

Design for Modeling and Control of Temperature Process in Downdraft Gasifier System: Simulation Studies

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ABSTRACT: Biomass Gasification is one of most favourable technology to fulfil the increasing energy demands of the world and also to reduce considerably the volume of biomass waste generated in developing societies. The operating temperature is the parameter affecting the quality of the biogas during gasification. Analyzing and understanding of the behavior of the temperature in a gasifier leads better control during gasification process. This paper presents the development of a mathematical modeling and control of biomass gasification process. The Response of the gasification temperature to the step changes by varying the airflow velocity have been studied. This dynamic model from the experimental study can be identified a first-order-plus-time-delay (FOPTD). The comparison between PI controller and PID controller were shows that the use PID controller improves the performance of process in terms of time domain specifications and provides better stability.

Keywords: Biomass gasification, downdraft gasifier, airflow effect, dynamic modelling, gasifier temperature process control, PID controller

I. INTRODUCTION

Sufficient biomass resources, affordable price and eco-friendly characteristic make biomass fuel over fossil fuels. And these factors also motivate the development of biomass fuel market. The amount of residual biomass which is produced from logging or other industries is huge. Making biomass fuel from these waste residues is a win-win choice. [1] [2]. Gasification is a robust proven technology that can be operated either as a simple, low technology system based on a fixed-bed gasifier, or as a more sophisticated system using fluidized-bed technology. The properties of the biomass feedstock and its preparation are key design parameters when selecting the gasifier system [3] [4]. The energy in biomass may be realised either by direct combustion use, or by upgrading into more valuable and useable products such as gas, fuel oil and higher value products for utilisation in the chemical industry or for

clean power generation. Up till now, gasification work has concentrated on woody biomass but recently sources of other biomass with large energy production potential have been identified, namely hazelnut shells [5] [6]. The effect of feed rate on the CV/composition of the product gas and the associated variations of gasifier zone temperatures are determined with temperatures recorded throughout the main zones of the gasifier and also at the gasifier outlet and gas cleaning zones [7] [8]. The results show that equivalence ratio (ER), bed material, temperature, particle size and carbon content of the biomass are the input parameters influencing the output of the gasifier the most. The temperature is most influencing parameter in the gasification process. [9] [10]. The PID controllers are popular among the industry because of its flexible design. The PID controllers used depends on the K_p , K_i , K_d fixed at the initial conditions [6]. The process involved in converting biomass into usable syngas is a highly nonlinear process. The system properties vary depending on the initial conditions of the system [11] [12]. The conventional controllers are good in controlling the fixed dynamics within the system. But the initial conditions vary for onset of each new cycle of gasification which results in low performance and efficiency of gas production [13] [14]. Therefore, a suitable controller with graphical user interface has to be implemented for providing efficient controlling the system and gas production [15] [16]. The advantage of using PID controllers is to tune the changing parameters in the non-linear conditions of the gasifying system [17]. The main objective of this research to do develop the mathematical model from the experimental study and also to provide the better controller for gasifier system.

II. SYSTEM DESCRIPTION

The downdraft biomass gasifier used for the study with coconut shell as a feed material. Coconut shell was used as the feedstock with size range 0.75-1.0 mm. The proximate and ultimate analysis of biomass as follows: moisture 10.53%, fixed carbon 13.10%, volatile matter 57.96% and ash

18.4%. The ultimate analysis was C 50.2 %, H 5.30%, N 0.0% and O 43.4%. The primary air is injected through the nozzles around the fringe of the throat to the gasifier and the preheated secondary air is delivered at the reactor's top. The reactor consists of two concentric shells of diameters 200mm and 300mm respectively, fabricated using mild steel. The upper part of height 700mm is cylindrical in shape while the lower part is conical with an altitude of 300mm. The inner shell constitutes a volume of 0.0243mm³. Filters are employed to remove tar and other fine dust particles. There are four thermocouples have been used in the drying, pyrolysis, combustion and reduction respectively.

