Enhanced Conventional PID controller for Temperature Control in Woody Gasifier using Searching Algorithms

P.Vjiay Daniel, A.Sanjeevi Gandhi

Abstract: ***This paper focused on the design of improved Proportional Integral and Derivative (PID) controller in terms of optimum parameters of PID by introducing various searching algorithms. This developed controller is used to control the temperature of the downdraft biomass gasifier. Now days the PID controllers are widely used in many industrial applications due to its simplified design procedures. Though, the key issue in PID controller design involved in the optimization of optimal PID parameters for ideal system performance. In this work the Particle Swarm Optimization (PSO) and the ANFIS based algorithm were used to obtain the PID parameters for the temperature control of downdraft biomass gasifier. The results of the simulation are obtained and it was observed that the optimized ANFIS PID controller is able to improve the performance of the closed-loop system compared to the Ziegler-Nichols tuning method, and PSO techniques with respect to the transient responses and performance indices.***

Keywords: ***PID tuning, PSO algorithm, ANFIS algorithm, optimization, Ziegler-Nichols Method, biomass Gasifier.***

I. INTRODUCTION

As a renewable and reliable energy source, biomass can be used to generate energy in the form of producer gas. Biomass considered to be reliable energy source because of no contributions to global greenhouse gas. The biomass can be converted into usage of fuel which can be consumed for heating, cooking and power generation purposes [1]. The downdraft gasifier involved different processes such as drying, pyrolysis, oxidation, and reductions. The heat produced during the oxidation process is being utilized to remove moisture in biomass at the drying zone. Likewise, the heat discharged during oxidation process is utilized for pyrolysis and reduction procedures to deliver unstable gases during the pyrolysis process. At the reduction process the Producer gas is formed and flow through gasifier gas outlet. In Literature numerous experimental studies have been completed to upgrade the quality and efficiency of producer gas. The temperature control of downdraft gasifier involves the understanding of biomass characteristics. The producer gas efficiency is mainly depending on the moisture content and size of feed material. The quality of producer gas and gasification efficiency are mainly based on the control temperature during gasification.

It is essential that to understand the temperature profile in biomass gasifier is necessary to improve the quality and efficiency of producer gas [2]. The gasification temperature on different zones in downdraft gasifier to be monitored and controlled for attaining better quality and efficiency [11]. The Proportional-Integral-Derivative (PID) controller has been successfully adapted in the mechanical process since it is simple in design procedure and implementation. Many methods such as trial-and-error, D-partitioning, Ziegler-Nichols, and pole placement are available to obtain the tuning parameters of PID controlled systems [3]. If the initial conditions are changed the tuned parameters may not provide the better results the leads the design of optimization methods. Many researchers have proposed optimization methods for conventional controller which works successfully when they have accurate and reduced order models. It is observed from the recent literature is that optimization procedures based on heuristic algorithms have become a promising instrument to attain PID tuning for various processes. [4, 8]. In recent years, great numbers of nature and bio inspired optimization techniques have been developed. The structural simplicity, ability to optimize and their speed of response are the main reason for using the Heuristic algorithms in process control. Due to the flexibility of conventional controller design procedures they can easily adapted to use the Heuristic algorithms in control system problems. It is observed that the regardless of the order of the models the Heuristic algorithms can be utilized to design of controllers for unstable process. The Particle Swarm Optimization and ANFIS are usually used in hybrid techniques due to their capability of searching global optimum, convergence speed, and simplicity. [5]

The aim of this work is to design PSO and ANFIS based algorithm to get the optimal PID parameters for temperature control of downdraft biomass gasifier. The comparative study is also carried out between ANFIS, PSO, and classical controller tuning method and the simulation results are obtained.

II. EXPERIMENTAL SETUP OF DOWNDRAFT BIOMASS GASIFIER

Gasifier is a unit which generates producer gas by thermo chemical conversion processes. The schematic diagram of downdraft biomass gasifier shown fig1.

