Application of UniSim Design to study the static and dynamic properties of a chemical technology equipment

Erforschung der statischen und dynamischen Eigenschaften einer chemischen Technologieausrüstung unter Anwendung von UniSim Design

Stefan Kiranov

Department of power engineering and automation, College of energetics and electronics at Technical university - Sofia, Sofia, Bulgaria, skiranov@tu-sofia.bg

Abstract — The static and dynamic simulation of a crude oil distillation column was presented. The aim of this work is to study the properties of this object from control point of view. Investigations of the column model behavior were carried out to obtain the transitional processes and the static characteristics. The specialized software package *UniSim Design* was applied. The achieved results of simulation are presented and discussed.

Zusammenfassung - Die statische und dynamische Simulation einer Rohöldestillation ist presentiert. Das Ziel der Arbeit besteht darin, die Eigenschaften dieses Objektes, unter Steuerungsgesichtspunkt zu erforschen. Das Rohuntersuchungsmodell wurde erforscht um die Übergangsprozesse und die statische Eigenschaften des Objektes zu erhalten. Die spezialisierte Software *UniSim Design* wurde implementiert für die Simulation. Die erreichten Simulationsergebnisse sind presentiert und diskutiert.

I. Introduction

The development of the necessary automatic control systems for technological equipment is based on the knowledge of the dynamic and static properties of the controlled technological objects. For the purpose of analyzing the technological objects (TO), their description is done by mathematical models of the processes in them [5].

Modern software tools for computer modeling allow the compilation of sufficiently precise models. Some of the best known products in this area are Matlab of Mathworks, AspenTech of Aspen [6], [7], UniSim Design of Honeywell, Wolfram Mathematica. By them, the TO study is performed in a simulation mode instead of experimenting with the actual objects.

In the present work are offered results of modeling the statics and dynamics of oil atmospheric distillation column. The study is conducted with respect to its main input and output technological variables.

It is used Honeywell's specialized software package for modeling and simulation UniSim Design [2], [3]. It allows the simulation of different chemical technology units and installations in both static and dynamic mode.

II. Simulation of the dynamics of the object

The technological scheme (Fig. 1) of the surveyed object consists of one main column for atmospheric distillation of oil with 29 trays, condenser in its upper part and three small distillation columns (strippers). The input streams are petroleum (crude oil) and working steam, and the output streams include non-condensed gases, gasoline, kerosene, diesel, atmospheric gas oil (AGO) and water.

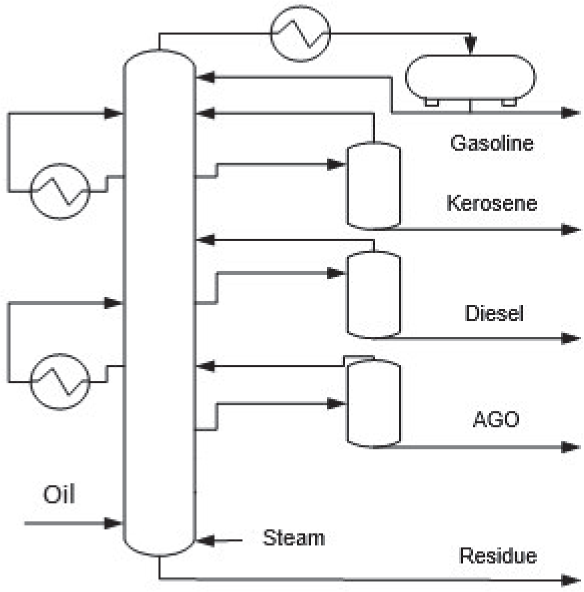

Fig. 1. Technological scheme of distillation column.

The block diagram of the object under consideration as part of the entire installation is shown in Fig. 2.

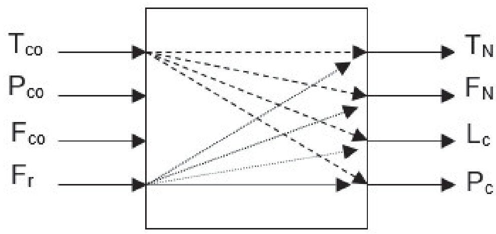

Fig. 2. Block diagram of the object.

The inputs covered by the study are: the temperature of the column feed T_{co}, its molar flow rate F_{co}, the reflux rate at the top of the column F_r and the pressure of the input raw material P_{co}. The outputs are: the temperature of the distillate (gasoline) T_N, the molar flow rate of the distillate F_N, the level of the condenser L_c and the pressure of the uncondensed gases in the condenser at the top of the column P_c.

