

On Study of Application of Micro-reactor in Chemistry and Chemical Field

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Abstract: Serving as a micro-scale chemical reaction system, micro-reactor is characterized by high heat transfer efficiency and mass transfer, strictly controlled reaction time and good safety performance; compared with the traditional mixing reactor, it can effectively shorten reaction time by virtue of these advantages and greatly enhance the chemical reaction conversion rate. However, problems still exist in the process where micro-reactor is used for production in chemistry and chemical field, and relevant researchers are required to optimize and perfect the performance of micro-reactor. This paper analyzes specific application of micro-reactor in chemistry and chemical field.

1. Introduction

Micro-reactor is also known as micro-channel reactor and is a joint name of a series of micro-chemical equipments including micro heat exchangers, microcontrollers and mixers. Study about micro-reactor technology in China is late and is understood and studied by relevant persons domestically in recent years as well as is applied in many fields including chemical engineering, pharmaceutical industry and biochemistry, which exerts a significantly important influence on further development in China's chemistry and chemical field.

2. Study on Characteristics of Micro-reactor

2.1 A Sound Heat Transfer and Mixing Efficiency

The micro-channel feature size within the micro-reactor is generally controlled between tens and hundreds of micrometers, and in the feature channel, the single-phase flow is also relatively low Reynolds numbers, and secondary flow mixing will be formed in its local parts through laminar diffusion affecting mixing. Moreover, the sizes of micro-reactor are in a micro-scale category, so the diffusion time required during its operation is very short and able to further enhance its own mixing process. Moreover, increase is made to some extent in mass transfer and heat transfer driving force in micro-reactor compared with traditional reaction force, so the diffusion area and volume flux in unit volume are further expanded, which is conducive to promoting the chemical reaction process. Moreover, there is an inverse relation between total heat transfer coefficient and channel sizes in micro-reactor, therefore the liquid heat transfer coefficient in micro-reactor can reach 10000WW/(m².K), and it should be one order of magnitudes larger than that of conventional heat exchanger. Moreover, the shrunken sizes are able to give a certain specific surface area to micro-reactor which can reach 10000 ~ 50000 m²/m³^[1]. Relevant study shows that the micro-reactor is able to effectively enhance transmission in the whole chemical reaction process and control mixing ^[2]. It is not easy to precisely control such process in traditional reaction devices, and easy to bring about problems like



local hot spots and uneven concentration distribution. While problems above can be effectively solved by virtue of highly efficient mixing and rapid delivery performance of micro-reactor which can well restrain a number of adverse reactions and thereby further enhance the purity of reaction products.

Moreover, in process of chemical experiments, many methods can be adopted to strengthen mixing results in order to further improve its mixing efficiency; generally speaking, the flow mixing is divided into active mixing and passive mixing, and among them, the former refers forming local secondary flow by virtue of external energy input which includes ultrasonic, acoustic vibration and pumping energy changing cyclically. The latter refers realizing fluid recombination by means of channel design and speeding of its mixing rate, and main models to speed up mixing efficiency are that multiple diaphragms should be set in micro-channel or liquid collision. Passive mixing is widely applied in chemical field due to its simple operation, while multichannel method is not available in active mixing because of its complex devices which is used in applications and bio-analysis field.

2.2 Direct Enlargement and Valid Enlargement Effect

In traditional chemical production, what production model is adopted is small test - middle pilot - large production, but it is difficult to effectively solve problems like flowing, mass transfer and heat transfer in the process of enlargement, and the production benefits in this chemical enterprise will be directly affect. It only needs to increase the number of micro-reactor rather than to adjust sizes of it in the enlargement production process by virtue of excellent performance of the micro-reactor, which shall effectively control flowing, mass transfer and heat transfer in method process. In the optimization process of entire reaction system, the application of micro-reactor only needs to simulate and analyze a single micro-reactor, and well avoid many problems from laboratory scale to pilot scale and then to industrialization production scale in traditional production process, effectively saving production space and operational response, and further enhancing safe production in the process of chemical reaction.

2.3 High Integration

The application of mature micro-processing technology is able to integrate multiple operating units like micro-mixing, micro-reaction, micro-heat transfer and micro-analysis and their matching devices in a reactive chip, and realizes a multi-functional operation of a single reaction chip on this basis as well as achieves monitoring and functional control of the entire micro-response system in order save production costs on the basis of improving chemical reaction rate ^[3]. For example, in the process of chemical production, the mixing and dwell time function can be integrated into the same area to form additional reaction performance. In the process of chemical production, the rational application of micro-analysis system is able to further improve automatic standard in the whole reaction process, and to effectively reduce various food caused by human factors. Moreover, the chemical system is characterized by excellent repeatability, so it greatly attracts parallel tests and equipment usage in daily life. With the introduction of concepts of China's lab-on-a-chip and desktop chemical plant, the micro-chemical system in the laboratory has become an essential platform for developing new products and processes.

2.4 Precise Control of Reaction Time

In micro-reactor, the dwell time of reactant is determined by the length of channel and the velocity of flow, so it can be said that the shorter the length of micro-channel and the faster the flow rate, the shorter the dwell time of reactants ^[4]. Therefore, in the process where micro-reactor is adopted for chemical production, the dwell time can be controlled precisely through controlling the length of micro-channel and fluid rate, so it is applicable for reactions where unstable active intermediates are involved. However, in inhomogeneous system, the flow pattern of fluid will change slightly after grasping the flow rate, which needs us to precisely control dwell time through changing the length of micro-reactor channel. In conventional intermittent servers, various by-products will occur as a result of different addition time of reactants, and the dwell time of reactants will be precisely controlled

through micro-reactor which will effectively protect the production quality of products and is capable of completing some reactions which cannot be completed in the macro process.

