

Waste-to-Energy Systems Modelling Using In-House Developed Software

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Thermal treatment of waste with heat recovery (waste-to-energy, WTE) belongs to one of the preferred options worldwide. WTE systems undergone fast development during last decades. Today they are featured as complex processes not only disposing waste with minimum impact on environment but also producing reliable and clean energy. In the paper, in-house developed software W2E is proved as a powerful tool supporting performance analysis of technologies in the field of thermal treatment of waste. Its features and possibilities are demonstrated through a case study involving a real WTE plant with annual capacity of 100 kt of waste. Model building procedure, model validation including rigorous analysis of operational data and practical use of the model are discussed in more details. Results of simulation (i.e. relationship between electricity and heat production under different operational conditions and fuel rate) are presented.

1. Introduction

Nowadays, there are about 400 Waste to Energy plants operating in the EU. None the less, only 20 % are disposed by incineration and more than 42 % of waste produced in EU is still landfilled. There is large potential for new Up-to-date technologies for energy recovery of waste. Waste becomes valuable source of clean and reliable energy, and in this way it contributes to reduce of primary energy sources consumption. These technologies are one of the preferred ways of waste treatment in the EU. Therefore building of new plants for waste incineration with energy utilisation is expected in many countries within EU. It is enforced also by legislative.

Whereas the former focus was mainly on minimization of negative impact on the environment as a consequence of more and more sweeping emissions limit, today maximum heat recovery and focus on electricity generation is the key driver for further development. The same trend can be observed by existing Waste to Energy plants operated in Czech Republic. They were oriented on major heat supply, but now the

production of steam is completed by cogeneration, which enables high efficient and flexible use of energy contained in the waste.

Expected projects of new plants and modernisations of present systems have to be based on simulation models and analysis, in which theoretical approach (thermodynamic processes) and experience from real plant operation is combined. For this reason a software W2E was developed in-house (Touš et al., 2009) as a supporting tool for creation of computational models based on energy and material balances. Results from W2E are verified on real operational data in this paper. The possibilities of process modelling in W2E software are also demonstrated.

Real operational values and experience obtained from existing incinerators are analyzed and transformed into suitable form applicable for computational models in W2E. These models also afford necessary data for other analyses, such as economic assessment or evaluation of the energy recovery efficiency - R1 formula (Grosso et al., 2010).

2. Software W2E

The W2E program is a supporting tool for technological processes simulation. It was originally created for waste to energy plants simulation, but it could be also used in a more general way - for modelling of various technological applications.

The formation of the simulation models consists in design of flow sheet. It takes place in graphical interface with intuitive operating (Fig. 1). The principle of composition of the model corresponds to other similar systems. It is based on using of various technological blocks which are interconnected by streams so more complex facilities can be simulated. Then setting of values and running of simulation follows. It is a similar principle as is used in other simulation software (Lam et al., 2010).

The software was developed in Java and computations use sequential-modular approach (calculations move from one computational node to another until parameters of all units are evaluated). It provides energy and material balances of modeled units.

The program enables easy extension of new technological blocks and streams, which makes this software very versatile. Source code of W2E is designed in the way that the addition consists of few operations. Any advanced programming skills are not needed. The development of the software is more extensively described in (Touš et al., 2009).

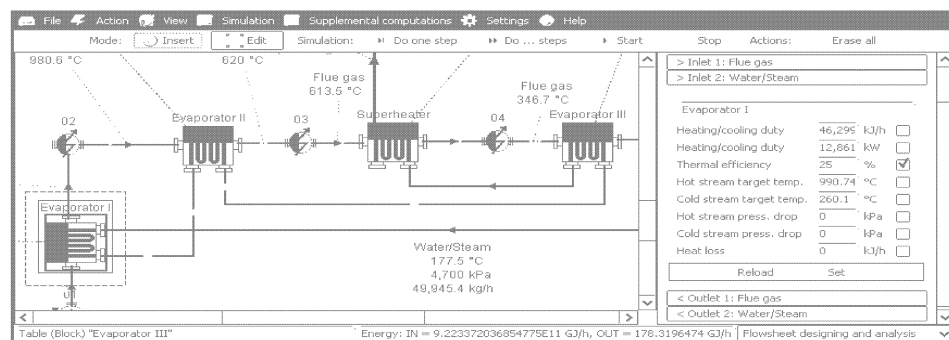


Fig. 1: User interface of W2E

3. Case study – computational model of real WTE plant

Model creation of real waste-to-energy plant in software W2E is presented in the paper. It was used information and values from the most modern and latest Czech municipal solid waste incinerator TERMIZO Inc., located in town Liberec. Due to technology concept used, reliability in operation and performance is such a plant considered as typical representative of up-to-date technology.

