ACHEMA 2022 – Heat Exchanger

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ACHEMA is an international exhibition for innovation and development in the process industry. Heat exchangers are necessary parts of many process engineering plants. This report intends to highlight the presented novelties in relation to heat exchangers at ACHEMA 2022. The trends and challenges of heat exchangers were explored in discussions with exhibitors and through presentations at the congress. The field of application for heat exchangers broadens as well as their performance increases. Existing designs are enhanced, traditional types of heat exchangers are combined, and software is developed based on both traditional models and artificial intelligence. An overview of relevant innovations and developments in heat exchangers is given.

Keywords: Heat exchanger, Heat transfer, Innovation, Process engineering, Thermal processes

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1 Introduction

ACHEMA (German: Ausstellung für chemische Apparatewesen) is an exhibition for the international process industry [1]. At ACHEMA 2022, 2211 exhibitors from 51 countries showed the latest equipment and innovative processes for the chemical, pharmaceutical, and food industries [2]. In contrast to 3737 exhibitors at ACHEMA 2018 [3], the number of exhibitors decreased by 40 %. In 2022, new topics are addressed concerning digital innovations and green zone [1]. However, the processes are well interconnected, and progress is made in all areas.

Thermal processes were represented by over 250 exhibitors and various topics in the congress. Heat transfer is omnipresent in process engineering plants. Heat exchangers are capable of transferring thermal heat from the hot fluid or solid material to the cold counterpart. Thus, heat exchangers are required for various process engineering plants. Due to the wide range of applications, an improvement in efficiency, a reduction of materials, and/or an expansion of the operation area benefits the entire plant, as well as the process industry and the environment. Therefore, industry and academia strive to improve existing heat exchanger concepts and develop new designs of heat exchangers. In this report, the developments and presented novelties in the field of heat exchangers at ACHEMA 2022 are summarized. Due to the integration of heat exchangers into other topics and the large number of companies and exhibitors, this report does not claim to give a complete review of heat exchangers nor of ACHEMA 2022. However, the subjective impression of novelties and innovations gained from the exhibition and various discussions with exhibitors is outlined.

2 Potentials and Challenges of Heat Exchangers in Process Engineering

Heat exchangers are integral parts of many process engineering plants transferring thermal heat of usually fluid flows. The fluid flows are separated by solid metal walls mostly made of stainless steel. Various applications require different types of heat exchangers. They are mainly characterized by the fluid phase (gas or liquid) with or without phase transition, the type of operation (continuous or discontinuous), the construction (e.g., tube-and-shell, plate, plate-and-shell), manufacturing, and different flows (counter-flow, parallel-flow, cross-flow). Heat exchangers follow the first and second law of thermodynamics. In addition, the kinetics of heat transfer describes the heat transfer rate. The heat transfer rate in heat exchangers is proportional to the heat transmission coefficient, the heat transferring surface area, and the temperature difference of the hot and cold fluid or solid materials, respectively. The heat transmission coefficient is mostly influenced by the medium, the material and geometry of the heat exchanger, and surface conditions. The heat transfer coefficient is subject to permanent improvement. For example, in heat exchangers, the flow in plates or tubes is optimized for a well-defined flow whilst keeping the pressure drop low. In addition, altering, e.g., fouling, is minimized to keep the heat transfer coefficient as

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high as possible. Therefore, the material must resist corrosion with the highest reasonable heat transfer coefficient. Typically, the quantity of heat, the type of fluids, pressure, and the temperature difference are given by the process. Hence, the heat exchange construction, flow type, and the selected material are designed according to the requirements. More information about heat exchangers and respective design insights are found in literature, e.g., VDI Heat Atlas [4].

The life cycle of heat exchangers is optimized lasting typically years or decades. The components alter during the operation and sometimes the process demands are changing. Although heat exchangers are built without moving parts, some issues and pitfalls occurring in practice were presented at ACHEMA 2022 [5]. Briefly, problems are likely to occur if the heat exchangers are operated at partial load, vibrations were not considered for the mechanical design, or the design is done with wrong data [5]. Heat exchangers are working well under the conditions they were designed for as long as the state-of-the-art design is applied [5]. Reuse for different applications or a change in the process conditions, such as mass flow, pressure, or temperature, requires remodeling and possibly a new design [5]. According to the presenter, the design margin should not exceed 20 % [5]. Therefore, only the design of heat exchangers under consideration of all requirements and contribution factors enables a smooth operation of the process and the integrated heat exchanger. Nevertheless, a change in the demands by the process itself or by altering the components requires remodeling of the integrated heat exchangers. Difficulties emerge when designing heat exchangers for non-stationary operations. However, specialized companies enable the design of heat exchangers even for complicated applications.

