BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXVI No. 3/2014	69- 74	Seria Tehnică

Simulation of Conventional Control Structure of the Catalytic Cracking Process

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Abstract

This paper presents the researches and the results obtained by the author regarding the conventional control of the catalytic cracking process. The first part of the paper describes the catalytic cracking process and the conventional control structure. The control structure is tested and evaluated on a software simulator developed in MTALAB. The simulation results can be used as reference for a future implementation of advanced control to catalytic cracking process.

Key words: *conventional control, PID algorithm, catalytic cracking*

Introduction

The cracking catalytic process is one of the main processes from the refineries, process that assures the converts heavy distillates like gas oil or residue to gasoline and middle distillates using cracking catalyst. The mains economic objectives of the catalytic cracking process are increasing the feed stock processing capacity, gasoline yield and octane improvement. These desiderates are achieved if the reactor assures a good conversion, prevents over-cracking that results in undesirable products and the regenerator assures a uniform combustion, minimum flue gas afterburning and less catalyst deactivation.

The fluid catalytic cracking process, illustrated in figure 1, consists of two equipments: the riser-reactor, where almost the endothermic cracking reactions and coke deposition on the catalyst occur, and the regenerator-reactor, where air is used to burn off the accumulated coke. The regenerator is a complex system, assimilated to a reactor with perfect mixing that has as aim the catalyst regeneration by the partial burning of the coke deposited on the catalyst.
The objective of the paper is to develop a simulator for conventional control structure of the catalytic cracking process.

The Conventional Control Structure

The requirements for a control system associated with a catalytic cracking process are as follows [1]:

1. ensuring operational safety through an adequate protection system against dangerous regimes work (eg. reversing of flow of the catalyst, exceeded maximum limits for reactor and regenerator temperatures, shutting down air blower, etc.);

2. ensuring a best possible conversion by taking account of the market requirements and operating restrictions of the plant;
3. providing a low residual coke concentration;
4. ensuring an operating regime without overshoots, using a system control adequate that can reduce the effect of the interactions.

The recommendations above were substantial reasons for develop a new control structure with better performances. The starting point for advanced control structures is the conventional control structure, depicted in figure 1, whose control loops are summarized in Table 1 [3, 4, 6].

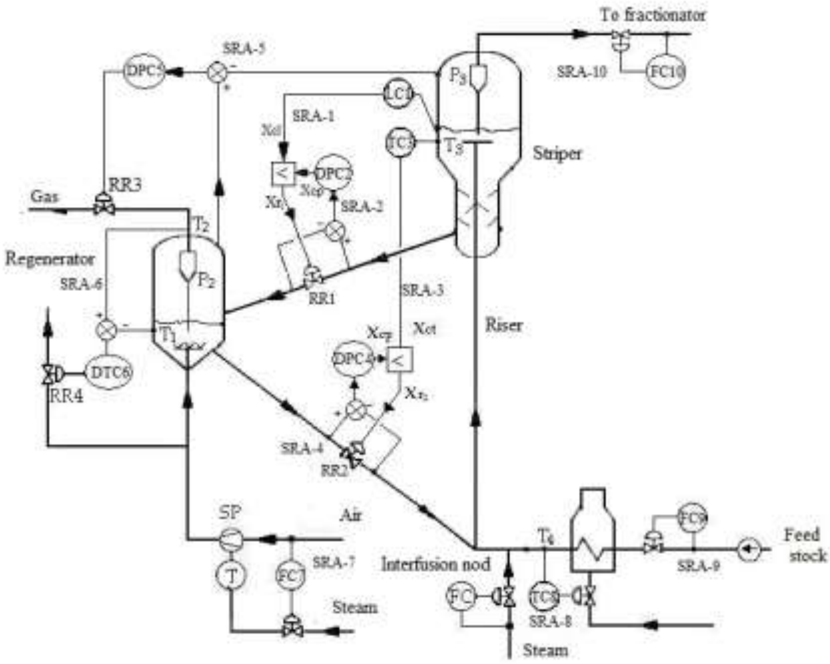

Fig. 1. The conventional control structure.

Table 1. The control loops of the catalytic cracking process.