The model was created for analysing the energy and combustion characteristics of the incinerator in context of the plant modernisation and second turbine stage installation. Therefore the model provides simulation of thermal stage, where the waste combustion and after-burning processes takes place, and heat recovery block, where heat contained in flue-gas is utilized for production of superheated steam. Flue-gas cleaning system isn't performed in the simulation.

3.1 TERMIZO waste-to-energy plant

This incinerator presents up-to-date waste-to-energy plant with capacity of approximately 12 t/h, that is 100 kt annually, when the plant is in operation more than 8000 h/a. Waste is incinerated on moving grate, heat released is then utilised in heat recovery steam generator. Produced steam is at 4 MPa and 400°C and is used in two stage turbine system. Most of the steam after it expands at the first turbine stage down to 1.1 MPa is available for central district heating system. The plant is also equipped with high efficient flue-gas cleaning system for strict emission limits fulfilment. Main production characteristics of the plant are presented in Tab. 1.

Tab. 1 Production characteristics of TERMIZO plant

Maximal stable heat production of HRSG	30.7 MW
Nominal amount of produced steam (at 4 MPa, 400°C)	35 t/h
Max. thermal output (steam at 1,1 MPa)	24.1 MW
Max. electrical output, first stage	2.5 MW
Max. electrical output, second stage	985 kW

3.2 Model building procedure

The procedure of the model building is presented in simplified scheme on Fig. 2. It consists of these main computational nodes:

- Primary combustion chamber where whole stoichiometric combustion takes place. The computational streams of waste and combustion air are transformed into streams representing flue-gas with high heat parameters and bottom ash.
- Secondary combustion chamber for after-combustion processes simulation. Flue gas parameters are significantly changed here.
- Heat recovery steam generator (HRSG) for the production of superheated steam (400 °C, 4 MPa) modelling. This equipment is simulated by blocks representing economizer, superheater, evaporator tubes in HRSG and part of evaporator tubes placed in secondary combustion chamber (this represents evaporator tubes which are cooling the walls of combustion chamber; the system is interconnected here; investigation of heat transfer in this section is described in (Jegla et al., 2010)).

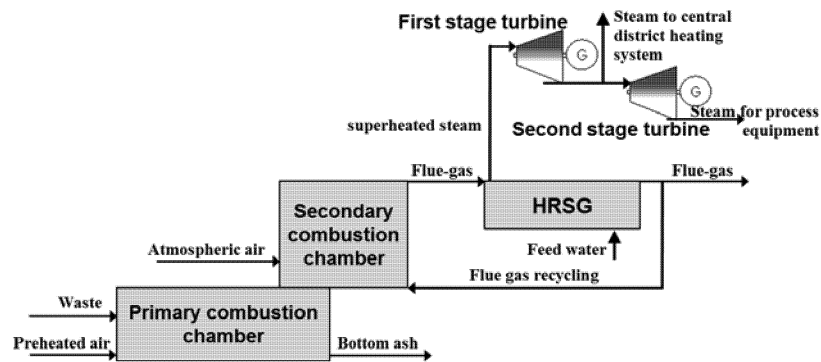


Fig. 2: Simplified scheme of model procedure

- First stage of turbine system transforms the heat contained in superheated steam to electricity. Used steam leaving this back-pressure turbine at low-pressure parameters (270°C, 1.1MPa) and it is further utilized in central district heating system and for technological purposes in the plant.
- Second stage of turbine system (backpressure 0.3 MPa) is used for electricity production if there isn't sufficient demand for heat in central district heating system. Low-potential steam from the turbine back-pressure is used within the plant and/or it is condensed in air-cooling system.

These blocks are connected by streams representing air, water/steam and flue-gas. Flue-gas recycling, energy supply for air and feed water preheating, heat losses and other additional parameters are also considered.

In this way complex model describing various processes and flows within the objective incinerator was created. Material and energy flows in main technological nodes, fundamental operational and production indicators and other necessary parameters for process monitoring and analyzing are computed.

3.3 Model input data

Real operational values from the incinerator are available for the model setting. This data includes parameters of main process streams, e.g. temperatures, flow rates or compositions of flue gas, water/steam and air.

One of main input parameters is waste lower heating value (LHV). Sufficient model without LHV as entering parameter cannot be compiled. Unfortunately, it is impossible to measure the heating value of heterogeneous and variable material such as municipal solid waste. LHV was determined according to Reimann formula (European IPPC Bureau, 2005).

