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Development of the chemical reactor V-star for continuous flow reactions

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Abstract. This article illustrates the new modeled reactor, that allows to change the process of the flow chemical reaction from batch tank to the continuous mode. The stage efficiency form 1 (ideal plug flow, IPF) to 50 stages in a continuous stirrer tank reactor (CSTR) was plotted and illustrated graphically. Moreover, the descriptions and possibilities of the new reactor (V-star) such as: temperature control, numbers of stages, movement-speed of the reactors platform are also shown in this paper work.

1. Introduction

Chemical reactions happen absolutely everywhere, so the process of converting one or more reacting (raw materials) substances into others (product) is considered as a chemical reaction [1]. In other words, after the redistribution of nuclei and electrons, new chemicals are formed. In industry, for chemical transformations, a chemical reactor is required, which can be assigned to a reactor - batch, semi-batch or continuous flow process reaction. [2] is to develop (convert into) the final product regardless of the state of aggregation of the raw materials (components) while observing the requirements of maximum process efficiency [3], [4]. Table 1 shows the qualitative issues to which the chemical reactor should be corresponding. Moreover, most of developing countries in the world experience an increasing demand for electricity to support their economic growth.

Table 1. Qualitative criteria for determining the usefulness of the reactor.

1. Creating a safe and stable reaction mode
2. High energy conversion of reactants
3. The minimum cost of the unit
4. Easy operation and operation of the reactor

In chemical laboratories and in industry, nowadays, it is considered as a big difficulty to transfer the state from a "batch" reaction process to a "continuous" mode, since for the first it is necessary to spend time on loading the initial substances (raw materials), mixing, on the collecting final products and further cleaning of the reactor, however, due to innovatively new-modeled V-star reactor, this problem can be solved in the course of homogeneous reactions, without resorting to the above listed stages [].

The processed studies at AMT – technology (Newcastle) have shown that, the more steps (stages) involved in the process flow, the conversion rate of the raw materials increases.
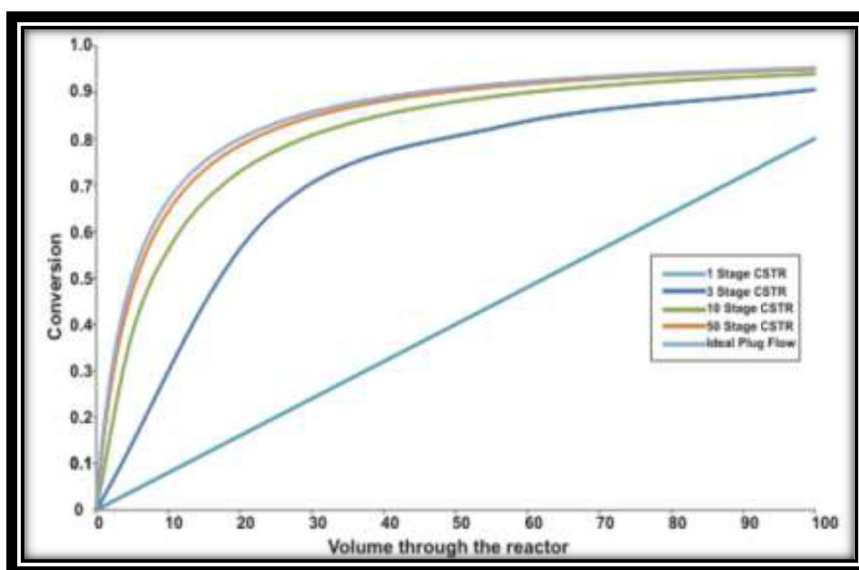

Figure 1. Graphical illustration of effectiveness of the stages in Continuous Stirrer Tank Reactor (CSTR).

The results of AMT - technology (figure 1) shows 5 varieties, where the number of stages are illustrated as: 1 (blue line45 °), 3 (blue line), 10 (green line), 50 (red line) and Ideal plug flow (light blue line). From the results the fact can be estimated that, the more stages, the better conversion of the raw materials, but its must be noticed that, the price of the reactor gets higher within increasing the number of stages of the reactor and it leeds to the cost of the chemical reaction process flow also to increase. Based on the above facts, the smaller number of stages, the more economically beneficial the reactor becomes and the process of converting the reagents (raw materials) into the product also becomes more cost-effective. Therefore, the prime cost of the product is one of the most important issue in chemical factory industry, so it is significant to reduce the cost of the product by using more efficient method but not harming the quality the product.

Nowadays, the chemical factories, where the crystallization process involves, the most of the process flows in a batch tank reactor, where it takes time to load (chemicals), mixing, emptying, cleaning and has a lot of waste (in general), so the idea of the V-star reactor is to transfer the crystallisation process from batch tank to continuous flow mode. The flow in the V-star does not run in the same way as in a plug flow and it is due to having series of mixing stages. However, there are enough mixing stages that can deliver very good mixing which can be as good as in plug flow [6].

