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Current Opinion in Chemical Engineering

Review

Recent developments of high-gravity (reactive) distillation in rotating packed beds

Isabel Pazmiño-Mayorga[1], Qing Li[2] and Anton A Kiss[2]

Gravitation dictates the allowable flow phases and the achievable mass transfer rates in classic distillation columns, which are tall for that exact reason. High-gravity (HiGee) devices use a high centrifugal field to increase the interfacial area through high-speed rotating packing, resulting in a large enhancement of gas–liquid mass transfer and thus smaller equipment volumes. HiGee is an effective process intensification approach to enhance both reaction and separation efficiency. Combining reaction and distillation in a HiGee equipment (R-HiGee) is a topic that attracts significant attention. This paper summarises recent developments in HiGee (reactive) distillation technologies, including process synthesis and design, modelling and analysis of rotating packed bed systems, and equipment design. It also highlights future directions for developments in order to facilitate the systematic evaluation and application of high-gravity (reactive) distillation technologies.

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Introduction

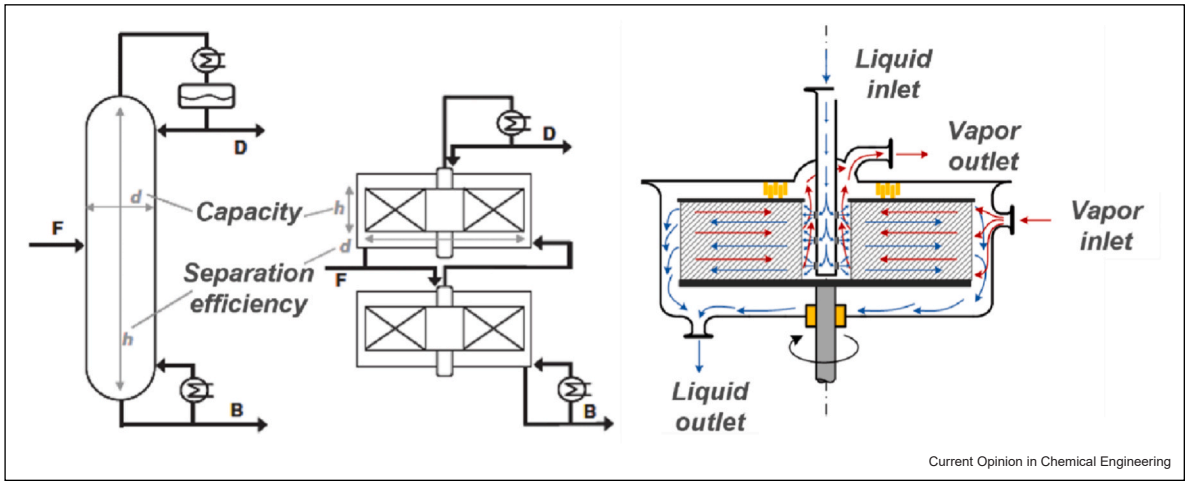
The application of high gravity fields to intensify transport phenomena has been investigated for over a century [24]. Particularly, high gravity equipment for distillation and reactions enhances gas–liquid mass transfer rates and catalyst wetting leading to reducing dramatically the equipment size compared to conventional reactive distillation columns [2]. HiGee technology applies a high centrifugal field using a specially shaped rotating device, consisting of a disk with mounted internals and an eye in the centre, to promote gas–liquid contacting. The high gravity field (100–1000 g) shifts the flooding limit and allows the use of dense packing materials with high interfacial area. For rotating packed beds (RPBs), height equivalent to a theoretical plate (HETP) values as low as 2–8 cm were reported [2]. For rotating zigzag beds (RZB), which are the HiGee equivalent of tray columns, a volume reduction factor of 4–7 is claimed for specific distillation processes compared to conventional columns. Figure 1 shows an analogy between conventional and HiGee distillation and a schematic of an RPB. The countercurrent flow in case of HiGee distillation is horizontal, meaning that the capacity depends on the height of the rotor, while the separation efficiency is given by the diameter of the rotor. This setup is used in a complete distillation process, which requires two RPBs for stripping and rectification.