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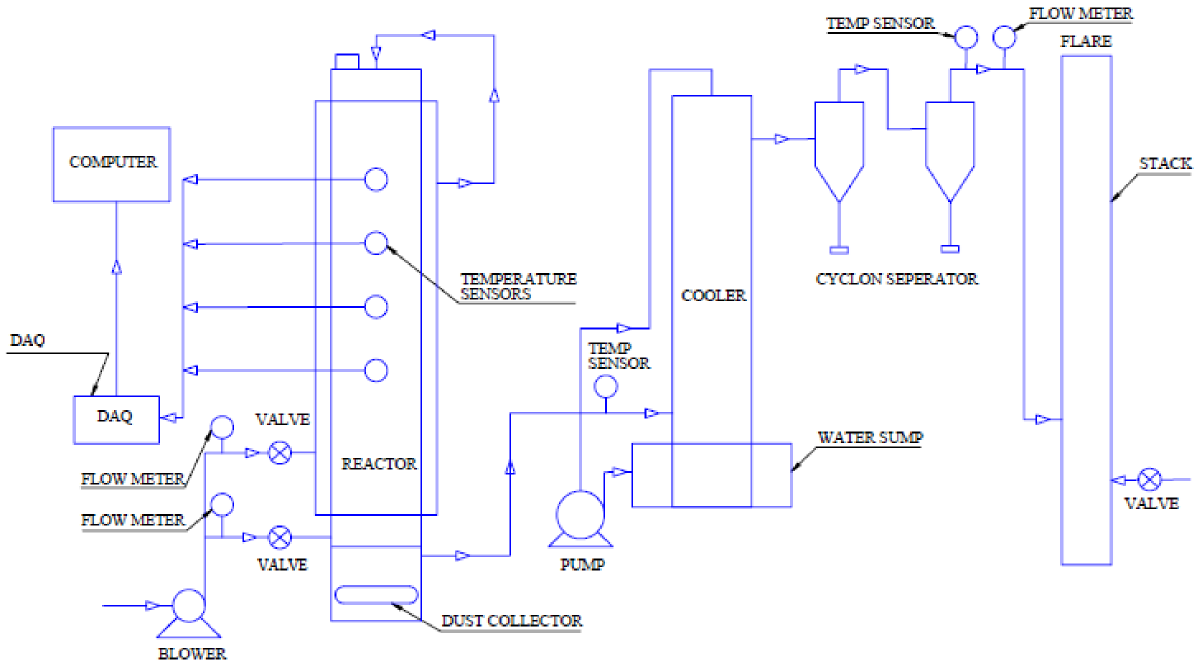

Fig. 1 Schematic diagram of downdraft biomass gasifier

The gasifier comprises of two concentric shells made of mild steel body having an outer diameter of 320mm and inner diameter of 200mm respectively. The space between shells offers channel for secondary air to flow, where the incoming air is preheated. The boiler with a total volume of $0.243m^3$, is divided into two parts where the top is cylindrical in shape with a height of 700mm and the bottom is conical in shape with a height of 300mm. The inner shell is lined with 3mm thick fire clay and to the bottom of the conical tank is fixed a grating. The hot gas evolving from the reactor is cooled using a cooling tower and the dust particles from the gas is removed using two cyclone separators. To remove the moisture and dust present in the gas, a bed of charcoal and rice husk are used. To remove tar and other fine dust particles, three other bag filters are being used. To stabilize the combustion inside the reactor at the beginning, an eductor is provided. Temperature was measured inside the reactor using four Type-K thermocouples located at different zones such as drying, pyrolysis, oxidation and reduction. The thermocouples are interfaced with the computer through the data acquisition system.

III. MATHEMATICAL MODELLING

In this study, the downdraft biomass gasification model was developed by providing step changes in combustion zone of the gasification Process. Airflow and biomass type are the most important factors influencing the temperature of a biomass gasifier. By assuming that the gasification process can be estimated by a first-order plus time delay system and the unit-step response look like an S-shaped curve with no overshoot.

