Development of innovative commercial dishwasher using gas-heated water for energy efficiency

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Abstract: *Commercial dishwashers are among the most important products for commercial kitchen personnel as they clean dirty products (plates, glasses, cutlery, etc.) in a short time (between 1 and 4 minutes according to the program). In recent years, customers' demands for energy-saving products have been increasing. Therefore, instead of using the electrical energy to be obtained after the combustion of natural gas in power plants, the use of direct natural gas in a commercial dishwasher contributes to reducing the carbon footprint. In this study, the original design studies of the combustion system of the innovative commercial dishwasher prototype using water heated with gas were carried out. For the first time in our country, the system that enables the heating of water with gas was designed as a module other than the existing commercial dishwasher. An independent combustion system has been developed to provide easy use to other commercial dishwashers on the market. Simulation studies have been used effectively in the design verification phase in order to provide the most efficient combustion conditions for different gases (natural gas and LPG) in the original designed combustion system. Combustion analyses were carried out by parametric study for different operating conditions. In the innovative commercial dishwasher prototype that uses water heated with gas, optimum temperature values have been obtained for effective washing at the water inlet and water outlet points of the uniquely designed combustion system. As a result of the tests and evaluations, the most effective working range of the innovative prototype was determined.*
Keywords*: COMMERCIAL DISHWASHER, COMBUSTION TECHNOLOGY, WATER HEATED SYSTEM DESIGN*

1. Introduction

Various models of commercial dishwashers (undercounter, hood type, conveyor, etc.) have wide areas of use depending on the size of the commercial kitchens. Our company produces all models of these commercial dishwashers for commercial kitchens. In our country and in Europe, commercial dishwashers are used with electrical energy. However, gas-heated water commercial dishwashers have usage shares in the North American market. There are various studies to improve energy efficiency on dishwashers.

Studies carried out in the research of scientific publications related to energy efficiency in the field of dishwashers have been determined to be related to household dishwashers [1-7]. Various studies in this field are summarized below;

Santori and his team investigated the operating performance of an adsorption household dishwasher using different desiccants such as 13X zeolite, microporous silica gel and SAPO-34 zeolite. Thermodynamic comparison of the indicated adsorbents was carried out on the basis of experimental measurement of the main thermophysical parameters such as specific heat, adsorption equilibrium curves and sorption enthalpy. They stated that they achieved 0.636 kWh of consumed electrical energy savings, 41% lower than the standard cycle performed by a standard household dishwasher with a class A energy label [1].

Mohedano and his research team evaluated household dishwashers with camera data processing (PEPT - Positron Emission Particle Tracking) system and simulation analysis (CFD - Computational Fluid Dynamics) under different operating conditions (with/without detergent, at various pump and wash arm speeds). Empty/full basket etc. during the washing process analyzed the water movements according to the variables. They stated that the detergent effect can be neglected in water movements and the effects of design data (washing arm, distribution of dishes, etc.) according to different dish areas [2].

Hauer and Fischer reported that energy consumption was reduced by up to 24% by reducing the energy consumption values from 1.05 kWh to 0.8 kWh in household dishwashers with zeolite mineral added drying system compared to the standard product. In addition, they reported that an environmentally friendly product was obtained by contributing to the reduction of CO_2 emission rates with the mineral additive drying system [3].

In 2021, 32.7% of our electricity production in Turkey was obtained from natural gas. [8].

The distribution of natural gas use in electricity generation in our country by years (2000-2019) is shown in Fig. 1 [9].

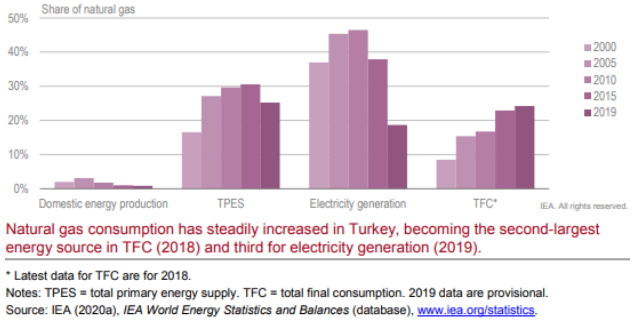

Fig. 1 *Share of natural gas in the Turkish energy system, 2000-2019 [9].*

The gross electricity generation distribution by primary source in the first ten months of 2021 in Turkey is shown in Fig. 2 [10].