No. SRA	Control variable	Manipulated variable	Brice requirements
1	The stripper level	The catalyst spent flow	Requirement 1
2	The pressure drop on the valve RR1	The catalyst spent flow	Requirements 1 and 4
3	The stripper temperature	The regenerated catalyst flow	Requirement 2
4	The pressure drop on the valve RR2	The regenerated catalyst flow	Requirement 1
5	The pressure difference between reactor and regenerator	The Gas flow	Requirement 1
6	The temperature difference in the regenerator	The air flow	Requirement 1
7	The air flow for combustion	The steam flow	-
8	The feed stock temperature	The flue flow for the pre-heating oven	Requirement 2
9	The feed stock flow	The feeding flow	Requirement 2
10	The pressure of the main fractionator	Reaction products flow	Requirement 1

The Implementation of the Conventional Control Structure

The conventional control structure for the catalytic cracking process contains ten feedback control loops based on PID algorithm. A typical feedback control loop based on PID algorithm is depicted in figure 2, where one can see the output of the controller u*(t)* as a sum of three components, respectively : proportional, integrative, derivative , which generates outcomes as detailed in papers [2, 5]. The dynamic command of a PID controller is calculated as below:

$$u(t) = u_0(t) + k_p(e(t) + \frac{1}{T_i}\int_0^t e(t)dt + T_d\frac{de}{dt}), \quad (1)$$

where u denotes the current command, u_0 – the initial command, k_p - the gain, T_i - the integration constant, T_d - the derivation constant[4].

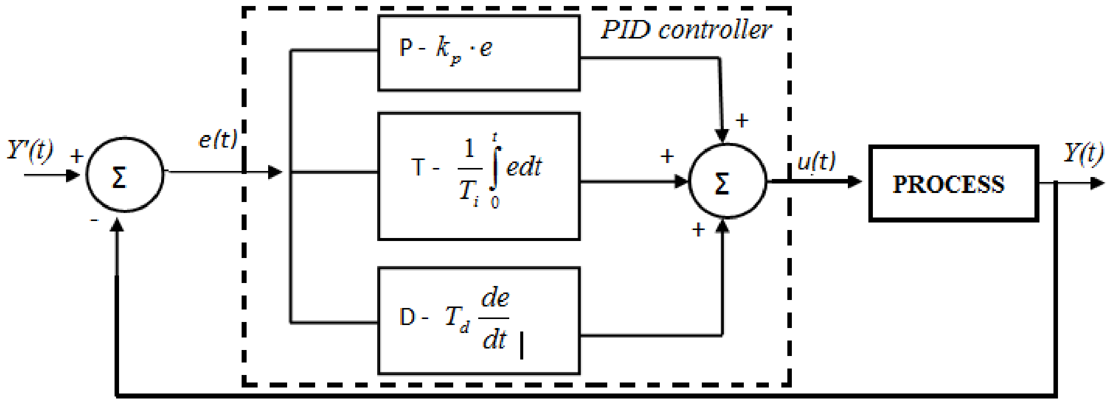

Fig. 2. The feedback control loop based on PID controller.

The constants k_p, T_i, T_d , known as tuning parameters, are directly influencing the performances of the control loop. The identification of the optimal values of these constants is obtained by the tuning controller which may be realized using analytical or empirical methods [3, 4, 5].

In order to analyze the performances of the conventional control structure, the process is considered to be represented by the mathematical model developed in paper [6]. This model has been validated for a middle operating point of an industrial plant characterized by the parameter values presented in table 2.

Table 2. The process parameter values for a middle operating point.

The process parameters	Variable	Value	Units
The feed stock temperature	T_{mp}	195	^0C
The regenerated catalyst temperature	T_{reg1}	709	^0C
The fresh feed flow	Q_{mp}	161750	kg/h
The contact ratio	a	4.59	-
The interfusion node temperature	T_{nod}	573	^0C
The output riser temperature	T_r	528	^0C
The striper inside temperature	T_s	528	^0C
The coke masic fraction on catalyst in striper	C_{cocs2}	0.13	-
The regenerator temperature	T_{reg}	722	^0C
The coke masic fraction on regenerated catalyst	C_{cocs3}	0.77	-

The Simulation Results

In order to test the performances of the conventional control for catalytic cracking process, the simulator was developed in MATLAB - SIMULINK® environment, simulator which allows the testing of the control structure by adjusting the setpoints and disturbances.

The dynamic evolution, presented in figures 3 - 9, highlights the results of the investigations of two main control loops (the stripper temperature system, SRA-3 and the regenerate temperature system, SRA- 6). The tunning parameters analytically obtained are presented in Table 3.

Table 3. Tuning parameters value for PID controllers.