Two groups of studies were performed in simulation mode.

The first group is studied the reaction of the output variables molar flow rate F_n and the temperature T_n of the gasoline and the level L_c in the condenser after applying a unit step change of the incoming oil temperature T_{co} at a constant value of the reflux rate F_r.

The other group is related to the reaction of the indicated output variables after a unit step change of the flow rate F_r at a constant temperature T_{co}. In both cases, the flow rate F_{co} and the pressure P_{co} are fixed values.

The first group of studies is carried out by a unit step change of T_{co} inlet temperature of 5 °C at a constant value of the reflux F_r. The investigations were conducted in the direction of increasing temperature in the range 322.6 - 347.6 °C. In the simulation, five transitional processes were captured for each of the channels considered in that range and were obtained six points of their static characteristics.

The resulting transitional processes are shown in Fig. 3, Fig. 4 and Fig. 5.

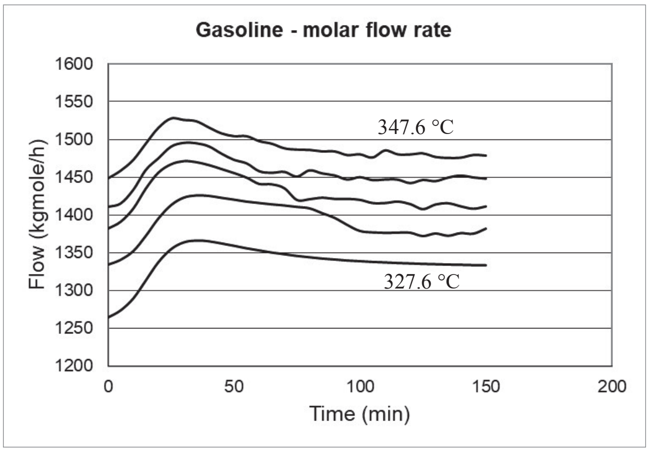

Fig. 3. Transitional processes at the channel inlet temperature – gasoline molar flow.

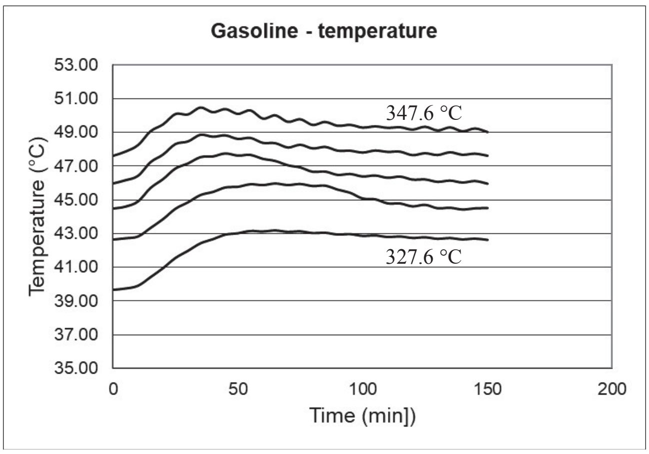

Fig. 4. Transitional processes at the channel inlet temperature – gasoline temperature.

The static characteristics of the channels under consideration are shown in Fig. 6, Fig. 7 and Fig. 8.

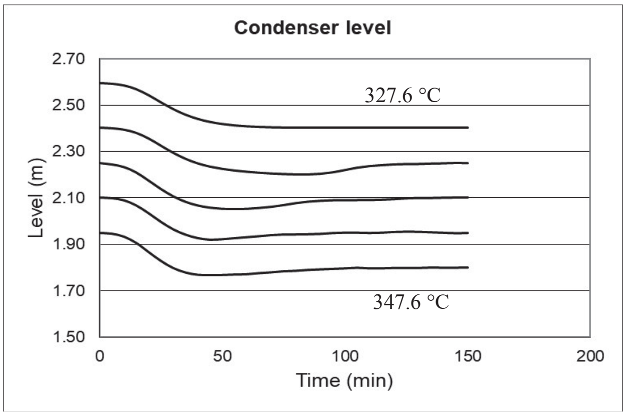

Fig. 5. Transitional processes at the channel inlet temperature – condenser level.