Technology development, particularly for intensified processes, needs advancing methods, equipment and materials simultaneously [26]. Process synthesis methods are needed to identify potential applications during flow-sheeting, and robust models and simulation tools adequate for a variety of chemical systems (reactive and nonreactive) are required to support process design to identify operating conditions and equipment dimensions. Conversely, hardware design and materials development that can withstand constant rotation and potential wearing of moving parts are also essential to enable the realisation of HiGee devices. Various rotating beds can be used, such as RPB with Blade Packing, Rotating Split Packing Bed, Rotating Zigzag Bed (RZB), Helical Rotating Bed, Multistage Spraying Rotating Bed, Waveform Disks and Torsional-Couette-Flow HiGee. This paper focuses on the latest progress in RPBs, covering process synthesis, design, modelling and advances in equipment design, including packing and rotor, liquid distributors and nozzles.

Synthesis and design of high-gravity (reactive) distillation

Due to the complex interactions between hardware, operating conditions and simultaneous phenomena, generic widely applicable models are out of reach [9],

Figure 1



Analogy between conventional and HiGee distillation [2] and schematic of a rotating packed bed [11].

which hinders the integration of RPBs into frameworks for process synthesis. Yet, HiGee equipment provides significant enhancement of mass transfer and needs to be included in synthesis frameworks, particularly for applications where modularisation is required [28]. According to Neumann et al. [16], the industrial production of hypochlorous acid via reactive high-gravity stripping has reached a mature technology readiness level. Nevertheless, no systematic design procedures exist to expand the application to other industrial systems. Reactive high-gravity stripping was also studied for the regeneration of spent caustic from liquefied petroleum gas sweetening in refineries. To guide the design, a laboratory-scale setup was built to deliver sensitivity analysis within a series of parameters, such as rotational speed, gas and liquid flow rates, reaction temperature, sodium hydroxide and sulphur concentration [40]. Process design via phenomena building blocks, using a superstructure-based approach and hybrid optimisation, seeks to generate feasible flowsheet variants, in which the RPB, an intensified equipment, is considered for vapour–liquid contacting [25]. Notably, rotational speed in RPBs offers an additional degree of freedom [15], which could be optimised to maximise the separation efficiency.

Pazmiño-Mayorga et al. [18] defined the temperature difference between the 'light and heavy representative components' as a characteristic term of the chemical system, which is evaluated in an operating window to screen the potential application of high-gravity reactive distillation. Following a heuristic approach, Pazmiño-Mayorga et al. [19] systematised key characteristics relevant for reactive HiGee distillation. For example, systems with mass transfer limitations and relatively fast kinetics are potential candidates for industrial implementation of reactive HiGee distillation. The apparent heat transfer limitations of RPBs, as noted by van der Schaaf and Schouten [29] and Rao [24], are well addressed in the methodology by evaluating the heat of the reaction. Although the short residence time is often seen as a drawback, it can be advantageous for systems with series reactions by providing favourable conditions to avoid by-products.

Modelling and analysis of rotating packed bed high-gravity (reactive) distillation systems

Modelling HiGee (reactive) distillation in RPBs is crucial for analysing high-gravity systems due to the lack of built-in HiGee modules in process simulation software. Nevertheless, there are only a small number of models describing mass transfer in HiGee gas–liquid contacting processes, and this number is even lower when it comes to distillation and solid-catalysed reactions.

Veeramuni et al. [30] developed a mathematical model applied to solid-catalysed reactive HiGee stripping tested on esterification reactions, deriving dimensionless governing parameters and solved in MATLAB. A rate-based approach was carried out later on by Hilpert et al. [7] to obtain correlations for gas-side volumetric mass transfer coefficient for distillation of binary and ternary mixtures, validated with data from distillation experiments at total reflux. The advantages of a rate-based model over an equilibrium model include accounting for equipment geometry and operating parameters linked to separation performance. However, this model is limited to separation tasks and does not consider reactions. Extending models of RPB to account for reactive distillation systems can be done by adding a reaction term to the component material balances and introducing

effectiveness factors when calculating the actual reaction rate if a solid catalyst is used [2].

The correlations developed by Hilpert et al. [7] account for mass transfer within the rotor although the experimental set up includes a test to evaluate the casing. At high rotational speeds and low liquid flow rates, an empty rotor and a packed rotor behave similarly. These results agree with Lukin et al. [15], who found that the absorption efficiency of an aroma compound occured primarily due to the casing because of a severe cavity zone effect. The contribution of packing was marginal, particularly at small scales. As a result, the contribution of the casing will decrease, while that of the packing will increase when scaling up.

