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PROTECTIVE COATINGS IN THE POWER BOILERS USED TO INCINERATE WASTE – FUEL CHARACTERISTICS OF WASTE AS THE SOURCE OF ENERGY

A general characteristics of waste management was presented. Municipal waste was characterised and its fuel properties were provided. Numerous thermal processes of waste utilisation were described such as an incinerating process, free-oxygen technology – pyrolysis, technology with oxygen deficiency – gasification and the plasma technology.

Keywords: surfacing by welding, surfacing layer, incinerator

1. Introduction

Waste was present in the mankind's life from the early beginning of the civilization development. On all the stages of the mankind development a way of managing waste was insufficient in comparison to the size and the way of its collection. An industrial revolution initiated a violent increase of problems and the dangers connected with an insufficient management of waste. Additionally, a process of a rapid development of an industry and a growing demographic increase intensified the amount of waste, making an ecological situation even worse. Degradation processes were increasing mostly in the industrial and urban developed areas.

Observing a modern society we claim that it produces a lot of different types of waste. There is a full range of waste by expanding an assortment of production. A systematic industrial development and a progressive grow of wealth result in an increase of consumption and a rise of waste. Therefore, the solutions, which allow to reduce such a vast amount of waste were sought and a good managing system of a waste collection was established.

Waste became to dump on the rubbish dump, compost, segregate or recycle. However, soon, power qualities of waste were noticed. Nowadays, we observe an impoverishment of natural supplies, therefore their price became much higher. Moreover, irrational management of possessed supplies and trusting a power safety on the coal plants only, may disturb a power balance in the future and force to use alternative power supplies including waste.

The aim of the article is to show the conditions, which are going to introduce a thermal system of municipal waste utilization with a description of a basic issues relating to waste management legislation, incinerating processes, technological solutions, used materials and making protective coatings.

There is a condition of a waste management presented in the introduction, which undoubtedly is different in different European countries by means of used solutions and possibilities. The article also pays attention to the power qualities of waste and its characteristics which allow to recover the power in the process of combustion. The concepts relate to incinerating process, pyrolysis, gassing and the plasma technology.

Utilisation of waste makes a lot of problems with exploiting burning units which incinerate either municipal or industrial waste, therefore it is impossible to avoid describing the main reasons of the corrosion processes and the methods to prevent them. Nowadays, the key factors are protective coatings used in the thermal waste utilisation boilers, so this issue and the description of samples pad welded by nickel superalloy Inconel 625 were presented in the article..

2. General characteristics – waste management

Waste management in Poland and in other developing countries is an important aspect of protecting natural environment [1]. The basic rule of dealing with waste is to reduce its dumping at the expense of its recovery and processing by using a technology based on the highest standards of the environment protection. European Union countries pay a great attention to the issues connected with the problems of the environment protection including the matters of waste management. Polish government, after joining EU, considerably changed legislation related to the environment protection and waste management by adjusting it to the requirements given to membership countries. In the National Plan for the Waste Management 2014 accepted by the Parliament at the end of 2010, the following main issues were established [3]:

- reduction of waste
- increase of recycling combined with a selective collection and segregation of waste
- reduction of an amount of dumped waste by its processing: biological, thermal, chemical with a particular consideration of the processes of energy recovery

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Plans of waste management specify the tasks, which are aimed to serve the protection of the environment based on the strategical assumptions of EU. Moreover, they include an updated analysis of the waste management in a given area, and specify the matters which should be used in recycling, recovery and waste neutralising [4].

The main priorities to prevent waste formation and waste management in the legislation are:

- reduction of an amount of waste
- reduction of an amount of dangerous substances and pollution from waste by using other methods than recycling that is a heat treatment
- increase of recycling and reprocessing
- recovery of energy from waste
- decrease of an amount of waste

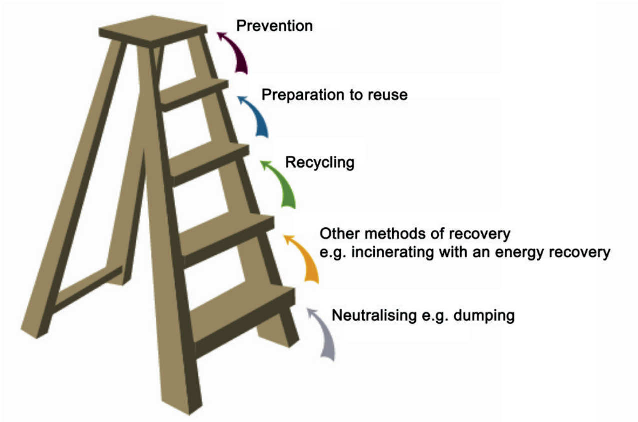


Fig. 1 A hierarchy ladder of waste management specified by the EU legislation

Such policy is aimed at reaching a balanced waste management by means of prevention as a preferable way of behaving, and neutralising as the last step in the hierarchy ladder. From the rest of waste, which cannot be reused or recycled in an economical or technical way, energy need to be recovered. This operation has a priority over dumping waste.