The response of increase in airflow velocity 50 Lpm to 100 Lpm is shown in Fig. 2. From experimentation the data is acquired which is used for System Identification to obtain transfer function model.

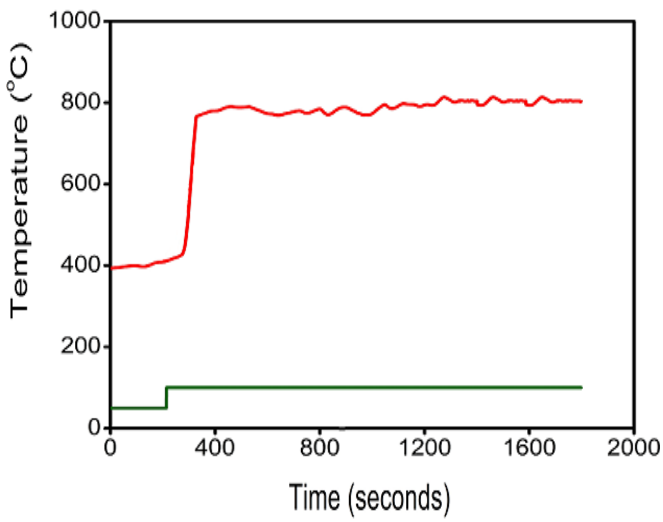

Fig. 2 Transient response

The calculations are as follows from the response:
(*K*) = (Final Temperature- Initial Temperature) / Change in Airflow
= (804-421) / (100-50)
= 383/ 50
= 7.66
Time constant (*T*) = time for the response to reach temperature T1
*T*1 = 63.2 % of (change in steady state) + offset
= 63.2 % of (804-421) + 421
= 663°C
Time constant = 115 seconds

$$\frac{C(s)}{U(s)} = \frac{8e^{-10s}}{115s+1} \qquad (1)$$

The transfer function model is shown in Eq. (1).

IV. DESIGN OF ANFIS BASED PID TUNING

In this section, for the optimal expectation of gain parameters to control the temperature of the downdraft gasifier ANFIS technique is utilized. The temperature of the system is constrained optimally by using this strategy. ANFIS is both the artificial neural system (ANN) and fuzzy inference system (FIS) [18]. Both participation capacities and oversee base the hidden estimations are obtained. By the ANFIS system by then the parameters of the participation work are streamlined. Here, the ANFIS uses the temperature error as inputs and conveys the optimal gain parameters of the PID controller as the yield. Generally, the fuzzy standards are made in perspective of the two input variables a_1 and a_2 and one output variable b of the Sugeno FIS. The standards are given by [19],

Rule 1: If a_1 is A_2, a_2 is B_1, then $b_1 = P_1 a_1 + Q_1 a_2 + R_1$ (2)

Rule 2: If a_1 is A_1, a_2 is B_2, then $b_2 = P_2 a_1 + Q_2 a_2 + R_2$ (3)

Where, P_1, Q_1, R_1 are the consequent parameters of the ith rule and A_i *and* B_i are the linguistic labels.