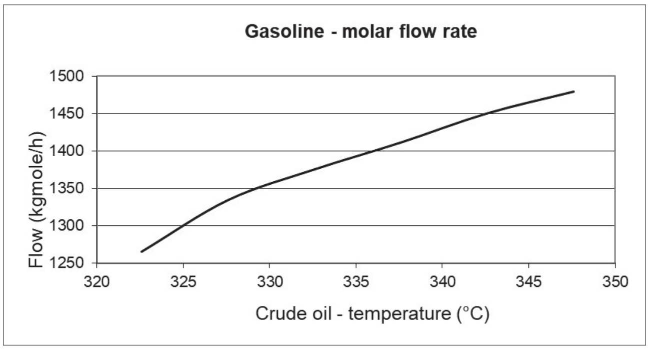

Fig. 6. Static characteristic at the channel crude oil temperature – gasoline molar flow.

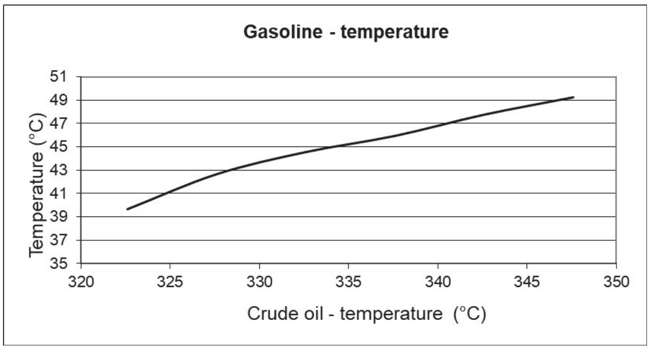

Fig. 7. Static characteristic at the channel crude oil temperature – gasoline temperature.

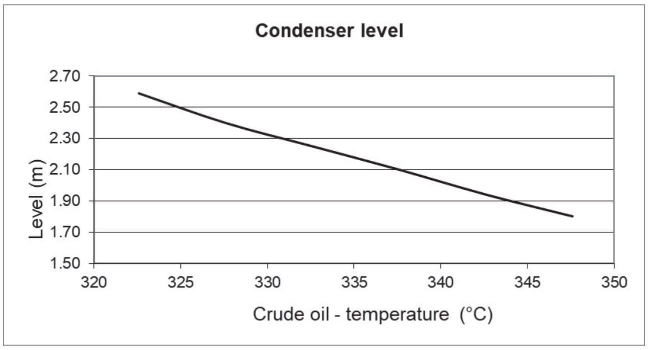

Fig. 8. Static characteristic at the channel crude oil temperature – condenser level.

In the second group of studies, a unit step change of reflux F_r of 100 kgmole / h in the direction of its increase in the range 900 - 1500 kgmole / h is applied. Six transitional processes were captured for each channel and were obtained seven points of their static characteristics. The transient characteristics are given in Fig. 9, Fig. 10 and Fig. 11.

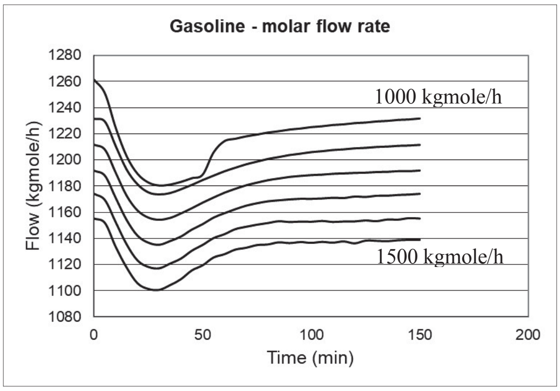

Fig. 9. Transitional processes at the channel reflux flow rate – gasoline flow rate.

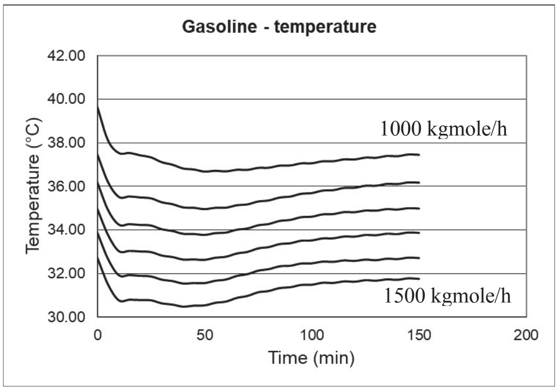

Fig. 10. Transitional processes at the channel reflux flow rate – gasoline temperature.