Additional UE assignments point, that only waste which was previously processed can be dumped on the rubbish dumps. Processing can be physical, thermal, chemical or biological, including sorting, which allows to change the characteristics of waste in order to reduce its amount, or dangerous qualities or to recover energy [5]. Therefore, in the EU policy a key strategy is to develop an incineration process as the basic technique used to get rid of waste, to increase the number of incinerating plants, and the percentage of burnt waste in all EU countries.

In Poland an amount of municipal waste is about 12 million tonnes, the majority of it, is dumped. It makes a serious burden to the environment due to the landfill gasses (inter alia methane)

An average amount of municipal waste in Poland per person in 2011 was 315 kg. Paradoxically, it is one of the lowest level, while an average in EU is 502 kg per person. A disproportion can result from the differences in the economic growth, and the fact that only 80% of Poles belong to the organised system of waste collection.

It is estimated that there is about 4 million biodegradable fractions in the bulk of dumped waste. According to the expectations of the National Plan for the Waste Management 2014, an amount of waste in 2020 will be about 14,2 million tonnes, and whereof 7,5 million tonnes will be biodegradable. It will be allowed to dump about 1,5 million tonnes, and about 6 million tonnes of organic waste will be processed in a different types of treatments [24]. Taking into account the fact that more than 70% of the household waste is dumped, it is the least favourable method on the ladder hierarchy of waste management. Incinerating waste is one of the options which will allow to recover energy, and become an alternative to continuously diminishing natural supplies.

Fig. 2 Municipal waste management in 2011 in Poland. Data from the Main Statistical Office

Thermal systems to transform waste will have a leading role. Mainly these, which have an additional option – obtaining thermal or electrical energy, and process steam used in the further processes. A development of civilisation brings an increase of collected waste, which is characterised by a considerable power potential. By means of incinerating waste, the problem of dumping becomes diminished. An Act on Waste gives a straight way to develop an energetic technology of power included in waste.

There is a huge interest of power industry in incinerating or co-incinerating of waste in the power boilers, which results in the possibility to produce energy from the renewable energy sources. Nowadays, a share of burnt waste, which is not a biomass fraction, is tiny. It is strictly related to the need of fulfilling additional requirements concerning protection of environment and exploiting processes. There are, in the rules of directives so called biodegradable fractions, which are a part of mixed municipal waste and can be aerobically or anaerobically decomposed by the microorganisms. There are also technical conditions, which specify a share of biodegradable fractions, included in the municipal waste and is due to heat treatment in the incinerating plants [6]. Fractions of municipal waste meet a definition of biomass which is included in the Directive 2009/28/WE. The definition states that biomass is susceptible to biological decay fractions of products, waste, farming and forestry residues and related to them other branches of industry, as well as municipal and industrial waste susceptible to biological decay [6]. On 23rd of January 2008 European Commission accepted a project of the directive which promotes the use of renewable sources of energy. It imposes on Poland and other member countries an obligation to reach a level of 20% of renewable sources of energy use by 2020. Therefore, incinerating waste and recovering energy out of it. Part of it will be classified as a renewable source of energy, which seems to be necessary not only in Poland, but also in developing countries.

One of the crucial limitations is to comply with the obligations imposed by European Union on Poland, which is an insufficient number and a processing capacity of systems used to recover and neutralise municipal waste. At present, there is only one incinerating plant in Poland. It is a relatively new plant, which was built in Warsaw in 2001 and its rated output is 42 000 Mg/year.

TABLE 1

A list of systems used to manage municipal waste in Poland (except of rubbish dumps) on 31st December 2009 [6]

Type of system	A number of systems in general	Total capacity power [thousand Mg]
Composting green waste and selectively collected organic waste (plant and animal)	89	602,3
Sorting selectively collected municipal waste	78	548,3
Sorting mixed municipal waste	26	581,7
Sorting municipal waste – mixed and selectively collected	50	1097,1
Incinerate plants	1	42,0
Fermentation plants	4	51,5
Plants of mechanically – biologically processed mixed municipal waste*	12	411,7
Total	**260**	**3334,6**

*except plants producing alternative fuel

According to the National Plan for the Waste Management a few more systems were planned to build i.e. in Łódź, Kraków, Białystok, Konin, Poznań, Szczecin, Bydgoszcz and Toruń, which aim is to neutralise about 2,4 million tonnes municipal waste per year and recover heat and electric energy.

