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JUSTIFICATION OF THE CHOICE OF WOOD PULP COMBUSTION PARAMETERS FOR CALCULATION OF RUNNING CROWNING FOREST FIRES IMPACT ON POWER ENGINEERING FACILITIES IN VIETNAM

The choice is justified for the values of specific carbon monoxide formation coefficient and the specific mass gasification rate required for mathematical modeling of the parameters and heat impact of running crowning forest fires on the power engineering facilities in Vietnam. The results of an experimental study of the combustion process of wood pulp samples of the trunks of the most common hardwood and coniferous trees of Vietnam are presented. For the flaming combustion, the experimental dependences of the specific carbon monoxide emission coefficient and the specific mass gasification rate on the time period of testing of wood samples were obtained. A comparison of the average values of these parameters with the data given in the literature was carried out. It is shown that the average experimental values of the specific mass gasification rate of all wood samples in terms of time are in the range between the corresponding values for coniferous and hardwood trees listed in the fire load database by Yu. A. Koshmarov.

Keywords: forest fire; modeling; specific mass gasification rate; specific carbon monoxide emission coefficient; carbon monoxide.

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Introduction

Forest fires can cause catastrophic destruction of energy facilities vital for the economy and security of a country, the breakdown of which can cause the human livelihood disruption.

Mathematical modeling of forest fires is a very complex, not completely resolved, multifactorial and non-linear problem [1–16]. The uncertainty of the thermo-physical and chemical properties of forest combustible materials does not allow a reliable calculation of the heat flux from a forest fire affecting energy facilities, such as electrical substations, thermal power plants, hydro-electric power stations, power lines, etc. In this regard, the study of the wood pulp combustion of Vietnamese trees is an actual scientific and practical problem.

The purpose of the article is to substantiate the source data for the mathematical modeling of the parameters and heat impact of running crowning forest fires on power engineering facilities in Vietnam.

To achieve this, the experimental studies of the combustion of wood pulp samples from the most common hardwood and coniferous trees of Vietnam were carried out.

Experimental facility and methodology of the experiments

Fig. 1 shows the scheme of the experimental facility proposed in the works [17–19].

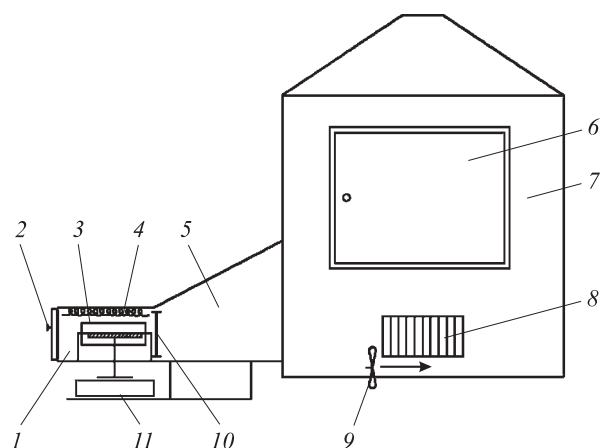


Fig. 1. Experimental facility functional diagram: 1 — combustion chamber; 2 — combustion chamber door; 3 — sample holder; 4 — electric heater; 5 — transition sleeve; 6 — exposure chamber door; 7 — exposure chamber; 8 — slide apertures; 9 — fan; 10 — fire screen (partition) of the transition sleeve; 11 — table with scales

The facility consists of a combustion chamber 1, which is connected to the exposure chamber 7 using the transition sleeve 5.

The internal volume of the combustion chamber is equal to $3 \cdot 10^{-3} \text{ m}^3$. Its walls are made of thick stainless steel sheet with the thickness of $(2.0 \pm 0.1) \text{ mm}$. Observations on samples of materials are carried out through a window made of quartz glass during testing. The selection of the test mode using the air exchange of the chamber with the room is carried out through the slide apertures on the side wall of the chamber.

The device for thermal blocking of the exposure chamber from the combustion chamber is located in the transition sleeve.

