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Evaluation of Combustion Models in a Porous Medium with Different Excess Air Ratios

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ABSTRACT: In this paper, the simultaneous study of the effects of the excess air ratio and the combustion mechanisms on the temperature and distribution of species in the porous medium burners with continuous porosity variation has been investigated. For this purpose, multi-step chemical kinetics have been used and their effects on the temperature profile, mass fraction of the main species and emission of pollutants for different values of the excess air ratio have been investigated. Problem-solving equations include continuity equation, momentum equations, gas, and solid phase energy equations, and the chemical equilibrium equation is solved using the finite volume method and the semi-implicit method for pressure linked equations algorithm is used for the relationship between velocity and pressure. The results showed that for excess air ratio of 1.5, the results of combustion mechanisms have the same accuracy in predicting the temperature profile and mass fraction of the main species, and then, for additional values of the excess air ratio, the results of the combustion mechanisms Show a slight difference. This is while the greatest difference in the results is observed for the stoichiometric condition. Also in stoichiometric conditions, the NO emission rate using the GRI-3.0 combustion mechanism is predicted to be zero, and for the rest of the coefficients of the excess air ratio, its value will be of the order of magnitude 10^{-6}.

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1. INTRODUCTION

Today's, saving fuel and reducing pollutant emissions are major goals for optimizing the performance of systems that use fossil fuels. Combustion in a porous medium is one of the new methods that are rapidly replacing by conventional methods. In 2013, Mohammadi and Hosseinpour [1] examined the effects of chemical mechanisms and wall temperature on the performance of porous media burners with constant porosity in the two preheating and combustion zones. They found that chemical mechanisms would not have many effects on the temperature profile, and as the chemical mechanisms become fuller, NO emission levels will be closer to the experimental values. They also found that by increasing the wall temperature, the maximum temperature and; consequently, NO emission of the burner output increased. Mohammadi and Hosseinpour [2] continued their research in 2014, to study the effects of porosity profiles on the performance and emission of pollutants in the burner. The results indicated that by applying the continuous porosity profile instead of constant porosity in the two preheating and combustion zones, the maximum value of the temperature and hence the amount of NO emission in the burner output decreases.

In 2017, Ganjalikhan Nasab et al. [3] studied the effects of different parameters such as optical thickness, porosity coefficient, excess air ratio and propagation ratio on the radiation efficiency in porous medium burners. They found that by increasing optical thickness, because of the absorption of energy by the solid phase increases, the radiation efficiency also increases. As porosity increases, due to the reduction of the specific surface area per unit volume of the solid phase, less energy is transferred from the gas phase to the solid matrix, which leads to Reduces the radiation efficiency. Furthermore, with the increase of the excess air ratio and the propagation ratio, the radiation efficiency decreases and by increasing the excess air ratio, the maximum temperature as well as the amount of CO and NO emissions in the combustion products decrease.

In the present work, the combustion of methane-air was studied in a two-zones of the porous medium burner (Fig. 1) [4]. For the simulation of chemical kinetics, three different mechanisms, including GRI-2.11, GRI-3.0 [5] and a mechanism with 17 species and 58 chemical reactions have been used and the effects of these mechanisms on the

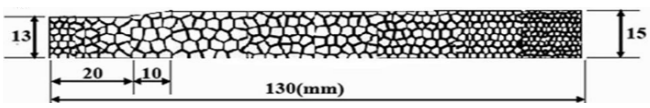

Fig. 1. A schematic of the understudy burner

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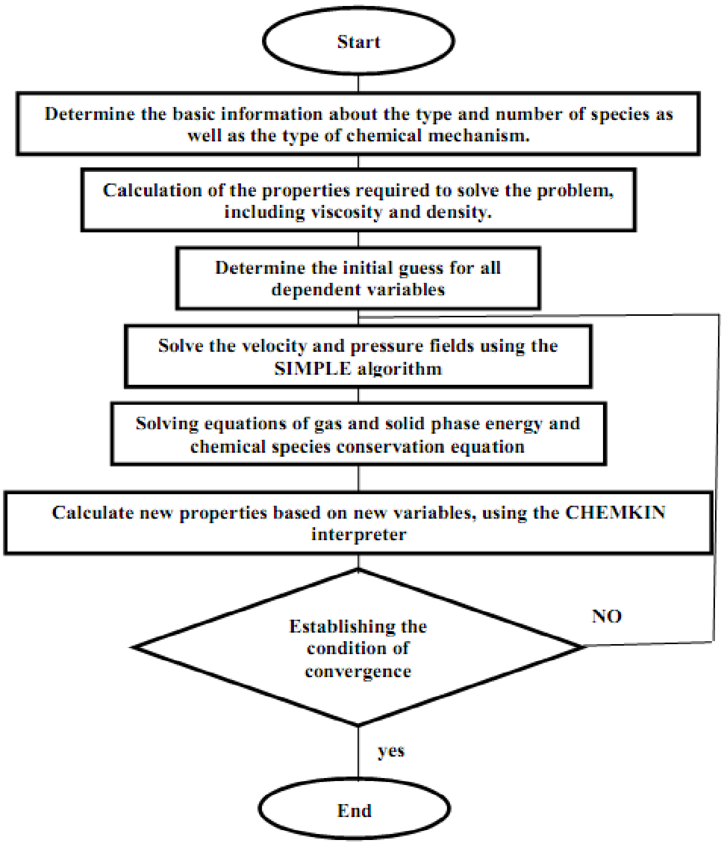