Although a concept to evaluate mass transfer performance considering the additional degrees of freedom associated with rotating equipment (e.g. rotational speed, rotor size, packing type) is yet to be developed, the HETP concept, borrowed from conventional distillation, is used to represent the radial distance of the unit, which is typically in the order of a few centimetres [27]. Improving the vapour-side mass transfer is particularly relevant for reducing the HETP even further. This reduction will allow the use of fewer rotors, resulting in more compact units.

Wang et al. [31] recently developed an improved mass transfer model for distillation in an RPB using a pilot-scale concentric ring rotating bed. For a total reflux operation, the results showed that more than 70% of the total mass transfer resistance occurs on the gas side. Additionally, Loll et al. [14] found that mass transfer occurs in the packing, the eye, the rotor and the casing. The authors proposed an updated expression to calculate the HETP, including contributions of the casing and the packing. Compared to the literature on distillation columns, a reduction of two- to five-fold HETP can be achieved [23].

Design enabled by computational fluid dynamics

Computational fluid dynamics (CFD) is a numerical method for simulating fluid flow to predict flow behaviour qualitatively and quantitatively, which is particularly relevant for RPB as traditional measurements are not possible within the rotating internals. The analysis can also be extended to include heat and mass transfer. CFD allows evaluation of the efficiency of novel designs for internals to inform prototyping — enabled with additive manufacturing — and subsequent experimental tests. Zawadzki et al. [37] provide a detailed description of the models available for multiphase flow, tools and guidelines for RPB simulations.

Examples of the use of CFD simulations include the work of Wu et al. [35], where observations performed with a high-speed camera were complemented with CFD simulations to understand the flow inside packing rings with a multiliquid-inlet RPB (MLI-RPB). Analysing hydrodynamic performance, Bai et al. [1] evaluated a new spherical rotor structure and compared it to a conventional rotor by evaluating the motion path of the liquid and contours of kinetic energy, pressure and liquid distribution in the packing.

Wojtasik-Malinowska et al. [34] presented a 3D numerical CFD model accounting for the effect of turbulence using two types of Reynolds Averaged Navier-Stokes equations: k-ε model and RNG k-ε fluid model. The simulation outcomes were consistent with the experimental results for the entire range of rotational speeds, while errors between the experimental and simulation results increased at high gas flow rates. These models were used for predicting dry pressure drop in RPBs for a CO_2 absorption process, where increasing the gas flow rate and rotational speed promoted an increase in the dry pressure drop.

Another model is based on 3D Eulerian porous medium, including interfacial, drag and dispersion forces, to study liquid dispersion inside the packing [41]. Traditional models using a volume of fluid method are computationally expensive, and the 3D Eulerian porous medium proved to be faster and accurate, which is particularly relevant for scale up and optimisation efforts. In an earlier study, Zhang et al. [42] evaluated the effect of multiple nozzles and nozzle width on liquid holdup and liquid distribution using 2D CFD simulations and proposed a liquid maldistribution index.

Equipment design for high-gravity distillation processes

The design and construction of HiGee (reactive) distillation equipment are different from those of conventional devices. The centripetal forces driven by high gravity increase the turbulence in the fluids, which may cause wear and attrition to the packing and the catalysts. Also, continuous rotation requires specialised rotors, liquid distributors and seals to ensure the reliability and availability of the equipment, preventing unnecessary downtime. Therefore, the design of HiGee equipment hardware is particularly important for advancing the technology.

Packing

Mass transfer intensification in high-gravity-driven devices is owed predominantly to the formation of thin liquid films. This is achieved through the design of packing that simultaneously provides large surface area, low pressure drop and efficient liquid distribution [15]. Typical packings used in RPBs include wire or knit meshes and foams.

With the advances in additive manufacturing, and the relatively small parts required in an RPB, the use of 3D printing has enabled detailed modelling of structured packing that can be manufactured rapidly and subsequently tested [3].

Table 1 summarises recent developments for packing enabled by additive manufacturing and discussed below. Qammar et al. [23] presented an experimental procedure to evaluate different RPB packings, including a novel zigzag packing using additive manufacturing.

