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WOOD WASTE AS COMPONENTS OF FUELS USED IN CEMENT PLANTS

This paper presents fuel molding technologies (PAS-i and PAS-r) with the participation of wood waste. These fuels are manufactured specifically for cement plants. The final product in the form of fuel derived from waste, meets the requirements of the recipient. In PAS-i fuel (Impregnated Solid Alternative Fuel), wood waste (sawdust) forms a matrix, to which slug and greasy waste materials are applied. Fuel PAS-r (Shredded Solid Alternative Fuel) is formed from combustible industrial and municipal waste which include wood waste groups. Fuel PAS-r is produced in the BMH installation. The presented tables include physical and chemical properties of PAS-r and PAS-i (fuels from waste) with respect to standards imposed by cement plants. Production of fuels from waste provides opportunities for managing types of wood waste that cannot be used otherwise.

Keywords: wood, waste, fuel from waste

Introduction

Increasing demand for consumer goods, results in an increase in the amount of waste. Storage must be the final link in the chain of rational waste management. Waste should be selectively collected and treated as a raw material – economically exploited. Recovery of valuable recyclables in terms of energy is a large part of waste recycling. These materials, as a result of processing, i.e. formation, receive a fuel nature with specific properties. A significant component of fuels formed from waste in terms of quantity is wood waste. Considering that a substantial part of waste originating from wood is contaminated (for example, with impregnating agents, lacquers, paints, oil derivatives. etc.), the appropriate way of dealing with such material is to utilize it as a constituent of waste derived fuels. The production of fuel from waste, therefore, enables managing the kinds of wood waste, which cannot be used otherwise. In Poland, waste derived fuels are used in cement plants as a substitute for conventional fuel. Rotary cement furnaces [Mokrzycki and Eliasz-Bocheńczyk 2004] burn for a considerably long time and with

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temperatures exceeding 1500°C, cause virtually all the components of waste derived fuels to be thermally destroyed. The ash obtained, accounts for a clinker additive. The production of cement clinker requires that the applied fuel is entirely combusted. Reaction of carbon and hydrogen oxidation proceeds correctly if the fuel is properly mixed with air and has a suitably high specific area. The fuel used must, therefore, be adequately crushed and mingled with other fuel types [Willitsch and Sturm 2003]. The annual use of waste derived fuels in the cement industry exceeds 1.2 million Mg and becomes a significant element of fuel economy in Poland. Within the European Union, waste derived fuels are increasingly applied in the energy sector [European Commission – Directorate General Environment 2003]. That is why the European Committee for Standardization (CEN) has introduced a system of classification and quality requirements for waste derived fuels (Solid Recovered Fuels – SRF) [Van Tubergen et al. 2005]. This system categorizes fuels formed from household waste as “solid fuel manufactured from other-than-hazardous waste” applied for energy recovery in combustion and co-combustion installations and fulfilling classifications and specifications given in CEN/TS 15359.

The aim of this work is to present the possibility of managing wood waste in the form of sawdust, chips, railway sleepers and others, also contaminated (often with hazardous substances). The indicated direction of such waste application (for energy recycling) as PAS-r and PAS-i components is to transform waste into a calibrated fuel with standardized properties, fulfilling specified technical rules, which guarantees its negotiability. Waste derived fuel, being a conventional fuel substitute, can be combusted or co-combusted with conventional fuels in various furnaces [Wei et al. 2009; Liu Ya. and Liu Yu. 2005], undergo gasification (forming combustible generator gas) [Arafat and Jijakli 2013, Zhou et.al. 2014] or pyrolysis [Velghea et al. 2011]. Utilizing waste derived fuels for energy recovery can, therefore, increase the share of renewable energy sources in fuel-energy balance.

Waste derived fuels – PAS-r and PAS-i

The production of fuels based on waste material, destined to substitute conventional, non-renewable fuels, is targeted at the overall decrease in energy demand throughout the economy by limiting the consumption of energy produced from conventional sources. Technologies for producing waste derived fuels are relatively energy-saving due to the simple technological systems being utilized.

The PAS-r fuel (from Polish „Paliwo Alternatywne Stałe rozdrobnione” – cushed Solid Alternative Fuel), based on household and industrial waste, is composed of various combustible materials, mixed in adequate proportions. Within the PAS-r fuel, waste of wooden origin can be found among others.

These include, for example bulk waste, in the form of furniture, wooden constructions, large used up wooden containers etc.