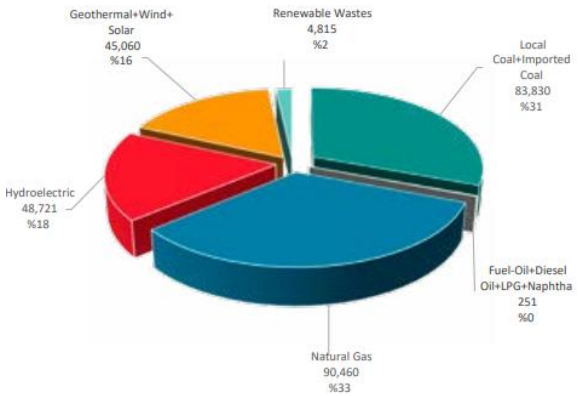

Fig. 2 *Gross Electricity Generation by Primary Source During the First Ten Months of 2021 (GWh). [10].*

In the coming years, in terms of energy efficiency, the use of natural gas in various applications instead of electrical energy will provide significant advantages in terms of the environment.

2. Methodology

With the data obtained from the concept development studies, the design activities of the commercial dishwasher prototype that heats gas and water were carried out. At the last stage of the design activities, the original designs were obtained before the prototype production by utilizing the simulation studies.

Within the scope of this study, the hood (guillotine) type commercial dishwasher was preferred among the existing commercial dishwashers in terms of the application of the original designed combustion system.

The main body of the hood type commercial dishwasher and separate combustion system is made of stainless steel (AISI 304) material.

The draft drawing of the commercial dishwasher prototype using gas and water is shown in Fig. 3.

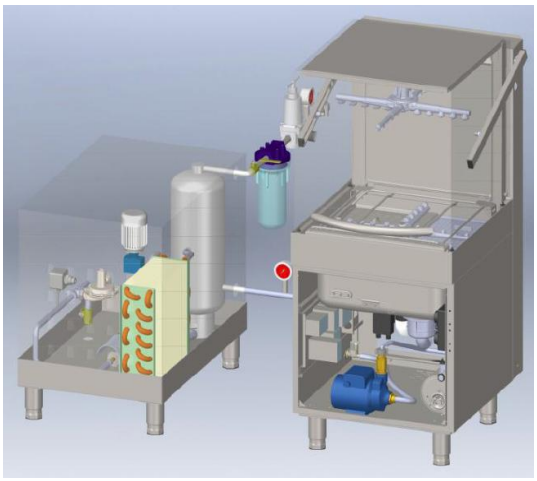

Fig. 3 *The draft drawing of the commercial dishwasher prototype using gas-heated water.*

With the combustion provided in the burner of the combustion system with simulation studies, temperatures close to the adiabatic flame temperature have been reached.

The uniquely designed combustion system consists of three separate parts. The first part consists of the burner where the combustion takes place, the second part consists of the heat exchanger water flow area and the third part consists of the copper heat exchanger.

In the heat exchanger area, after this temperature is transferred to the water, it has been observed that the temperature towards the chimney section decreases, but there is still a usable heat energy in the flue gas.

In the original designed combustion system of the innovative commercial dishwasher prototype, which uses water heated with gas, a boundary layer is placed on the wall areas. Studies were carried out by applying a sweep mesh to a certain region of the flow.

For this reason, it has been seen that a lower capacity heat load can be sufficient by using this energy. Examples of simulation studies on temperature, combustion products, heat exchanger zone heat exchange in a uniquely designed combustion system are shown in Figure 4-7.

Originally designed combustion system of the innovative commercial dishwasher prototype is shown in Fig. 4.

