DEVELOPMENT AND DESIGNING OF MACHINES AND TECHNOLOGIES FOR BRIQUETTE AND PELLET MANUFACTURING BY DRY AND WET PROCESS

by

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In this paper we present achieved results of the Laboratory for Combustion of the Faculty of Occupational Safety in Niš, Serbia, obtained by analyzing and designing of technologies and machines for manufacturing of briquettes and pellets by dry and wet process and identification of technological parameters of briquette manufacturing from waste biomass and coals like: humidity and granule, minimal formation pressure, adhesive type and minimal participation, as well as the possibility of designing biobriquettes with physical-chemical and energy properties given in advance.

Key words: *manufacturing of briquettes, biomass, coal, adhesives.*

Introduction

Research team of the Faculty of Occupational Safety in Niš, Serbia, is performing research in the field of biomass utilization for purpose of energy obtaining since 1994. This long term research can be divided into 3 phases.

Phase 1 was ended in 1998, and its results are sublimated in [13]. In this phase, work on examination and classification of energy sources in the form of waste biomass in Serbia and on briquette manufacturing by dry process without adding adhesives was completed.

Phase 2 was started in 1998 and ended in 2000 [11]. In this phase the examinations were performed in the following areas:

(1) New technologies for briquette manufacturing (wet process), including composite biobriquettes and coal briquettes with addition of sulphur sorbents,
(2) Physical properties, and
(3) Combustion of manufactured briquettes.

Phase 3 lasted from 2000 to 2005 and contained the following directions:

(1) Examinations of the new adhesives to be used for enlarging of very moist biomasses and coals, without previously drying them, applying dry technological process of briquette manufacturing. Typical raw materials of this kind are:

– humid waste materials in primary processing of forest biomass with mass content of moisture in material of up to 50%,
– humid fine fractions of solid fossil fuels from primary processing of coals on mine-terminals whose moisture content value is up to 50% deduced on working mass of the material,
– pieces of bark from primary processing of cylinders in paper and cardboard industry with very high moisture content, and
– wastes in industry of stone fruit processing, *etc.*

(2) Examinations of high energy content biobriquettes with given physical-chemical and energy properties that satisfy the following conditions:
– made by waste biomass,
– easy for stoking a fire and manipulation directly with paper container,
– are of high, in advance defined, heating value, in the range from 20 to 32 MJ/kg,
– during combustion, they form diffusible flame of minimum height 0,5 m, with possible special effects related to flame color and pleasant combustion smell,
– combustion time is minimum 2 h,
– they contain minimal amount of ash, in the purpose of easier fire-box cleaning,
– composition of gaseous products of combustion from the ecological point of view is satisfactory, and
– are applied only in spaces with fireplaces.

(3) Designing and manufacturing of prototypes of the press for briquette manufacturing.

In this paper, achieved results in all 3 phases of research, related to identification of technological parameters of briquette manufacturing out of waste biomass and coals are presented.

Material and method

Materials

Biomass

In experimental work for biobriquette manufacturing, more than 40 different wasted biomasses were used as a raw-material: peach-stone, beech-saw, oak-saw, corn-cob and tree, nut-shell, stem of grape, sunflower tree, grape-vine cutting waste and boiled rape, sour cherry-stone, *etc*.

Elementary composition and technical analyses of the mentioned biomasses can be found in references [9, 10, 12, 13].

Coals

For coal and "bio-coal" briquette manufacturing, following types of coals and coal dust were utilized: "Soko", "Mazgoš", "Bogovina", "Marica – istok", "Beli breg", "Resavica", and "Borovica".

Elementary composition and technical analyses of the mentioned coals can be found in references [9, 11, 12, 15].

Adhesives

Adhesives are substances of organic or inorganic composition that have ability to, after mixing with material for briquette manufacturing, linking, and solidification, connect particles of briquette material, giving briquettes form and satisfactory strength and enduringness properties

Adhesives of organic and inorganic origin are currently equally used for briquette manufacturing processes, with a tendency of more significant utilization of inorganic ones.

In the past experimental work, the following adhesives were used:

– organic adhesives – "Guar" flour, molasses, polyvinyl-alcohol, "Fidekol" 301, carboxyl-methyl cellulose, modified glucosans, sulfide gelatin, "Dinkol", paper pulp, dextrin, semicellulose, paraffin, and bone glue, and
– inorganic adhesives – gypsum, clay, water glass, cement, concrete, whitewash, magnesite adhesive, *etc.*

Method

The following machines were used for briquette manufacturing in laboratory:

(I) laboratory manual press,
(II) hydraulic extrusion press, and
(III) Pneumatic press for pellet manufacturing.