Regarding the importance of this parameter it was realized rigorous analysis of computed values using sophisticated statistical tool. Average LHV of incinerated waste was determined as 10.7 MJ/kg with statistical deviance 4.6 MJ/kg. The value is normally distributed, this is illustrated on Fig. 3 a).

Before the whole model creation the obtained data was revised. It aims to detection of inadequate values, which can cause unwanted influence on model results, gain other important information and verification of process presumptions.

Statistical analyzing of the obtained values went together with the revision. It results to advanced research of relations between incinerator processes. Occurrence of different operational regimes (boiler thermal output vs. fuel rate) is shown as an example in Fig. 3 b).

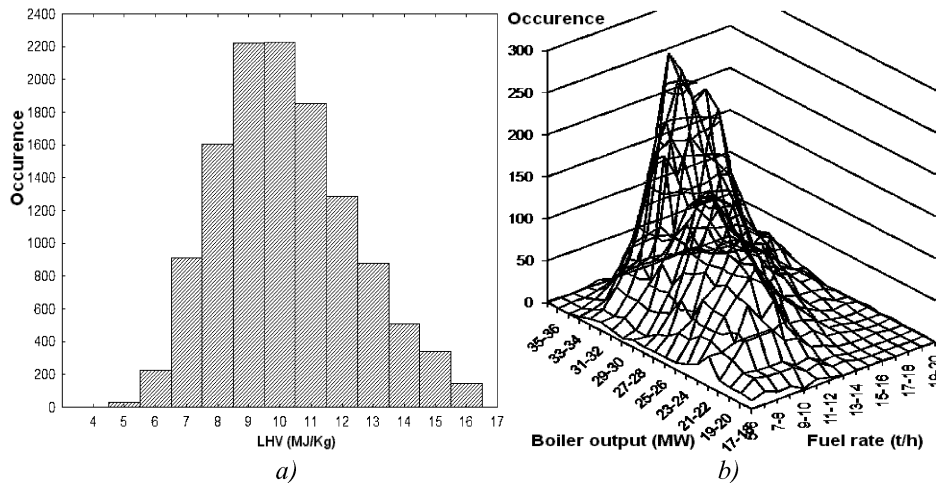


Fig. 3: a) Statistical distribution of fuel LHV; Fig 3: b) different operational regimes

3.4 Model validation

Model result values were confronted with real parameters obtained from operating of the TERMIZO incineration plant and very good agreement is found.

The results have very good correspondence to the original system values and energy and mass conservation law.

4. Results of simulation

Values obtained from model agree to real plant data and enable various analyses of different process parameters. The model provides information about streams and nodes in plant thermal stage and heat recovery block, and it affords data for other analyses.

In this paper simple characteristics of energy and heat production are presented on Fig. 4. The relationship between energy parameters (produced steam and electricity) and throughput of waste is shown. The fuel LHV and other input parameters were set on average operational values in this case.

5. Conclusions

The paper proves that previously developed software W2E (Touš et al., 2009) affords quality data which correspond to real operational values, and thus it is a full-featured

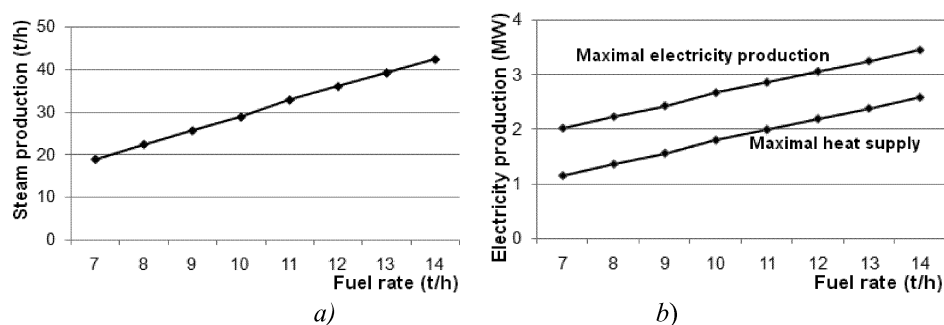


Fig. 4: Dependencies of a) produced steam b) electricity production and fuel throughput

instrument for creation of energy and material balances based models. The software significantly improves complex material and energy analyzing for various technological applications. It provides very valuable information for different facilities design, especially for the WTE plants projection.

The created model is widely applicable, it enables monitoring and comparing effects of different operational regimes and its result data are useful for other techno-economic analysis of waste combustion.

Acknowledgement

We gratefully acknowledge support of the MŠMT of the Czech Republic within the framework of research plan No. MSM 0021630502 "Waste and Biomass Utilization focused on Environment Protection and Energy Generation" and of National Research Programme project 2B08048 "Waste as raw material and energy source" (WARMES).

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