Development of an environmentally friendly commercial kitchen cooker using hydrogen as fuel

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Abstract: *Commercial kitchen cookers are widely used in various capacities and fuels (natural gas, LPG, etc.). Depending on the decrease in fossil resources and the increase in energy needs, several researches in alternative fuels have been accelerated. Especially in recent years, R&D studies and investments in renewable and environmentally friendly energy sources (solar, wind, biomass etc.) have increased. In line with the EU's Renewable Energy Directive (Directive 2018/2001/EU), it is aimed to use at least 32% renewable energy sources by 2030. Significant R&D gains have been achieved with the cooperation of industry-university in order to use hydrogen as clean energy as an environmentally friendly alternative energy source for commercial kitchens. In this work, we developed an environmentally friendly commercial kitchen cooker prototype using hydrogen with a uniquely designed burner has been achieved. Results show that using hydrogen in commercial kitchens is promising if hydrogen safety is locally possible.*

Keywords*: COMMERCIAL KITCHEN COOKER, HYDROGEN TECHNOLOGY, BURNER DESIGN*

1. Introduction

Concerns about global warming and the environment have been increasing in recent years, along with the use of fossil fuels (natural gas, coal, etc.). For this reason, studies on the dissemination of renewable energy sources (solar, wind, biomass, etc.) are increasing [1, 2]. In this respect, hydrogen has gained importance in studies to use it as an alternative fuel in various fields [3-8].

Various model cookers are indispensable for cooking in commercial kitchens (restaurants, factories, shopping malls, etc.). The use of various gas fuels (natural gas and LPG, etc.) instead of electricity in commercial kitchen cookers is preferred by many enterprises for economic reasons. However, alternative renewable fuel researches are increasing in line with the risk of fossil fuels in terms of the environment. In addition to the use of hydrogen alone, studies have been carried out on the combustion performance with natural gas [9, 10], methane [11-13], ammonia [14] etc.

The envisaged situation for various application areas of hydrogen in the energy system in the future is given in Fig. 1 [15].

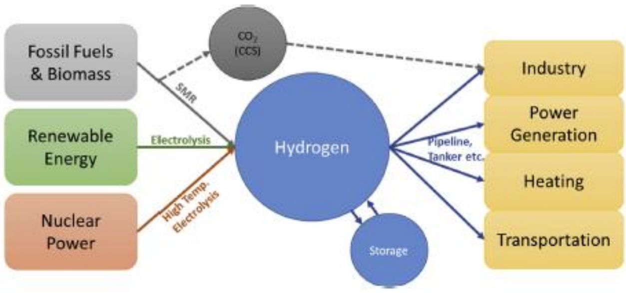

Fig. 1 *Various application areas of hydrogen in the energy system in the future [15].*

There is no study for hydrogen as an alternative fuel in commercial kitchen cookers. However, various studies have been conducted on hydrogen in households and portable type cookers/stoves. Various studies in this field are summarized below;

The hydrogen cooking process obtained from a proton exchange membrane electrolyzer (PEM) with solar energy using photovoltaic panels was carried out by Topriska and her team. They stated that the hydrogen production mechanism established in the simulation studies was sufficient for cooking small amounts of food [16].

Rivera and his team compared conventional fuels (LPG, charcoal, firewood) with hydrogen obtained by electrolysis in cooking in developing countries. Compared with conventional fuels, hydrogen has a significant impact on fossil fuel consumption, climate change, ozone depletion, etc. emphasized its superiority over other fuels in terms of properties. However, they stated that more research should be done on hydrogen for developing countries [17].

The hydrogen operation of the design-specific glass-ceramic cooking unit was evaluated by Fumey and the scientific study group. Performance test applications of the developed system were carried out under the DIN EN 30-2-1: 2005-08 standard. According to this standard, high-efficiency values of up to 80% have been achieved. The cooking unit is made in the dimensions of 400x290x94 mm. The active area of the combustion system was also 2x176 cm^2 [18].

The combustion unit for working with hydrogen is formed from a highly porous (>90%) SiC foam ceramic structure. The porous SiC foam ceramic structure provides advantages due to its high-temperature stability and good thermal shock resistance. SiC foam has been used with different pore sizes. The schematic representation of the combustion system is given in Fig. 2 [18].

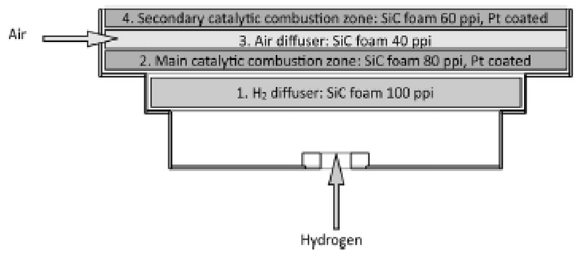

Fig. 2 *Schematic representation of the SiC foam ceramic containing hydrogen combustion unit. [18].*

Singh and his research group have evaluated the hydrogen economy. A comparison of the energy values of various fuels is shown in Fig. 3 [19].