Laboratory manual press

This press is shown in fig. 1, and detailed description is given in references [10, 13].

The set of tools for performing experimental works are shown in fig. 2 [10].

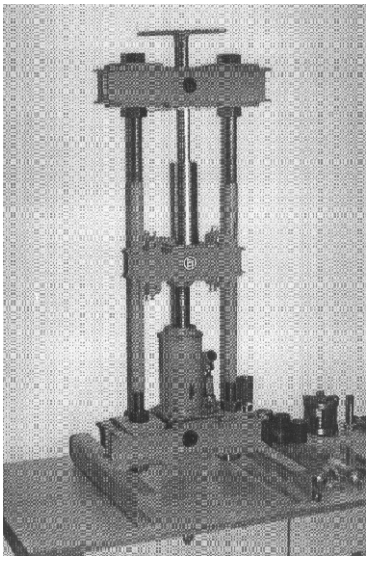

Figure 1. Laboratory press for coal and biomass briquette manufacturing [13]

Hydraulic extrusion press

Press is from the group of extrusion machines with hydraulic drive and is shown on fig. 3, and detailed description is given in references [10, 14].

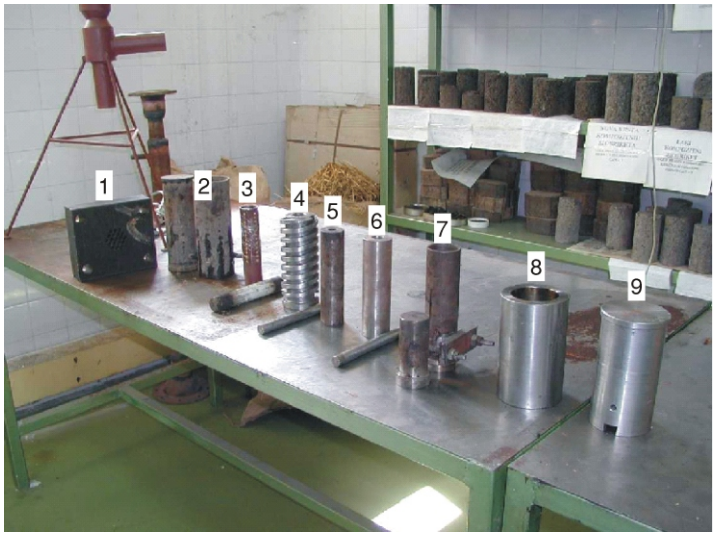

Figure 2. Tools for briquette manufacturing by dry and wet process [10]
1 – tools for extrusive hydraulic press for pellet manufacturing d = 9 mm, 2 – tools with perforated matrix for dry processes of briquette manufacturing d = = 82 mm, 3 – tools with perforated matrix for dry processes of briquette manufacturing d = 35.25 mm, 4 – tools with charge load and closed matrix d = = 20 mm, 5 – tools with charge load and closed matrix d = 16 mm, 6 – tools with charge load and closed matrix d = 22.5 mm, 7 – tapered tools with open matrix d = 50 mm and cone angle α = 1.527°, 8 – tapered tools with open matrix d_1 = 75 mm, d_2 = 42 mm and cone angle α = 14.92°, 9 – tapered tools with open matrix d_1 = 65 mm, d_2 = 45 mm and cone angle α = 9.2°

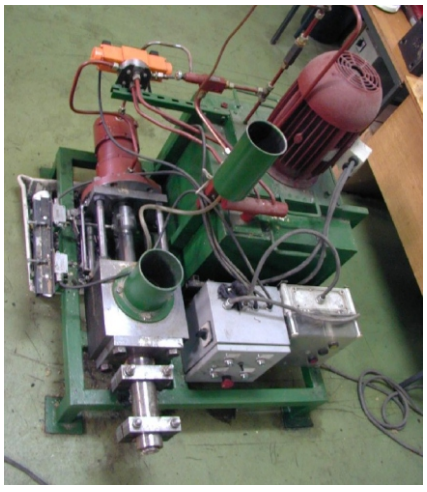

Figure 3. Laboratory hydraulic extrusion press [10]

Pneumatic press for pellet manufacturing

This machine is primarily assigned for laboratory researches related to possibilities of manufacturing of pellets and making tablets from different powdered materials and mixtures with special emphasis on possibility of pellet manufacturing from explosive and inflammable materials. Plant is completely automatic, and thus provides possibility of understanding all significant parameters that would be present in serial industrial manufacturing (fig. 4) [15].

