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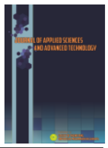

Process Control on the Platformer with the Adaptive Neuro-Fuzzy Inference System (ANFIS) Method

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ABSTRACT

Catalytic naphtha reform (platformer) is the main process carried out in oil refineries to increase low octane naphtha into high octane gasoline. The Reformer will meet a wide range of products that require operating flexibility. Process optimization can be done by controlling using the ANFIS method. This optimization requires an accurate process model that is applicable in a wide range of operating conditions, therefore simplifications are made in the kinetic model modeling. This model provides three temperature profiles and concentrations of important hydrocarbons (naphthene, paraffin, and aromatic) throughout the reactor. The optimal control scheme using the ANFIS method is used to maximize the aromatic yield, following the reactor inlet temperature limit. The results obtained were compared with the aromatic results without control and using control with the neural network method. The results showed that the ANFIS method has the ability to control the process. Furthermore, the results obtained from the process are used to determine the pressure of the process during the reaction.

INTRODUCTION

The catalytic reformation carried out in the Catalytic Reformer unit is a process used in oil refineries to convert the light petroleum distillate fraction (naphtha) into premium reformate, Benzene, Toluene and Xylene (BTX), and Hydrogen. Almost every refinery in the world has a reformer with the aim of producing products that will increase the octane number of motor vehicle fuels or be used to produce products with high levels of aromatics which will be used as raw materials in the petrochemical industry [1-10]. raffinate, is used as a component in low-octane blends for gasoline or as a solvent. As raw material for Catalytic Reformer is Naphtha which is a petroleum fraction from distillation which occupies a percentage of 15-30% of crude oil by weight, and boils at temperatures between 30 °C and 200 °C. This complex mixture consists of hydrocarbon molecules with 5 -12 carbon atoms, which belong to the Paraffin, Olefin, Naphthene and Aromatic (PONA) group. The development of increasing standards for engine fuel efficiency is achieved by increasing the compression ratio so that it requires fuel with a higher octane number. The interacting variables in the Catalytic Reformer Unit are operating conditions (reactor pressure, hydrogen-hydrocarbon ratio, velocity in the chamber, and reactor temperature), feed quality and type of catalyst are variables that affect the reactions that occur in the reactor [11-15].

Controlling the operating conditions of the process within the constraints of the interacting variables in the reactor is an optimization method to improve reactor performance in order to provide a product with a high octane number. Advances in artificial neural networks and fuzzy logic provide potential for approaches in complex intelligent control systems. Complex intelligent control systems offer two unique features that distinguish them from conventional controllers namely the ability to imitate rule-based decision-making and learning capabilities [16-20].

This study aims to: Conduct training on the control of input variables using the Adaptive Neuro-Fuzzy Inference System (ANFIS), obtain control performance on the optimum Catalytic Reformer system and obtain operating process pressure on various compositions of the final product from platforming.

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EXPERIMENTAL METHOD

Procedure

This research begins by taking literature data which contains thermodynamic data and field data of the catalytic reformer process as the variables needed for simulation. The literature data required for the simulations are thermodynamic and reaction kinetics parameter data [21-23]. Based on the preparation of chemical reactions that occur in the catalytic reformer, simulations are carried out to determine the temperature profile and concentration of each component from the beginning of the reaction to completion which is represented by the weight of the catalyst fraction. The temperature and concentration profiles of each of these components are then used as training/learning materials for the ANFIS-based simulation system which will then be used as process control. Process control is carried out by minimizing disturbances due to changes in concentration. Control results based on ANFIS will be compared with the desired Aromatic results until the optimal temperature parameter is reached.

Research Material

The materials used in the research are data obtained from previous research literature.

Research methods

This research begins by taking literature data which contains thermodynamic data and field data of the catalytic reformer process as the variables needed for simulation. The literature data required for the simulation are thermodynamic and reaction kinetics parameter data . Based on the preparation of chemical reactions that occur in the catalytic reformer, simulations are carried out to determine the temperature profile and concentration of each component from the beginning of the reaction to completion which is represented by the weight of the catalyst fraction. The temperature and concentration profiles of each of these components are then used as training/learning materials for the ANFIS-based simulation system which will then be used as process control. Process control is carried out by minimizing disturbances due to changes in concentration. Control results based on ANFIS will be compared with the desired Aromatic results until the optimal temperature parameter is reached [24-25].