Apart from the prospects of rapid manufacturing and flexibility in the design of internals, Wen et al. [33] took advantage of additive manufacturing via selective laser sintering to produce a wire mesh packing featuring a controllable cross-sectional area. The cross-sectional area along the radius was maintained constant by varying the fibre diameter and the opening area of one cell between fibres. As a result, a higher specific surface area potentially enlarges the gas–liquid interface area, and a lower porosity results in more momentum to liquid, intensifying the effect of the centrifugal force. This work also provides correlations to predict the gas–liquid effective interfacial area and the liquid-side volumetric mass transfer coefficient suited for 3D-printed plain-woven wire mesh packing. An Archimedean spiral packing, characterised by constant spacing between each turn of the spiral and therefore a constant cross-sectional area throughout the packing, was tested for an aroma compound, a type of fine chemical produced via a bioprocess. This packing also aims to avoid liquid maldistribution and changes in the phase load along the radius [15].

Wen et al. [32] studied the effect fibre cross-sectional shapes that can impact the liquid flow behaviour. Combinations of vertical and horizontal fibres with circular, elliptical, and quadrangular cross-sectional shapes were manufactured using digital light processing 3D printing. It was found that rounded fibres favoured flow around the fibre, while sharp edges resulted in minimum liquid velocity and maximum positive pressure.

Zhan et al. [39] studied the influence of packing surface wettability in RPBs on the regeneration of spent caustic in an oil–water two-phase system. Hydrophilic surface-modified (ISP), nonsurface-modified (NSP), and hydrophobic surface-modified (OSP) wire mesh packing were prepared and employed in the RPB for regeneration experiments. The results showed that the regeneration performance, in terms of oxidation and separation efficiency, follows the order ISP > NSP > OSP. This indicates that surface-modified packing has the potential to enhance reaction and separation in the RPB.

Zawadzki and Blatkiewicz [36] developed a universal dry pressure drop model for baffle-based structured internals in RPBs. Following the Darcy-Weisbach approach, the model takes into account linear pressure drop due to friction, local drops due to changes in gas flow direction and pressure drop due to rotation. The predicted overall pressure drops had relative errors of less than 18%. Later, they proposed a method for quick prototyping of internals via 3D printing [38]. Packing geometries evaluated included variations of baffle-type (zigzag, half-bow baffle, D-shape baffle), spiral and tray column analogues. The funnel structure of the methodology has heuristic decision gates (Gate 1: printability, Gate 2: dry pressure drop) to decide the geometries that will proceed to the final experimental stage (wet pressure drop, mass transfer area).

Rotors

For mechanical operation, Bai et al. [1] investigated material leakage caused by damage to bearings and shaft seals due to unbalanced rotor vibration in conventional RPBs. To address this issue, they proposed a spherical rotor structure (Figure 2). This new design provided a more uniform liquid phase distribution, increased liquid holdup and lower gas pressure drop, resulting in a more balanced operation that reduces vibration and damage to the rotor, bearing and shaft seal. Additionally, efforts to reduce blockage in systems containing solids were evaluated using a mesh-pin reactor, which features a wire mesh in the inner part of the rotor and self-cleaning pins in the outer area [13]. Liquid holdup was measured using X-ray computed tomography scan, and correlations were derived from these measurements. Following one of the advantages of modular equipment and numbering up, it was demonstrated that a two-rotor configuration could achieve more theoretical stages than a single rotor [20].

Novel liquid distributor concepts

Several types of distributors have been considered to enhance RPB performance by ensuring a uniform liquid distribution in the packing and good catalyst wetting.

Multiple liquid inlet points along the radius and a combination of wire mesh packing rings and hollow annular zones can enhance the performance of RPBs by increasing the mass transfer coefficient (Figure 3). Wu et al. [35] investigated an MLI-RPB reactor using stereolithography, a 3D printing technique, to create a detailed packing arrangement of a complex geometrical model. The flow behaviour was evaluated using high-speed photography, complemented by CFD simulations. Measurements included droplet and film sizes. The formation of liquid bridges was observed within the packing, which eventually broke down into droplets in the outer rings or at higher rotational speeds. The liquid holdup inside the packing rings was impacted greatly by rotation and less by the liquid flow rate. Zhang et al. [41] evaluated the effect of rotational speed, bed porosity, liquid flow rate, liquid nozzle size and number of nozzles

Table 1

Recent packing developments enabled by additive manufacturing.