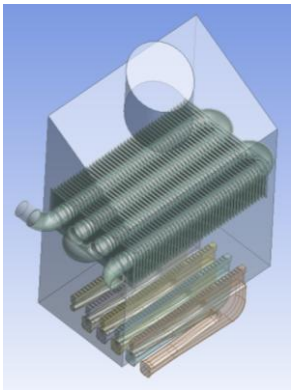

Fig. 4 *Originally designed combustion system of the innovative commercial dishwasher prototype.*

The view of the mesh distribution in the original design combustion (water heating) system design is shown in Fig. 5.

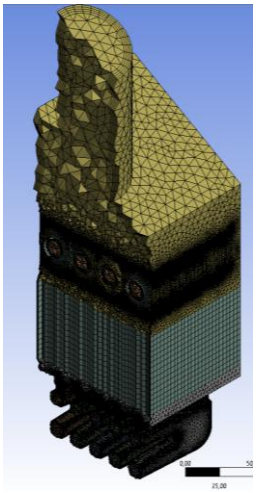

Fig. 5 *The view of the mesh distribution in the original design combustion system design.*

The simulation study of temperature change in the working process of the original designed combustion system of the innovative commercial dishwasher prototype is shown in Fig. 6.

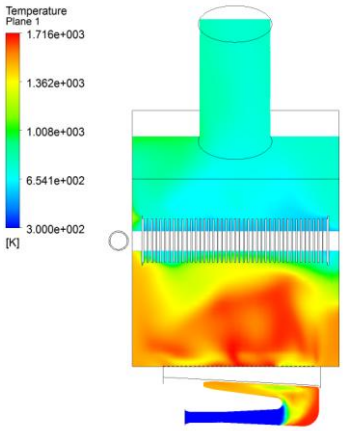

Fig. 6 *Simulation of temperature change in the working process of the original designed combustion system of the innovative commercial dishwasher prototype.*

Simulation analysis of combustion products in a uniquely designed combustion system.

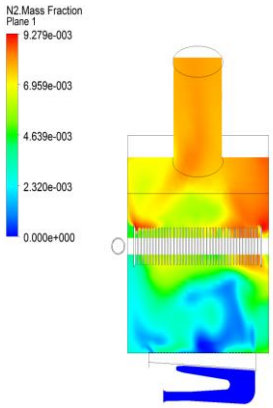

Fig. 7 *Simulation analysis of combustion products in a uniquely designed combustion system.*

The fact that almost all of the oxygen is consumed during the combustion process and the N_2 formation reaches its highest levels in the exhausted gas is an indication that the combustion is complete, and the simulation data shows that the project will be successful.

3. Experimental procedure

The photograph of the innovative commercial dishwashing machine prototype using gas-heated water used in the testing and evaluation phase is shown in Fig. 8.

Fig. 8 *Front view of the innovative commercial dishwasher prototype.*

A photograph of the original designed module providing gas-heated water is shown in Fig. 9.

Fig. 9 *A photograph of the original designed module providing gas-heated water.*

Tests and evaluations of the innovative commercial dishwashing machine prototype using water heated with gas were made according to different gases (natural gas and LPG) and various operating conditions (gas pressures, gas application time, etc.).

4. Conclusions

The most important innovative aspect was the efficient use of gas-heated water for the first time in our country, in the studies carried out with R&D systematics in the original designed commercial dishwashing machine prototype. The gains obtained through various R&D activities are shown below;

By comparing the data in the combustion simulation studies with the data obtained during the test phase, the efficient operation of the innovative prototype using different gases (natural gas and LPG) was ensured.

Different injector diameters (Ø0.90 mm for natural gas and Ø0.65 mm for LPG) and different gas pressures (20 mbar for natural gas and 30 mbar for LPG) have yielded positive results in terms of efficient combustion, depending on the gas usage in the uniquely designed water heating system.

A temperature increase of approximately 65°C was observed between the water inlet temperature and the outlet temperature of the uniquely designed water heating system. It has been determined that a lower capacity heat load may also be sufficient.

As a result of the test and evaluation studies, the prototype of the commercial dishwasher using gas-heated water was successfully obtained. Thus, for the first time in our country, the innovative commercial dishwasher prototype that uses direct gas (natural gas and LPG) instead of electrical energy has been achieved with scientific data.

Acknowledgment

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