MODELLING OF ENERGY AND MASS EXCHANGE IN PLANT FOR PROCESSING OIL

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Abstract: *The technological process in a plant for processing oil has been analyzed. Reasonable approximations and the used dependencies have been accepted. A model has been created used the finite element method. Algorithm was developed to model the process in the plant. The blocks of the algorithm are describing the incoming and dissipated energy to the environment. The evaporation process of the light fractions, moisture and change of the energy state of the mix is also modeled. Based on the developed model, software is created that displays the process parameters plotted as a function of time.*
Key-words*: model, plant for processing fuel oil, management.*

1. INTRODUCTION

Processing of oil is characterized as a process consuming large amounts of energy per unit of production. It's necessary to seek solutions to reduce the energy consumption in the processing of oil. To achieve the required product quality with less energy consumption, the process needs to be modeled. Based on the model using simulation we search such control effects in which the energy consumption is the lowest. There are systems for control and management [1] for processing of petroleum products. Their major drawback is that the process is not modeled.

The goal of the study is to develop a model describing the process in handling oil. The model is designed to control plant for production of fuel oil.

2. SPECIFICITY OF THE PROCESS

The object of the study is the processing of heavy oil. The aim of the process is to remove heavy fuel oil excess moisture and some light fractions. The installation is loaded cyclically with oil for processing and after completion of the cycle appears processed oil. Heavy fuel oil is heated in a boiler through burner. Above the boiler is formed a zone of evaporation over which is located a container for the separated water vapor. In order to condense the water vapor, it passes through a cooler, in which cooling water circulates [3].

During the process is processed mainly oil, which is not suitable for usage. This makes the installation up to date regarding the environmental pollution because it is a waste-free process. The technology involves filling the system with crude oil, heating it to a certain temperature and maintaining the temperature of the heated oil for a period of time. To reduce the temperature of evaporation of the water the pressure in the installation is reduced. The evaporated water vapor and light (mild) fractions by cooling they condense and are taken out from oil.

The finite elements method is used for modeling [4, 2]. The modeling is done in time which is divided into small intervals. The energy and material exchange in the system is described for each time interval.

3. BASIC APPROXIMATIONS AND DEPENDENCIES

The rationale of the basic approximations is presented in detail in [3]. In the modeling process it's being assumed that the temperature of the hot gases in the heating zone is the same. It is also assumed that the parameters of the processed oil are the same for the boiler and evaporator.

The power of the energy loses to the environment is calculated with dependencies for convection for heat exchange and conduction. Considering the inertial properties of the structure of the fuel oil and water, is carried out by means of calorimetric equation [4].

The incoming energy into the mix is allocated for the partial evaporation of determined fractions and is used to increase the temperature of the fractions.

The evaporation of the fraction begins after reaching the temperature of vaporization. It is assumed that the energy of evaporation is proportional to the difference between the boiling temperature of the composition and temperature of the mix. A coefficient that characterizes the intensity of evaporation is also added.

It's being assumed that the temperature of the components is equal to the temperature of the mix.

4. SIMULATION OF THE PROCESSES OF PLANT PROCESSING OIL

The algorithm is shown on Figure 1. In block 1 the initial conditions are set. In block 2 masses of the individual fractions are calculated. Block 3 is intended to set the initial values of variables - the virtual astronomical time and the initial temperature of the mix and the masses of the various factions.

According to the chosen modeling method, the time has to be broken down into small intervals. This is accomplished for different the time steps: 3, 4 and 20.

The modeling of the temperature maintenance of the oil by a set value for the control system is presented in blocks 5, 6 and 7. For this purpose is monitored, if the temperature of the mix is greater than the set value (t_{mix}^{set}). If it's not greater, the temperature of the gas in the boiler is set to be equal to (t_{mix}^{set}) (block 7). If the temperature of the mix has reached the set value in block 6, the gas temperature in the boiler is set to be equal to the temperature of the mix. When we have equality of the two temperatures in the subsequent calculations no energy is introduced into the installation.