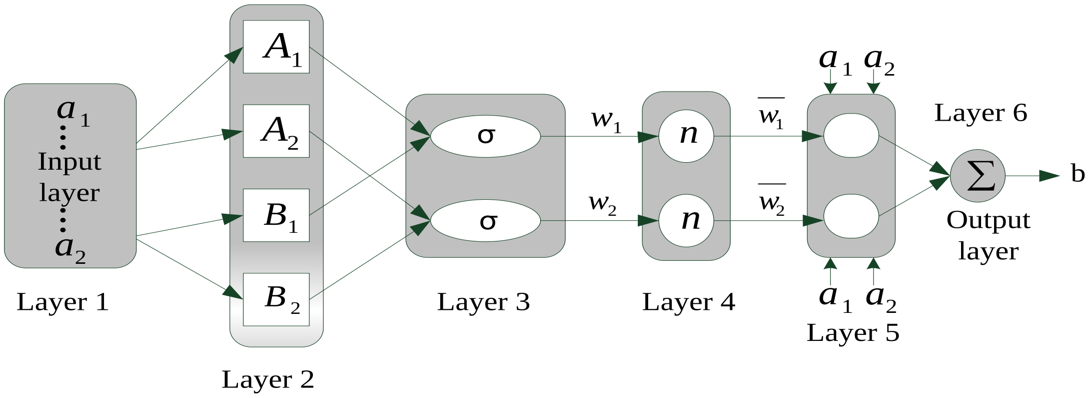

Fig. 3 Structure of ANFIS model

From the output layer to the input nodes the key learning guideline of ANFIS is the back-propagation gradient decent which figures the error signal recursively. With the membership functions are adjusted in the midst of the learning system, the weights and bias related. The decrease of error esteems exhibits the gradient-descent system helps the computational work of the parameters acquiring and their adjustments. At the point when the gradient is procured the optimization routine may change the parameters and the error gets restricted thus. Exactly when the training procedure gets completed, the optimal gain parameters for the controller are made. The generated signal is used to control the temperature of the downdraft gasifier. The structure of the proposed ANFIS is appeared in fig. 3.

V. DESIGN OF PSO BASED PID TUNING

PSO is a computation method and parallel evolutionary algorithm. Here particles are the random candidate solutions. As a randomized velocity every particle has been doled out and through the problem space it is moved iteratively [17]. So far by the particle itself it is pulled in towards the location of the best fitness accomplished thus far over the whole population (global adaptation of the algorithm) by the location of the best fitness accomplished.

Step 1: Initialization

Initialize a population array of particles with time interval and error of the temperature as the input and optimal gain parameters of the PID controller as the output.

Step 2: Random Generation

Generate the random values of gain parameters of the PID controller. They are usually selected as uniform random numbers in the range [0, 1].

$$rand_1, rand_2 \in Uniform\,[0,1] \qquad (4)$$

Where, $rand_1, rand_2$ is the random behavior of the particles.

Step 3: Evaluation

The error is determined by the following relation

$$Error = \frac{1}{2}\sum (T_V - D_V) \qquad (5)$$

Where, T_V is the target value, D_V is the desired value.

Step 4: Updating Particle Position and Velocity

The iteration of t value is set as 0 and each particle is described by the position $o_i(t)$. At minimal value the position of $o_i(0)$ is randomly selected from the domain of the function. The "fitness" of each position is calculated in each iteration t. The resultant value is compared with the local (*l*) best solution $I_i(t)$ and also compared with global (g) best solution $I_i^{global}(t)$. Then replace the local with global best solution if local best is more efficient than global best. Otherwise, keep the unchanged global best solution. By considering $\Delta = 1$ after comparison the updating process is executed for position by the following equation is derived as follows,

$$o_i(t+1) = o_i(t) + \Delta t . w_i(t+1) \qquad (6)$$

$$w_i(t) = \omega . w_i(t) + a_1 . y_1 (I_i(t) - o_i(t)) + a_1 . y_1 (I_i^{global}(t) - o_i(t)) \qquad (7)$$

Where i represent the number of particles of swarm, t indicates the iteration number, ω is the inertia weight,

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a_1, a_2 is the acceleration parameters indicate the cognitive and social factors respectively. a_1, a_2 is responsible for varying the particle velocity towards I_i, I_i^{global}. y_1, y_2 is the two random functions with uniform distribution range of [0, 1]. Where number of particles of swarm represented as i, iteration number indicates t. Repeat for each particle until the best particle position and velocity are reached.

Step 6: Final Process

Until the point when it achieves the minimum error value or achieves the maximum number of iterations rehash the process. To decide the optimum gain parameters of the PID controller after the specified procedure is finished, the controller can be utilized.