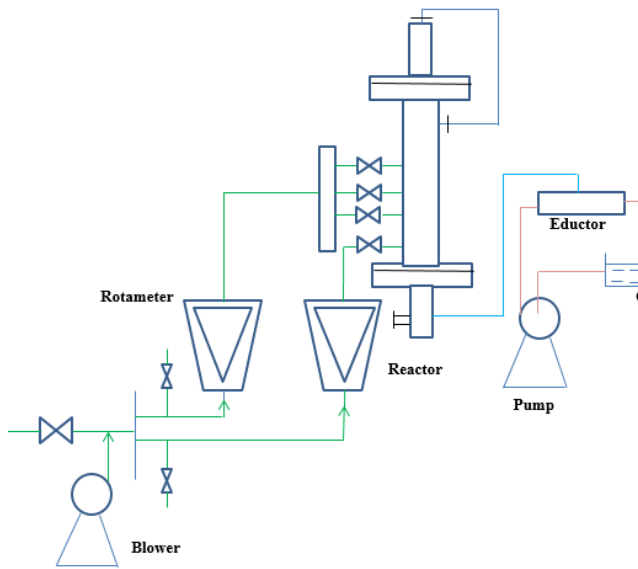


FIGURE 1. EXPERIMENTAL CONFIGURATION OF THE GASIFIER.

The output from the thermocouple is amplified to the required range. Then the AURDINO MEGA microcontroller used as DAQ, the LABVIEW is used to get digital temperature output.

III. MATHEMATICAL MODELLING OF THE GASIFICATION PROCESS

The mathematical model is developed in the biomass gasification system by providing a step response. Experimental study have been identified as first order system with time delay. Here the step is applied by varying the airflow velocity from 50 lph to 100lph. The corresponding first order system $G(s)$ given below: [11][12][19]

$$G(s) = \frac{K}{\tau s + 1} e^{-\theta s} \quad (1)$$

Where, K-gain
 τ -Time Constant
 θ -Time Delay

The empirical model is developed using experimental data from the open loop system. The open loop identification is conducted under step change [11] [12][18]. The measurements taken at the combustion identified as T. The model is developed based on the open loop step response data on the combustion zone temperature (T).

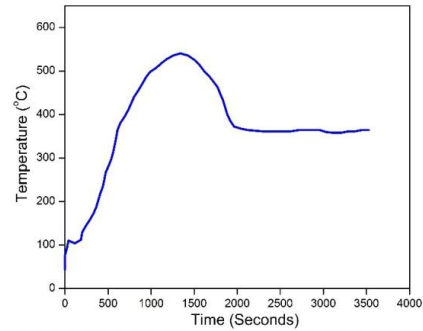


FIGURE 2: STEP RESPONSE FOR COMBUSTION ZONE TEMPERATURE

Figure 2 shows the combustion zone temperature profile in the gasifier operated under step response. This figure represents the first process, that is, the step change in gasifier temperature from 100°C to 400°C. The approximate model is developed using a first order system plus time delay.

$$K = \frac{\Delta \text{Output}}{\Delta \text{Input}} = \frac{400 - 100}{100 - 50} = \frac{300}{50} = 6$$

Time constant (T) = time for the response to reach the combustion zone temperature

$$T = 63.2 \% \text{ of (change in temperature) + offset} \\ = 63.2 \% \text{ of } (400-100) + 100 \\ = 352.8^\circ\text{C}$$

Time constant = 650 seconds

Thus, substituting the values for K, θ (estimation from graph), τ into Equation 4 gave the following:

$$G(s) = \frac{6e^{-10s}}{650s + 1}$$

Hence the final transfer function for the given system is obtained.

IV. PID CONTROLLER FOR BIOMASS DOWNDRAFT GASIFIER

Proportional-Integral-Derivative (PID) algorithm is widely used in process industry currently. Process like heating and cooling systems, fluid level monitoring, flow control and pressure control often use PID to control. PID controller is not an adaptive controller, hence the controller has to be tuned frequently and whenever load changes. Auto-tuning of these controllers becomes difficult for complex systems [13]. A standard method of setting the parameters is through the use of Ziegler-Nichols' tuning rules [14] [15]. The response of PI controller output is shown in Figure.4. Then response of PID controller output is shown in Figure.6.

