بسم اللّه الرحمن الرحيم

HOSSAM MAGHRABY

شبكة المعلومات الجامعية

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التوثيق الالكتروني والميكروفيلم

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لم ترد بالأصل

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THERMAL BEHAVIOUR OF A VERTICAL LUBRICATING OIL HEATING FURNACE

BY

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M.Sc. (Eng.),

B.Sc. (Eng.), Diploma of Higher Studies (Eng.)

A Thesis Submitted to Menofiya University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Mechanical Power Engineering

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ABSTRACT

The efficiency of the lubricating oil heating furnaces used for reducing the viscosity and preparing for new processes depends to a great extent on their design. In order to compute the efficiency of these furnaces, a study of the combustion process and the rate of heat transfer from the combustion gases to the furnace walls is necessary. Experiments on a geometrically similar model enables this study.

In the present work, the model scale 1:10 of one full-scale furnace installed at Alexandria Petroleum Company in a battery of four such furnaces is constructed. Experiments are carried out to study the combustion aerodynamics, the heat flux distribution along the furnace model as well as the rate of heat transfer. Also, both the average total heat transfer coefficients of the combustion gases were estimated in this investigation.

Using the principles of geometrical, thermal and dynamic similarity, the results obtained on the furnace model are estimated to the full-scale furnace and consequently the thermal efficiency is computed.

The furnace model is fired by natural gas injected from a circular multi-nozzle burner header. This model is divided into six water-cooled segments; five of them represent the radiation zone while the sixth one forms the convection zone.

The experimental study of this research is divided into two parts; the first part is concerned with preliminary experiments on the circular multi-nozzle burner header with cold model using air jet and with hot model firing Butane gas. The test rig is located at the still atmosphere. The experiments of this part were carried out to study the flame characteristics such as flame length, flame cone angle and the mean burning velocity. Empirical formulas for calculating the flame length and the flame cone angle are estimated.

The second part of the experimental study was done on the furnace model with multi-nozzle burner header to study the performance characteristics of this furnace. These characteristics include the flame aerodynamics, the total heat transfer rate, the distribution of the combustion gases temperature along the furnace and the total heat flux distribution on the furnace walls. The average overall total heat transfer coefficient of the combustion gases and the average overall resultant gas temperature were calculated to help in selecting the optimum thickness of the furnace walls insulation.

The measurements taken on the furnace model to fulfill the target of this study were gases temperature, the surface wall temperature for each segment along the furnace, the mass flow rate of the air admitted for combustion, the mass flow rate of injected natural gas, the injection pressure of natural gas, the mass flow rate of the cooling water to each segment, the water inlet and outlet temperatures to and from each segment. The total heat transfer to the walls of each segment of the furnace model is calculated.

The effect of the following parameters on the furnace model performance characteristics are investigated in the present study:

1- The fuel injection pressure (P_f).
2- The air-fuel ratio (A/F) expressed by the excess air factor (λ_a).
3- The number of burner nozzles and their arrangement.
4- Fuel type such as Butane, Natural Gas, Blended Processes Gases and Fuel Oil (Mazot).
5- The injection of a certain amount of rich carbon content fuel such as Acetylene in the stream of the main gaseous fuel used (Natural Gas) was investigated theoretically due to technical difficulties.

A mathematical model is constructed for computing the combustion characteristics and the rate of heat transfer along the furnace model. The study in this theoretical approach is based on the Zonal Exchange Method which is strongly validated by applying the Well Stirred Model technique. A specially devised computer programme has been established for carrying out the calculations of this model.

A comparison is made between the calculated and the measured results to evaluate the computation techniques used. Fair agreement between them was obtained.

Also, another 2D numerical model using (k-ε) technique was constructed for modelling the turbulent diffusion flame used in the present work. The governing equations for this model were solved using the SIMPLE technique.

The results of this research were:

1) Increasing the natural gas injection pressure from 3 to 8 bar at the same excess air factor increases the gas temperature, the surface wall temperature, the total heat flux on the furnace walls, the average overall total heat transfer coefficient of the combustion gases, the average overall resultant gas temperature, the flame jet mean velocity and the furnace thermal efficiency.

2) On the other hand, it was found that increasing the excess air factor from 1.14 to 1.90 at the same fuel injection pressure decreases the gas temperature, surface wall temperature, the total heat flux to the furnace walls, the rate of heat transfer. In contrast, the average overall total heat transfer coefficient and flame jet mean velocity increase. Furthermore, it is clear that the performance characteristics will be affected when increasing the number of operating nozzles in the burner from two to eight.

3) Empirical formulae for estimating both the flame length and the flame cone angle have been deduced as a function of the fuel injection pressure, back pressure and the fuel nozzle diameter.

4) The application of the results obtained on the furnace model to the full-scale furnace showed the possibility of increasing the thermal efficiency of the full-scale furnace from 44% to 56% leading to annual saving of one million U.S.$ for each furnace.

5) Moreover, this study concluded that with equal Nusselt number (N_u) in both the full-scale furnace and the furnace model, the thermal similarity factor multiplied by the geometrical similarity factor is almost equal one.
6) The results of the mathematical model used for modeling the turbulent diffusion flame proved that decreasing the air-fuel ratio from 26 to 18 leads to increasing the initial momentum entering the computational domain and hence increases both the flame length and width. Moreover, the high temperature zone inside the flame jet will be shifted near the fuel jet outlet while both the temperature levels inside the flame jet and its turbulent kinetic energy will be increased by decreasing the air-fuel ratio from 26 to 18.