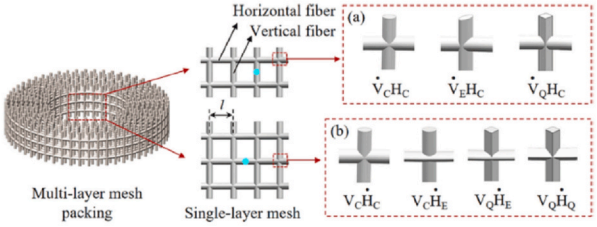
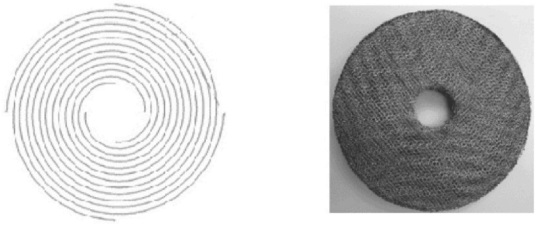
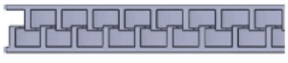
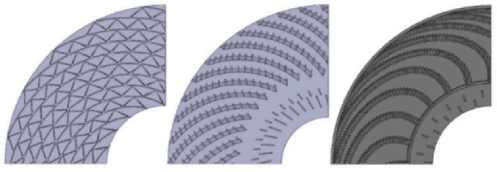
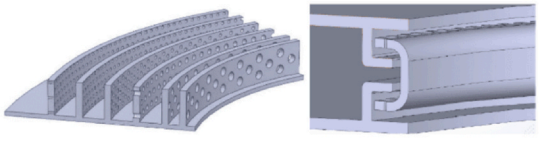
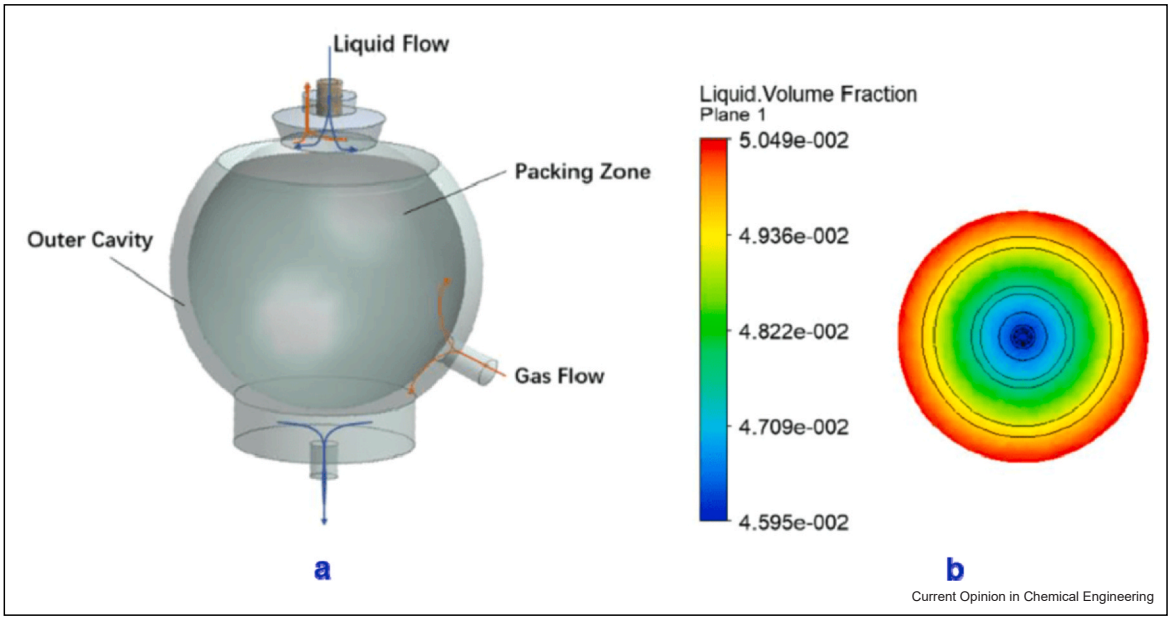
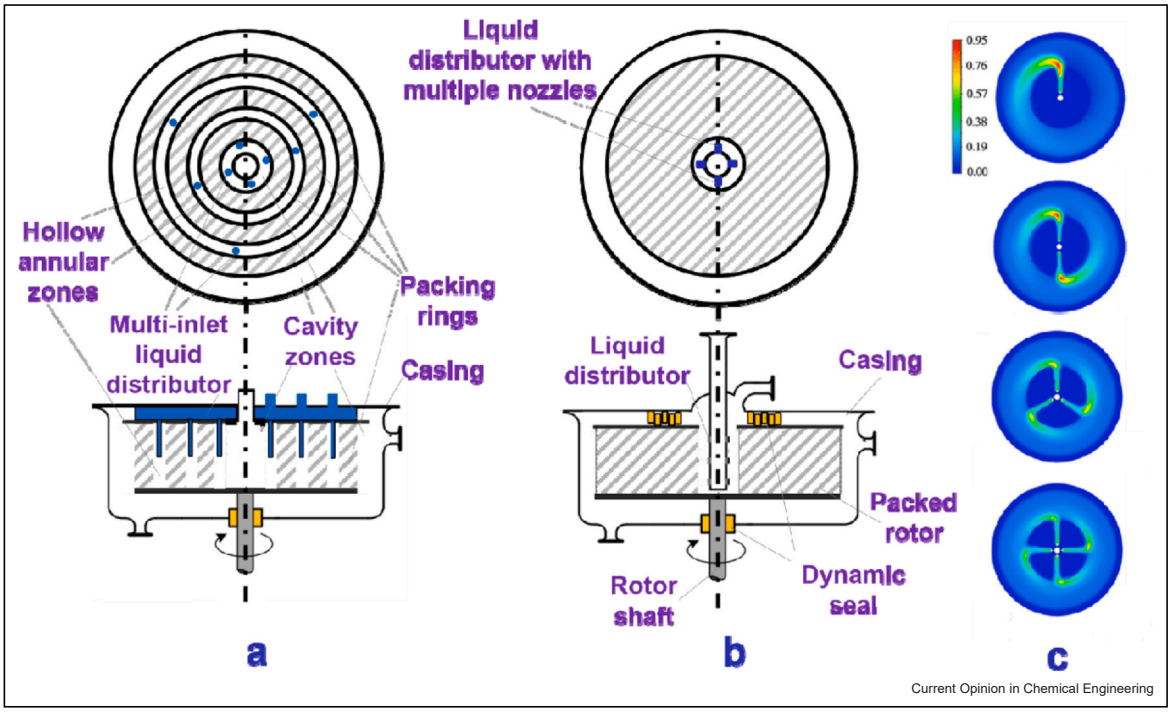
Wire meshes			
Controllable cross-sectional area e.g.VFCO Variable fibre diameter and constant opening size			(Wen et al., 2020)
Fibre cross-sectional shape V: vertical H: horizontal C: circular E: elliptical Q: quadrangular			(Wen et al., 2022)
Archimedean spiral Left: schematic Right: welded wire mesh packing			(Lukin et al., 2021)
Structured			
Baffle type	Zigzag		(Qammar et al., 2019)
			(Zawadzki et al., 2024)
	Half-bow baffle		
	D-shape baffle		
Spiral			
Tray-column analogue Left: perforated plate Right: Bell-plate			

