposes, as boilers fuel or after cleanup for the co-generation units.

SUMMARY

The results are obtained on the basis of the financial support of Czech Science Foundation when solving the project No. GAČR 101/04/1278 “Biomass energy parameters” with Prof. Ing. Jiří Surý, DrSc. as the participant, who is patentee of fixed-bed gasification unit (patent No. 293431). Thanks to these possibilities were obtained these summary results in the fixed-bed gasification process, which confirms that it is necessary to process the biomass in the two phases. By it is possible to avoid the higher content of dioxins escaping to the atmosphere. It is one of the few forms how to ecologically and

economically utilize the biomass energy. It is the opportunity for farmers who may take advantage of waste biomass and purposely grown biomass. The farmers may be growers, processors but also energy producers and thereby extend their business activity.

SOUHRN

Využitelnost biomasy pro proces zplyňování

Biomasa jako jeden z obnovitelných zdrojů energie má velkou budoucnost ve využití, zejména pro získávání různých druhů energie (teplo, el. energie, plyn). V souladu s energetickou koncepcí ČR a plnění ukazatelů ve využívání obnovitelných zdrojů do roku 2010 byl uskutečněn výzkum termofyzikálních vlastností biopaliv. Na základě tříletého projektu „Energetické parametry biomasy“ bylo získáno procesem spalování a zplyňování značné množství výsledků. Pomocí provedených spalovacích a zplyňovacích zkoušek různých druhů paliva (biomasy) se dospělo k výsledkům, které nebyly doposud zatím publikovány. Získané hodnoty jsou uvedeny v palivových listech, které jsou rozděleny do čtyř částí. Obsahují informace o složení paliva, složení popela, podmínkách zkoušek a přehledu sledovaných veličin. Sledování probíhalo pro proces spalování, fluidního zplyňování a zplyňování v pevné vrstvě. Byla sledována tato paliva: akát, bříza, topol, vrba, buk, borovice, smrk, amarant, len, pšenice, řepka, saflor, sléz, šťovík a kukuřice.

biomasa, zplyňování, pyrolýza, obnovitelné zdroje, zkoušky zplyňovače, pelety, brikety

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ČSN 83 4740 Ochrana ovzduší. Stanovení emisí oxidu uhelnatého ze stacionárních zdrojů. Metoda infračervené absorpční spektroskopie (Air pollution control. Determination of carbon monoxide emissions from stattionary sources. Infrared absorption spectroscopy method)

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