As for the PAS-i fuel (from Polish ,,Paliwo Alternatywne Stałe impregnowane" – Impregnated Solid Alternative Fuel), wooden waste, in the form of sawdust, form a matrix, into which various sludge-like and greasy materials are introduced. PAS-r and PAS-i fuels are produced by the SITA STAROL company from Chorzów, which belongs to the SITA SUEZ consortium. A list of types and amounts of wood based waste used in SITA STAROL to produce waste derived fuels in 2014 is shown in table 1. Each waste type has a designated code, according to the Waste Catalogue (Journal of Laws, No. 112, pos. 1206 dated September 27th 2001).

Table 1. Types and amounts of wood based waste used in SITA STAROL in Chorzów to produce waste derived fuels in 2014

Waste code	Type of waste	Amount [Mg]
03	**Waste from wood processing and production of boards, furniture, cellulose mass, paper and cardboard**	
03 01 04*	contaminated chips	10.61
03 01 05	wooden waste	15.53
03 01 05	chips	0.50
03 01 99	wooden waste and plywood, contaminated with cardboard	355.30
03 01 99	sawdust	3967.95
12	**Waste from forming and physical / mechanical treatment of metal and plastic surfaces**	
12 01 17	sawdust	1548.46
15	**Container waste; sorbents, wiping textiles, filtration materials and safety clothes not mentioned in other groups**	
15 01 03	wooden containers	0.48
17	**Waste from construction, repair and dismantling of buildings and road infrastructure (including soil and ground from contaminated areas)**	
17 02 01	demolition wood	1.69
17 02 04*	wood waste containing or contaminated with hazardous substances – railway sleepers	16.36
Sum		**5916.449**
20 03 07	Part of bulky waste is wooden	359.802

*Indicates hazardous waste.

The primary type of wood waste applied in PAS-i fuel production is sawdust, constituting of a sorbent (40-50% of mass). Among wood waste, being a component of the PAS-r fuel, waste from the code 03 01 99 form the largest group. These are often contaminated with different materials such as cardboard, textiles, and waste from the furniture industry.

Raw material composition of a waste derived fuel must guarantee physical, chemical, fuel and emissive properties imposed and expected by the recipient (in this case, cement plants). The selection of waste types, therefore, and their mutual mass proportions is always preceded by the analysis of their fuel, physical and chemical parameters [Król 2013, Stowarzyszenie Producentów Cementu 2008]. The manufactured fuel undergoes quality control. As previously mentioned, the fuel has to fulfil standards with regards to its fuel, its physical and chemical properties, as well as the amount of heavy metals, imposed by the receiving cement plant [Marszałek Województwa Śląskiego 2010], for example:

- average calorific value of the product: 15 MJ/kg,
- ash content below 30%,
- humidity below 30%,
- bulk density within the range of 0.3 to 0.5 kg/m^3,
- maximum sulphur content: 2.5%,
- chlorine and other halogens content: below 0.3%,
- heavy metals content: mercury – below 2 mg/kg of dry mass, chromium – below 400 mg/kg of dry mass, sum of cadmium, mercury and thallium – below 10 mg/kg of dry mass.

In the case of fuel bricketing, various kinds of adhesives may need to be applied (which may also be industrial waste), because these types of fuels must possess a specified mechanical strength [Białecka 2006].

PAS-i fuel formation

Shredded wood derived waste, is the primary constituent of the PAS-i fuel (tab. 1). These form a matrix. The groundwork of sawdust in relation to sludge-like (for example, from cleaning tanks for oil derived substances and grinding sludges – below 5% in quantity), liquid and greasy waste being applied to it, functions as a sorbent. It is subsequently mixed with (i). shredded waste containers after paints, lacquers, oil emulsions and thinners as well as overdue chemicals; (ii). grinding dusts, polyethylene and polypropylene, as well as other waste containers, for example paper. Figure 1 depicts a block diagram of the technological process of PAS-i fuel production.

The unitary energy demand to produce 1 Mg of Impregnated Solid Alternative Fuel equals 10-16 kWh.

PAS-r fuel formation

The PAS-r fuel is manufactured using a Finnish installation provided by BMH Wood Technology (fig. 2), capable of processing 1200 Mg of waste daily.

Considering the composition variety of waste directed to the fuel production, a series of mechanical unit operations is required, such as:

- sorting,
- drying,
- shredding,
- metals separation,
- mineral fraction separation,
- packing.