2. Results and Discussion
From the laboratory studies curried out at Chechen state university, citing a converting factor and economic beneficiation, it was determined that the V-star will be consisted of 6 stages (6 pipes of the same size with

the same diameter) parallel to the moving platform on the horizontal (left-right). Each stage (pipe) on both sides has interchangeable tips that have 2, 3 or more holes, and this makes the possibility to connect the stages with each other with a pipe, for example, at the end of stage 1, a pipe is attached that goes to the beginning of stage 2, the end of stage 2 to the beginning of stage 3, etc. The sixth stage is the final stage and, accordingly, at this stage where the process of the reaction is completed. Incase of highly exothermic reactions where the heat needs to be removed as quickly as the product is produced, at the 5th and 6th stages heat exchangers were installed to cool (crystallise) the final product. The graph below shows the results of converting possibilities the reactors with stages 1, 6 and 50 against the value (volume) of the modeled V-star reactor (figure 2).
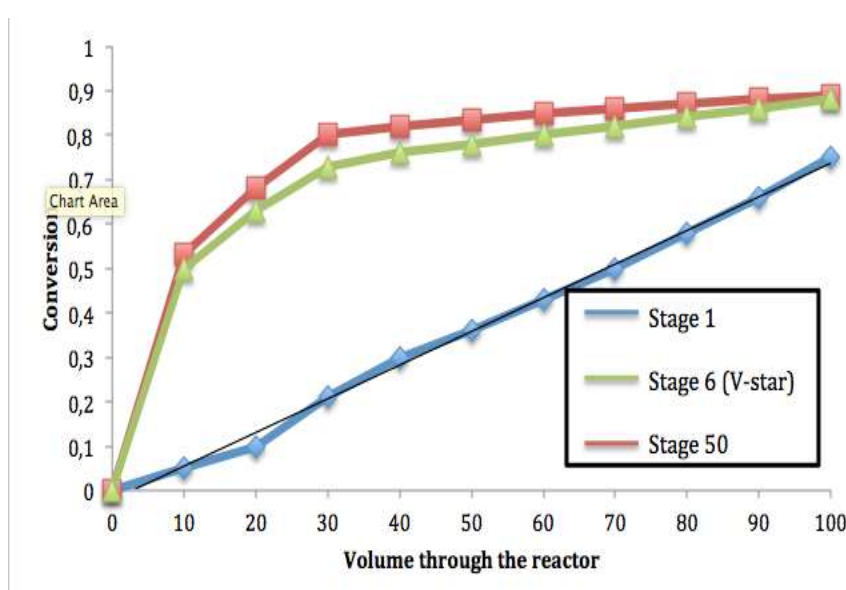

Figure 2. The conversion percentage of the raw materials against the value (volume) through the V-star reactor, with the different number of stages in the chemical process flow.

Based on the data above (figure 2), it should be noted that the 6-stage reactor shows almost the same effect of mixing the reagents, as shows within 50 stages. Therefore, V-star is a more cost-effective continuous flow reactor than decree of 10 or more phased transitions. It is important to note that the 6-stage V-star has a high conversion rate of chemical reagents (raw materials) into the product, which agrees to the criteria given in Table 1 above.

The process of supplying the raw materials to the reactor is carried out using peristaltic pumps, where the number of injection apparatus depends on the amount of the reagents. The starting materials must be in a liquid phase or in dissolved form so that the pumps can continuously pump "reagents" into the V-star and convert them into the final product. From the beginning stage 1 the reagents can be heated up within heat exchangers, where the temperature of the stage (tube) can be increased up to 50 $^\circ$C and at the same time at the final stages, stage 5 and 6 the temperature can be decreased down to 5 $^\circ$C. Therefore, the crystallisation process occurs at the final stages, where the temperature starts to decrease (from stage 5 − 6). Peristaltic pumps have the function of adjusting the rate of supply of reagents to the reactor, which accordingly makes it possible to increase or reduce the rate of chemical reaction. Increasing the feed rate of reagents increases

the rate of chemical reaction, the reverse process (decrease) occurs when the injection of raw materials is slowed down.

The reactor also has the ability to control the speed of horizontal movement of the platform. Increasing the speed of the platform allows speeding up the process of shifting the reactants and thereby speeding up the process of obtaining the final product. However, there are chemical reactions that take place (process) too quickly and therefore, by reducing the speed of horizontal movement of the platform, additional time for conversion (chemical reaction rate) of the initial reactants can be achieved.

V-star does not require a large consumption of electricity, lots of labors, it is very easy to use and set up, therefore, it can be argued that the reactor meets criteria 3 and 4 listed in Table 1.

3. Conclusion

From the above illustrated data, the fact can be noted that, the V-star is a kind of cell model, where at each stage there is a perfect mixture of reactants. Moreover, by having stages it is easy to emergency stop the process flow of the reactants (starting materials or product) at certain stage and all it goes to the safeties. V-star reactor allows to decrease the prime cost of the final product, so the companies can cheaper sell the product or earn much more benefits.

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