There are slide apertures 8 on the side wall of the exposure chamber with a cubic volume of 0.5887 m^3 and with the upper part in the form of a cone.

Shielded electric heater 4 and the sample holder 3 are placed in the combustion chamber.

Electronic scales 11 on which the sample holder is located, allow you to measure the sample mass with an error not exceeding $\pm 1 \text{ mg}$. The scales are installed on the table, which position is adjustable up/down.

Temperature measurements in the exposure chamber are carried out continuously using 32 low inertia armored thermocouples. The range of measured temperatures is from minus 40 to $+1100 \text{ }^\circ\text{C}$. Measurement error does not exceed $\pm 1.5t \text{ (}^\circ\text{C)}$.

The density of the heat flux coming from the shielded electric heater to the surface of the sample material is measured by a water-cooled Gordon sensor with an error not exceeding $\pm 8 \%$.

The composition of the gas-air environment in the exposure chamber is determined using a multichannel gas analyzer with ranges of gas concentrations measuring (with maximum accuracy of $\pm 10 \%$ by vol.) carbon monoxide CO — 0–1 % by vol., carbon dioxide CO₂ — 0–5 % by vol., oxygen O₂ — 0–21 % by vol.

The tests were carried out in the mode of flame combustion, which was provided by the density of the incoming heat flux of 60 kW/m^2 . The surface temperature of the heater was $750 \text{ }^\circ\text{C}$.

The experiments were carried out according to the following method.

A previously weighed sample of the material having a room temperature was placed on the sample holder seat.

After stabilization of the operation mode of the electric heater, the combustion chamber door was opened and the seat with the wood sample was placed in the sample holder. Then the fire screen of the transition sleeve was opened, and the combustion chamber door was closed. The sample ignited.

During the experiment, concentrations CO, CO₂, O₂ were continuously measured, as well as sample temperature and mass.

Further, the specific mass gasification rate ψ_{spec} ($\text{kg}/(\text{m}^2 \cdot \text{sec})$) was determined by the following formula:

$$\psi_{spec} = \frac{1}{F} \frac{dM}{d\tau}, \quad (1)$$

where F — sample surface area, m^2 ;

M — current sample weight, kg ;

τ — test time, sec .

To predict the toxicological situation with regard to forest fires, it is necessary, first of all, to know the concentration of carbon monoxide, therefore, in experiments, the specific carbon monoxide formation coefficient was determined L_{CO} at every instant according to the following formula:

$$L_{CO} = \frac{V}{\psi_{spec} F} \frac{d\rho_{CO}}{d\tau}, \quad (2)$$

where V — exposure chamber volume, m^3 ;

ρ_{CO} — medium volume density CO in the exposure chamber, kg/m^3 .

Input data

In order to perform mathematical modeling of the parameters and thermal effects of running crowning forest fires, it is necessary, first of all, to know the lowest working heat of combustion Q_{low}^{work} (MJ/kg) and specific mass gasification rate of wood pulp.

The data analysis given in the works [20, 21], shows that the lowest working heat of combustion of coniferous and hardwood wood is in the range $Q_{low}^{work} = 13.8 \div 21.2 \text{ MJ/kg}$. Therefore, if its average value of 17.5 MJ/kg is used, the error compared to its true value does not exceed 27 %.

We will carry out measurements of the specific mass gasification rate of wood pulp samples of Vietnam trees, shown in Table 1. The sizes of the wood samples were $0.1 \times 0.1 \times 0.02 \text{ m}$.