Analysis Method

1. Results of Training with the ANFIS method

In this section, a predictive control mechanism will be carried out using the Takagi Sugeno ANFIS (Adaptive Neuro Fuzzy Inference Systems) method. This prediction uses the following mechanism:

a. Loading simulation data feed (Paraffin, etc.)
b. Generating ANFIS
c. ANFIS training
d. Testing ANFIS

2. Optimal Control Optimization with ANFIS method

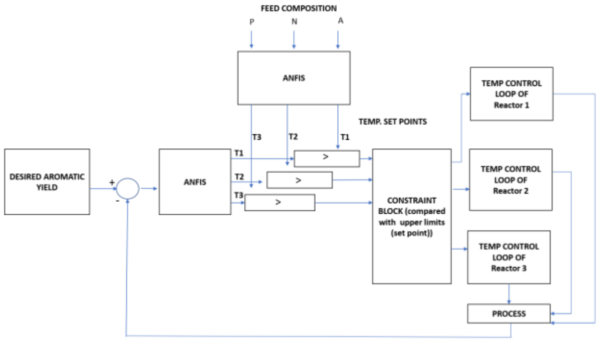

Figure 1. Controller in Platformer using ANFIS

The role of the controller using the ANFIS method is to minimize disturbances caused by the composition of the feed [26]. This block determines the feed composition as input (paraffin, naphtha, aromatic) and produces the optimal set point in temperature control of the three reactors.
ANFIS performance minimizes the index with the following standards [27]:

$$J = \sum_{i=1\ to\ 3} (Nadi - Naai)^2$$

Where
Nadi = Desired aromatic yield
Naai = Real aromatic yield

The input to this diagram is the error, the difference between the current yield and the desired yield. The desired yield is the yield with the desired process conditions criteria, namely the maximum inlet temperature of all reactors and the maximum amount of aromatics from the feed. The set point temperature is given according to the table containing information on the catalytic reformer used in the petrochemical industry in Table 1.

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Table 1. Set Point Temperature

Aromatic in bait	Range Galat	T1(K)	T2(K)	T3(K)
14 - 20	25 - 30	770	780	790
21 - 24	22 - 24	764	775	785
25 - 28	19 - 21	760	769	780
29 - 34	14 - 18	756	764	775
35 – 44.5	4 - 13	750	760	770

The output of this ANFIS Control is the set point of temperature control in the three reactors. Between the two sets (one from ANFIS for feedback and the other from ANFIS feedback), the maximum value is selected and compared to the limit value in the constraint block. If the value is above the upper limit, the default value is selected. These values are used as the set points of the 3 reactor controllers. The results obtained are the fractional weight profile of the VR catalyst as the dependent variable and the concentration of the product in percentage of the individual components of Paraffin (P), Naphtha (N) and Aromatic (A) as independent variables.

3. Model Testing and Data Analysis

Model testing is done by comparing the data obtained from the control results using the ANFIS method with the results obtained with previous studies and systems without controllers [27,28] to see whether the ANFIS method can control the platformer.

4. Reaction Pressure under Operating Conditions From Control Results

To find out the relationship between reaction pressure and operating conditions from the control results, look for Figure 2, namely Yield as a function of temperature at various reaction pressures.

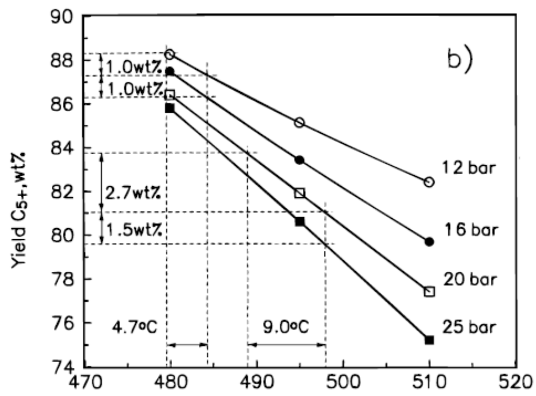

Figure 2. Yield as a function of temperature at various reaction pressures

RESULTS AND DISCUSSION

1. Results of Training With The ANFIS Method

The Results Of The Training Using The Anfis Method Give The Following Results:

