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Design and Analysis of a Natural Gas-Fueled Flameless Hot Air Generator

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Abstract

The process of flameless combustion relies on the recirculation of exhaust gas, which prevents the generation of nitrogen oxides (NOx) while maintaining the system's high level of thermal efficiency. Natural gas is both environmentally and economically favourable. The use of flameless combustion helps to address pollution and combustion stability. In addition to reducing emissions, this research can aid in minimising consumption and, more crucially, lowering harmful exhaust emissions. Therefore, the goal of this study is to design a laboratory-scale Flameless Hot Air Generator (F-HAG) fueled by natural gas fuel. SolidWorks was used to create a cylindrical shape of F-HAG and to analyze the thermal analysis of operating temperature range from 800°C to 1200°C. Results of the thermal analysis showed that the refractory ceramic layer can store and maintain the heat inside the F-HAG . Findings of this paper will help to demonstrate F-HAG design capability to produce flameless combustion .

1. Introduction

The process of flameless combustion relies on the recirculation of exhaust gas, which prevents the generation of nitrogen oxides (NOx) while maintaining the system's high level of thermal efficiency. The term "re-circulated exhaust gas" refers to the exhaust gas that is used in flameless combustion and is defined as the exhaust gas that is re-circulated and mixed with the combustion air prior to the reaction. Alternatively stated, natural gas is not a renewable resource. Due to energy demands, this is a significant challenge for humanity. It cannot be refilled once they have been depleted. On the other hand, natural gas is both environmentally and economically favourable. The use of flameless combustion helps address pollution and stability concerns. In addition to reducing emissions, this research can aid in minimising consumption and, more crucially, lowering regulations for harmful exhaust emissions. Therefore, the goal of this study is to design a laboratory-scale flameless hot air generator fueled by natural gas.

2. Materials and Methods

This section provides an overview of the methodology employed in the study. In addition, a description of the method used for data collection and the procedures employed to conduct this research are provided.

2.1 Conceptual design

The conceptual design includes the application of creative stimulus approaches, the use of physical concepts and qualitative reasoning, and the ability to discover and utilize knowledge. The term "brainstorming" refers to this approach of generating new ideas. It is a method for generating new concepts. As ideas are exchanged, new concepts are formed, and a chain reaction of new ideas is set into motion.

2.2 Embodiment design

The step in which the structure is embodied is known as the embodiment design phase. The strength of the component, the materials to be utilised, the size, form, and space compatibility are all considered during the design phase. Major changes will be prohibitively expensive once we get passed the design phase. Preliminary design is a term used to describe this step of the design process. Product architecture, configuration design, and parametric design are all part of embodiment design. Embodiment design is comprised of these steps.

At this point in the process, we have reached the product architecture stage of the embodiment design process. Organizing a product's physical components to accomplish a certain goal is what we mean by its "product architecture". It is crucial to choose the architecture of a product after it has been designed in a way that maximizes its potential as a commercial success. Creating a product schematic is the first step that must be taken. The design of the configuration is the second step in the embodiment design process. At this point, the overall proportions and shapes of the components will be determined. Solid work software will be used to model and simulate the project and customise the components that will determine how well it works. That's not all; the type of material to be utilised and how it's made are also going to be decided here. The parametric design stage is the final phase of the embodiment design process. The goal of parametric design is to find model parameter values that balance performance and cost to get the best possible outcome. The tolerance and final dimension will be decided at this point.

2.3 Details design

Assemblies and general assembly drawings are all included in the detail design, which is a detailed specification of the geometry, materials, and tolerances for every item in the system. The design is iterated upon while also providing plans, specifications, and projections during this step of the process. The comprehensive design may use outputs such as two-dimensional and three-dimensional models, cost estimations, and procurement techniques. Most of the time, an accurate estimate of the project's entire cost can be determined at this point. To meet the demands of today's manufacturers, sophisticated design has become a common feature in many products' development stages.