3 Research and Development

The recovery of process heat reduces the energy demand, improves efficiency, and saves costs. As reported in the congress, companies ponder upgrading their plants with innovative heat exchangers or to recover more process heat with newly integrated heat exchangers. As an alternative to the conventional fluid-to-fluid heat transfer, one fluid can be replaced by a solid body. The solid body is potentially heated with electricity transferring the heat to the cold fluid. In areas with an explosive atmosphere, electric heat exchangers are suited for heat transfer. In addition, heat coming from combustion may be replaced by electricity, especially provided by renewable resources (e.g., sunlight, wind, water). Thereby, resources are conserved, exhaust gas aftertreatment is not necessary, and greenhouse emissions are reduced. Since the first application of heat exchangers, the improvement of existing designs, as well as the development of new types, is ongoing.

The heat exchangers, exhibited at ACHEMA 2022, mostly consisted of stainless steel. However, stainless steel potentially corrodes quickly in oxidative media. Therefore, materials with higher chemical resistance are considered to be installed in corrosive media. Manufacturing and operating heat exchangers made from non-standard materials require expertise in material science and modeling but lead to improved reliability, extended lifetime, and reduced maintenance cost. Corrosive media, such as acids or leaches, especially under high temperatures indicate the utilization of resistant materials. Hence, some exhibitors focus on the development of heat exchangers with innovative materials. The company Graphite Technology Ltd. offers heat exchangers and other components for applications in corrosive fluids. The company states the high corrosion resistance and thermal conductivity of graphite compared to other corrosion-resistant metallics or composites. Especially for processes with oxidative media and high temperatures, the graphite components are impregnated to further increase the resistance and reliability. The products are resistant to corrosion, water and steam hammering, vibrations, and mechanical and thermal shocks. The applications range from agrochemical and heavy chemicals, electrolytic refining, and mining of metals, to fine chemicals and pharmaceuticals.

At ACHEMA 2022 insights in the research area of heat exchangers were presented. Innovative heat transfer equipment and new developments were discussed in sessions. The InnovA4Mix project is a joint project of certain universities (Technical University of Braunschweig (TU Braunschweig), University of Kassel, Technical University of Munich (TUM), and Paderborn University) together with industry partners. This project aims to the development of energy-efficient innovative heat exchangers. In contrast to refrigerants, there are few data for phase transitions of chemicals synthesized and processed in the chemical industry [6]. The TUM investigates the heat transfer characteristics of structured surface tubes for pure substances and binary mixtures [6]. In particular, the outer heat transfer of structured tubes was compared with smooth tubes conducting experiments with pure substances and binary mixtures [6]. In the framework of InnovA4Mix, the TU Braunschweig analyzes the performance of pillow plates in thermosiphon reboilers for mixtures [7]. Thermosiphons do not require pumps but must be designed according to the fluids' thermodynamics and dynamics. The research aims to expand the efficiency as well as the operating range of thermosiphons. The influence of the process parameters, e.g., submergence, temperature, and pressure on the thermosiphon reboilers, was presented [7]. In addition, the modeling approaches and simulation results were explained [7]. In literature, e.g., shown in the VDI Heat Atlas [4], the heat transfer for a phase transition is estimated with correlations for the design of heat exchangers. However, most correlations are derived from measurements of refrigerants and copper surfaces [8]. The heat transfer for pure as well as binary

mixtures of hydrocarbons and alcohols is analyzed during phase transition [8]. The existing correlation is validated. Thereafter, improvements for stainless steel and fluids handled in the process industry might be gained. In the future, an improved understanding of heat transfer possibly enhances the efficiency and the operation range of heat exchangers and thereby plants and processes.

4 Combination of Traditional Types of Heat Exchangers

At ACHEMA 2022, combinations of existing types of heat exchangers were presented. Several companies leveraged the high heat transfer rates in plate packs and overcame drawbacks like limited operation temperature and pressure in plate heat exchangers. The company VAU Thermotech GmbH & Co. KG presented the VAU COMPEX. It is a new product series combining tube bundles, plate, and spiral heat exchangers and is shown in Fig. 1.