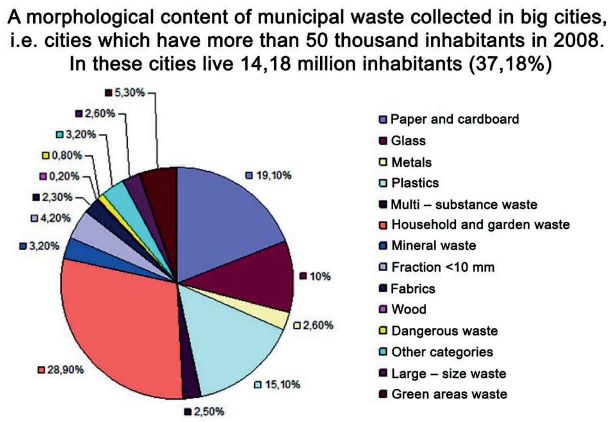
Now, a part of mentioned projects is being designed or performed.

3. Municipal waste as a source of energy and its fuel properties

A type and a quality of fuel have an impact on it in the process of combustion. There are following factors which have an influence on the process of combustion: a chemical composition of fuel and ash, a content of volatile elements, ballast, moisture, calorific value, density etc. The more fuel is inhomogeneous, and the quality is worse, the system of combustion must be more measured. A composition is a key factor which decides about the possibilities to use thermal methods of the municipal waste utilisation, and it is called a morphology of waste. Municipal waste makes an inhomogeneous mixture of materials with changeable parameters such as granulation, chemical composition and physical properties. Morphological analyses of municipal waste which allow to describe its physicochemical properties have been made for many years and they show a variable composition of waste. Therefore, a specification of an amount of municipal waste on a given area, and a description of a composition should become a base in designing technological solutions in waste management.

The Ministry of Environment provides the data that an amount and a composition of waste depend on the level of economic growth, wealth of the society, a character and a size of an administrative unit (a city, or a village), part of the year, and other social and economical factors [3]. Household waste and another waste collected by the modern society reflect production and consumption. Waste includes different materials and chemical substances, which are in use in the society. It also includes pollution, which is made by waste. It particularly refers to those households where waste includes small amount of mercury, cadmium, dioxane and another pollution. Thus, it is necessary to deal with it very carefully not to spread pollution into the environment.

Underneath, as an example, there are differences in the composition of waste depending on the place of its make



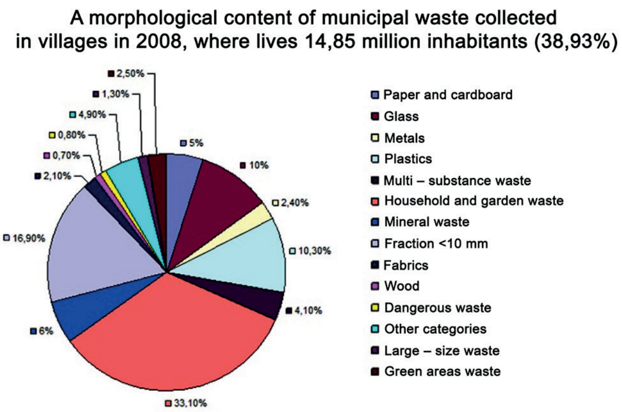


Fig. 3. A morphological content of waste

There are many fractions such as a biodegradable biomass fraction, plastics, or so called indifferent fractions from the energetic properties point of view in municipal waste [11]. The first two fractions decide about a possibility to incinerate waste. However, there is also waste, which is dumped because of the economical situation or a lack of a proper technological processes. Although it possess a lot of flammable substances and can be treated as fuel, or used to make formed fuel. Incinerating power fractions of municipal waste is entirely different than burning homogeneous fuel. It is a pure coincidence that shows us what we will deal with due to the lack of stability of the content that is a type and an amount of flammable substance. Waste is characterised by a changeable in time diversity of substances, which has an influence on the quality of burnt gases and ash, as well as the process generating undesirable chemical compounds such as heavy metals. A source of heavy metals (Cu, Cd, Co, Cr, Pb and Zn) is paper, food waste, rubber and leather. A content of chlorine in waste is also important due to an emission of dioxane and furane, which are undesirable chemical components in the process of combustion. Modern incinerating plants are considerably reducing mentioned substances. During a thermal process, which takes place in the temperature over 700°C, most of the dioxane resolves into elements such as carbon dioxide, water and hydrogen chloride. Small amount of dioxane which is not disintegrated is stored and than removed in the process of burnt gasses treatment.