3. Results and Discussion

3.1 Conceptual design

The F-HAG is made up of numerous components and subassemblies that work together as a whole.
The breakdown of F-HAG into its constituent parts can be seen in Fig. 1.

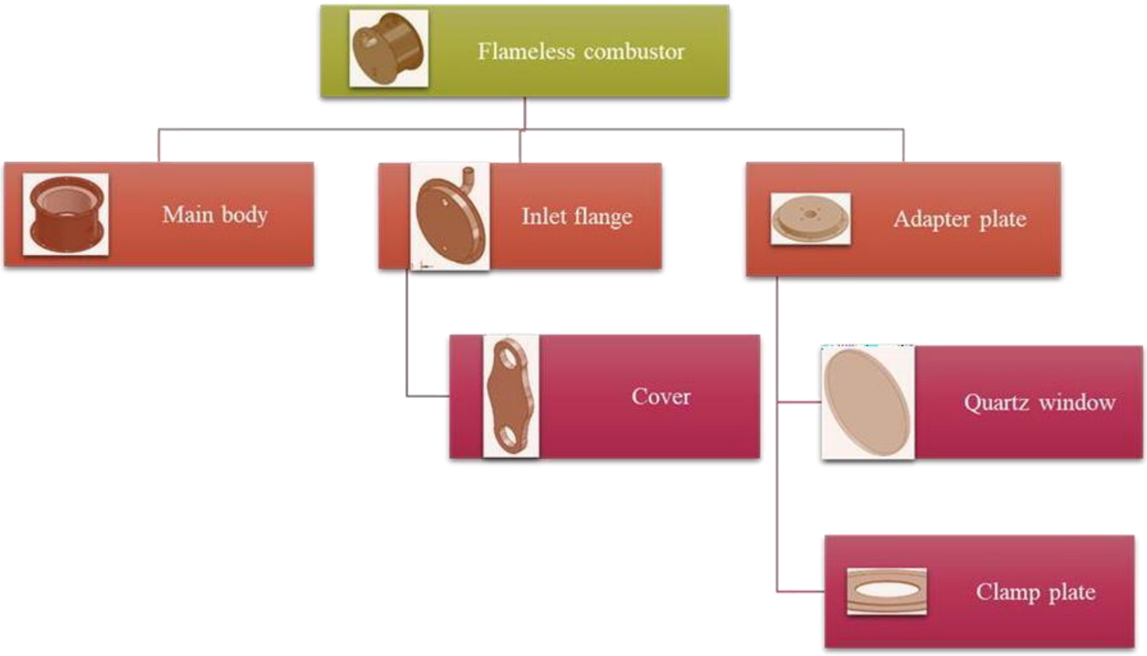


Fig. 1 *Component decomposition*

3.2 Embodiment design

Figures 2 and 3 depict the F-HAG components organizational structure.