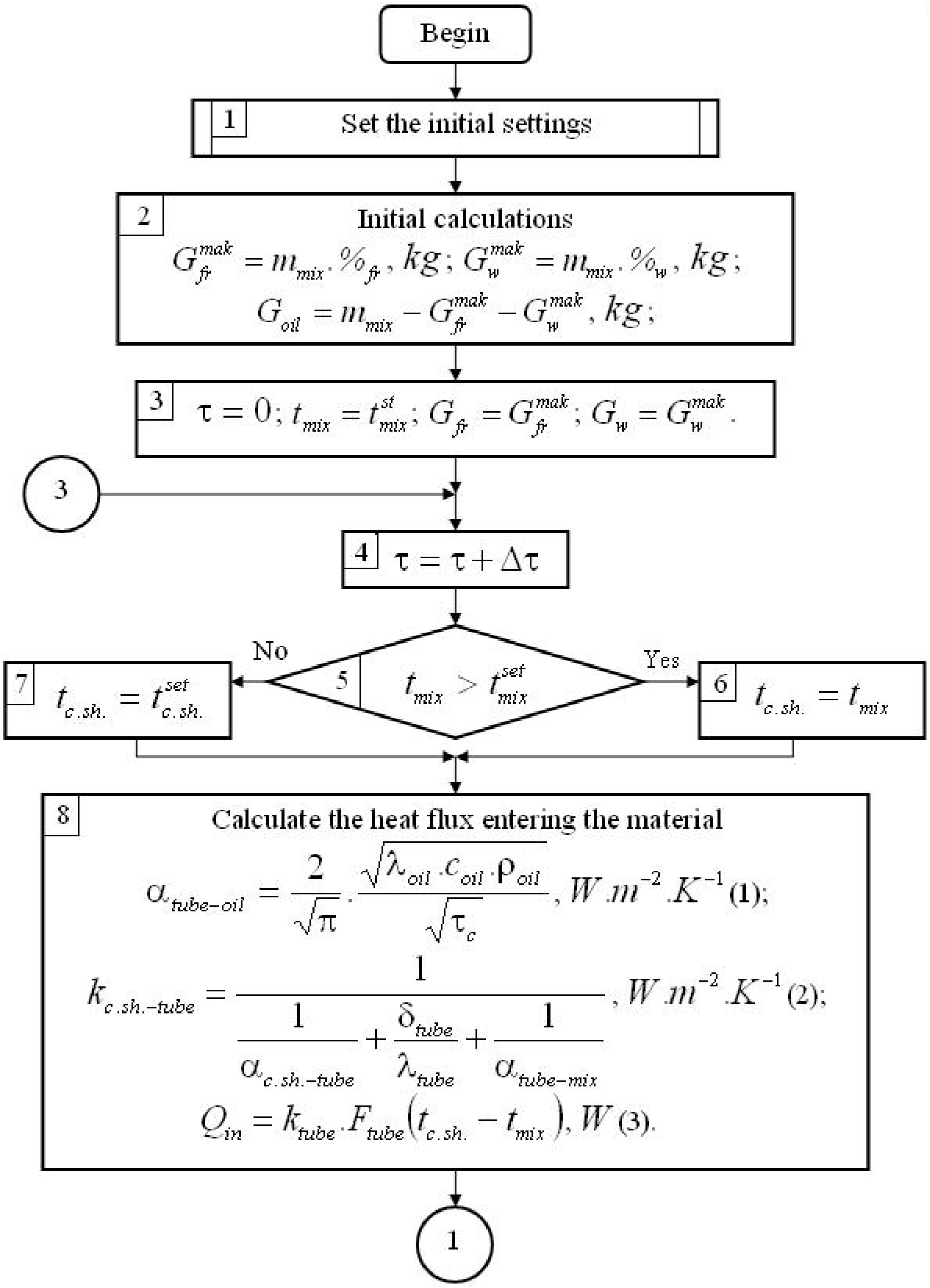

Fig. 1.a Algorithm for simulating the processes of plant processing oil

In block 8 is calculated the heat flow entering in the material. First the coefficient of convective heat transfer between the tube and the mix is calculated (1). By dependence (2) the coefficient of heat transfer is calculated. Equation (3) determines the power of the heat flux entering the mix, consisting of oil, water and light fractions.

