Conference Paper

Energy Efficient Technology of Solid Domestic Waste Recycling in Shaft Furnaces of Cupola Type

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Abstract

The technology of high-temperature pyrolysis (over 850°C) performed in an energy plant based on a shaft melting unit is one of the most efficient ways of solid domestic waste neutralization and recycling. It includes preliminary preparation in the extruder, high-temperature pyrolysis under the conditions of shaft furnace smelting with addition of solid fuel, cleaning and use of pyrolysis gases as a fuel in the boiler. The generating solid waste represents safe mineral components.

Keywords: solid domestic waste, recycling, extruder, shaft melting unit, pyrolysis gas, superheated steam

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Virtually for all regions of the Russian Federation where the share of the urban population reaches 70% one of the main tasks in the sphere of environmental protection is to solve the problem of neutralization and recycling of domestic waste. Of these, the waste forming in the residential areas is the most problematic one due to a complex morphological composition and distributed sources of formation [1]. According to the statistical average data, 1 to 1.4 m^3 of solid domestic waste (SDW) is formed for every Russian urban dweller per year. Moreover, the quantities of domestic waste continue growing but areas for waste burial are reducing [2].

The technology of high-temperature pyrolysis (over 850°C) is one of the most efficient ways of SDW neutralization and recycling. This technology implemented without air access or with a limited quantity of air is capable to provide the following [3]:

- Completely neutralize domestic waste of all types;
- Reduce the waste volume in 10-20 times and the waste mass in 3-4 times;
- Produce inert waste residues incapable of the negative impact on the environment, i.e. secondary resources which are environmentally safe and can be stored at the site for further use in different industries for production of commercial products, i.e. construction materials, etc.;

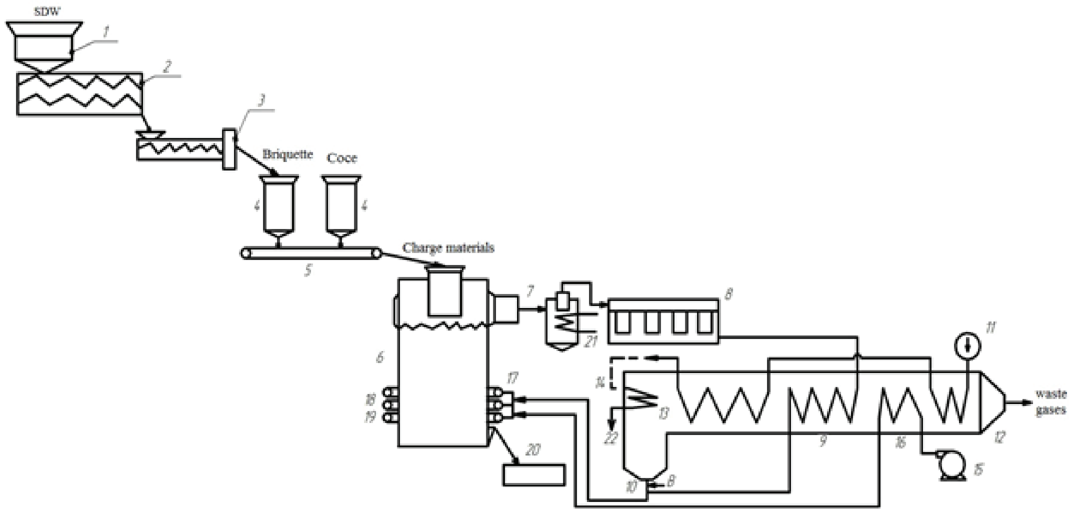

Figure 1: System of SDW recycling in the shaft melting unit: 1 – SDW hopper; 2 – preliminary SDW disintegration; 3 – extruder; 4 – briquette and coke bins; 5 – conveyor; 6 – cupola furnace; 7 – cyclone; 8 – bag filter; 9 – pyrolysis gas preheater; 10 – boiler furnace; 11 – water pump; 12 – economizer; 13 – heat-exchanging surfaces of boiler; 14 – steam superheater; 15 – air fan; 16 – air recuperator; 17, 18, 19 – burners; 20 – utilization of undecomposed SDW; 21 – temperature stabilizer of pyrolysis gases; 22 – steam consumers.

- Produce gaseous fuel in the quantity up to 1.0-1.4 m^3/kg of waste with the calorific value up to 11 MJ/m^3 [4].

The above advantages of domestic waste pyrolysis technology are best manifested when waste is thermally treated in shaft furnaces of cupola type. A wide experience in engineering, modernization and industrial operation of these furnaces [5–8] leads to the following conclusions:

- Technology of SDW recycling can be implemented regardless of the waste chemical composition and without additional preparation;
- Energy efficient and highly productive operation of the shaft furnace is ensured by heat conditions with a high thermal efficiency coefficient at minimum capital and operational expenditures at a restricted area where production equipment is located;
- Secondary waste in the form of pyrolysis gas is used as an energy source for generation of hot water, steam or electric power;
- Secondary waste in the form of mineral melt is an environmentally safe resource for production of crushed stones or heat insulating materials.