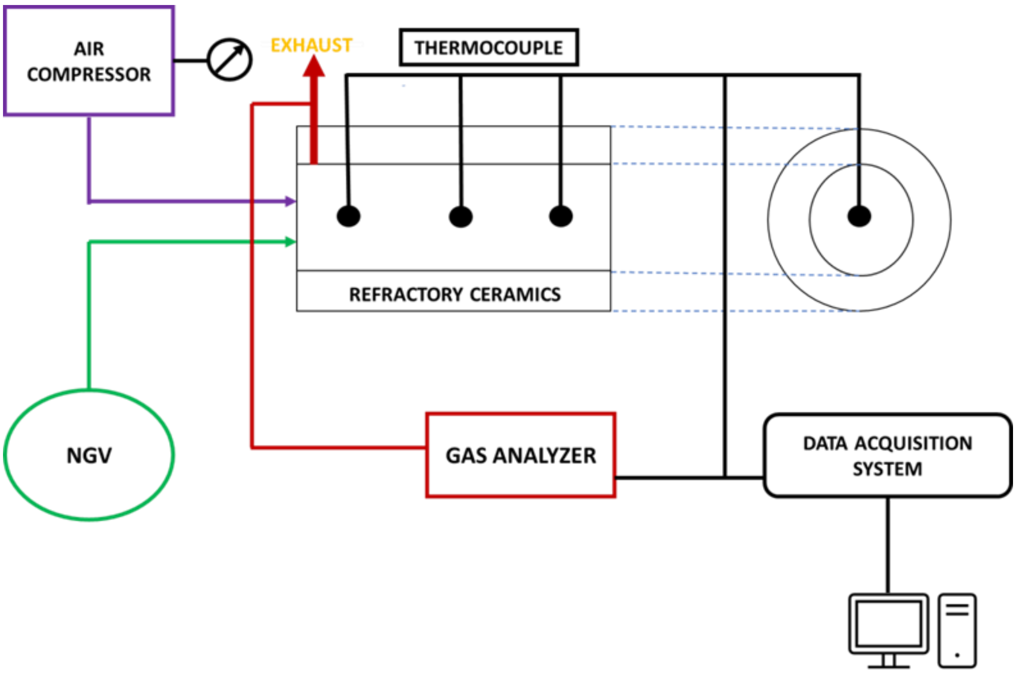
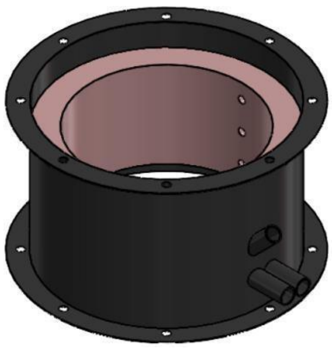
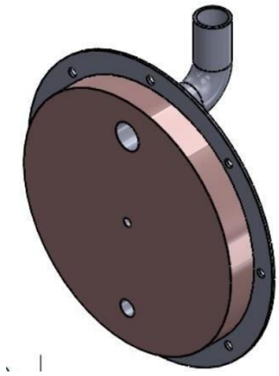


Fig. 2 *Schematic diagram of the experimental setup*

Fig. 3 *Geometric layout of F-HAG*

In the design process for any physical thing, selecting materials is critical. Table 1 is a list of the materials that have been chosen for this project.

Table 1 *Material selection*

Part	Material selection (Description)
	Stainless steel (High thermal resistance)
	Stainless steel & refractory ceramic (High thermal resistance)
	Stainless Steel (High thermal resistance)

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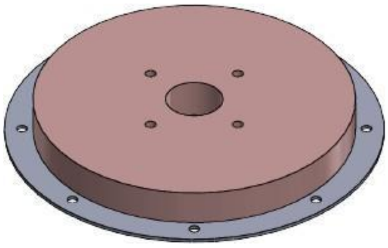
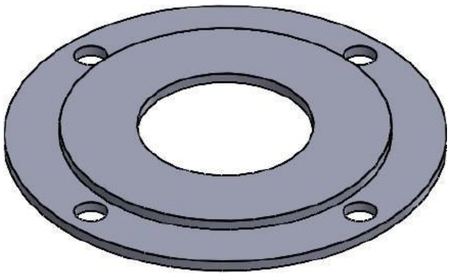
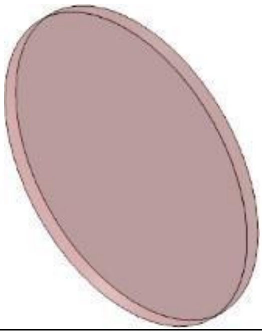
	Stainless steel & refractory ceramic (High thermal resistance)
	Stainless steel (High thermal resistance)
	Quartz glass (High thermal resistance)

Figure 4 (a) and (b) shows the thermal ceramic analysis of an 800°C and 1200°C flameless hot air generator. The refractory ceramic layer has achieved its goal of storing and maintaining heat in the combustion chamber. The red color part represents the high temperature occur while the blue color part represents the low temperature occur.