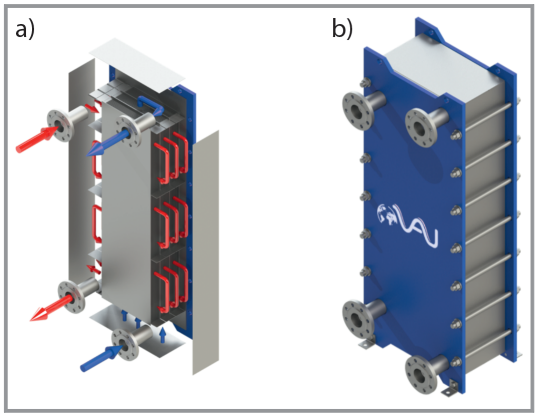

Figure 1. a) Flow scheme and b) image of VAU COMPEX heat exchanger (VAU Thermotech GmbH & Co. KG).

In Fig. 1a, the fluid on the primary side flows from the inlet at the top through the plate pack and exists at the bottom of the heat exchanger. The fluid on the secondary side flows from the bottom to the top through the plate back. An image of a VAU COMPEX heat exchanger is presented in Fig. 1b. According to the company, this design offers high heat transfer rates similar to plate heat exchangers while keeping the pressure drop low and allowing small temperature differences between the fluids. The high heat transfer coefficient leads to a compact apparatus dimension and material savings. Furthermore, the product series is almost maintenance-free due to the absence of gaskets.

The company Vahterus claims to be inventor, pioneer, and market leader of plate-and-shell heat exchangers. Their plate-and-shell heat exchanger is fully welded and without gaskets. According to the company, the high performance of the plate-and-frame design as well as pressure and temperature capabilities of tube-and-shell design are leveraged. In addition, the size and material are decreased as well as the likelihood of fouling is minimized due to higher turbulence compared to tube-and-shell heat exchangers. The operation range is adjusted for temperatures and pressures between 77 K and 873 K and from "vacuum" to 15 MPa, respectively. Vahterus manufactures and operates plate-and-shell heat exchangers for cryogenic applications. Plate-and-shell heat exchangers for liquefied natural gas are one of the company's research and development foci.

Some industrial applications are placing high demands on process safety. Specialized safety heat exchangers are developed for difficult applications such as plants with sensitive measurements, or processes producing and handling reactive fluids. The company FUNKE Wärmetauscher Apparatebau GmbH (Funke) presented a safety shell-and-tube heat exchanger. The operation area of the safety shell-and-tube heat exchanger is in processes whenever separation between the fluids is mandatory. Mixing of the fluids in heat exchangers disrupts the operation and may cause damage to downstream components. Besides that, the fluids would be contaminated, and the heat exchanger must be repaired or replaced. With the safety shell-and-tube heat exchanger, Funke offers a heat exchanger with notification beforehand of a mixing of the two media. In addition to the traditional tube-and-shell design, this heat exchanger consists of a third chamber filled with a special barrier fluid or "vacuum". The SWF-HE safety shell-and-tube heat exchanger is shown in Fig. 2.

In Fig. 2a, the design of the SWF-HE safety shell-and-tube heat exchanger is illustrated. The SWF-HE consists of four connections – the inlets and the corresponding outlets for the cold and hot fluid, respectively. The primary fluid flows through the bundle of tubes while the secondary fluid surrounds the bundle on the shell side. A pressure indicator (Fig. 2a in blue) monitors the pressure in the security chamber. The tube bundle is shown in more detail in Fig. 2b. A double pipe system, illustrated in Fig. 2b, is connected with hydraulic expansion during manufacturing. The structure of the inner pipes can also be seen in Fig. 2b. The free volume, created between the inner and outer tubes, is predefined by the structure of the inner pipes. An early alarm is

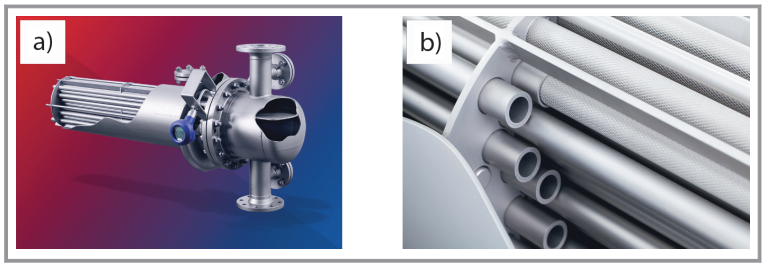

Figure 2. a) SWF-HE safety shell-and-tube heat exchanger and b) detail view of the SWF-HE (FUNKE Wärmetauscher Apparatebau GmbH).

sent to the operator if one of the two fluids penetrates the safety space. The early alarm allows the scheduling of maintenance of the operating heat exchanger. Thus, the SWF-HE increases the processes' safety and reliability.

