The modification of temperature control at each stage of V-star continuous flow reactor

Ibragim B Musaevich¹, Rumyantsev E Vladimirovich², Bamatov D Musaevich³ and Bamatov D Musaevich⁴

¹FGBOU VO "Chechen State University", 32, Sheripova str., Grozny, 364024, Russia
²Ivanovo State Polytechnic University, 21, Sheremetjevsky ave., Ivanovo, Russia
³University of Surrey. Stag Hill, Guildford, GU 2 7XH, United Kingdom.
⁴FGBOU VO "Chechen State University", 32, Sheripova str., Grozny, 364024, Russia

E-mail: ibragim-1991@mail.ru naturer@yandex.ru, bamatov-1993@mail.ru, bamatov-dzhamalay@mail.ru

Abstract. This research paper is about the modification of continuous flow reactor (V-star), with a temperature control by using huber (Unistat 705) with an oil flow for each stage on the chemical aggregate. Besides, one of the most important role of this project is to illustrate the change of chemical reaction from batch into continuous flow due to better controlling the process at each stage of the reactor. Besides, the modification follows by installing the thermo-sensors at each stage of V-star and their signal transfer to the control panel. Finally, in this article, the results of the reactor tests are illustrated, to demonstrate the possibilities of modified V-star.

1. Introduction

Chemical reactors are used to develop the final product nevertheless of the aggregation state of the raw materials while observing the requirements of the highest process effectiveness [3]. There are main requirements for the new modeling reactors that must be noticed [6].

- Increase reactor productivity;
- Ensuring a high yield and improving its quality;
- Reduction of operating costs, primarily due to energy costs;
- Increase of controllability and safety of work;
- Reduce the cost of manufacturing the reactor.

There are many ways to fulfill the above requirements in the development of the new reactor, but the one most related to all necessities is – control the temperature conditions of the modeling chemical aggregate during the mixing process of liquids:

- A significant increase in the reaction rate due to the change temperature to obtain the chemical reaction optimal value. From the temperature dependence it is known fact, that every 10°C increase give an increase in the reaction rate by 2-4 times [4, 5]. Conversely, increasing the temperature is not increasing the rate of the chemical reaction, cause if the energy of the
reaction were to reach at certain point, where the reactants will start to degrade and it will lead to decrease the speed of the reaction, so the temperature for each stage of mixing should be in at convinced range, otherwise the quality of the product may suffer. Thus, the operational control of temperature conditions can significantly increase the productivity of the reactor. This simultaneously leads to into two requirements above, a reduction in the cost of the reactor due to a decrease in its internal volume and a decrease in operating costs (primarily, by increasing the energy efficiency of the reactor);

- Improving the quality of the products. This is achieved by optimizing the temperature regimes at each stage of mixing;
- Increase of controllability and safety of work is provided due to the temperature control system, which minimizes the occurrence of emergency situations.

Besides, the operational control of the temperature at each stages of the reactor, that makes the possibility to use it to obtain the product that requires rapid temperature changes at various stages of mixing process. Thus, the development of the chemical aggregate with a temperature control system is an urgent task, which allows fulfilling the main requirements for the new reactors to be advanced to industry.

1.1 Chemical processes and reactors.
There are many ways of converting the reagents (fluids) into final (internal) product, however, the mixing process of liquids proceeds in the chemical reactor, and usually the idea of using an aggregate is to obtain emulsions, solutions and suspensions. Within mixing, a uniform distribution of the phases or components is achieving in the entire volume and their close interaction as well. Mixing is commonly used in the production of synthetic acids, crude oil, cooling varnishes, paints, oils, additives, greases and etc. Nowadays, there are two main mixing technologies are used for reagents to convert into products – batch tank and continuous flow reactor. When the first technology is used, it is necessary to spend time within loading the components into the tank, mixing them, collecting the formed product and additional cleaning the device for further process work (mixing) [1].

Mixing procedures are characterized by two most important factors, energy consumption and mixing efficiency. Within success of mixing is usually understood due to the quality of the succeeded results of mixing in time. Therefore, this value differs on several factors, determined primarily by the purpose of the process (preparation of the suspension, acceleration of the chemical reaction and etc.) [2]

Continuous flow reactors have a number of advantages: higher productivity, energy efficiency, a narrow range of particle size distribution with excellent reproducibility of processes, the compactness of the reactor, better environmental friendliness of production, better economic performance of the reactor (including lower operating costs). Due to these advantages, potential buyers of reactors prefer aggregates with continuous flow processes possibilities, and further developments in this area are associated with an increase in the efficiency of such as reactors.