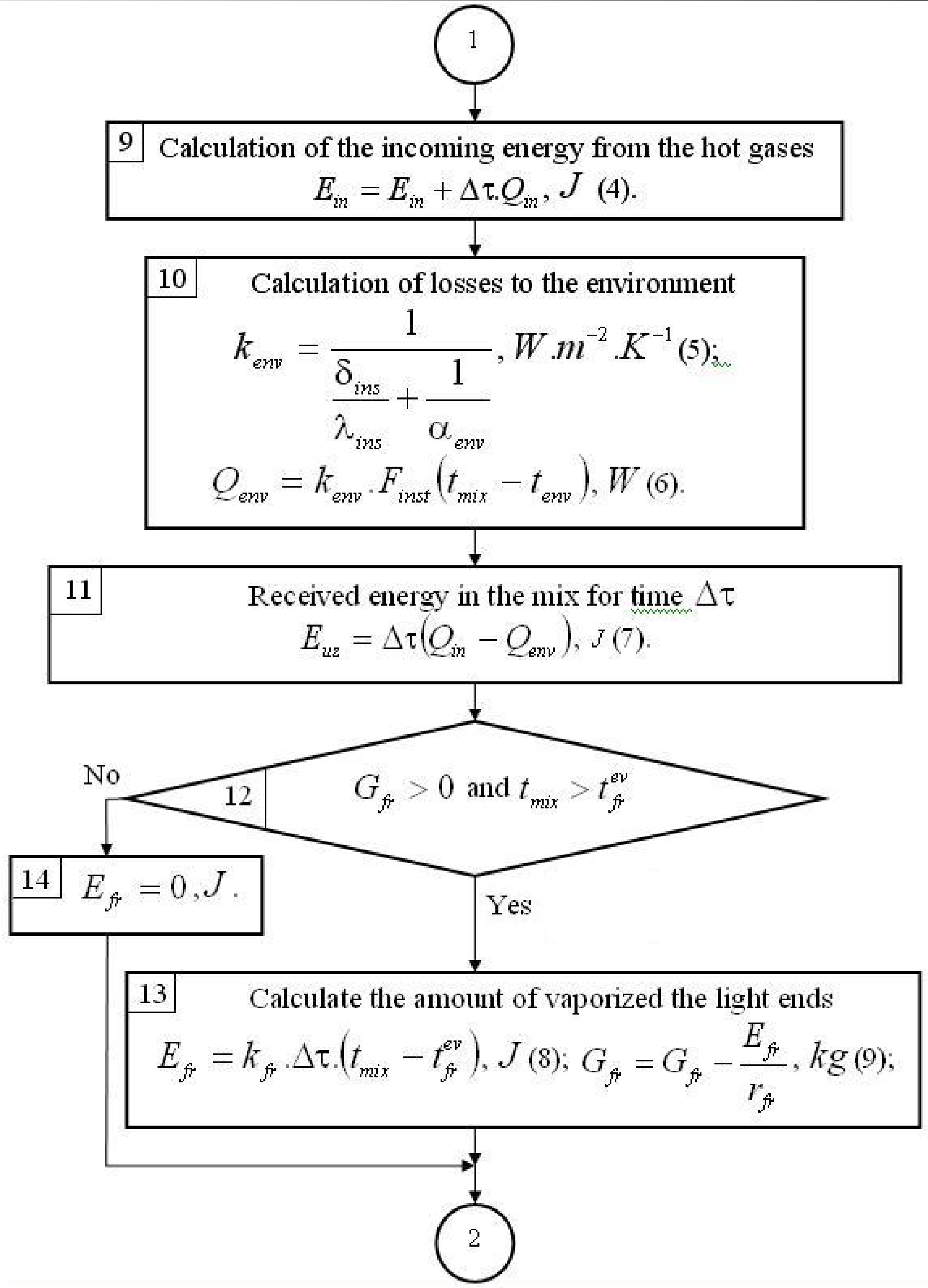

Fig. 1.b Algorithm for simulating the processes of plant processing oil

Based on the calculated value of the thermal power flow the current value of the received energy in the boiler from hot gases is determined.

The energy losses to the environment are calculated in block 10. Equation (5) determines the value of the coefficient of heat transfer between the installation and the environment. Because of the