Figure 2



Spherical rotor. **(a)** Physical model with liquid and gas inlet and outlet ports, **(b)** contour of distribution of liquid [1].

Figure 3



Liquid distributor. **(a)** Multi-inlet liquid [35], **(b)** multiple nozzles, **(c)** liquid holdup distribution for multiple nozzles from a CFD simulation [41].

on the liquid holdup and fluid flows. A more uniform liquid distribution and improved liquid holdup were found when the number of nozzles increased from one to four, potentially improving mass transfer performance.

Hacking et al. [6] focused on the design of perforated mesh rings to mitigate liquid maldistribution. The liquid redistributor consists of concentric perforated rings, known as redistribution rings, which play a key role in energy dissipation. When the droplets of liquid collide with the redistribution rings, the distribution and mixing of the liquid are enhanced, greatly contributing to the overall mass transfer and potentially increasing the packing efficiency. In contrast, the droplets suspended in the gas phase have a much smaller effect on the mass transfer due to the short residence time and low friction between the liquid and gas phases [5]. High convective heat transfer coefficients can be obtained through the impingement of jets or droplets on a heat exchanging surface, such as heat exchange tubes placed inside the packing next to the redistribution rings. Increasing the liquid flow rate raises the heat exchange coefficient, while the effects of rotational speed and gas flow rate were found to be negligible [4].

A correlation of liquid-side mass transfer suited for pilot-scale RPBs was developed, which included terms describing the empty rotor and casing, as well as the packing. Special attention was paid to the geometry, location and type of nozzle, where — the more common — full jet and flat fan nozzles were evaluated [8]. Although similar trends were observed with the two types of nozzles, the authors suggest that flat fan nozzles produce more uniform wetting of the packing and larger mass transfer area in the eye of the rotor, which may have a more significant influence with packed beds of larger height.