2. Methodology and results
The reactor was modeled with a parallel moving platform, on which there are 6 identical tanks, connected to each other with pipes and T-junctions, thus, that makes up the internal volume of the reactor. In each of the containers with a volume of 1 liter, one mixing step is implemented. To obtain information of the temperature conditions at each stage, there were 6 temperature sensors (TS) placed into the tanks (stages). The digital thermal sensors DS18B20 were used as temperature sensors. The involvement locations of the temperature sensors were determined in the T-junction. To control the temperature regimes, each container was “wrapped” with copper tubes in which liquid from huber (figure 1) is circulates. Huber oven was allowing to maintain the temperature of the circulating fluid from minus 75 ° C to plus 250 ° C. High system performance was illustrated by huber (Unistat 705) due to its minimized internal volume.
2.1 An automated control system.
Data for the operator were displayed on a special system control panel (figure 2) with basic requirements for the operation of the developed reactor. To implement this project, a Python-based SDK were used that allows users to freely combine thermo calculations with the others output. This tool allowed to customize standardize, with real-time data-driven decision, which makes to help reduce data processing errors.

The modified reactor (V-star) has the following consumer qualities and parameters:

- Low weight of the reactor, ensuring its mobility - not more than 15 kg
- Reactor dimensions - not more than: 80 cm length, 50 cm height, 50 cm width.
- High productivity - at least 10 liters of finished products per hour with six-stage mixing.
- The number of stages of mixing - 6
- Temperature range of reactions from minus 750°C to plus 2500°C
- Feed rate of reagents from (100 ml per hour - up to 10 liters per hour)
- Mixing speed - from 10 movements to 1000 movements per minute
- Number of temperature sensors (TS) - 6
- High coefficient of mixing of reagents, leading to a high yield. This is achieved by horizontal mixing of the platform and by controlling the temperature at each stage of the chemical process, energy efficiency.

![Figure 1. Huber (Unistat 705) from LabTex with a temperature diapason -75°C to + 250°C.](image)

Taken at the Phys-Chemical Methods of Research of Bio-Chemical Department. Leeds University.
From the above figure (figure 1) two different color numbers can be noticed (green and red) which stated for: Red number – illustrates the temperature inside of huber oven and green number states for the temperature of oil processed to the reactor. The temperature accuracy of the Unistat is 0.1 °C.

V-star was tested by running within oil through all the stages of the reactor, where the TS were recording the temperature data and sending the obtained information to the control panel desk, which illustrated bellow in figure 2.

![Figure 2. Control panel with temperature (° C) readings at different stages of the reactor. Taken at the Phys-Chemical Methods of Research of Bio-Chemical Department. Leeds University.](image)

From the figure above (figure 2), the initial readings of each TS clearly shows that, the process is well controlled through all the stages of the reactor, where the temperature at 1-st stage – 207.6 °C, at 2-nd stage – 29.1 °C, 3-rd stage 207.5 °C, 4-th stage – 207.9 °C, 5-th stage – 207.3 °C and 6-th stage is 0.1 °C. At the last stage (stage 6) the product (oil) was collected at 0.1 °C. By using a peristaltic pump the flow rate of the process was set at 1ml/s.

3. Conclusion
To sum up, the reactor V-star was modified to improve the temperature control at each stage of the reactor and the tests show very promising results. More studies in terms of possibility of the modified reactor are required to change the chemical technology from batch into continuous processes for other chemical processes. Moreover, future study will be based on the heat transfer between pipes from huber and V-star.

Reference
[1] Ibragim M Bamatov, Evgenie V Rumyantsev and Dzhabrail M Bamatov 2019 Development of the chemical reactor V-star for continuous flow reactions *IOP Conference Series: Materials Science and Engineering* **537** 032020
[2] Chernobylskiy I I 1975 *Machines and apparatus for chemical production* (Moscow: Engineering) pp 30-55
[3] Fuad M N M and Hussain M A 2015 Systematic Design of Chemical Reactors with Multiple Stages via Multi-Objective Optimization Approach 12th International Symposium on Process Systems Engineering and 25th European Symposium on Computer Aided Process Engineering 31 May
[4] Zumdahl, Steven S and Zumdahl Susan A 2003 *Chemistry* (Houghton Mifflin Co)
[5] Connors K 1990 *Chemical Kinetics* (VCH Publishers)
[6] Bamatov I 2017 Development of the chemical reactor V-STAR for continuous flow reactions. *Chechen State University Journal 6* (2) 205-7