A morphological content of waste relates to its fuel properties, and each waste element has a particular heat of combustion. On the other hand, heating value of municipal waste as fuel depends on the content of fuel that is a content of flammable elements, moisture, inflammable elements, organic fractions etc. for the energetic use of waste it is a heating value, which is of great importance in assessing energetic properties of waste treated as fuel. Plastics have the highest heating value. A criterion of waste flammability is usually the border of its autothermal combustion, which was conventionally set up on a level of 6,0 MJ/kg. It reflects the following characteristics:

- moisture content about 40%
- content of inflammable fractions about 22%
- content of flammable fractions about 38%

A process of autothermal combustion of waste is desirable and allows a thermal transformation of waste without adding additional fuel and enables to recover a part of power included in the flammable components of waste.

Municipal waste in the developed countries has exceeded a boundary heating value of 6000 kJ/kg many years ago. Assessment rates of municipal waste, which were confirmed by researches, show that waste in Polish big cities are allowed to be autothermally incinerate [2].

4. Thermal processes of waste utilisation

There are many technologies which enable to manage and neutralise waste, the most common are dumping, composting or a thermal processing. It can be stated that none of them can exist separately, because not all waste can be either entirely dumped or composted. Therefore, it became vital to make a system of waste management, where each technology of waste processing has a proper place. Due to so called integrated waste management it is possible to make a complex utilisation of a vast range of municipal waste. It guarantees a maximum recovery of included products, useful raw materials and power [1]. Except of reducing an amount of waste and its recycling, a heat treatment is the last indispensable stage in a modern and balanced system of waste management.

Gaining a substantial amount of heat is one considerable advantage in the process of a thermal utilisation of waste. Moreover, a thermal utilization reduces a load on rubbish dumps, and first of all, it allows to save the use of mineral fuel.

.It is worth considered that thermal processes are very complex phenomenon, mentioned processes depend on many factors. Therefore, it is difficult to describe a process, which takes place in the thermal utilisation of non-standard fuel such as for example waste (municipal, industrial or medical). Without any doubts, mentioned fuel is different from the conventional one by its content and many different physical and chemical features. It makes a thermal process of waste utilisation more difficult and makes more dangers to the environment. The common aim of all thermal processes of waste utilisation is to use an energetic potential in a possible and easy way without much influence on the environment.

According to the Waste Act a thermal change of waste is a waste combustion by its oxidation, and also other heat treatment processes of waste, which include pyrolysis, gassing, and plasma technology if the substances made that are made in those processes include combustion [7]. It results from the above definition that combustion is a final process in the waste utilisation, and other technologies are in-between stages, nevertheless finally leading to combustion.

Pyrolysis and partly gasification (gassing) require an external heat source, while in the process of combustion – a content of energy in waste is usually satisfactory to maintain the process without adding another fuel. The first two processes are used mostly in heat treatment of waste in fluidized boilers.

Co-incineration with conventional fuel is also ranked as heat treatment methods of utilisation. National and community laws allow to change waste thermally during other technological processes. Co-incineration different groups of waste with conventional fuel (hard and brown coal) in power boilers, in the aspect of waste management, is an interesting solution, especially due to co-incineration of fuel with RDF (Solid Recovered Fuel) type of waste fuel. This name is used to describe all kind of waste which was processed in order to get a proper heating value.

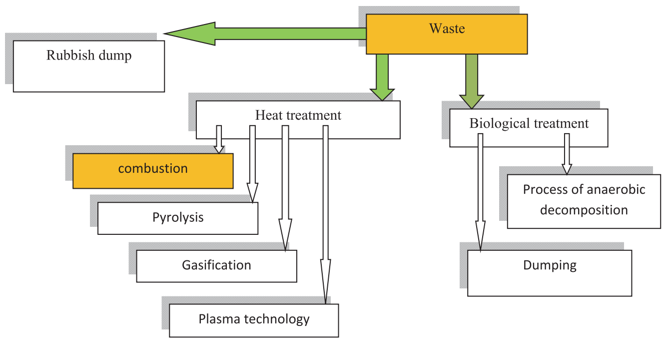


Fig. 4. Available methods of waste processing

5. Combustion

Fuel combustion as a thermal process is the main source of heat. A concept of combustion refers to a fast chemical reaction connected with releasing considerable amount of heat and light [8]. To burn fuel it is necessary to supply a suitable amount of oxygen, which is mostly delivered with air (incinerating). The basic substance which takes part in combustion is fuel. Fuel and air used in incinerating are called substrates, while combustion gases and solid rests (ash and slag) are combustion products. Each fuel consists of flammable parts and the ballast (mineral substance and moisture), and inflammable gaseous elements such as nitrogen or carbon dioxide. Chemical and physical constitution of a substance is the key information which determines its usefulness as fuel.

