Calculation of the Thermal Parameters and Change in The Share of Emissions of Harmful Substances During Combustion of Water-Fuel Emulsion

S Y Toropov, V I Berg, V A Petryakov and N A Mostovaya

Industrial University of Tyumen, 38 Volodarskogo st., Tyumen, 625000, Russia
E-mail: allbert-@mail.ru

Abstract. The article investigates the possibility to improve efficiency and ecological compatibility of fuel oil with use water-fuel emulsion. The calculation of the thermal parameters and change in the share of emissions of harmful substances during combustion of water-fuel emulsion and optimal water content in water-fuel emulsion.

1. Introduction
Recently in the world is observed the essential growth of consumption of energy resources, such as oil, natural gas, fuel oil is Fuel oil is the most widespread type of the liquid fuel intended for combustion in heating boiler room to generate heat.

So, Oil Transporting Joint Stock Company «Transneft» uses fuel oil in volume of not less than 10,000 tons per year for heating of production and administrative buildings and for heating of viscous and high-viscous oils Furnace fuel oil has similar structure with crude oil and it is characterized by considerable viscosity, density, content of high-molecular substances and petroleum resins. Currently fuel oil is considered ineffective and ecologically dirty type of fuel [1].

One of the promising ways to improve efficiency and ecological compatibility of fuel oil is the use of water-fuel emulsion, which is a compound of fuel oil and water at the molecular level, where the water becomes the catalyst for improving and accelerating the combustion process [2].

The aim of research is the calculation of the thermal parameters and change in the share of emissions of harmful substances during combustion of water-fuel emulsion.

2. Materials and methods
In the course of research were studied physical-chemical properties of furnace fuel oil of the M-100, including conditional viscosity which was studied with the help of the viscometer at 80 and 100 °C. Theoretical dependence was constructed using of standard values of viscosity at 80 and 100 °C has taken from GOST 10585-99. On the basis of the obtained results was constructed experimental dependence of conditional viscosity from temperature, it is shown at Figure 1.

In the process of calculating the thermal parameters were investigated the dependence of the maximal temperature of combustion water-fuel emulsions from the percentage of water in it [3].

To determine the amount of heat in the combustion process, coefficient of efficiency and change in the share of emissions of harmful substances (emissions of oxide of nitrogen) was made a comparison of experimental data from water-fuel emulsions and furnace fuel oil M-100 by combustion, the results are presented at Figures 2-4. Experiment was made in the closed furnace chamber with using the thermometer and a gas analyzer.

To determine thermal parameters such as heat capacity, the number of formed heat and coefficient of efficiency was created the mathematical model of the combustion process and energy conservation equation in a closed combustion chamber [4].

We write the continuity equation:
\[
\frac{\partial \rho}{\partial t} + \text{div}(\rho \vec{u}) = 0, \tag{1}
\]

where \(t\) - independent variable, \(\rho\) - mass density, \(\vec{u}\) - rate of movement

the conservation impulse equation:

\[
\rho \left( \frac{\partial \vec{u}}{\partial t} + \vec{u} \cdot \nabla \vec{u} \right) + \nabla \rho = 0, \tag{2}
\]

energy conservation equation:

\[
\rho T \left( \frac{\partial S}{\partial t} + \vec{u} \cdot \nabla S \right) = \frac{\rho \chi}{\tau} q - Q(T), \tag{3}
\]

where \(\tau\) - burning time, \(S\) - entropy, \(q\) - heat of combustion

After transformation of this system, we write the energy conservation equation:

\[
C_v \rho T \frac{d}{dt} \ln \rho = \frac{\rho \chi}{\tau} q - Q(T). \tag{4}
\]

3. Results and Discussion

Figure 1 shows the theoretical and experimental dependences of relative viscosity from temperature.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{The dependences of the relative viscosity of fuel oil M 100 from the temperature.}
\end{figure}

The figure shows that the theoretical and experimental dependences differ. It can be a reasonably high percentage of paraffin and petroleum resin in the fuel oil, which negatively influence the combustion process.
Figure 2 shows the graphical dependence of the amount of heat formed by the combustion of water-fuel emulsion and oil fuel from the excess air.

![Dependence of heat formed by combustion of water-fuel emulsion and oil fuel from excess air](image)

**Figure 2.** Dependences from heat loss $q$ from the coefficient of excess air.

Figure 3 shows the dependences of the coefficient of efficiency of water-fuel emulsion and fuel oil from the excess air.