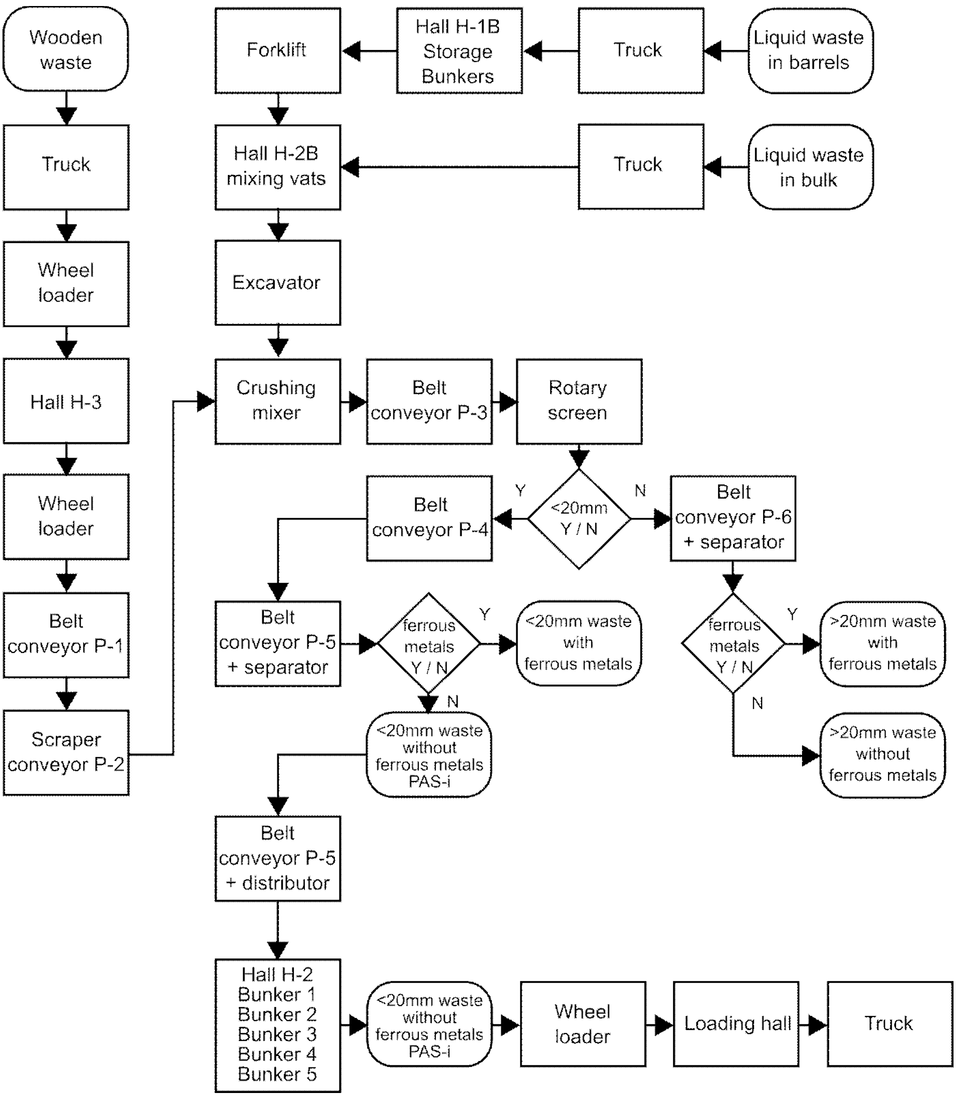

Fig. 1. Block diagram of the PAS-i fuel production line

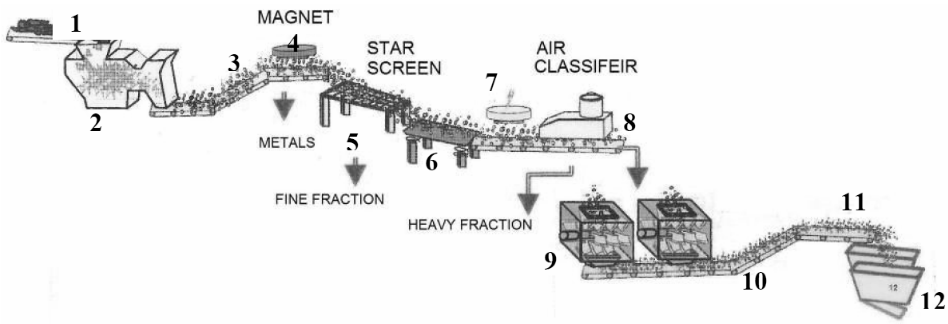

Fig. 2. BMH installation scheme

Waste processed into a formed fuel is delivered to the production plant by road transport, unloaded in the production hall, next to a step feeder, or outside the hall, from where they are loaded using a wheel loader on a step feeder (1) or directly to the crusher's feed funnel. These are subsequently crushed in a Tyrannosaurus coarse crusher (2) into the maximum size of 80 × 80 mm. The remaining oversized material is directed to a separate bunker. Crushed waste gets transported by the belt conveyor (3) under a stationary magnetic separator (4), where ferrous metals of less than 80 mm in size are extracted. The following device is a fine fraction separator (5), which removes glass, sand, fine stones and biodegradable waste smaller than 12 mm. The primarily purified material (sized 12 to 80 mm) gets directed onto a vibrating feeder (6), which widens and unifies the waste stream, that first passes under an eddy-current separator (7), where non-ferrous metals are extracted (expected size of this fraction is 12-80 mm), and then falls into an air classifier (8), which separates the stream into light and heavy fractions. Heavy fraction is composed of sand, remainders of metals, glass, ceramics, wood, plastics, biodegradable substances and others. This fraction also has the size of 12-80 mm. The following conveyor directs the light fraction into two parallel Monster fine crushers (9) which shreds the material into the grain size of 30 × 30 mm maximum. The final product passes to an ascending conveyor (10) and a stacking conveyor (11), which puts the fuel into several storage bunkers. There is a by-pass within the fine crusher setup, which extracts the overflown 80 × 80 mm fraction. The stacking conveyor is equipped with slide gates, which enable filling of a specified storage bunker.

The unitary energy demand to produce 1 Mg of the PAS-r fuel is estimated to be around 23 kWh, what is caused by the necessity of applying more energy – demanding shredding processes and full mechanization and automation of the installation.

Fuel, physical and chemical parameters of PAS-i and PAS-r fuels

The quality of the produced waste derived fuels with respect to fulfilling the plant standard as well as requirements imposed by recipients is assessed by the plant's Quality Control Laboratory.