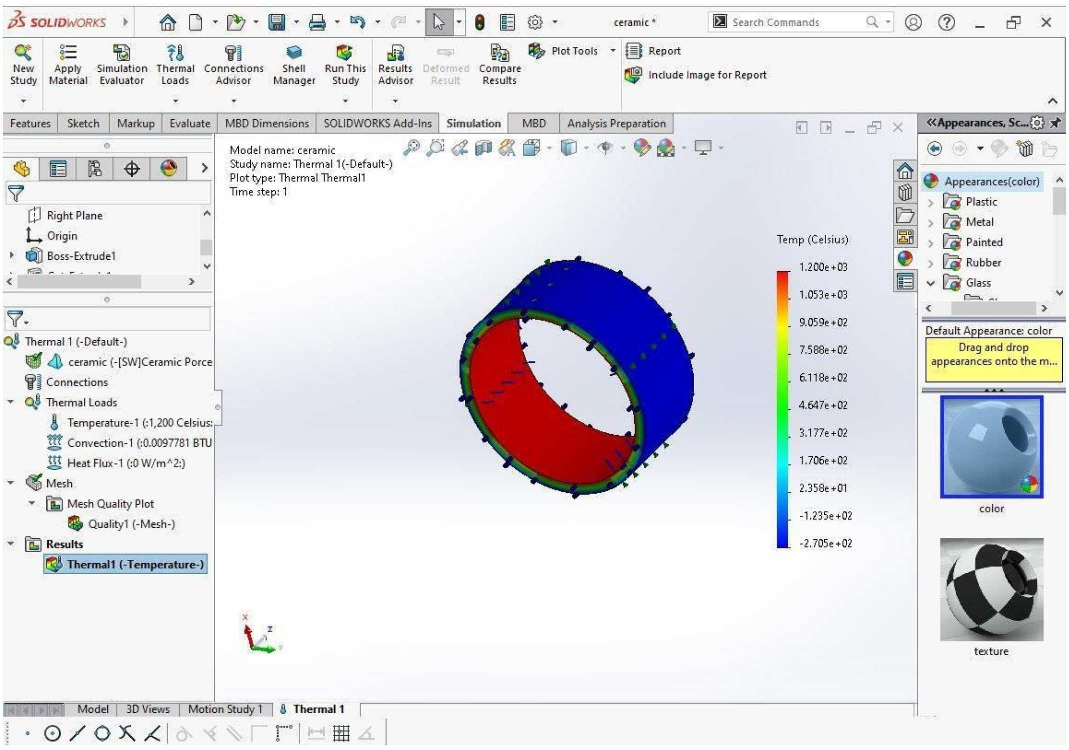


Fig. 4(a) *Maximum temperature*

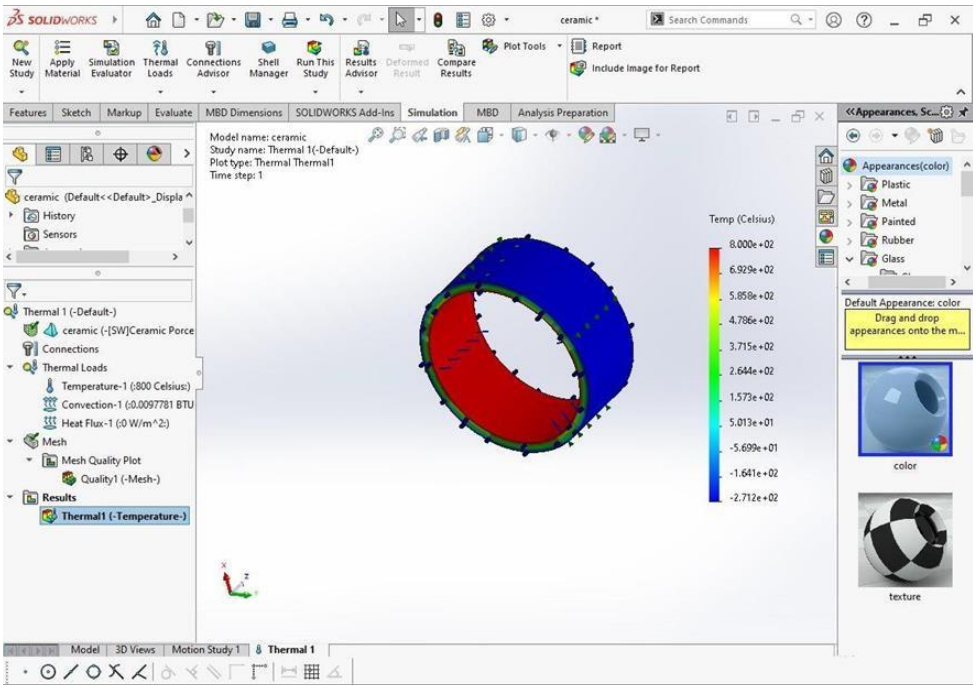
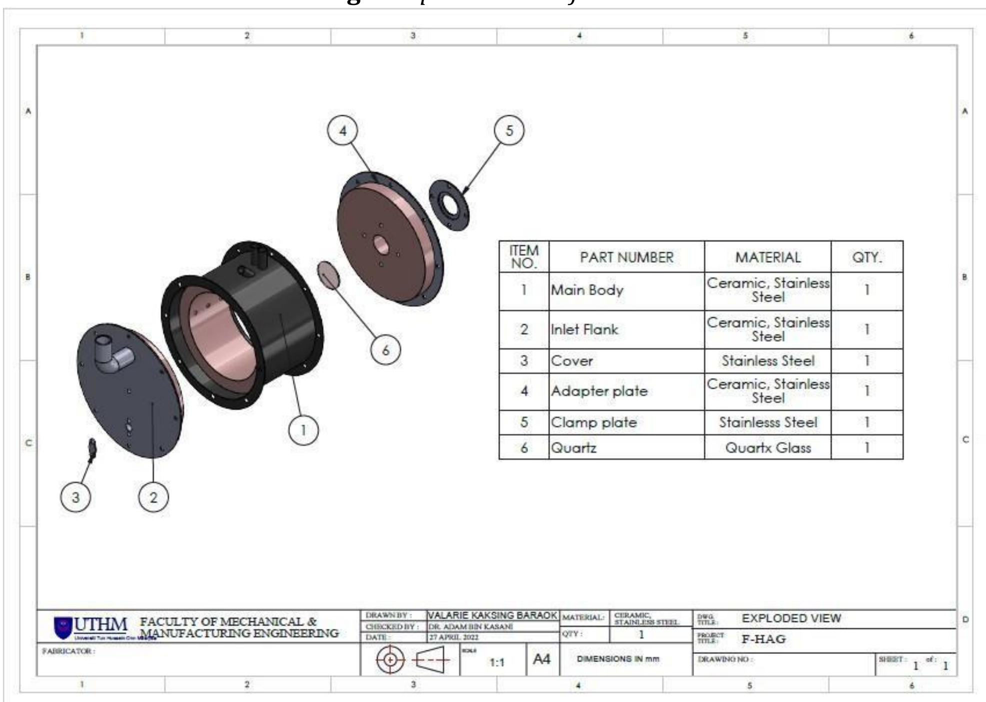


Fig. 4(b) *Minimum temperature*

3.3 Final design

The drawing for the flameless hot air generator will be structured to consider the sub-assembly procedure. The dimensions, the material, and the number of components will also be depicted in the diagram as shown in Figure 5. The actual product of F-HAG can be seen in the Figure 6.