Combustion belongs to the methods of waste heat treatment, which is a process of decay of organic elements of waste. The process takes place in the temperature above 600°C. The temperature of combustion has an influence on an efficiency of exhaust reheat of carbon dioxide and an emission of many volatile pollutants from the furnace, and a share of volatile elements in the ash. Moreover, the temperature of combustion depends on the speed and stability of the process. These parameters decide about the construction of furnace. Furthermore, the process of combustion is characterized by the lower cost of waste processing, a possibility to process a bigger amount of waste, and an ability to recover heat from burned waste.

On the other hand, waste combustion causes a lot of worries connected with emission of pollutants typical for mineral fuel (CO_2, CO, NOx, SO_2 and dust) and heavy metals. The process of combustion is uneasy to control, mostly due to the fuel composition, because waste is difficult fuel. Nevertheless, combustion is a basic method of heat treatment of waste, while pyrolysis and gassing are used in the complex systems.

6. Pyrolysis – oxygen free technology

Generally speaking a process of pyrolysis can be characterised as a thermal decomposition of a substance in a high temperature. Molecules are degraded (decomposed) into smaller compounds in the high temperature. Moreover, the process takes place in the closed system, without bringing any substrates (air) from the outside. The aim of pyrolysis is a decomposition of waste into solid, liquid and gaseous products so after a proper purification they can be used as fuel or a raw material. The pyrolysis products are as follows: flammable gasses, water and oil condensate and solid residue [8].

There are two types of pyrolysis depending on the temperature: low temperature pyrolysis (in case of coal fuel processing called low temperature carbonization), which takes place in the temperature about 450 - 750°C, and high temperature pyrolysis (called high temperature carbonization) in the temperature about 900 - 1100°C. Depending on the kind of decomposition of solid, fluid or gaseous fuel, it is called degassing and cracking correspondingly.

Pyrolysis method requires an initial preparation of waste and a precise purification of recovered gas. Waste which is made in this method is toxic, and cannot be dumped with municipal waste. Moreover, a content of heavy metals is higher than in slag from the incinerate plant.

Despite the fact that pyrolysis of waste is at present a niche process of a thermal utilisation of waste due to a lower watt-hour efficiency, lower efficiency and the higher costs of implementation is considered as one of the technologies of dangerous waste processing. One of the reasons, which has an influence on its development is a possibility to control the parameters of pyrolysis. Furthermore, a NOX or SO2 is much lower than in the combustion processes [8] due to a better supervision over a thermal process of waste processing and its control.

7. Gasification - a technology with a deficiency of oxygen

Gasification is a change of solid and liquid substances such as biomass, coal, waste into gas, which makes a mixture of methane, hydrogen, and carbon monoxide. A process of gasification can be an initial stage before a process of incinerating, or as a process which makes a raw material used in a further chemical production [8]. Gasification is implemented in a very high temperature in a deficiency of oxygen or water vapour. Above technology is intensively developed, because it is very favourable in case of using waste as fuel. Gas which is made in this process is used to produce thermal or/and electric energy, and properly purified can be used in the engine generators. Gas boiler-rooms for a traditional natural gas can be replaced with a gasifying system, which both allows waste utilisation and a production of energy. A process of gasification allows more effective than in case of a traditional combustion, utilisation of different waste, leading to about 80% reduction of waste in total.

8. Plasma technology

Plasma technology of neutralising waste, as one of few, has great possibilities to neutralise different kind of products and dangerous waste, which due to its toxic properties requires maximum level of destruction. There are numerous materials such as industrial sewage and sediment, which include heavy metals, used oils, asbestos waste, hospital, biological waste, slag, dust, process gases [9].

Generally speaking, plasma technology is the process of incinerating by plasma torches, operating in the temperature around 5000°C such products as municipal and industrial waste, biomass and coal. In these conditions, all the chemical bonds are broken, and there are not any conditions to make dioxane and other dangerous substances. After purifying hot gasses from e.g. heavy metals, there is a process gas, which can be used in heating boilers, gas turbines or power boilers to produce for example electricity. This process does not cause any emission of harmful substances into the atmosphere, and the by-product of incinerating is slag, which is used as an aggregate to build roads. The key issue is that the plasma method belongs to the thermal methods, and is not an incinerating process as the EU law regulations state.

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