good insulation it is approximated that the temperature of the structure is equal to the temperature of the mix. Dependence (6) defines the power of the heat flow losses to the environment.

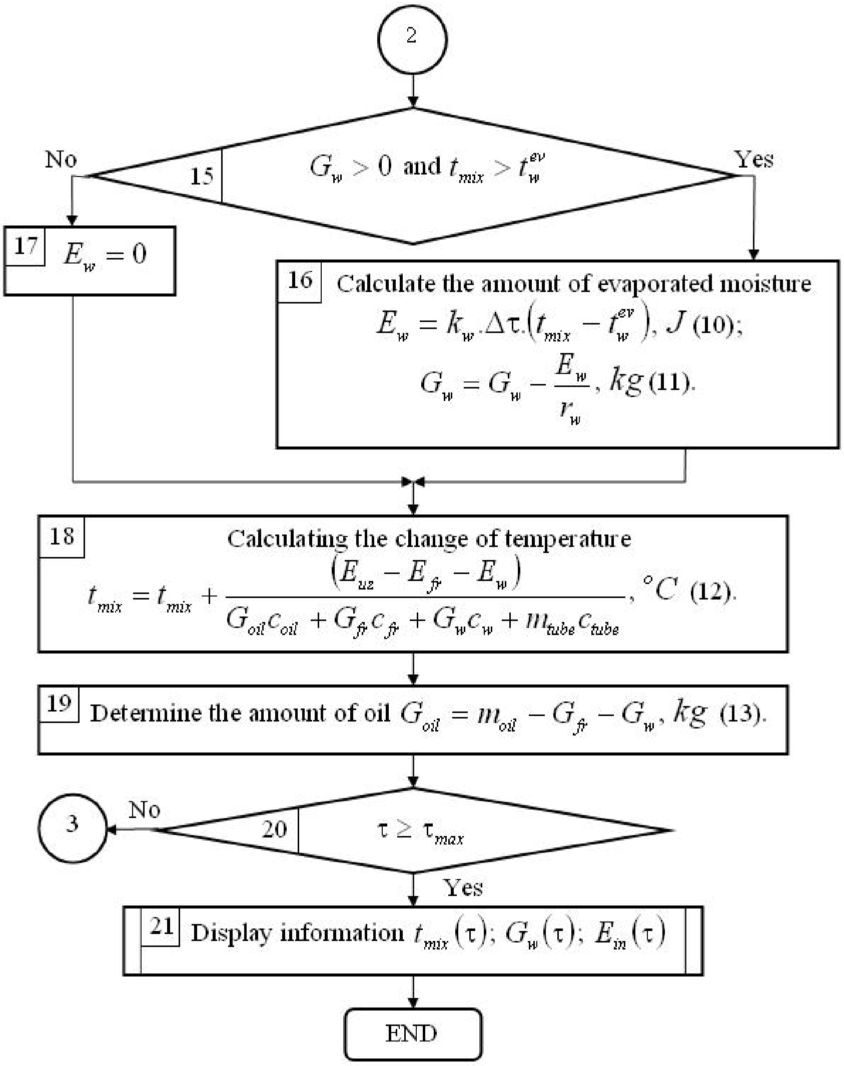

Fig. 1.c Algorithm for simulating the processes of plant processing oil

After taking into account the losses to the environment in block 11 it's calculated the current value of the received energy in the mix for time Δ τ.