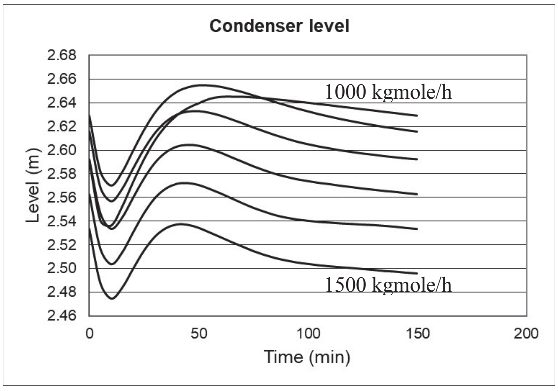

Fig. 11. Transitional processes at the channel reflux flow rate – condenser level.

The static characteristics are presented in Fig. 12, Fig. 13 and Fig. 14.

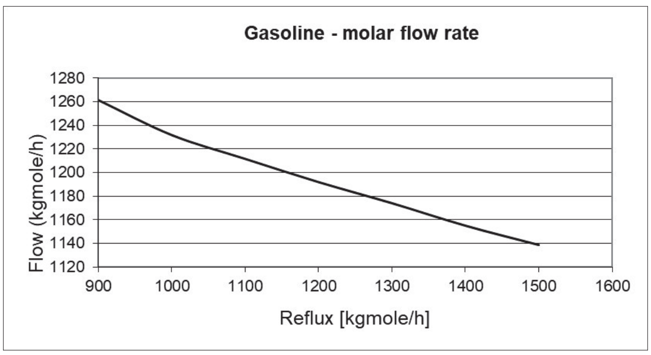

Fig. 12. Static characteristic at the channel reflux flow rate – gasoline flow rate.

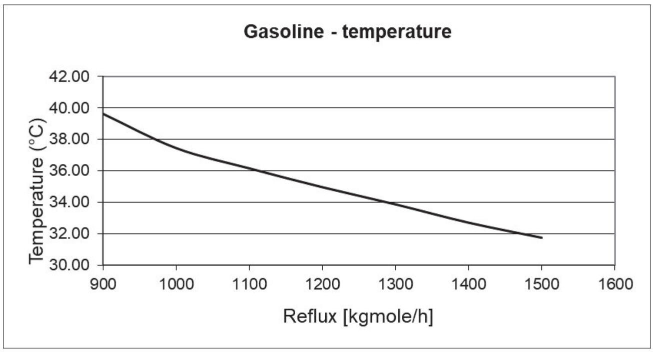

Fig. 13. Static characteristic at the channel reflux flow rate – gasoline temperature.

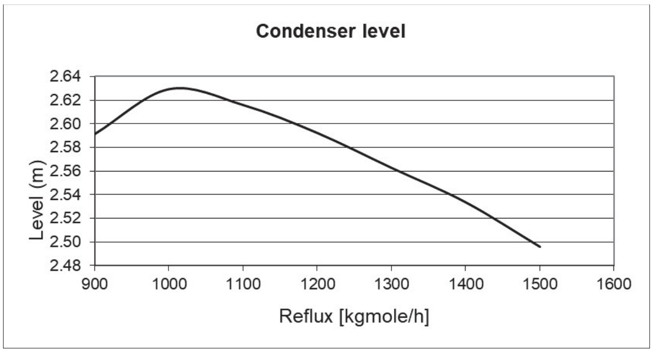

Fig. 14. Static characteristic at the channel reflux flow rate – condenser level.

III. Conclusion

The simulations performed with the model of real column show that the input variables - feedstock temperature and distillate flow rate in the recirculation loop (reflux) significantly affect all output variables - quantity and temperature of the distilled gasoline and the level of the distillate in the condenser.

Analysis of the data from the simulations gives grounds for the column to be considered as an inertial and non-linear object with significant interactions between its channels.

The dynamics of the object on the studied channels shows that the transition time is high (100-150 min).

The resulting static characteristics can be considered as linear in the small range around the work point. The graphs of these characteristics shown above expose that there is a static non-linearity in a wider operating range.

The study presents that the temperature of the inlet stream and the reflux flow significantly affect the amount of distillate removed. From the control point of view, the input temperature can be considered as a disturbing effect, and the flow in the recirculation circuit can be used for control purposes as a controlling action.

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