![Dependence of efficiency of water-fuel emulsion and fuel oil from excess air](image)

**Figure 3.** The dependence the coefficient of efficiency of boiler from the coefficient of excess air.

Figure 4 shows the dependence of the emissions of nitrogen oxides water-fuel emulsion and fuel oil from the excess air.

![Dependence of nitrogen oxides emissions on excess air](image)

**Figure 4.** The dependence of the emissions of nitrogen oxides from the coefficient of excess air.
Figure 4. The dependence of the emissions of nitrogen oxides from the coefficient of excess air.

In the research, process was also applied additive MgO. In the contact zone of water and material of the boiler presents vanadium, which stimulates the destruction of the protective layer of Fe₂O₃ at the metal, leads to corrosion of the boiler elements [5,6].

The magnesium oxide binds sulfur oxide SO₃, is formed of magnesium sulfite, which is destroyed.

\[
\begin{align*}
3\text{MgO} & \rightarrow \text{Mg}_3\text{V}_2\text{O}_8 \\
\text{SO}_3 + \text{H}_2\text{O} & \rightarrow \text{H}_2\text{SO}_4 \\
\text{SO}_3 + \text{MgO} & \rightarrow \text{MgSO}_4
\end{align*}
\]

As a result of decrease in the concentration of sulfuric acid in the flue gases lowers the dew point. Owing to interaction of additive with sulfur the amount of harmful emissions is reduced significantly

4. Conclusion
Consider the use of water-fuel emulsions based on fuel oil for combustion in boiler rooms, heating buildings and industrial objects. As a result of researches, it is revealed that the water-fuel emulsion has higher coefficient of efficiency and allocates bigger amount of energy in the combustion process. As a result of the analysis of data of the thermometer the dependence of a heat of water share in a water fuel emulsion, it is presented in figure 5.
Figure 5. The theoretical dependence of heat from the water content.

The figure demonstrates that with increasing proportion of water the heating process decreases, that negatively influences heating process. It is revealed that in order to avoid more reduction of heating process optimal is the addition of 15% water. Thus, the article is shown of the calculation of the thermal parameters of the combustion of water-fuel emulsion, which it is a promising kind of fuel.

References
[1] Lebedeva E A, Kocheva M A, Luchinina A E, Sharov A V and Khokhlova E N 2010 Energy-saving technologies of consumption and production of heat Privolzhsky Scientific Journal 3 82-88
[2] Geller C V 2010 Preparation of water-fuel emulsions by wave dispersion J. News of heat supply 4 21-23
[3] Vengerov A A and Brand A E 2014 Oil cavitation treatment to prevent formation of paraffin deposits J. Natur. and intellect. resource. of Siberia. 15 36-37
[4] Melnik A Yu, Minikaeva S N, Pavlov S B and Kharlampidi Kh E 2012 Effect of water on diesel fuel specifications Bulletin of Kazan Technological University 24 213-215
[5] Brand A E, Vershinina S V, Vengerov A A and Mostovaya N A 2015 Applying the technology of hydrodynamic cavitation treatment of high-viscosity oils to increase the efficiency of transportation IOP Conf. Ser.: Mater. Sci. Eng. 93 012005
[6] Isakov A Ya 2004 Simulation of microexplosion of droplets of water-fuel emulsion J. Izvestiya vuzov - Technical Science 4 94-97
[7] Mamadaliev, R.A., Kuskov, V.N., Popova A.A., Valuev D.V., Alloying elements transition into the weld metal when using an inventor power source, J. IOP Conference Series: Materials Science and Engineering. 127 (2016) p. 1-7
[8] Valuev, D.V., Malushin, N.N., Valueva A.V., Dariev, R.S. Mamadaliev R.A. Manufacturing component parts of mining equipment with application of hardening technologies, J. IOP Conference Series: Materials Science and Engineering. 127 (2016) p. 1-7
[9] Antip'ev, Y.N., Nevolin, A.P., Zemenkov, Yu.D. 1981 Operation of intermediate pumping stations on transport of gas saturated oils. (1981) NEFT. KHOZ, 10, pp. 46 ISSN: 00282448
[10] Kurushina V and Zemenkov Y 2014 Innovative cyclical development of the Russian pipeline system WIT Transactions on Ecology and the Environment 190-2 881-8 DOI: 10.2495/EQ140822