5 Software Development and Digitalization

The digitalization of the process industry was one main topic at ACHEMA 2022. In addition to traditional modeling and design, digitalization enables an increase in the efficiency of processes and contributes to a decrease in energy consumption. Computational fluid dynamics (CFD) is a state-of-the-art tool for flow optimization in heat exchangers. The process engineering community has recognized the potential for intelligent monitoring software. Intelligent monitoring and predicting software allow all-day and full-time monitoring and optimization. Thereby, the root of observed issues as well as the most important process parameters are possibly determined. Statistic models are able to extract information in case physical-based models are impractical or absent. Thereby, both traditional physical modeling and statistical modeling contribute to process optimization. Software, based on physical and statistical models, analyzes process conditions and potentially detects problems beforehand of the occurrence of performance loss or further issues. In the future, new methods will be developed for the improvement of heat exchangers.

In heat exchangers, heat transfer fluids are required for transferring the heat from the hot to the cold part. The heat transfer fluid is chosen based on the process parameters; however, it alters during process operation. The company Eastman Chemical Company presented, Fluid Genius™, a digital platform for heat transfer optimization. Artificial intelligence (AI) predicts the condition of heat transfer fluids in the corresponding heat exchanger. Therefore, time series of fluid analytics, such as the acid number, the moisture content, and the fraction of low and high boilers, are recorded, monitored, and leveraged for modeling. According to the company, the AI model is capable to analyze as well as predicting the fluids' condition. Thereby, maintenance is predictable, and the lifetime of the fluid is enhanced. A longer lifetime of the fluid as well as a lower fouling rate of the heat exchanger's components saves resources and energy. In addition, a predictable lifetime avoids unscheduled shutdowns and thereby increases the reliability of the plant.

In addition, software is developed for intelligent condition monitoring and predictive analytics by the company Tranter. A pilot program has already disclosed the potential of deploying software in dry mill ethanol plants. The basis for data analysis and inferences are sufficient measurements in type (e.g., mass flow, pressure, temperature) and frequency. The minimum frequency of sampling events is twice the maximum frequency of the original event according to the Nyquist-Shannon theorem. Thus, events with high frequency are only detected with a sufficient sampling rate. Short-time external forces, such as hot and humid weather can be captured with Tranter's software. The analysis and prediction of patterns give insights into the heat exchangers and the process behavior. In particular, key thermodynamic parameters and Key Performance Indicators (KPIs) are inferenced to the future. For example, the prediction of the amount of heat, the heat transfer coefficient, and the pressure drop is of fundamental interest.

Besides software novelties based on AI models, traditional design software is a key subject to further development. The company VAU Thermotech GmbH & Co. KG. presented a design software for heat exchangers. The VX Thermo Optimizer (VXTO) for the design of brazed plate heat exchangers for VM- and Exel-Series, is expanded to model hybrid fully welded plate heat exchangers. The software calculates the requirements for the heat exchanger based on the process information, e.g., properties of the fluids, mass flows, and temperature, and recommends suitable types and design sizes of heat exchangers.

6 Conclusion

Research and development are fundamental for future innovations. The process industry is invested in innovations not only in the framework of heat exchangers. At ACHEMA 2022, the interconnection between the specialized companies could be experienced. The presented novelties and developments showed the potential of hardware and software progress. The operation range of heat exchangers is increased by leveraging different types of heat exchangers, new designs for safety heat exchangers are on offer as well as more durable materials in heat exchangers are developed and integrated. Besides the novelties, traditional types of heat exchangers are optimized to increase efficiency while reducing the pressure drop, the cost of maintenance, and the amount of material. Additional software for heat exchangers helps the customer in selecting a suitable type of heat exchanger and its design. Progress in modeling enhances the performance of entire plants as well as integrated parts, e.g., heat exchangers. Specialized companies do not only develop and manufacture heat exchangers but also deploy and offer operational services. Heat exchangers are integrated into almost every process. Therefore, the performance of heat exchangers will remain subject to improvement in the process industry.

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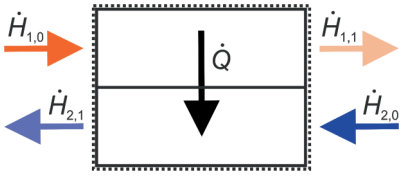

Essay: This ACHEMA report reviews selected novelties and innovations in the area of heat exchangers. The performance of various types of heat exchangers is improved. The progress in corrosion-resistant components, the combinations of traditional heat exchanger designs, and the latest software are highlighted.