The moisture content of the samples was measured with ZNT 125 Electronic moisture meter with measuring range 5–50 % and error measurement $\pm 2 \%$. The samples humidity did not exceed 8 % (see Table 1), which cor-

Table 1. The considered tree species of Vietnam

Number of sample	Name (english, vietnamese)	Tree kind	Humidity, %
1	Acacia auriculiformis, keo	Deciduous	< 5
2	Chinaberry, xoan		< 5
3	Pine, họ thông	Coniferous	< 5
4	Eucalyptus camaldulensis dehnhardt, bạch đàn	Deciduous	8
5	Dimocarpus longan, nhãn		7

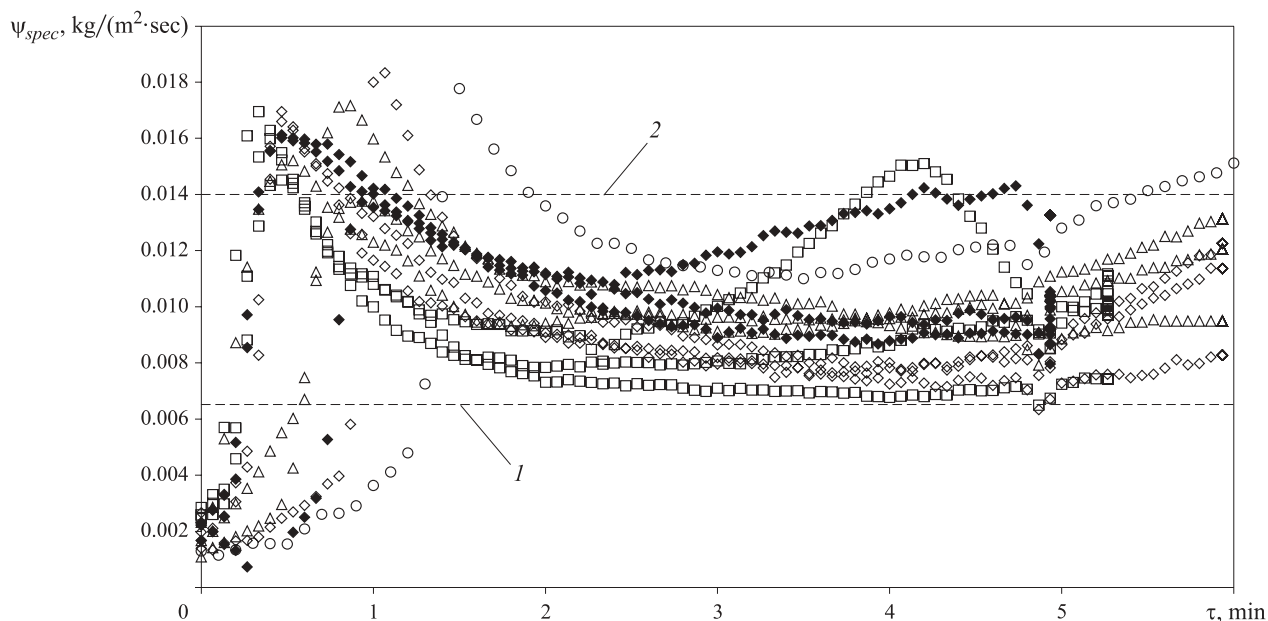


Fig. 2. The dependence of the specific mass gasification rate of wood pulp from the period of sample testing: $\square$ — No. 1; $\triangle$ — No. 2; $\blacklozenge$ — No. 3; $\circ$ — No. 4; $\diamond$ — No. 5; 1 — coniferous trees, $\psi_{spec} = 0.0063 \text{ kg}/(\text{m}^2 \cdot \text{sec})$; 2 — hardwood trees, $\psi_{spec} = 0.014 \text{ kg}/(\text{m}^2 \cdot \text{sec})$ [21]

responds to the humidity of Vietnamese trees in the most fire-hazardous dry period of the year.

Study results and their analysis

Fig. 2 shows the experimental dependence of the specific gasification rate of wood samples on the test time period.

Fig. 2 shows that local values ψ_{spec} after 2 minutes of tests are in the range of 0.0063 up to 0.014 $\text{kg}/(\text{m}^2 \cdot \text{sec})$, where lower limit corresponds to the combustion of coniferous trees, and the upper — hardwood ones [21].

Fig. 3 shows the experimental dependence of the specific carbon monoxide formation coefficient on the time period. Analysis of the experimental results shows that the value of the specific carbon monoxide formation coefficient is negligible at the initial stage of testing. This is explained by the fact that during this period the oxygen concentration is almost constant and is equal to the concentration in the air of the room and carbon monoxide is oxidized to dioxide CO_2 . As the concentration of O_2 decreases concentration of CO increases rapidly.