2.5 High Security

One main goal in the process of chemical production is to eliminate safety loopholes and to guarantee efficiency of chemical production and feasible operation under this premise. The amount of reactants in the micro-reactor belongs to a trace level, which allows many hazardous reactions to operate with high efficiency and safety, for instance the potential explosion results will be obtained when some highly exothermic reactions and high temperature reactions are conducted in micro-reactors. Micro-reactor is also capable of a good temperature control and cooling, and energy reduction can also ensure safety of the entire system. Even it is in the production of toxic and hazardous substances, micro-reactor is capable of effectively controlling the reaction process, and weakening hazards of relevant liability accidents to some extent.

3. Analysis of Main Application Field of Micro-reactor

3.1 Fine Chemical and Pharmaceutical Industry

In the fine chemical industry and the pharmaceutical industry, over a half reaction may mainly benefit from continuous process of micro-reactor technology. With the continuous development of China's chemical production technology, the micro-reactor is widely applied in fine chemical industry and pharmaceutical industry, and its driving force is development needs of process, product yield, and well safe production.

In the field of fine chemicals, many reactions require highly to temperature, and even some require temperature under several hundred degrees or dozens of degrees, which needs to add materials in order to effectively control the reaction temperature, while it is impossible to complete such operation by other conventional reactors. In the process where micro-reactor is applied for production, we can make use of features of micro-scale to effectively control temperature and the reaction time as well as to perfectly ensure a smoothness of relevant reaction. When new drugs are manufactured in the pharmaceutical industry, it is a time-consuming and costly project, while it is still an issue concerned by relevant medical researchers about how to effectively screen good quality drugs in the process of development. After integrating micro-reactor technology and gene analysis equipment, one shall find that drug screening is supported by internal non-turbulent environment and high sensitivity biometric system integration which are effectively capable of the high-throughput drug screening, so the micro-reactor technology is able to lower costs for chemical screening in the field of drug research and development, and able to reduce the number of trials and actual costs, therefore it is widely applied in the field of drug research and development. Such as in the process where micro-generators are used for fluorinated drugs production, it takes only 9 months to produce 500 kg high-quality products from the laboratory scale, while the yield coefficient ups to 99% in the process where cascade micro-reactor synthesizes fine chemicals and drugs. So it can be said that the continuous flow micro-reactor is able to push fine chemicals and pharmaceutical work toward economic-orientation, high-quality orientation and safe production orientation.

3.2 Biochemistry

Biosynthesis of important compounds has been demonstrated in genetic engineering subjects, because the complexity physiological system and many factors directly limit the product yield and control to reaction conditions, they also show inadaptability of large scale industrial production. The micro-reactor technology, as an alternative, is able to effectively eliminate these shortcomings and suitable for industrial production. Moreover, micro-reactor technology has entered into the field of biocatalysis through combining micro-reactor technology and biocatalysis and it is also a key green project. For example, some common types of enzyme micro-reactors are able to demonstrate excellent performance in homogeneous phase, heterogeneous phase and inhomogeneous systems. With the

continuous development of medical technology in China, the application of enzymes is widely used in diagnosis, and micro-reactor involving the enzyme is applied in analysis and detection field to some extent. Therefore, the use of enzymes in the detection process is relatively small, and is outstanding in protein hydrolysis, and people can make full use of advantages of high specific surface area of micro-reactor to fix enzymes on fixed carriers and make a delicious reactor, which is also an important application of micro-reactors in biology. The screening inhibitor shall be extracted through the way that fixes acylcholinesterase in the micro-reactor while the application of capillary electrophoresis in the immobilized enzyme micro-reactor can be carried out, and it boasts of low costs and short time advantages in handling samples. Moreover, micro-reactor technology provides convenience for analyzing DNA, and is able to amplify DNA fragments for double times for further study in the process of bio-organic synthesis, which means the DNA amplification technology.

4. Development Prospect of Micro-reactor

Compared with traditional reactor technology, micro-reactor technology is outstanding in high mass transfer and heat transfer efficiency, short reaction time, non-enlargement effect, high safety and high degree of integration, and is able to significantly strengthen relevant chemical reaction processes, which is an innovation in chemical industry field in current stages and is able to provide a high efficient and convenient platform for further development in chemistry and chemical field. However, there are still shortcomings in the application process of micro-reactor in current stages, which requires that the key development should be placed in the following aspects during the development process of micro-reactor technology in the future:

① In terms of theories: Currently, many macroscopic theories fail to meet the demand of micro-reactor in a micro-scale, which require us to optimize and perfect the theoretical system in micro-reactor. ② In terms of scope of application: At this stage, although many reactions are made by micro-reactor in chemistry and chemical field, there are still insufficient appropriate development routes for some reactions, requiring us to integrate micro-reactor technology into more extensive reaction systems. ③ In terms of processing technology: In order to further enhance the application results of micro-reactor, the relevant researchers are required to develop advanced micro-reactor manufacturing technology, and especially the micro-channel design and production processes. The manufacturing process must be simple and efficient and the costs must be low in production process. ④ In terms of function: We need to further strengthen the integration level of micro-reactor during its production, to improve ability of implementation, monitoring and control, and to ensure that the reaction process can be in line with the needs of sustainable development.

5. Conclusions

In recent years, with the continuous development of China's chemistry and chemical industry, micro-reactor is widely used, and it further promotes the development of China's chemistry and chemical industry in return. This paper studies and analyzes the application characteristics and fields of micro-reactor, and proposes several suggestions for development in current stage, hoping to provide theoretical support for further development in microbial technology.

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