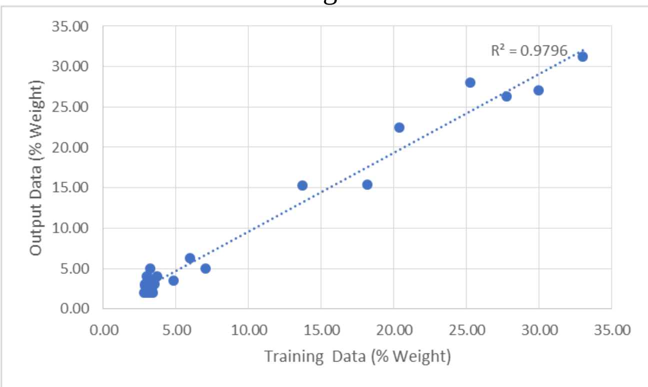

Figure 3. Results of control training using the ANFIS method for Paraffin

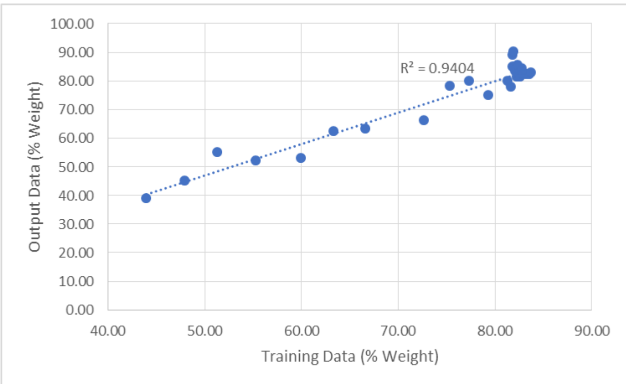

Figure 4. Results of control training using the ANFIS method for Naphta

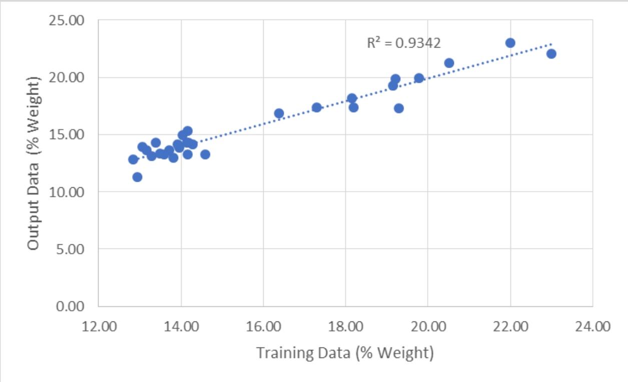

Figure 5. Results of control training using the ANFIS method for aromatics

From the results of the training above, the correlation between the Training Data and the output of the ANFIS method is as follows:

Table 2. Correlation of Training Results for Paraffin, Naphtha and Aromatic

	Correlation
Paraffin	0.9796
Naphtha	0.9409
Aromatic	0.9342

The results of the training show that the ANFIS method has a correlation between the data and the output of the ANFIS method so that it can be continued to carry out control simulations.

2. Results of Dynamic Model Simulation on various concentration profiles of Aromatic, Paraffin and Naphtha compositions

Platforming functions to reform Paraffin and Naphtha into Aromatic by using a catalyst so that there is an increase in the percentage of Aromatics in the final product. In this study, control simulations using ANFIS have been carried out on different Aromatic, Paraffin and Naphtha composition variables, namely the profile of one bait with an Aromatic composition of 27%, Paraffin 40% and Naphtha 33%, the profile of the two baits with an Aromatic composition of 34%, Paraffin 33 % and Naphtha 33% and the profiles of the three baits with the composition of Aromatic 44%, Paraffin 23% and Naphtha 33%.

The results of the dynamic model simulation in b are obtained from a mathematical model using the thermodynamic and kinetic parameters of the reformer at different feed concentrations with the simulation without controller, the controller simulation using the Neural Network method and the control using the ANFIS method as shown in Figures 6 to 8.