Fig. 5 *Exploded view of F-HAG*



ITEM NO.	PART NUMBER	MATERIAL	QTY.
1	Main Body	Ceramic, Stainless Steel	1
2	Inlet Flank	Ceramic, Stainless Steel	1
3	Cover	Stainless Steel	1
4	Adapter plate	Ceramic, Stainless Steel	1
5	Clamp plate	Stainlesss Steel	1
6	Quartz	Quartz Glass	1

3.4 Previous research on emission by using natural gas

As shown in Figure 7, thermodynamic improvements in combustion efficiency and power output suggest a higher flame temperature. However, the long residence time of molecular nitrogen in regions of peak temperature with high oxygen availability for a few seconds above 1800 K or milliseconds above 2200 K will result in NO_X

production. Because oxidation creates free nitrogen in combustion air or fuel, it is referred to as "thermal NOx" in chimneys. It is determined primarily by the stoichiometric diabatic flame temperature of the fuel, which is the temperature attained when burning a theoretically correct mixture of fuel and air in an insulated vessel (Xing *et al.*, 2017).

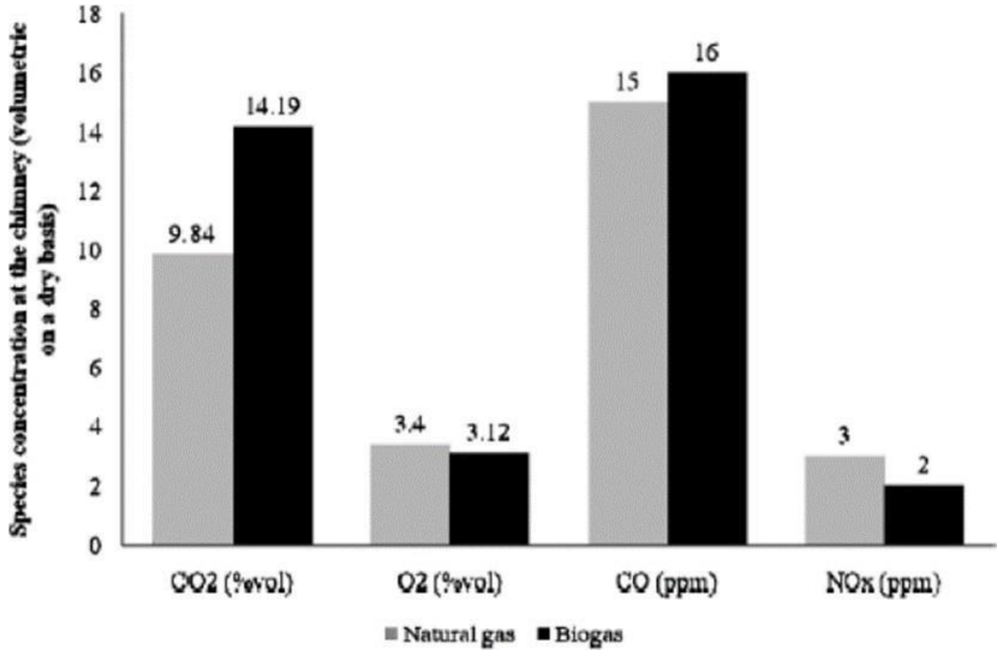


Fig. 6 *CO_2, O_2, CO and NO_x emissions at the chimney (Flameless mode). (Colorado et al., 2010)*

4. Conclusion

The objective of this project was to design a Flameless Hot Air Generator that could be powered by natural gas. Therefore, the objective of the project has been successfully completed in a manner that satisfies. According to the findings of the prior research, it has been established that using flameless combustion results in decreased concentrations of CO, CO_2, and NO_x emissions since complete combustion takes place. There are three distinct forms of nitric oxides that are generated as a byproduct of the combustion of natural gas. To begin, it takes place at extremely high temperatures. Second, it occurs in fuel-rich environments. Thirdly, it is produced when wood is burned as a source of fuel.

It was to be anticipated that the concentration of oxygen would have a considerable impact on the amounts of carbon dioxide and carbon monoxide that were present. Since there is more oxygen available to combine with the fuel carbon during this process, the greatest amount that can be generated is achieved when there is a presence of one hundred percent oxygen. On the other hand, if all the other variables remain unchanged, the concentration of CO will decrease while the concentration of oxygen will increase.

Acknowledgement

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