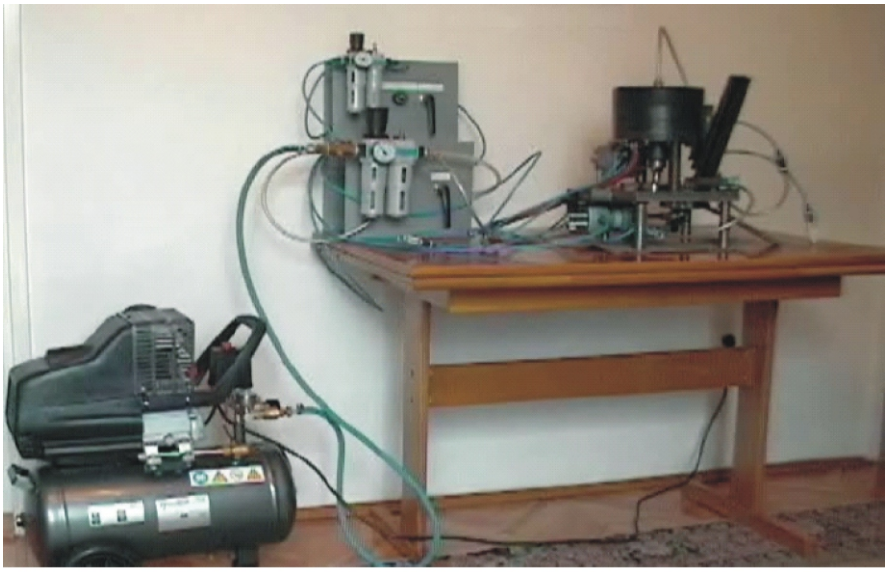

Figure 4. Laboratory pneumatic press for pellet manufacturing [15]

Results of research

In the Laboratory for Combustion of the Faculty of Occupational Safety in Niš, the following technological processes of biobriquette forming have been differentiated.

(I) *Technological process of briquette forming by dry procedure, without any adhesives, of one kind of unprepared biomass*

Solitary heavy biobriquettes were obtained out of unprepared biomass (tab. 1). During this process, biomass size was constrained by tools dimensions. After 20 to 30 days, cracks were noticed on this biobriquettes, because of the intercorpuscular linking forces decreasing [13].

Table 1. Overview of the biobriquettes obtained by dry technological process of briquette manufacturing from one kind of unprepared biomass [13]

No.	Biomass type	Forming pressure [MPa]	Volume mass [kg/m^3]	Biomass granules [mm]	Humidity [%]	Heating value [MJ/kg]
1	Cannabis – tree	280	1152	∅ 15	6.0	15.9
2	Pine – cone	280	1063	Natural size	8.45	16.4
3	Boscage – complete	280	1081	∅	6.3	15.0
4	Corn – cob	280	956	∅ 30	6.5	16.9
5	Corn – tree	280	990	∅ 20	6.6	16
6	Fir – cone	300	1098	Natural size	8.3	16.9
7	Locus tree – wattle	350	1039	∅ (15-20)	7.2	17.1
8	Oak – wattle	350	1039	∅	7.2	16.8
9	Willow – wattle	350	1073	∅ (15-20)	7.7	16.5
10	Poplar – wattle	350	1020	∅ (15-20)	–	–
11	Reed – tree	350	1122	∅ (5-15)	5.5	15.5
12	Pine – pins	300	908	Natural size	6.6	18.5
13	Grape vine – cutting waste	300	990	∅ 15	6.8	15.6
14	Raspberry – cutting waste	300	960	∅ 15	9.7	16.0

(II) *Technological process of briquette forming by dry procedure, without any adhesives, of one kind of prepared biomass*

Solitary heavy and medium weighted biobriquettes were obtained using this process (tab. 2). Here, briquette cracks were noticed, similar to previous group [13].

