IMPORTANCE OF MATHEMATICAL MODELING IN INNOVATION

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Abstract: *Mathematical modeling is the key parameter in designing new devices. Renewable energy technologies are getting higher importance in the near future. Mathematical modeling of circulating fluidized bed (CFB) biomass combustion could improve both their design and operation, reduce any associated problems and facilitate the implantation of this technology. A good understanding of the combustion and pollutant generating processes in the gasifier can greatly avoid costly upsets. Presently, there is a focus on developing models of CFB for burning biomass and waste material. The objectives of these models are to be able to predict the behavior with respect to the combustion efficiency, fouling problems and pollutant emissions performance of different fuels or mixtures in commercial CFBs. In this study, importance of mathematical modeling in designing CFB biomass gasifiers is investigated in view of innovative solutions.*

Keywords: INNOVATION, MODELING, INDUSTRY 4.0, CFB

1. Introduction

In its simplest definition, innovation is to develop and implement new and different ideas. These ideas can be developed to solve previously unresolved issues or respond to previously unmet needs. Or many of the already existing products and services can be more beautiful, more useful, more useful to people. Innovation is carried out with the realization of these ideas and the emergence of products, services or methods of work, followed by the start of the sale of these products and services or the implementation of business methods [1].

The innovation process is defined as the transformation of knowledge into economic and social benefit. Therefore, it is a whole of technical, economic and social processes. The desire for change in individuals and in society requires a culture of openness to innovation and a culture of entrepreneurship. Individuals with an innovative culture of thought create new ideas.

Simulation studies are a powerful helper in problem solving and there are several reasons for this widely used. First of all, complex systems can be examined in a more convenient and analytical way through simulation. In addition, new strategies enable the testing of new parameters and new operating conditions, enabling the performance of the system to be evaluated in new situations without jeopardizing the system itself [2]. In addition, different system designs are made and these designs are compared.

Today, many different biomass combustion technologies are being developed. Circulating fluidized bed (CFB) technology offers high efficiency while reducing NO_x and SO_2. Fluidized bed with high pressure air fluidized sand particles in the base of the system. During the combustion of biomass components in the bed, compressed air force biomass components are suspended. When biomass is suspended, the unburnt particles which are directed to the chimney by air pressure are kept in cyclones and sent back to the bed and burned. Since the bed temperature is lower than in other biomass combustion technologies, NO_x emmisions are also reduced.

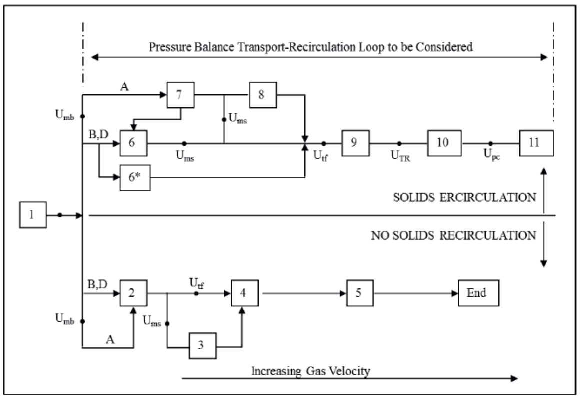
In this study, importance of mathematical modeling in designing CFB biomass gasifiers is investigated in view of innovative solutions.

2. Biomass and Circulating Fluidized Bed (CFB)

Due to the world population growth and developing technology, the need for energy increases day by day. In recent years, energy efficiency, alternative fuel options, renewable energy sources, energy consumption problems, and environmental solutions are the main topics that occupy a major place in the world energy agenda. Biomass energy, which is concerned with all the above issues and which has become increasingly important in today's energy use; It stands out with its potential to be considered within the scope of sustainable development, environmental awareness and energy efficiency. Biomass is a renewable energy source that has some important advantages, such as sustainability, ease of accessibility and undesirable effects on the environment. Biomass energy has a wide application area around the world with its environment-friendly, sustainable energy production and environmental management. For this reason, the importance of biomass in energy production in the world has gained importance [3-5].

3. Mathematical modeling of CFB Systems – Performance Improvement

Mathematical modeling and simulation techniques has become an important and popular tool in the fluidization system design, optimization, and scale up in the last years [6]. Zhang et. al were developed operation diagram for CFBs. Other than other developed works which defined as work map, the study allows to designers to delineate the optimum working characteristics of CFBs. Also, the experimental findings were emprically correlated [7]. Operation modes of the system is given in Fig. 1.