Fig. 2. Flowchart numerical simulation algorithm

temperature profile, mass fraction of species and emission of pollutants have been investigated. Also, the effects of the excess air ratio on the results of various combustion mechanisms have been shown.

2. METHODOLOGY

In this paper, the governing equations including continuity equation, momentum equations, solid phase energy equation (porous matrix), gas phase energy equation and Species conservation equations are discriminated based on the finite volume method and pressure and velocity are coupled by the Semi-Implicit Method for Pressure Linked Equations (SIMPLE) algorithm. By using a multi-step reaction mechanism, the resulting system of algebraic equations is stiff and conventional iterative methods like Tridiagonal Matrix Algorithm (TDMA) lead to divergence, to solve this problem, the operator splitting method is used [1, 2].

3. RESULTS AND DISCUSSION

Figs. 3 to 8 show the gas temperature profile and various chemical species for different excess air ratio and chemical kinetics.

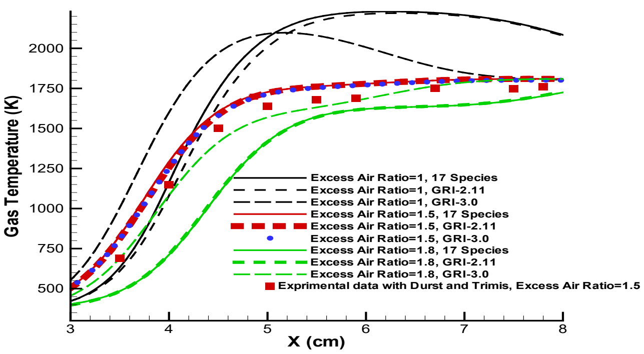

Fig. 3. Gas temperature diagram using the GRI-3.0, GRI-2.11 and 17-species mechanisms for different values of the excess air ratio [6]

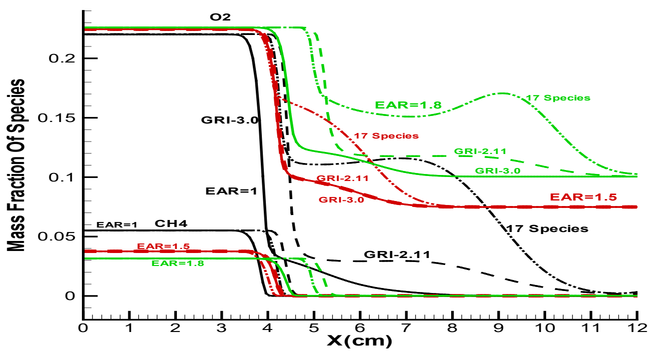

Fig. 4. Diagram of the mass fraction of species using the combustion mechanisms GRI-2.11, GRI-3.0 and the 17-species mechanism for different values of the excess air ratio

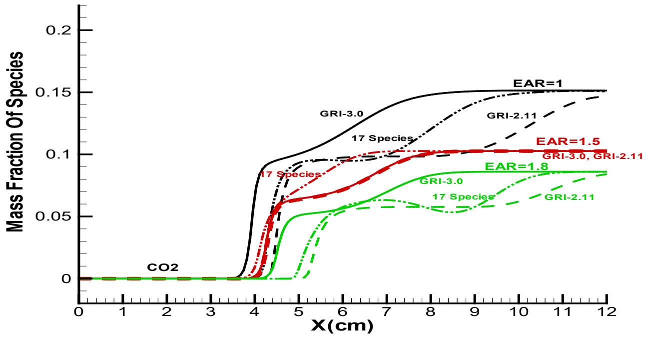

Fig. 5. Diagram of the mass fraction of CO_2 species using the combustion mechanisms GRI-2.11, GRI-3.0 and the 17-species mechanism for different values of the excess air ratio