Mean values during the experiment ψ_{spec} and L_{CO} shown in table 2.

It can be seen from table 2 that:

- experimental mean values ψ_{spec} are in the range of 0.0063 $\text{kg}/(\text{m}^2 \cdot \text{sec})$ for coniferous trees 0.014 $\text{kg}/(\text{m}^2 \cdot \text{sec})$ — for hardwood trees [21];
- experimental mean values L_{CO} are significantly less (more than 2 times) compared to those ones given in the database [21].

It can be seen from Fig. 2 that the dependences of the specific mass gasification rate of wood on the time

period have a maximum at the beginning of the gasification process. The time period taken to reach the maximum values does not exceed 0.5–2 minutes, depending on the type of wood, after which there is a relative stabilization of wood gasification process.

The values of the specific carbon monoxide formation coefficient according to Fig. 3 approximately in 2 minutes after the start of combustion is negligible. Then

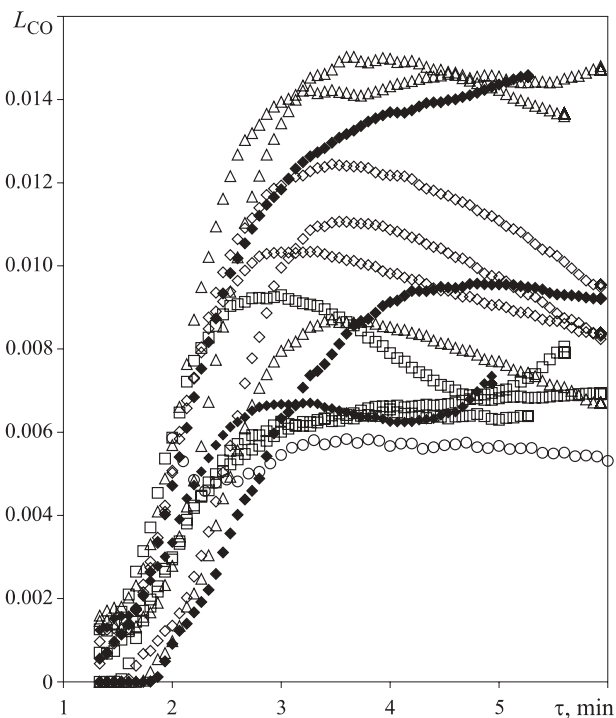


Fig. 3. The dependence of the specific carbon monoxide formation coefficient from the period of sample testing: $\square$ — No. 1; $\triangle$ — No. 2; $\blacklozenge$ — No. 3; $\circ$ — No. 4; $\diamond$ — No. 5

Table 2. Average values ψ_{spec} и L_{CO} during the experiment

Number of sample	ψ_{spec} (kg/(m ² ·sec))		L_{CO}	
	This article	[21]	This article	[21]
1	0.0093	0.014	0.0052	0.024
2	0.0102		0.0107	
3	0.0113	0.0063	0.0073	
4	0.0127	0.014	0.012	
5	0.0091		0.008	

within 1–2 minutes (depending on wood species) there is their sharp growth to the maximum values. This results from the fact that eventually there is a reduction of oxygen concentration in the combustion chamber (see Fig. 1) and not all carbon monoxide is oxidized to dioxide.

The obtained average experimental values of the specific mass gasification rate and the specific carbon monoxide formation coefficient for pulp samples of the most common hardwood and coniferous trees of Vietnam can be used to calculate the characteristics of running crowning fires.

Conclusion

Experimental studies of combustion process wood pulp samples of the most widespread hardwood and coniferous tree species of Vietnam allow to prove the choice of values of the specific carbon monoxide formation coefficient and the specific mass gasification rate, required for mathematical modeling of the parameters and heat impact of running crowning forest fires on the power engineering facilities in Vietnam.

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