Pyka et al. [21] proposed using multiple rotors to improve liquid distribution. They developed a rotating baffle distributor, which enabled uniform liquid distribution across multiple rotors, leading to better wetting of the packing. The effect of rotational speed on the number of theoretical stages and the liquid holdup were investigated. The separation performance showed one theoretical stage higher than a conventional liquid distributor, namely, a nozzle. A rotating baffle distributor was manufactured using stereolithography.

Seals

Seals are important for reactive HiGee devices as the heat of reaction may promote changes in temperatures, and some reactive components can cause corrosion (e.g., acids). Abrasion and wear are typical issues that reduce the seal tightness, allowing undetected bypasses, which can negatively impact separation performance. Loll et al. [14] investigated the fluid bypasses between the inner rotor walls and the outside of the annular discs using a zigzag packing with seals. The use of seals increased the mass transfer efficiency compared to unsealed packings. Pyka et al. [22] focused on vapour bypasses and proposed a labyrinth and a floating ring sealing, which resulted in a more efficient operation in terms of the number of transfer units.

Considering that many industrial systems involve toxic or polluting substances, some of them may require foolproof sealing. Magnetic coupling of the rotor and the motor is an appropriate solution, which eliminates the need for seals, thereby preventing, for example, volatile organic compounds (VOC) emissions and fire hazards [24].

Industrial applications

The industrial application of HiGee distillation includes binary mixtures (e.g. alcohol–water, acetone–water, ethyl acetate–water, methanol–butanol, dimethylformamide (DMF)–water, dimethyl sulfoxide (DMSO)–water) and ternary mixtures (e.g. ethyl acetate–toluene–water, methanol–formaldehyde–water, methanol–toluene–water, methanol–DMF–water, methanol/di-methoxy-methane/water) — see the detailed review paper of Cortes Garcia et al. [2]. Since 2017, there have been no new major industrial applications of reactive HiGee distillation. The only pilot scale (line-test) setup for reactive HiGee stripping was reported by Zhan et al. [40] in China for the regeneration of spent caustic systems based on their laboratory-scale tests and mathematical models.

In addition to the technical hurdles, the costs associated with HiGee technology play a key role in the decisions to apply this technology at an industrial scale. Although HiGee distillation can reduce the equipment size, it does not offer energy savings. In fact, the operating cost is higher due to the electrical energy needed for high-speed rotation, as the fluid in each rotor of an RPB stage needs to be accelerated. It is especially worse for the zigzag RPB, where the fluid is accelerated and decelerated for each ring. For example, for a 100 tonnes per day CO_2 capture process for flue gas from a coal-fired power plant [10] and for a 14.4 tonnes per day methanol dehydration process [12], the operating cost increased due to the additional power input by 9.8% and 8.9%, respectively, compared to fixed packed bed processes. In other cases, the electrical energy needed for high-speed rotation can lead to an increase of even up to 50% in overall energy usage.

However, RPB can be also the more expensive option for capital expenditure (CAPEX) due to the more expensive rotating systems used. For the CO_2 capture process reported by Jung et al. [10], the CAPEX of the RPB columns is 2.4 times higher than that of the packed bed option. However, the reduction of the packing volume can range from 8.5 to 14.9 times, using a 30 wt% MEA solvent as the baseline. Similarly, Kruber et al. [12]

claimed that the CAPEX for the RPB is approximately 31.5% higher than that of a conventional column, primarily due to the rotors used in the RPB. Notably, different cost models make large differences (can be around 50%) in CAPEX especially for the scale up of systems [10]. Despite the cost deficiency, an RPB system may still be beneficial due to its significant reduction in the apparatus height and volume, which makes it inherently safer (due to the smaller holdup). In addition, the rotational speed in an RPB offers an additional degree of freedom that enlarges the operating window and aids flexibility during operation.

The low holdup and high throughput of RPBs lead to low residence times, which can be essential for separation of thermally sensitive components. Also, the low holdup allows for quick ramping up and down of the throughput, which may be beneficial in industrial systems where green energy availability is intermittent and energy costs are significantly fluctuating.

Challenges for high-gravity (reactive) distillation

The challenges relate to the development of both software (tools and methods) and hardware.