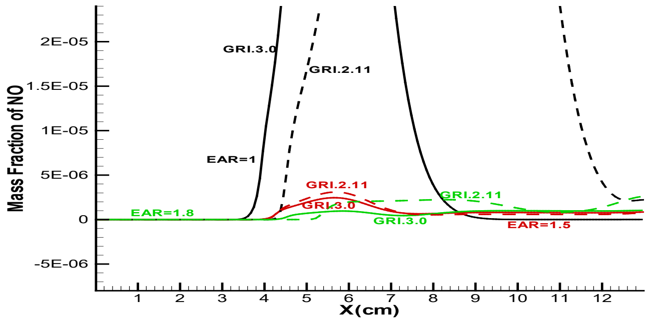

Fig. 7. Diagram of the mass fraction of NO species using the combustion mechanisms GRI-2.11, GRI-3.0 for different values of the excess air ratio

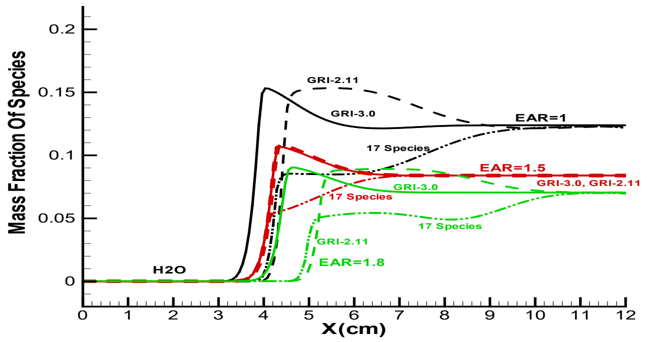

Fig. 6. Diagram of the mass fraction of H_2O species using the combustion mechanisms GRI-2.11, GRI-3.0 and the 17-species mechanism for different values of the excess air ratio

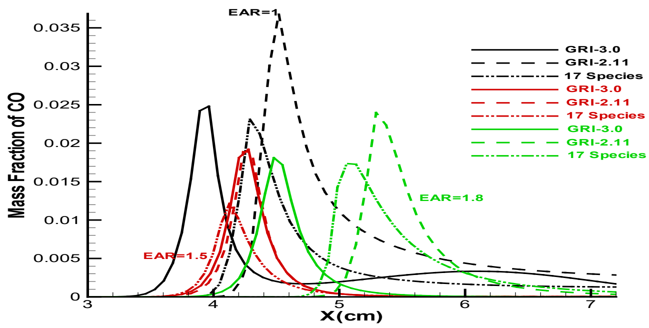

Fig. 8. Diagram of the mass fraction of CO species using the combustion mechanisms GRI-2.11, GRI-3.0 and the 17-species mechanism for different values of the excess air ratio

4. CONCLUSION

- The highest levels of emissions carbon dioxide, nitrogen monoxide, and carbon monoxide are related to stoichiometric conditions.
- By increasing the excess air ratio, the amount of emission of carbon monoxide and nitrogen monoxide is reduced.
- In an excess air ratio of 1.5, the results of all three chemical mechanisms GRI-2.11, GRI-3.0, and the mechanism of the 17 species are approximately the same, and it is possible to reduce the computational time by using 17 species mechanism instead of GRI-3-0. Because species are reduced from 53 species to 17 species.
- Under stoichiometric conditions, the amount of emissions nitrogen monoxide using the GRI-3.0 mechanism is predicted to be zero, and for the rest of the coefficients of the excess air ratio, its value will be of the order of magnitude 10^{-6}.

REFERENCES

[1] I. Mohammadi, S. Hossainpour, The Effects of Chemical Kinetics and Wall Temperature on the Performance of Porous Media Burners, Heat and Mass Transfer, 49 (2013) 869-877.

[2] I. Mohammadi, S. Hossainpour, Investigation of the Effects of Several Porosity Variation Profiles on Performance and Pollutants Emission of the Porous Media Burners, Fire and Materials, 40 (2014) 3-17.

[3] H. Shabani Nejad, A. Gandjalikhan Nassab, E. Jahanshahi, Numerical Study on Radiant Efficiency of a Porous Burner under Different Conditions, Journal of Thermophysics and Heat Transfer, 32(2) (2017) 1-8.

[4] M. Farzaneh, R. Ebrahimi, M. Shams, M. Shafiey, Two-Dimensional Numerical Simulation of Combustion and Heat Transfer in Porous Burners, Engineering Letters, 15(2) (2007) 370-375.

[5] http://www.me.berkeley.edu/gri-mech.

[6] F. Durst, D. Trimis, Compact Porous Medium Burner and Heat Exchanger for Household Applications, EC project report (contract no. JOE3-CT95-0019), (1996).

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