Table 2. Overview of the biobriquettes obtained by dry technological process of briquette manufacturing from one kind of prepared biomass [13]

No.	Biomass type	Forming pressure [MPa]	Volume mass [kg/m^3]	Biomass granules [mm]	Humidity [%]	Heating value [MJ/kg]
1	Beech – saw	20	1050	0-3	6.6	15.15
2	Beech – tiny waste	20	1083	0-10	6.7	15.15
3	Bitter oak – saw	20	1062	0-3	6.5	15.4
4	Fir – saw	20	1041	0-3	6.5	16.9
5	Ash – sawdust	20	1122	0-10	6.2	15.3
6	Wheat – straw	20	1015	0-10	6.2	15.4
7	Grape – vine – rape	20	1064	Natural size	6.7	17.2
8	Tobacco – dust	20	1276	0-0.1	–	10.7
9	Tobacco – tiny waste	20	1034	0-3	–	12.6
10	Corn – leaf	20	912	0-10	–	–
11	Sunflower – shell	20	933	0-8	7.5	19.3
12	Sunflower – shell with dust	20	840	0-8	25	16

(III) *Technological process of briquette forming by dry procedure, without any adhesives, of two or more kinds of prepared biomass and coal.*

Six different types of bio-coal based on coal dust “Borovica” and coal “Soko”, beech-saw and sulphur sorbents were obtained (tab. 3) [11].

(IV) *Technological process of briquette forming by dry procedure, of one or more kinds of biomass or biomass and coal, with addition of the adhesives*

This procedure was used for the most detailed research, related mainly to organic and inorganic adhesives examination, and the most important results of this group of researches are:

Table 3. Types of composite briquettes made of biomass, coal and sulphur sorbents (bio-coal) [11]

No.	Biomass	Coal	Sulphur sorbent	Mass content [–]	Forming pressure [MPa]	Volume mass [kg/m^3]	Granules of biomass coal sorbent [mm]	Biomass and coal humidity [%]	Heating value [MJ/kg]
1	Beech saw	Coal dust "Borovica"	—	0.7 0.3 –	15-20	692	0-3 0-3 –	6.675 3.69	15.15
2			Limestone “Visočica”	0.7 0.29 0.01	15-20	716	0-3 0-3 0-0.04	6.675 3.69	15.00
3				0.7 0.283 0.017	15-20	676	0-3 0-3 0-0.04	6.675 3.69	14.89
4				0.7 0.275 0.025	15-20	727	0-3 0-3 0-0.04	6.675 3.69	14.77
5				0.7 0.268 0.032	15-20	646	0-3 0-3 0-0.04	6.675 3.69	14.67
6		Brown coal “Soko”	–	0.5 0.5 –	20	1288	0-3 0-3 –	6.675 14.69	15.875

– specially applied briquettes for combustion in fireplaces [10], and
– briquettes obtained out of wet biomasses and coals, with the moisture content in basic material up to 45,8% (briquettes were dry after 30 day of exposure to air) [9].

In this paper, only one part of these results will be presented (tab. 4).

Table 4. Some kinds of the composite briquettes for combustion in fireplaces and briquettes manufactured from wet biomasses and coals obtained by dry process with the adhesives addition [9, 10]

No.	Type of biomass/coal	Adhesive	Adhesive mass content [–]	Forming pressure [MPa]	Volume mass [kg/m^3]	Biomass granules [mm]	Humidity [%]	Heating value [MJ/kg]
1	Beech sawdust	Paraffin	0.4	25	760	2-15	7	26
2	Sunflower shell	Paraffin	0.4	25	630	5-8	7	28
3	Grape stem	Paraffin	0.4	25	900	15	7	21
4	Grapevine cutting waste, milled	Paraffin	0.2	21	806	0-2	7	20
5	Sunflower tree, milled	Paraffin	0.5	25	807	0-2	7	29
6	Sour cherry stone, milled	Paraffin	0.2	28	987	0-2	9	21
7	Rice peel	Paraffin	0.3	22	437	0-6	7	21
8	Corn cob, milled	Paraffin	0.2	25	722	0-2	7	21
9	Sour cherry stone, whole	Paraffin	0.2	25	700	Natural size	9	21
10	Oak saw	Paraffin	0.2	25	752	0-2	7	20
11	Beech saw	“Guar” flour	0.02	6.25	285	0-2	42	16
12	Beech saw	Modified glucosans	0.1	8	376	0-2	42	16
13	Beech saw	Carboxyl methyl cellulose	0.1	9	487	0-2	42	16
14	Beech saw	“Dinkol”	0.15	7	303	0-2	42	16
16	Beech saw	Gypsum	0.3	6.2	539	0-2	42	15.5
17	Beech saw	Water glass	0.2	7	324	0-2	42	15.5
18	Cylinder bark	Gypsum	0.08	5	252	Natural size	40	–
19	Coal “Mazgoš”	Carboxyl methyl cellulose	0.05	10	730	30	45.8	16.1
20	Coal “Mazgoš”	Polyvinyl--alcohol	0.05	9	692	30	45.8	16.1