1. Packed Bed
2. Bubbling Fluidized Bed (A, B, D: Powders of Geldart Classes)
3. Slugging Bed
4. Turbulent Fluidized Bed
5. Elutriation/Carry-over
6. Bubbling transport
6*. Bubbling Fluidized Bed with an internal draft tube
7. Bubble-free dense transport
8. Slugging dense transport
9. Turbulent dense transport
10. CFB
11. Homogeneous Dilute Phase Transport

Fig. 1. *Operation modes [7]*

In a study conducted by Gungor, various parameters of the fluidized bed biomass gasifier were simulated. The studied model is 1D, steady state and isothermal. In addition, it is based on on the two-phase theory of fluidization. Simulated model were also compared and validated with the test results. For solid calculation, The single-phase back-flow cell model is utilized (Fig. 1.a). For gas phase two-phase model were used (Fig. 2.b)

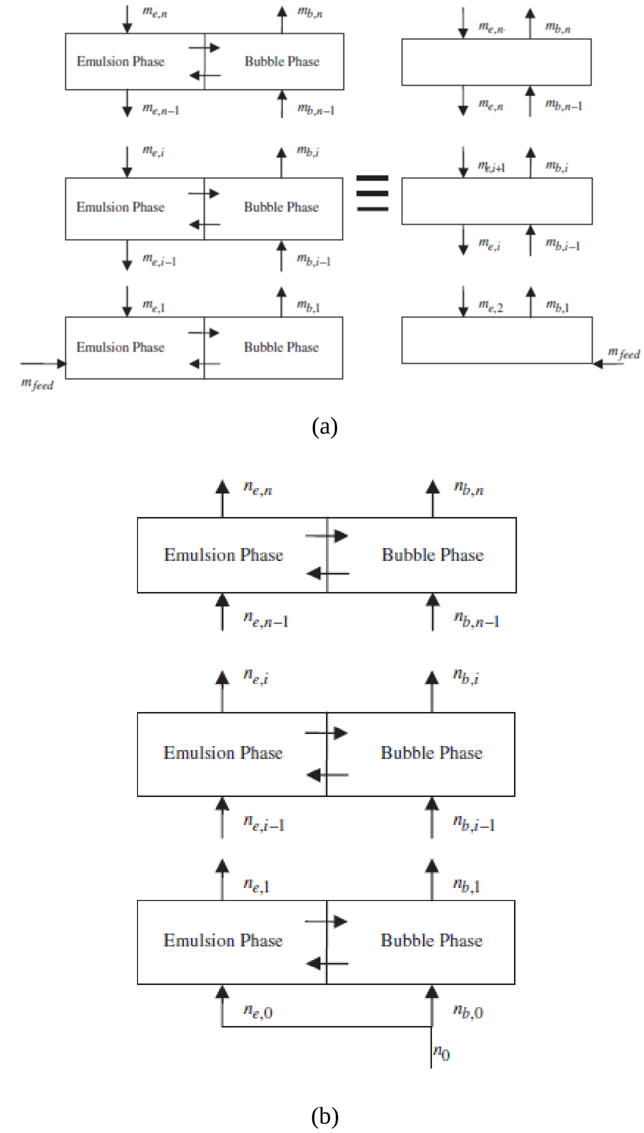


Fig. 2. *A single-phase back-flow cell model (a), Two-phase model (b) [4]*

Koçer et. al investigated the potential hydrogen production from greenhouse rediues. Pepper and tomate pomace were blended in different rates for the tests. Also a numerical model were developed. Flowchart of the study is given in Fig. 3 [3]. As a result, the study were proved that greenhouse wastes has a potential for hydrogen production. Mirmoshtaghi et. al investigated effect of various parameters on CFB biomass gasification application. In the work, genetic algoritm and partial least square-regression were used to optimize input paremeters for three different output targets [8]. In a research performed by Zhu et. al, 3D large-scaled CFB risers were analysed. Developed material-property-dependent sub-grid drag modification were validated with simulation model [9]. Doherty et. al investigated the impact of air preheating on the performance of the CFB biomass gasifier. Simulation study was performed with ASPEN Plus simulation software. The developed model was calibrated with the test values. Investigated CFB biomass gasifier system is shown in Fig. 4 [10]. Gungor analysed the combustion efficiency and emission performance of CFB biomass gasifier with simulation method. FORTRAN language were used in the simulation study. Gauss-Seidel iteration were utilized in the