The modeling of the process of evaporation of the light fractions is shown in blocks 12, 13 and 14. In block 12 is monitored if the temperature of evaporation of light fractions is reached and is there more light fractions to be evaporated. In the performing of the two conditions at block 13 by dependence (8) the energy used for evaporation of the light fractions is determined for the time interval Δ τ.

On the basis of the determined energy of evaporation and the specific heat of evaporation the mass of the vapor fraction is calculated (9). If at least one of the conditions in block 12 is not met, in block 14 the value of energy for evaporation of fractions is set to zero. In blocks 15, 16 and 17 is modeled the evaporation of moisture in the mix. When the conditions for reached temperature of vaporization and the presence of moisture are met, the algorithm continues to block 16. Using equation (10) in block 16 is determined energy for vaporization and using equation (11) - the mass of the evaporated moisture. If at least one of the conditions in block 15 is not met, the energy for evaporation is set to zero.

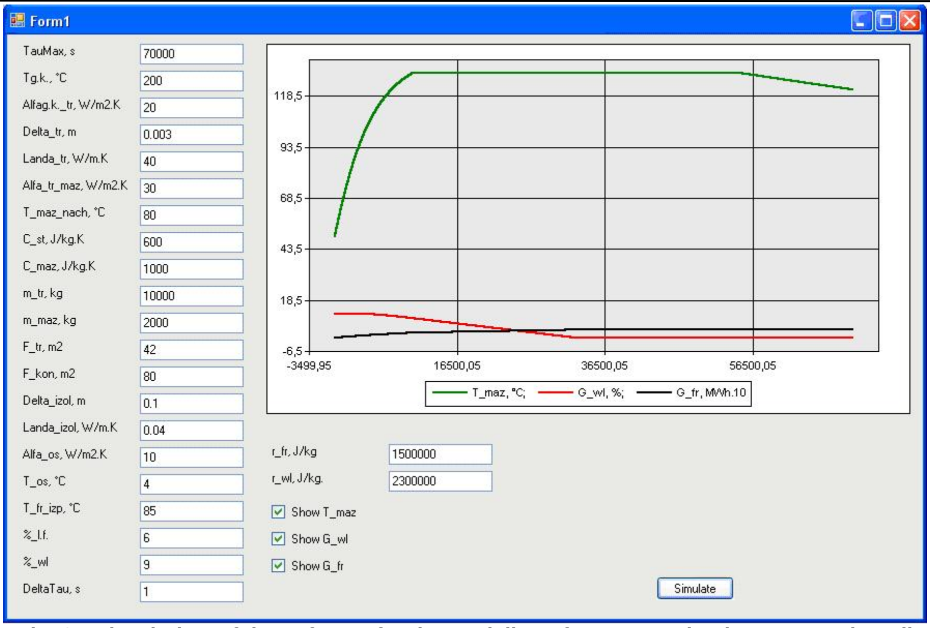

Fig. 2 Main window of the software for the modeling of processes in plant processing oil

The determination of changes in temperature of the mix comprising of oil, moisture and light (mild) fractions, is calculated in block 18. For this purpose, the energy received in the mix and energy to evaporate moisture and light (mild) fractions is taken into account. The calculation is based on the calorimetric equation. In block 19, the current mass of oil in the mix is determined. When the maximum time for simulation in block 20 is reached, the results of the calculations are displayed in block 21. On fig. 2 is shown the main window of the software for the modeling of the processes in the plant for processing oil, created on the basis of the developed model.

5. RESULTS AND CONCLUSIONS

The technological process in a plant for processing oil has been analyzed. Reasonable approximations have been accepted and used in during the modeling. An algorithm was developed to model the process in the plant. The algorithm models the incoming and dissipated energy to the environment. The evaporation process of the light fractions, moisture and change the energy state of the mix are also modeled. Based on the developed model, a software has been created, that displays the process parameters as a function of time. The model is suitable for controlling process. By choosing appropriate control effects the model can provide solutions to ensure the necessary quality of the processed oil with less energy consumption.