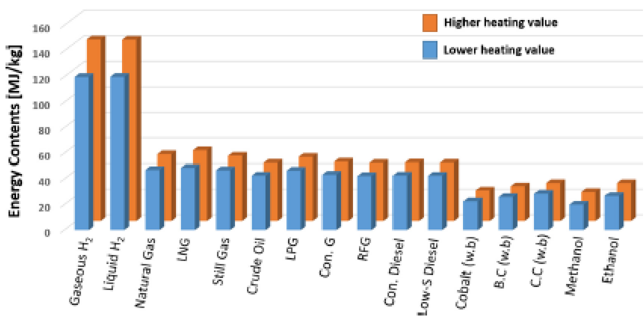

Fig. 3 *Energy heating values of various fuels. [19].*

Depending on the development of the conditions related to the acquisition, storage, and safety of hydrogen, its usage areas as the clean fuel of the future will increase. It is expected that the importance of hydrogen as an alternative fuel will increase in the coming years due to the environmental problems caused by fossil fuels.

2. Methodology

First of all, the original design of the hydrogen burner was developed for the burner used in commercial kitchens. The innovative hydrogen burner is made of stainless steel (AISI 304) material.

Combustion analysis was performed by parametric study for different pressures and burner hole diameters. It has been determined at which burner hole diameter and pressures the maximum value of 650ºC is reached, which is determined according to safe use, depending on the material properties for the under-pan temperature. As a result of the trials, the operating range of the system was determined.

In addition, with the visible results obtained from the analyzes, how the flames are shaped, the chemical conditions of the fuel and air in the system, and at the time of combustion were obtained. The temperatures formed under the cooker and in flames are presented visually.

The technical drawing of the burner using hydrogen as fuel in a commercial cooker is given in Fig. 4.

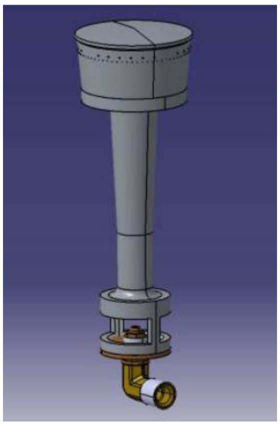

Fig. 4 The technical drawing of the burner using hydrogen as fuel in a commercial cooker.

A view of the innovative commercial kitchen cooker prototype (top view) is given in Fig. 5.

Fig. 5 View of the innovative commercial kitchen cooker prototype (top view – surface with H_2 logo).

It has also been painted green to make the innovative prototype appear environmentally friendly. View of the innovative commercial kitchen cooker prototype using hydrogen as fuel is given in Fig. 6.

Fig. 6 View of the innovative commercial kitchen cooker prototype using hydrogen as fuel.

3. Experimental procedure

The hydrogen used in the test phase was obtained from the hydrogen gas cylinder. High purity hydrogen (99.999%) is used in the innovative commercial kitchen cooker prototype with a unique design. During the test phase, special connection equipment (flowmeter, regulator, etc.) was used between the hydrogen gas cylinder and the innovative commercial kitchen cooker prototype.

The sensitivity of the burner, which was developed with a unique design in a commercial kitchen cooker that uses hydrogen as an alternative fuel, to different hydrogen pressures was evaluated according to various operating conditions.

Pot bottom temperature simulations according to burner hole diameters from 0.25 mm to 0.4 mm (respectively hole diameters 0.25, 0.3, 0.35 and 0.40 mm) for 8 mbar fuel pressure, are shown in Fig. 7.

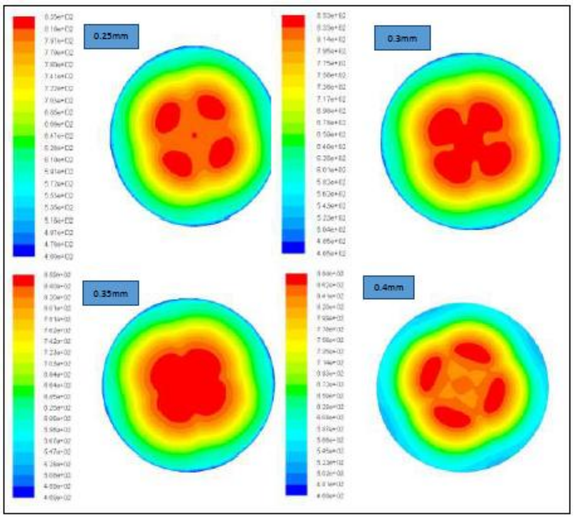

Fig. 7 Pot bottom temperature for 8 mbar fuel pressure.

Efficiency measurement tests of high purity hydrogen were carried out according to EN 203-2-3 standard (Gas heated catering equipment - Part 2-3: Specific requirements - Boiling pans).

4. Conclusions

With R&D studies, an innovative prototype was obtained with the original burner that uses hydrogen as fuel in the eco-friendly cooker for commercial kitchens. The gains achieved through R&D activities are given below.

Simulation studies were carried out according to 16 situations according to different hydrogen fuel pressures (8, 14, 20, and 32 mbar) and different burner hole diameters (0.25, 0.3, 0.35 and 0.4 mm). In the evaluations made with simulation analysis, it was determined that combustion with hydrogen was at 8 mbar fuel pressure and 0.3 mm burner hole diameter.

It has been determined that all values are close to each other in the evaluations made according to different burner hole diameters at the lowest value of the fuel pressure (8 mbar).

It has been observed that the temperature values increase in direct proportion to the increasing fuel pressure values.

As a result of the test and evaluation studies, the innovative burner, which works in harmony with hydrogen, in the prototype of the commercial kitchen cooker was achieved. Thus, it has been achieved to reduce the innovative product's CO and NOx emission values in an environmentally friendly manner. It has been shown that hydrogen can be used efficiently in commercial kitchen appliances as an alternative fuel.

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