Basic fuel parameters are measured: humidity, ash content, calorific value, sulphur and chlorine content within the combustible material. Additionally, the concentration of selected heavy metals and their sum is measured.

Example analysis results for two separate batches of PAS-i and PAS-r fuels are given in table 2.

Table 2. Fuel parameters of waste derived fuels and heavy metals content

Property	unit	PAS-i	PAS-i	PAS-r	PAS-r
Moisture content	[%]	16.4	14.6	16.1	20.4
Ash	[%]	17.0	16.2	6.8	7.9
LHV	[kJ/kg]	23949	24237	17668	16559
S	[%]	0.48	0.43	0.25	0.31
Cl	[%]	0.36	0.39	0.66	0.63
Ni	ppm	304	286	41	44
Pb	ppm	130	124	103	119
Cd	ppm	1,5	1.5	4	5
Cr	ppm	82	85	118	203
Cu	ppm	425	420	218	121
Mn	ppm	535	411	160	156
Co	ppm	11	21	14	27
Tl	ppm	>5.0	>5.0	>5.0	>5.0
V	ppm	5.4	5.0	6.0	6.0
Sb	ppm	68	76	35	41
As	ppm	0.6	1.4	5.0	1.5
Hg	ppm	1.4	0.8	0.4	0.4
Metals in total	ppm	1563.9-1568.9	1431.7-1436.7	704.4-709.4	723.9-728.9

Parameter values from table 2 show, with respect to standards imposed by cement plants (cited in point 2), that the final product – formed waste derived fuel – fulfils the recipient's requirements.

Conclusions

Wooden waste of various forms, different granularity and homogenization, often contaminated with hazardous substances, may be applied in energy recovery, when used to produce waste derived fuels.

Even though these constitute a multi-material mixture and are considered "difficult" fuels, they still possess strictly calibrated properties. They also count as renewable fuels. When undergoing thermal processing, they can become an energy source, part of which originates from a biodegradable fraction and, as such, is considered energy from a renewable source. There exists, therefore, a possibility to classify a share of the chemical energy that comes from biodegradable fractions' within the chemical energy of the total waste mass.

The application of forest biomass in a fuel allows green certificates to be obtained. In Poland, according to the URE terminology (Energy Regulatory Office), the forest biomass covers: clean biomass from forests (usable wood), remainders from forest industry as well as from industries processing its products.

PAS-r and PAS-i fuels and their production technologies presented in this paper prove that in the case of waste with energy potential, the most suitable direction is energy recovery realised through fuel production.

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