VI. RESULTS AND DISCUSSION

In this test case the set point of 800^{o}C with ANFIS, PSO and Z-N technique are analyzed. Fig 4 shows the response of the system with ANFIS, PSO and Z-N technique. The IAE, ISE and ITAE error measurement parameters are analyzed under set point 800^{o}C.

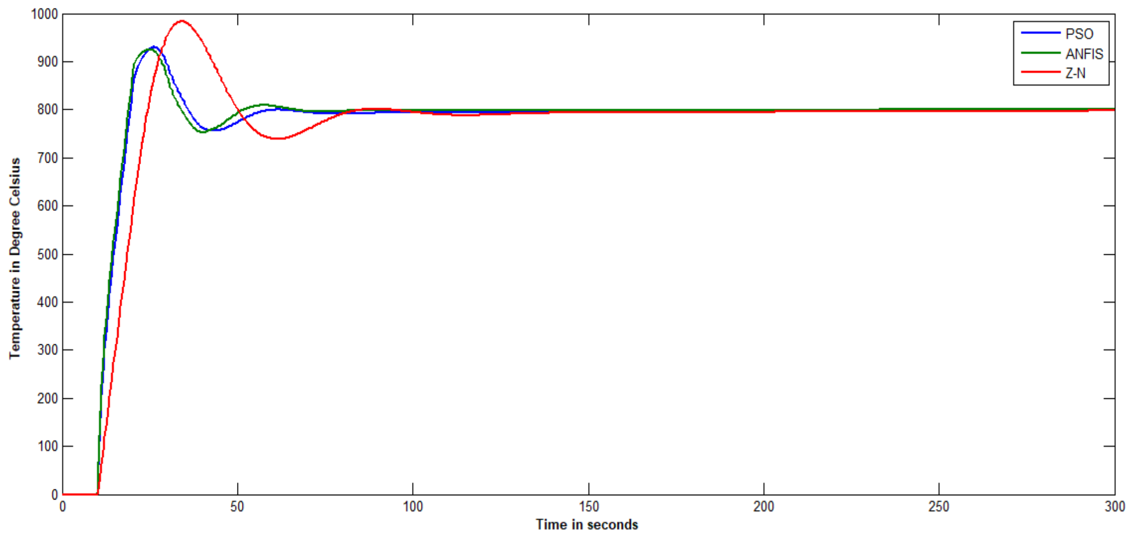

Fig 4. Comparisons of ANFIS, PSO and Z-N tuned Response

Table 1. shows the time domain specification of the system with ANFIS, PSO and Z-N technique. The IAE, ISE and ITAE error measurement parameters are shown in Table 2.

Table. 1 Comparison of Time domain specifications

Solution techniques	Rise Time	Settling Time	Over shoot	Under Shoot
Z-Z	88	140	190	90
PSO	19	74	124.5	42.5
ANFIS	24.5	103	184	61.2

Table. 2 Performance indices

Solution techniques	ISE	IAE	ITAE
Z-N	7.962 e^6	1.403 e^4	1.403 e^5
PSO	7.812 e^6	1.283 e^4	1.283 e^5
ANFIS	9.842 e^6	1.873 e^4	1.873 e^5

In addition, the PSO technique gives impeccable performance and optimally provides rise time, settling time, overshoot time and peak time. From the overall analysis, the PSO technique gives the best results on current strategies.

VII. CONCLUSION

The ZN, PSO and ANFIS tuning methods have been designed for biomass downdraft gasifier. The comparison of Time domain specifications and the performance indices are studied. The response of Z-N tuned controller takes 140 seconds to reach the set point. The PSO and ANFIS controller takes 74 seconds and 103 seconds respectively. Also, the performance indices are found to better when compared with the Z-N. It is observed that the performance indices of the PSO tuned PID controller is much superior to the Z-N and ANFIS tuned PID controller. Compared with the conventionally tuned system and ANFIS, the PSO tuned system provides an adequate closed loop dynamic and performance indices for biomass downdraft gasifier.

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