

Thermal Design of Gas-Fired Cooktop Burners Through ANN

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INTRODUCTION

Recent advances in the applications of ANN have demonstrated successful cases in time series analysis, data mining, civil engineering, financial analysis, music creation, fishing prediction, production scheduling, intruder detection, etc., making them an important tool for research and development[1]. ANN and evolutionary computation(EC) techniques have been employed successfully in solving real-world problems including those with a temporal component[2]. In another work[3], a hybrid method based on a combination of evolutionary computation and neural network(NN) has been used to predict time series.

In the world of databases, various ANN-based strategies have been used for knowledge search and extraction[4]. Intelligent neural systems have been constructed with the aid of genetic algorithm-based EC techniques and these systems have been applied in breast cancer diagnosis[5]. Genetic algorithms(GA) have been applied to develop a general method of selecting the most relevant subset of variables in the field of analytical chemistry to classify apple beverages[6]. New ANN methods enable civil engineers to use computing in different ways. Besides as a tool in urban storm drainage[7], ANN and Genetic Programming(GP) have been implemented in the prediction and modelling of the flow of a typical urban basin [8]. In the latter case, it was shown that these two techniques could be combined in order to design a real-time alarm system for floods or subsidence warning in various types of urban basins. ANN models for consistency, measured by slump, in the case of conventional concrete have also been developed[9]. In a time series prediction of the quarterly values of the medical component of the Consumer Price Index(CPI), the results obtained with both neural and functional networks have been shown

to be quite similar[10]. Dimensionality reduction, variable reduction, hybrid networks, normal fuzzy and ANN have been applied to predict bond rating[11].

A recent online survey through the ISI Web of Knowledge using keywords such as “ANN” and “thermal design” would reveal only ten relevant SCI publications[12]. In the area of food processing, ANN was used to predict the maximum or minimum temperature reached in the sample after pressurization and the time needed for thermal re-equilibration[13]. The accurate determination of thermophysical properties of milk is very important for design, simulation, optimization, and control of food processing such as evaporation, heat exchanging, spray drying, and so forth. Generally, polynomial methods are used for prediction of these properties based on empirical correlation to experimental data. However, it was found that ANN presented a better prediction capability of specific heat, thermal conductivity, and density of milk than polynomial modeling and it was suggested as a reasonable alternative to empirical modeling for thermophysical properties of foods[14].

Numerical simulation of natural circulation boiling water reactor is important in order to study its performance for different designs and under various off-design conditions. It was found that very fast numerical simulations, useful for extensive parametric studies and for solving design optimization problems, can be achieved by using an ANN model of the system[15]. ANN models and GA were applied for developing prediction models and for optimization of constant temperature retort thermal processing of conduction heating foods[16]. ANN technique has been used as a new approach to determine the exergy losses of an ejector-absorption heat transformer (EAHT)[17]. The results show that the ANN approach has the advantages of computational speed, low cost for feasibility, rapid

turnaround, which is especially important during iterative design phases, and easy of design by operators with little technical experience.

Computational fluid dynamics approach is often employed for heat transfer analysis of a ball grid array (BGA) package that is widely used in the modern electronics industry. Owing to the complicated geometric configuration of the BGA package, an ANN was trained to establish the relationship between the geometry input and the thermal resistance output [18]. The results of this study provide the electronic packaging industry with a reliable and rapid method for heat dissipation design of BGA packages. Thermal spraying is a versatile technique of coating manufacturing implementing large variety of materials and processes. An ANN was developed to relate processing parameters to properties of alumina-titania ceramic coatings [19]. Predicted results show globally a well agreement with the experimental values.

It can be seen that applications of ANN in thermal design is scarce and this article aims to explore the application of an ANN in gas-fired cooktop burner design.

BACKGROUND

Cooktop Design Goals

Gases that trap heat in the atmosphere are often called greenhouse gases. They include carbon dioxide, nitrous oxide, methane, and ozone. Individuals can produce greenhouse gas emissions directly by burning oil or gas for home heating and cooking or indirectly by using electricity generated from fossil fuel burning. In the last 200 years, mankind has been releasing substantial quantities of greenhouse gases into the atmosphere. These extra emissions are increasing greenhouse gas (GHG) concentrations in the atmosphere, enhancing the natural greenhouse effect, which is believed to be causing global warming.

To combat the global warming problem, gas suppliers and manufacturers of cooking appliances are trying to find ways of improving energy efficiency with reducing greenhouse gas emissions. In view of the number of controllable factors and responses to be studied, Design of Experiments (DOE) is often used for such kind of empirical investigations. The authors therefore proposed to combine DOE technique with

the ANN approach for solving the multiple input and multiple output (MIMO) design problem. To achieve optimal thermal efficiency and greenhouse gas emissions, a back-propagation ANN was used to simulate the operating conditions and the implementation details are illustrated through a real-life case.

EMPIRICAL STUDY

A three factor, three level, Full Factorial Design (with 3 repetitions) was employed to investigate the complex relationships of three design parameters of a cooktop burner, viz. the Reynolds number, the equivalence ratio, and the load-height (distance from nozzle to bottom surface of cookware). The range of Reynolds number (Re) considered varies from 400 to 700. A tailor-made cooktop burner with a ring of 128 mm diameter is used and circular nozzles (diameter = 6 mm) were used in the experiment. Fuel-rich flames (corresponding to equivalence ratios ranging from 1.4 to 1.8) similar to real-life cooking situations were employed in the experiments. The load-height ranges from 24 mm to 32 mm (corresponding to a H/d ratio varying from 4 to 8). To allow for different spacing between groups of nozzles, four configurations of the cooktop burner were considered, viz. 2-nozzle 6-section, 3-nozzle 4-section, 4-nozzle 3-section and 6-nozzle 2-section configurations. These nozzle configurations were labeled 1, 2, 3 and 4 respectively (Fig. 2). A total of 108 experiments were carried out for each configuration. Experiment results showed that the configuration of 3-nozzle 4 section based on the predetermined input conditions of Re=550, EqR=1.6 and H/d=8 would give the best thermal efficiency (62%) and acceptable CO and NO_x emissions,

- Burner efficiency model

The thermal efficiency of a burner is defined as the percentage of the thermal input transferred to the water in the loading vessel. It was determined by measuring the elapsed time for a standard 4 kg load of water to be heated from 30°C to 80°C and the corresponding consumption of LPG. Mathematically, the thermal efficiency is calculated as:

$$\eta = (MC_p \Delta T / Q_{H_v}) * 100\% \quad (1)$$

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