The system of equipment for domestic waste recycling in an energy plant based on a shaft furnace of cupola type is shown in Figure 1. The waste recycling technology used for development of this system includes SDW accumulation without preliminary sorting

Parameter	Value
Unit production rate	Up to 6 t/h (as per charged burden)
Solid fuel consumption	Max 0.3 t/h
Pyrolysis gas flow rate	Max 100 m^3/tT
Air blast flow rate	Max 1000 m^3/t
Air preheating temperature	Up to 450-600°C
Pyrolysis gas output	Min 1000 m^3/t with calorific value min 11000 kJ/m^3
Output of solid secondary resources	Depending on ash content but max 10-15%
Steam capacity of the unit	Min 350 kg/t
Recommended dimensions of the building for installation of the shaft melting unit	Length min 30 m; Width min 20 m; Height min 25 m
Recommended dimensions of the building for arrangement of pyrolysis gas cleaning and combusting equipment	Length min 25 m; Width min 20 m; Height min 20 m

Table 1: Parameters of SDW Recycling Technology.

in a special hopper (1), SDW preparation (as a source raw material) for treatment, heat treatment with production of mineral portion of waste in the form of molten mass and utilization of secondary energy and material resources.

SDW preparation for recycling includes minimum two stages: disintegration and preliminary homogenization (2) and lumping (3) of domestic waste. The first stage, i.e. disintegration, uses the experience of iron and steel works in preparation of iron-ore materials in mechanical grinders producing the final product in the form of fine homogenized mass. Because of its capabilities, this equipment was included in the SDW recycling system at the disintegration stage for producing a homogeneous mass used at the next stage, i.e. lumping.

It is reasonable to produce lumped materials 60-80 mm in diameter with required physical and chemical properties in a most efficient way in the extruding machine. The extrusion technology for lumping disperse materials is widely spread in the industry [9–11] and represents a continuous technological process when high-viscosity materials are pressed through a shaping tool (extruding head, die) to receive a product of the required shape. The main process equipment for treatment of pasty mixed-phase disperse mass of disintegrated SDW in lumped briquettes by the extrusion method includes screw, ram and disc extruders. The type of the extruder is selected during design engineering of the system.

The next important stage in the SDW recycling technology is preparation of the burden for heat treatment. The initial cupola burden consisting of mineral briquettes and lump solid fuel of low activity (coke, coal, coke briquettes) in the quantity of 3-5% located in the bins (4) is formed on the common conveyor (5). Carbon components in the burden provide necessary gas permeability of the layer at the next stages of heat treatment. Supply of burden components in the shaft melting unit is arranged in such a way that the fuel layers and SDW briquette layers are supplied to the melting unit successively. In addition, it is necessary to provide leak tightness of the burden charging system.

Thermal energy required for execution and termination of physical and chemical processes during SDW treatment is provided in the furnace bottom using burners installed at three levels around the perimeter of the furnace shaft (17, 18, 19).

Pyrolysis gas generated without air access during SDW heat treatment can contain up to 10 g/m^3 of dust components. This secondary resource is separated during two-stage cleaning of waste gases which includes a cyclone (7) and bag filter (8). Undecomposed solid products remaining after heat treatment in the areas of pyrolysis, CO_2 reduction, oxidation of carbon components are delivered to the melting zone. In this zone mineral components turn into a liquid state and they are removed from the work space in the form of the molten mass through a separate tap hole. Changing the composition of the initial burden, it is possible to control the chemical composition and viscosity of the liquid phase. If there are metallic components in the liquid phase, they can be separated as a component by specific weight during settling in the hearth. The mineral melt up to Hazard Class 4 is a mixture of silicon, calcium, aluminium and magnesium oxides. The experience of Mednogorsky Copper Sulphur Plant (Mednogorsk) shows that its further utilization can be made in the form of crushed stones for road construction by pouring and crystallization of the mineral melt or in the form of heat insulating products (pumice, continuous fiber, mineral-cotton products) used in construction of residential and industrial facilities.

For temperature stabilization of waste gases above the dew point, a cyclone is provided with the temperature stabilization system using a water cooler (21). Pyrolysis gas cleaned of dust and sublimates in the bag filter is preheated in one of the boiler sections (9) up to 350-450°C to stabilize conditions for its further flame combustion in the boiler furnace (10). The boiler furnace has a pilot burner running on pyrolysis gas for ignition of the gas/air mixture. The maximum temperature in the boiler furnace is kept at the level not exceeding 1000-1100°C. The resulting combustion products warm up the boiler elements (13) for generation of saturated steam. If it is necessary to receive superheated steam, a heat exchanging section (14) can be installed in the boiler furnace. Water required for boiler operation is supplied from the pump (11) through the economizer (12).

Thus, the suggested boiler system provides simultaneously hot water from the economizer and saturated or superheated steam that can be used for heating or power-producing purposes. For deeper heat recovery of pyrolysis gas combustion products, a fan (15) and air heater (16) can be installed. They can preheat air supplied through tuyeres to the unit up to the temperature of 400-450°C. In addition, stabilization of unit performance parameters is achieved.

1. Conclusions

1. The proposed technology of high-temperature solid domestic waste recycling in the shaft melting unit is energy efficient and resource saving as it can provide complete disposal of current domestic waste and recycling of existing waste dumps with generation of pyrolysis gas in the quantity up to 1200 m^3/t and safe mineral waste.

2. Thermal operation of the technological system does not require significant inputs of mineral fuel at a relatively high value of the thermal efficiency coefficient up to 70% which can be achieved at a minimum consumption of solid fuel equal to 5% in relation to the charged burden.

3. The proposed technology significantly reduces emissions of greenhouse gases as their quantity is connected with combustion products of pyrolysis gas and insignificant coke additions.

4. The proposed technology of solid domestic waste recycling is based on the experience of thermal operation of cupola furnaces as there is a wide experience in using cupola furnaces in metallurgy, machine-building and construction materials industry. This knowledge and experience can be successfully used for design engineering and construction of the solid domestic waste recycling system.

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