PID controller	K_p	T_i	T_d
SRA-3	0.9	4	0
SRA-6	0.5	5	0

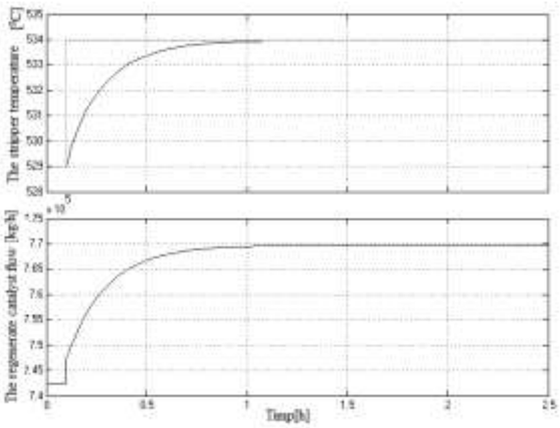

Fig. 3. The dynamic evolution of the stripper temperature when controller set point increase from 529 ^{0}C to 534 ^{0}C.

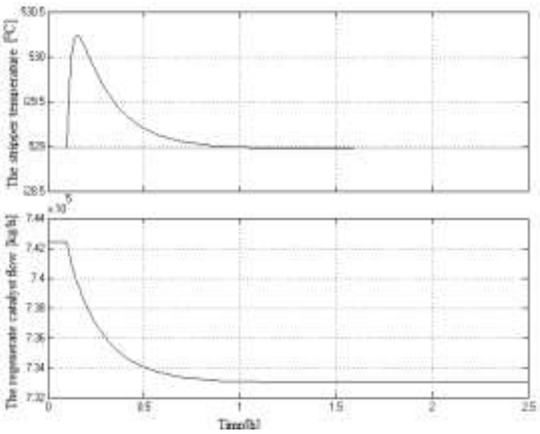

Fig. 4. The dynamic evolution of the stripper temperature when the disturbance feed fresh increase from 195 ^{0}C to 215 ^{0}C.

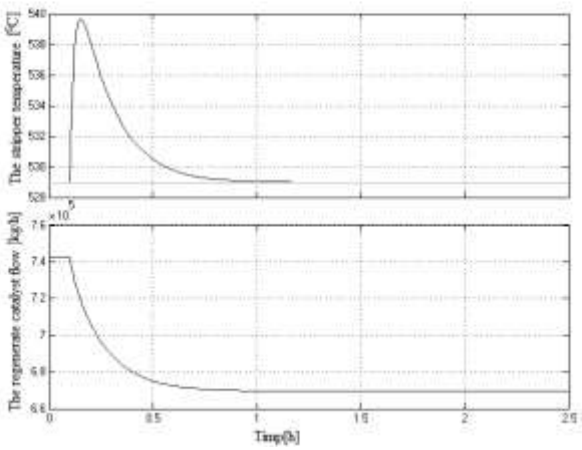

Fig. 5. The dynamic evolution of the stripper temperature when the disturbance catalyst regenerate increase from 709 ^{0}C la 729 ^{0}C.

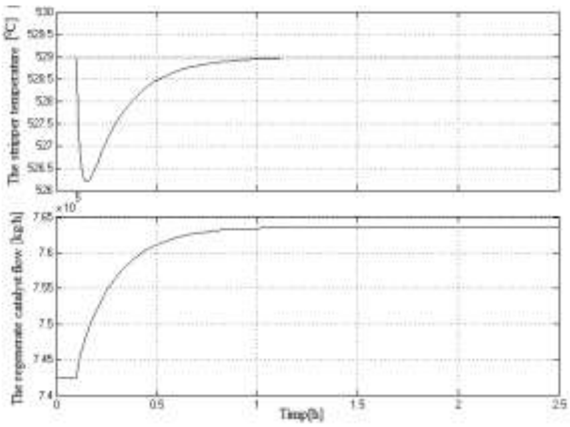

Fig. 6. The dynamic evolution of the stripper temperature when the disturbance fresh feed increase from 161750kg/h la166750 kg/h.

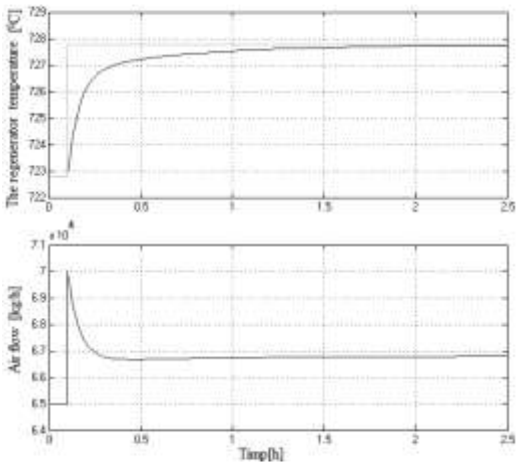

Fig. 7. The dynamic evolution of the regenerator temperature when the controller setpoint increase from 722 ^{0}C to 727 ^{0}C.