Table.1. Indications of parameters

№	symbol	dimension	parameter
1	c_{fr}	$J.kg^{-1}.K^{-1}$	Specific heat capacity of the light fractions
2	c_{oil}	$J.kg^{-1}.K^{-1}$	The specific heat capacity of fuel oil
3	c_w	$J.kg^{-1}.K^{-1}$	The specific heat capacity of water
4	E_{fr}	J	The energy for vaporization of light fractions
5	E_{uz}	J	Incoming useful energy in the mix
6	E_w	J	Energy for water evaporation
7	F_{inst}	m^2	The outer surface of the plant
8	F_{tube}	m^2	The surface of the tubes in the combustion chamber
9	G_{fr}^{mak}	kg	Initial mass of light fractions in the mix
10	G_w^{mak}	kg	Initial mass of water in the mix
11	G_{fr}	kg	The mass of light fractions in the mix
12	G_{oil}	kg	The mass of the heavy fuel oil in the mix
13	G_w	kg	The mass of water in the mix
14	$k_{c.sh.-tube}$	$W.m^{-2}.K^{-1}$	Coefficient of heat transfer between the hot gases in the combustion chamber and the pipes
15	k_{env}	$W.m^{-2}.K^{-1}$	Coefficient of heat transfer between the plant and the environment
16	k_{fr}	$W.K^{-1}$	Coefficient quantified energy for evaporation of light fractions

17	k_w	$W.K^{-1}$	Coefficient characterizing the amount of energy to evaporate water
18	m_{mix}	kg	Initial mass of the mix of oil, water and light ends
19	m_{tube}	kg	The mass of the structure
20	Q_{env}	W	The power of the heat flows from the installation to the environment
21	Q_{in}	W	The power of the heat flows from the hot gases to the installation
22	r_{fr}	$J.kg^{-1}$	The specific heat of vaporization of the light fractions
23	r_w	$J.kg^{-1}$	The specific heat of water evaporation
24	$t_{c.sh.}$	^oC	The current value of the temperature of the hot gases in the combustion chamber
25	$t_{c.sh.}^{set}$	^oC	The set value of the temperature of the hot gases in the combustion chamber
26	t_{env}	^oC	The temperature of the ambient air
27	t_{mix}	^oC	The current value of the temperature of the mix
28	t_{mix}^{set}	^oC	The maximum set temperature of the mix
29	t_{fr}^{ev}	^oC	The temperature of evaporation of the light fractions
30	t_w^{ev}	^oC	The temperature of water evaporation
31	$\alpha_{c.sh.-tube}$	$W.m^{-2}.K^{-1}$	The coefficient of convective heat transfer between the hot gases in the combustion chamber and the pipes
32	$\alpha_{tube-mix}$	$W.m^{-2}.K^{-1}$	The coefficient of convective heat transfer between the pipes in the combustion chamber and the mix
33	δ_{ins}	m	The thickness of the insulation
34	δ_{tube}	m	The thickness of the tubes
35	λ_{ins}	$W.m^{-1}.K^{-1}$	The coefficient of thermal conductivity of the insulation
36	λ_{oil}	$W.m^{-1}.K^{-1}$	The coefficient of thermal conductivity of the fuel oil
37	λ_{tube}	$W.m^{-1}.K^{-1}$	The coefficient of thermal conductivity of the pipes
38	ρ_{oil}	$kg.m^{-3}$	Density of heavy fuel oil
39	τ	s	Current value of the astronomical time
40	$\tau_{мак}$	s	The maximum values of the astronomical time
	$\Delta\tau$	s	Discrete change in the astronomical time
	$\%_{fr}$	%	The initial content of light fractions
	$\%_w$	%	The initial water content

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