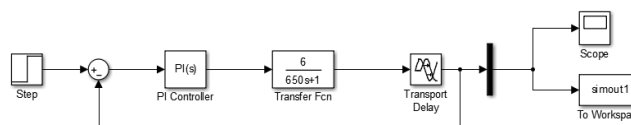


FIGURE 3. PI CONTROLLER FOR DOWNDRAFT GASIFIER

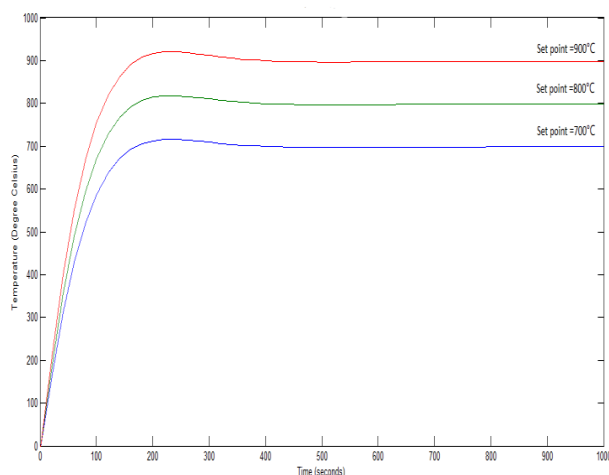


FIGURE 4. PI CONTROLLER RESPONSE WITH SET POINT =700°C , 800°C AND 900°C

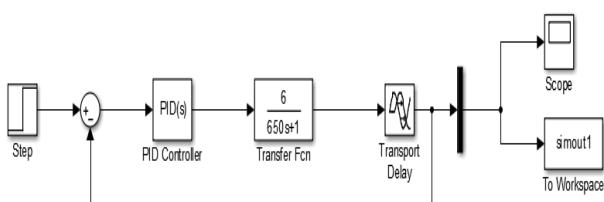


FIGURE 5. PID CONTROLLER FOR DOWNDRAFT GASIFIER

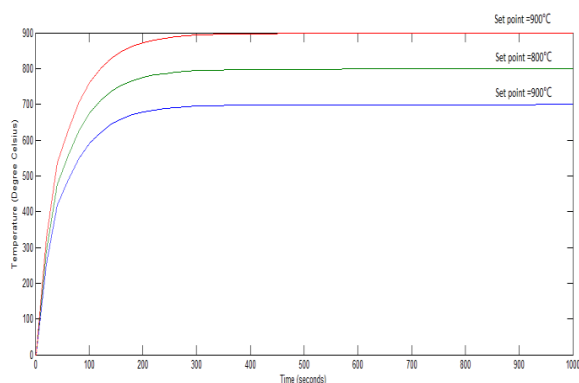


FIGURE 6. PID CONTROLLER RESPONSE WITH SET POINT =700°C , 800°C AND 900°C

V. RESULTS AND COMPARISONS

The PI controller results were compared with PID controller results. The settling time taken for the downdraft biomass gasifier is shown in Table 1 for the following set points 700°C, 800°C and 900°C respectively.

TABLE 1

COMPARISON OF CONTROLLERS IN TEMPERATURE PROCESS

Set Point (°C)	Settling Time (Seconds)	
	PI Control	PID control
700	800	370
800	650	350
900	550	320

From the experimental study we observe that the time taken for manual control is high compared to the PID controller. Therefore by implementing PID controller the performance of the system will improve in terms of settling time.

VI. CONCLUSION

The Open loop identification is studied using experimental data on the gasification process and a dynamic model for the biomass downdraft gasifier has been developed. The PI and PID controllers have been developed for the first order plus time delay model. Both PI and PID controllers were given different step input to test the performance. It is observed that the PID controller providing less overshoot and settling time during the temperature control process which proves that PID gives better performance for the control of temperature in biomass gasification process. Further improving the performance, intelligent control techniques are to be implemented.

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