Challenges in software/methods development

- Models for HiGee processes are not readily available in commercial simulation software, making it difficult to include HiGee technology in systematic process synthesis and design.
- Considering the recent computational progress, CFD-coupled mass transfer simulations (particularly in CO_2 capture) can surpass the rate-based approach and could be applied to physical and reactive distillation, as mass transfer resistances vary by system.
- Evaluating mass transfer limitations is challenging due to the complex interactions between operating conditions, hardware, and simultaneous phenomena.
- Scaling up HiGee equipment requires measurements or estimations of local mass transfer in different regions of the rotor [7], making it difficult to generalise scaling-up rules. Inaccurate assumptions about geometry can lead to significant over- or under-predictions, particularly depending on equipment size.
- Validation of correlations applicable to multicomponent separations is lacking because most experimental demos focus on binary or ternary separations [7].
- The lack of adequate capital cost models makes evaluating RPB-based processes at commercial scale challenging. Accurate cost models are essential for informed decision-making and advancing this technology.

Challenges in hardware development

- Due to the high rotational speed, moving parts are prone to abrasion and wearing [22]. Hence, design of parts such as seals, rotors, casing and packings is fundamental to avoid flow bypasses and unnecessary downtime.
- Packing wettability and catalyst erosion limit the type of chemical systems that can exploit the benefits of HiGee (reactive) distillation.
- *In situ* cooling or heating can make HiGee unsuitable for reactive separations, which have large heat of reaction [24,29]. However, heat exchange inside the rotors and within the reaction zone can expand the range of reactions that could take place inside the RPB by using heat exchange tubes placed inside the packing [4]. Alternative ways to mitigate hot spots in RPBs include using coils for heating and cooling [9,17].

Conclusions

This paper reviewed the latest progress in the synthesis, design and modelling of RPBs, including the latest developments on hardware design and prototyping, particularly enabled by additive manufacturing. HiGee (reactive) distillation has shown significant benefits due to its enhanced vapour–liquid mass transfer, resulting in smaller equipment sizes. Despite its advantages over classic distillation columns in various applications such as methanol/water or ethanol/water separation, caustic regeneration, and the production and separation of hypochlorite, HiGee (reactive) distillation has seen limited adoption at an industrial scale. Integrating and optimising catalytic reactions within HiGee systems are important to ensure good performance at extreme pressures and temperatures, thereby enlarging the operating windows and making HiGee technology suitable for a broader range of chemical systems. Although HiGee (reactive) distillation can reduce equipment size by about six to eight times, it does not offer energy savings. In fact, the electrical energy needed for high-speed rotation results in an increase of about 10% and even up to 50% in overall energy usage.

Future research should address several challenges in HiGee technology. In terms of hardware, improving mechanical complexity and reliability can be achieved by developing efficient corrosion- and wear-resistant packing materials that also extend gas–liquid contact time, enhancing separation capabilities, and to improve heat dissipation. These developments can help overcome limitations in the number of achievable stages, especially concerning the scale of operation (i.e. throughput). Additionally, improving the dynamic balance of large RPBs and engineering issues of bearing lubrication at distillation operating temperatures need to be addressed. Although fast prototyping enabled by 3D printing has allowed the development and evaluation of different types of packings, the design and manufacturing capabilities of engineering high-gravity

distillation equipment need to be enhanced particularly for larger pieces of equipment.

Regarding methods, design methodologies that consider the additional degrees of freedom offered by various hardware features are important. Although various correlations to predict liquid-side and vapour-side mass transfer coefficients have been developed, dependence on hardware configuration (i.e. rotor, liquid distributor) and size of the operation requires more precise heat and mass transfer models that enable the development of appropriate control strategies for high-gravity (reactive) distillation. As a result, industrial applications could be envisaged once robust and validated models derisk the implementation at large scales. To address the lack of commercial software for HiGee technology, one could create a reliable '*HiGee (reactive) distillation*' block as a user-subroutine in commercial software (e.g. Aspen Plus) by modifying the mass transfer coefficient parameters and interfacial area parameters of the current rate-based equations for conventional distillation columns. Additionally, models implemented in other platforms (e.g. MATLAB, gPROMS, Aspen Custom Modeler) could be made available to further advance the development of HiGee technology.

Thus, although HiGee (reactive) distillation technology is not yet widely applied industrially, there is clear room for its innovation and research and to foster the implementation of both on-shore and off-shore applications of chemical processes.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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