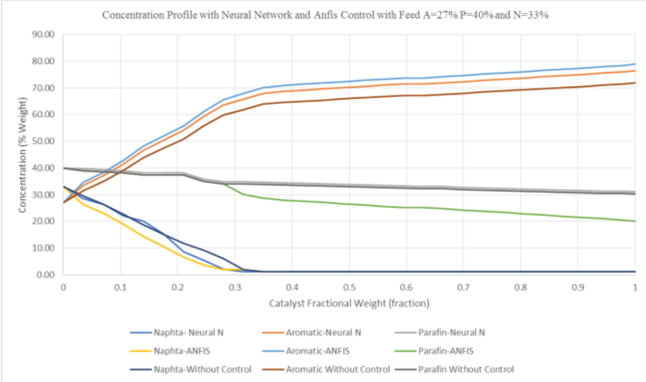

Figure 6. Concentration Profile with Neural Network (nn) control method, ANFIS method (anf) and without control (wc) at 27% Aromatic feed content

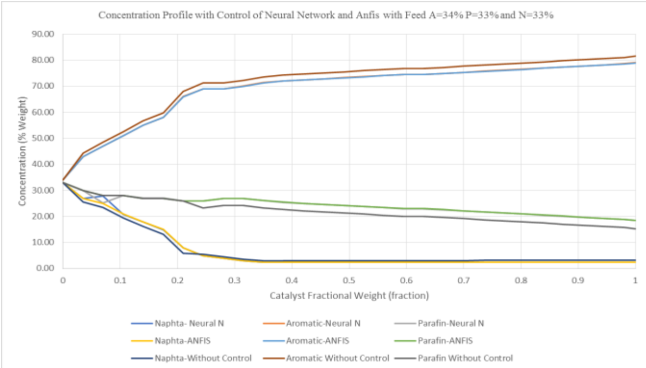

Figure 7. Concentration profile with Neural Network control method (nn), ANFIS method (anf) and without control (wc) at 34% Aromatic feed content

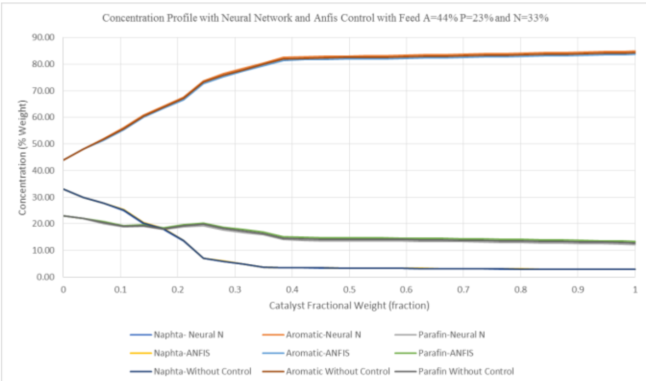

Figure 8. Concentration Profile with Neural Network (nn) control method, ANFIS method (anf) and without control (wc) at 44% Aromatic feed content

From the results of control with the ANFIS method, the following results are obtained:

Table 3. Comparison of Product Concentration in Uncontrolled condition, Control with Neural Network Method and with ANFIS Method

Aromatic Content			
Bait Composition	**Without Control**	**Neural Network Control**	**Control with ANFIS**
A=27% P=40% N=33%	71.86	76.45	78.90
A=34% P=33% N=33%	79.00	79.08	81.53
A=44% P=23% N=33%	83.73	84.32	84.91

Where:
A = Aromatic
P = Paraffin
N = Naphtha

Based on the relationship obtained from Figure 2, it can be obtained process pressure with the results in the table below:

Table 4. Relationship between Aromatic Yield and Pressure

Bait Composition	Aromatic Content	Pressure (Bar)
A=27% P=40% N=33%	78.90	19.5
A=34% P=33% N=33%	81.53	14.8
A=44% P=23% N=33%	84.91	12.0

The results obtained indicate that the increase in the aromatic content of the higher yields, the process will run at lower pressures.

CONCLUSION

1. The results of the training simulation on the input feed and reaction pressure variables using the Adaptive Neuro-Fuzzy Inference System (ANFIS) show that this artificial intelligence method has the ability to control the Catalytic Reformer Unit
2. The simulation results using the ANFIS method showed an increase from the Neural Network method respectively by 3.2% on baits with 27% aromatic content, and 3.09% on baits with 27% aromatic content. While the bait with a level of 44% the results obtained are 0.7%
3. For heavy naphtha (above 34% aromatic) the operating temperature is treated as the optimal temperature (no temperature control setting is required).
4. Operating pressures at the aromatic content of the feed 27%, 34% and 44% are 19.85 bar, 14.54 bar and 12 bar

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