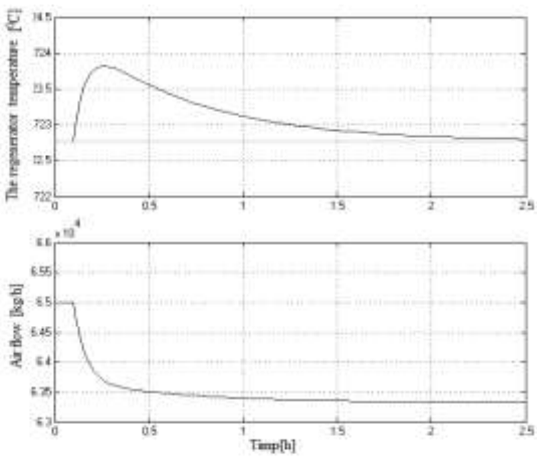

Fig. 8. The dynamic evolution of the regenerator temperature when the spent catalyst increase from 528^{0}C la 534 ^{0}C.

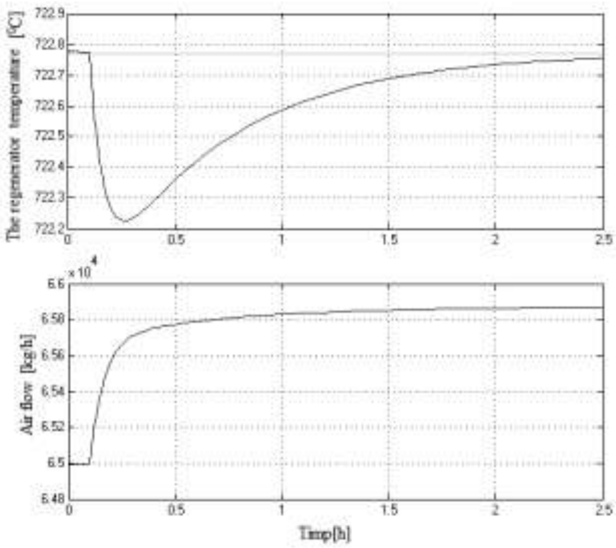

Fig. 9. The dynamic evolution of the regenerator temperature when the catalyst flow increase from 742432kg/h to 75432 kg/h.

Conclusion

This paper presents the research of the author regarding the simulation of the conventional control structure for the catalytic cracking process.

The structure contains ten feedback control loops based on PID algorithm. For testing the conventional control structure, a simulator in the in the MATLAB –SIMULINK® environment was elaborated. The control performance is benchmarked on the process simulator with several test types.

The tests were designed to evidence the control structure behavior for typical situations during an operating process.

Acknowledgements

The work has been funded by the Sectorial Operational Programme for Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398.

References

1. Brice, J.C., Krikorian, K.V. – Improve FCC Profitability with Better Control, *Hydrocarbon Processing*, p. 83, 1983.
2. Bucur, G., Popescu, C. – *Automatizări industrial, Indrumar de laborator*, Editura UPG Ploiesti, 2006.
3. Cîrtoaje, V. – *Teoria sistemelor automate, Analiza elementară în domeniul timpului*, Editura Universităţii din Ploiesti, 2004.
4. Marinoiu, V., Paraschiv, N. – *Automatizarea proceselor*, Vol.II, Editura Tehnica, Bucuresti, 1992.
5. Mihalache, S. – *Elemente de ingineria sistemelor*, MatrixROM, 2008.
6. Popa, C. – *Reglarea ierarhică a procesului de cracare catalitică*, MatrixROM, 2013.

Simularea structurii convenţionale de reglare a procesului de cracare catalitică

Rezumat

Această lucrare prezintă cercetările şi rezultatele obţinute de autoare cu privire la reglarea convenţională a procesului de cracare catalitică. În prima parte a lucrării este descris procesul de cracare catalitică şi structura de reglare convenţională. Structura de reglare este testată şi evaluată pe un simulator in MATLAB. Rezultatele simulărilor pot fi utilizate ca referintă pentru implementarea unei structuri avansate de reglare pentru o instalatie de de cracare catalitică.