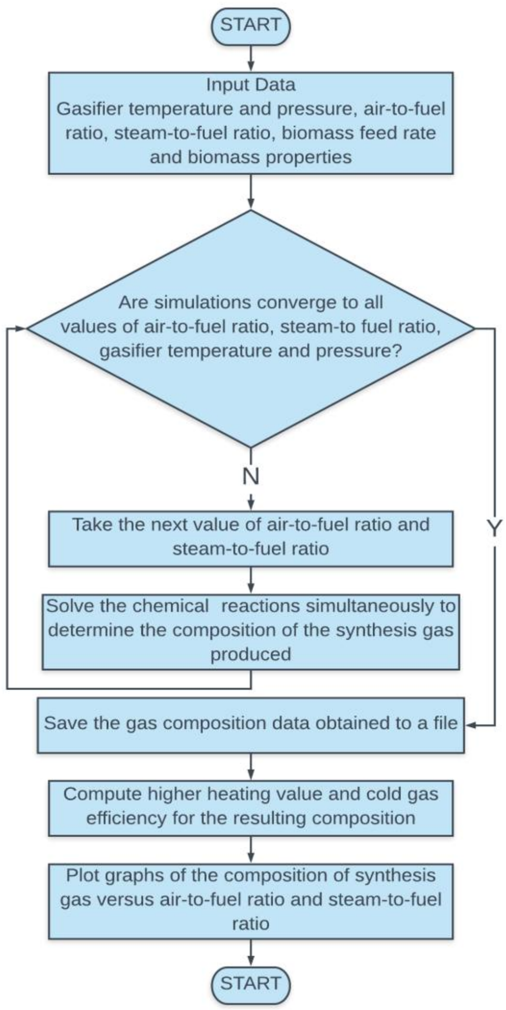


Fig. 3. *Flowchart for the biomass gasifier system model [3]*

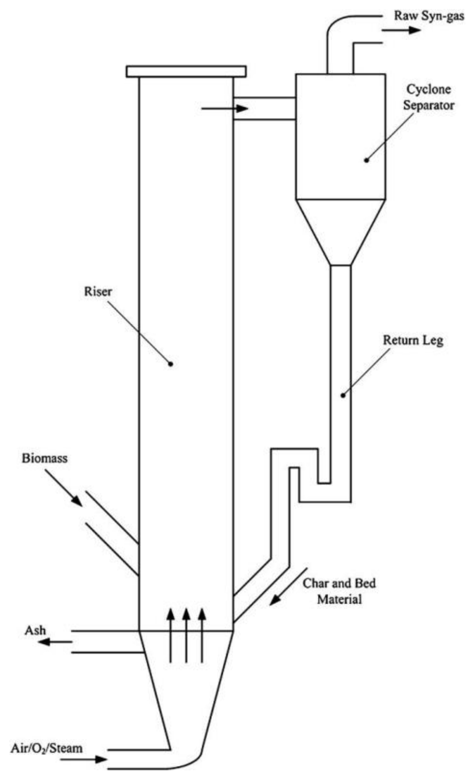


Fig. 4. *Investigated CFB biomass gasifier system [10]*

solution procedure. According to the findings, carbon monoxide emissions were increased as excess air increment. Results showed that biomass based fuels can be used for energy generation in CFB systems. Flowchart of the system model is illustrated in Fig. 5 [11].

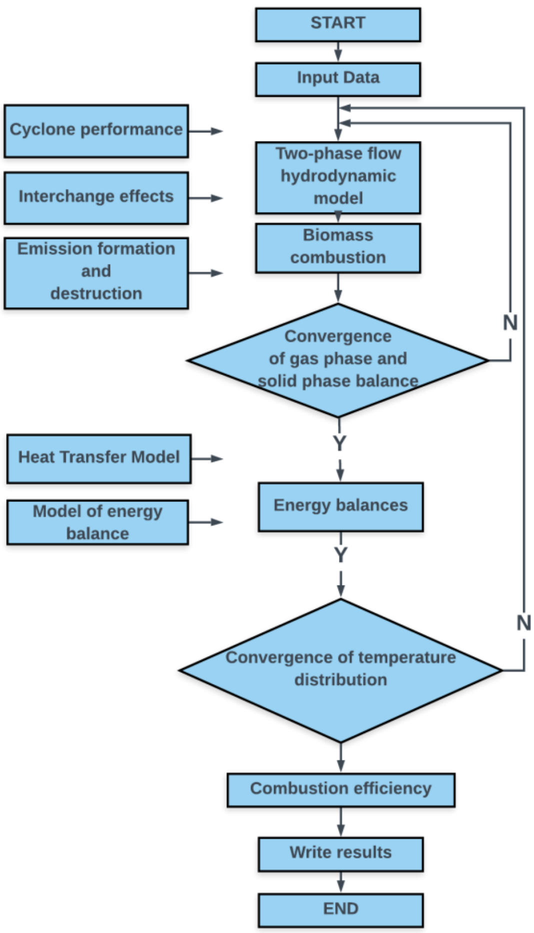


Fig. 5. *Flowchart of the CFB biomass gasifier system model [11]*

CFB systems were also analysed with computational fluid dynamics (CFD) approach. It is possible to understand the behaviour of the different parameters in CFB systems with CFD software such as ANSYS FLUENT. Researchers investigated various areas such as carbon capture process [12], particle conversion [13], supercritical boilers [14], cluster movement prediction [15] with CFD. Also there are many different developed CFD approaches for improving the performance of the CFB systems [16-19].

5. Conclusion

Mathematical modeling is an important approach for performance improvement of the CFB systems. Innovative solutions also helps to achieve the goals of Industry 4.0. As known, production with minimum losses is very important in transition to Industry 4.0. This goal can be achieved with innovative solutions. System optimization is provided by mathematical modeling and simulation approaches. Besides, the input parameters of the system are determined. When the studies about CFB systems were examined, it was seen that the designs using the models were compared with the experimental procedure and optimal designs could be made. At the same time, visual representation of mathematical modeling will guide the designers.

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