(V) *Technological process of briquette forming by wet procedure, of one or more kinds of biomass or biomass and coal, with addition of the adhesive.*

Medium and light weighted composite biobriquettes and heavy and medium weighted coal briquettes were obtained using so called wet process, which has a property that moisture content is not a factor of limitation (tab. 5). Beside moisture, biomass (or coal) granule is not a factor of limitation in this technological process, neither. During briquette forming, its natural or forced drying is required.

Table 5. Some kinds of coal briquettes and biobriquettes obtained by wet process of briquette manufacturing [11]

No.	Coal/Biomass	Adhesive	Adhesive mass content [–]	Formation pressure [MPa]	Volume mass [kg/m^3]	Granules [mm]	Humidity [%]	Heating value [MJ/kg]
1	Coal dust "Soko"	Paper pulp	0.1	0.233-0.583	738-794	0-15	14.69	16.54
2	Coal dust "Soko"	Paper pulp	0.2	0.117-0.583	588-677	0-15	14.69	16.51
3	Coal dust "Soko"	Paper pulp	0.3	0.233-0583	558-628	0-15	14.69	16.49
4	Coal dust "Soko"	Semicellulose	0.3	0.117-0.583	724-811	0-15	14.69	16.80
5	Coal dust "Soko"	Semicellulose	0.2	0.29-0.583	783-828	0-15	14.69	16.72
6	Coal dust "Soko"	Semicellulose	0.1	0.233-0.583	864-1030	0-15	14.69	16.64
7	Nut shell	Paper pulp	0.5	0.3-0.5	420	Natural size	13.25	17.6
8	Sour cherry stone	Paper pulp	0.2	0.3-0.5	481	Natural size	7.475	–
9	Beech saw	Paper pulp	0.5	0.3-0.5	380	0-3	6.675	17.28
10	Rice peel	Paper pulp	0.6	0.3-0.5	315	Natural size	8.24	15.84
11	Sour cherry stone	Semicellulose	0.3	0.583	502	Natural size	7.475	–

All the manufactured briquettes are examined according JUS B.H1., B.H8., and D.B9. [1-8].

Conclusions

In the previous research, in the Laboratory for Combustion of the Faculty of Occupational Safety, the following has been done:

– performed analyses of present coal and biomass briquette manufacturing technologies,
– won briquette manufacturing technologies with and without adhesives addition, by dry as well as wet briquette manufacturing processes, and
– designed and constructed 3 laboratory presses for briquette and pellet manufacturing out of biomass and coals.

In the end, it can be concluded that humidity and granule of biomass and coals are not limiting factors in briquette manufacturing any more, and that is possible to manufacture briquettes out of any combustive material if technological process and an adhesive are carefully chosen (fig. 5).

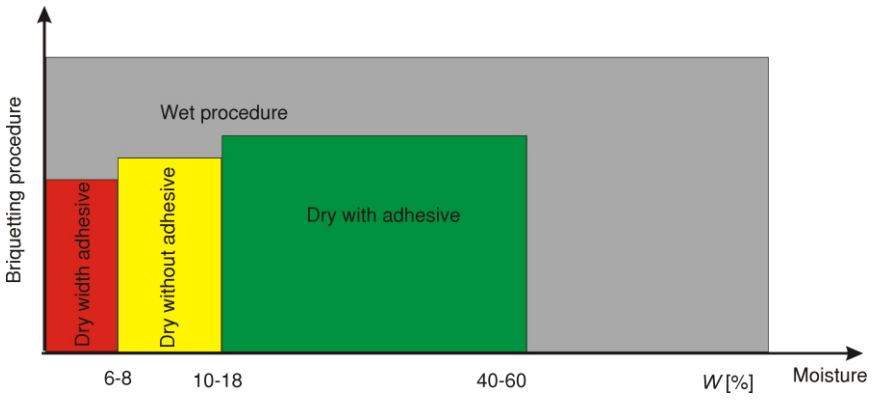

Figure 5. Dependency between humidity of the material and applied technological process of briquette manufacturing

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