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# NeXRing - High Performance Packing for Demanding Applications

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The development process of Sulzer's NeXRing is presented using the example of two common ring sizes. It includes well-known methods such as absorption and distillation tests but also new methods like simulations of randomly bulked ring beds based on discrete element method (DEM) and mechanical strength tests in a column with industrial relevant diameter. Comparisons with standard 3rd generation rings demonstrate a significant performance improvement of the new 4th generation ring family.

## 1. Introduction

Sulzer's NeXRing™ is a high performance random packing of the 4th generation. Since the development of the first member in 2014, six other ring sizes joined the packing family. They cover the industrially relevant range of specific area and serve all typical ring applications. Until now, more than 300 industrial columns with diameters up to 8.5 m are equipped with the NeXRing. This paper delivers insight into the development process that led to this successful product.

*Figure 1: NeXRings in different sizes.*

## 2. Design study and numerical random packing simulation

In randomly packed beds, it is of importance how the rings fall and how they are positioned and oriented to each other. On one hand, the surface area of each packing element should be available to the liquid flow as much as possible; on the other hand, the elements should be oriented in a way that allows gas to flow easily through the packed bed at low pressure drop. It depends mainly on the shape of each element how those packing elements will fall and orient in a packed bed.

Usually a packed bed is defined by specific surface area and void fraction: specific surface area is the surface area of one element multiplied with the number of elements per packing volume, and void fraction is calculated with specific surface area and sheet thickness. The number of packing elements per volume is usually determined by counting the rings that have been filled physically in a test volume. However, producing prototypes just to evaluate this number is expensive and time consuming. Therefore, simulation tools help

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obtaining the desired number of elements per volume and a first impression of ring orientations without manufacturing prototypes.

For NeXRing development, the software Pasimodo® by the German company Inpartik GmbH was used. The particle-based simulation tool uses a DEM combined with multibody simulation (MBS) features. The coupling of those methods allows analyzing not only the dumping process itself but also the interaction between particles during dumping and settling, which is of high importance when simulating open and/or complex structures (Inpartik 2018).

*Figure 2: Output of Pasimodo® for dumped I-Rings*

For evaluation of the simulation results, one bed consisting of Sulzer's I-Ring™ was simulated. A typical bed of the well-known ring is shown in Figure 2. It looks very similar to a real packed bed and typical phenomena as nesting, i.e. two or more rings are moved into each other and entangled, can be found as well. Furthermore, characteristic values of the bed can be calculated and compared to measurements. As shown in Table 1, deviations for piece count (number of elements per volume) and specific surface area were found to be in a range comparable to measurement reproducibility. Those figures and data show the good quality and quantity for prediction of packed bed characteristics with new complex ring shapes.

*Table 1: Evaluation of Pasimodo® results for dumped I-Ring #50*

| | simulated | Measured | deviation |
|---|---|---|---|
| Piece count | 15,570 $m^{-3}$ | 15,500 $m^{-3}$ ±500 $m^{-3}$ | 0.45 % |
| Spec. surface area | 98.8 $m^2/m^3$ | 100 $m^2/m^3$ ±3.5 $m^2/m^3$ | -1.2 % |

## 3. Hydraulic and absorption tests

After finding a proper ring shape and size via simulation, production and testing of first prototypes were carried out. Sulzer's test centre in Winterthur, Switzerland, enables testing of packing prototypes in different column sizes and applications: for first absorption testing, one column with flexible inner column diameters between 250 and 500 mm was used. A blower feeds ambient air, which passes the column once and is released at the top to the ambient. Counter-currently liquid is fed from a storage tank to the top of the column and flows back to the storage at the bottom. With that facility, standard absorption tests with air/$CO_2$-NaOH system for determination of effective interfacial area (Duss et al., 2001) are possible but also absorption tests for determination of $k_G$ and $k_L$ (Hegely et al., 2017).

Since effective interfacial area is highly important for gas sweetening and other absorption processes, the following plot concentrates on that specific absorption test system. As shown in Figure 3, the effective interfacial area was measured for common packing types of the 3rd ring generation as Nutter Ring or Sulzer's I-Ring. Additionally the interfacial area measured in a NeXRing bed of similar size is presented. For each liquid load different F-factors were applied, which explains the indicated scatter of data points. It is found that all three rings show very similar values over the wide range of liquid loads and it can be stated that NeXRing #2 is equivalent to Nutter Ring #2.5 and I-Ring #50 in regards of interfacial area.

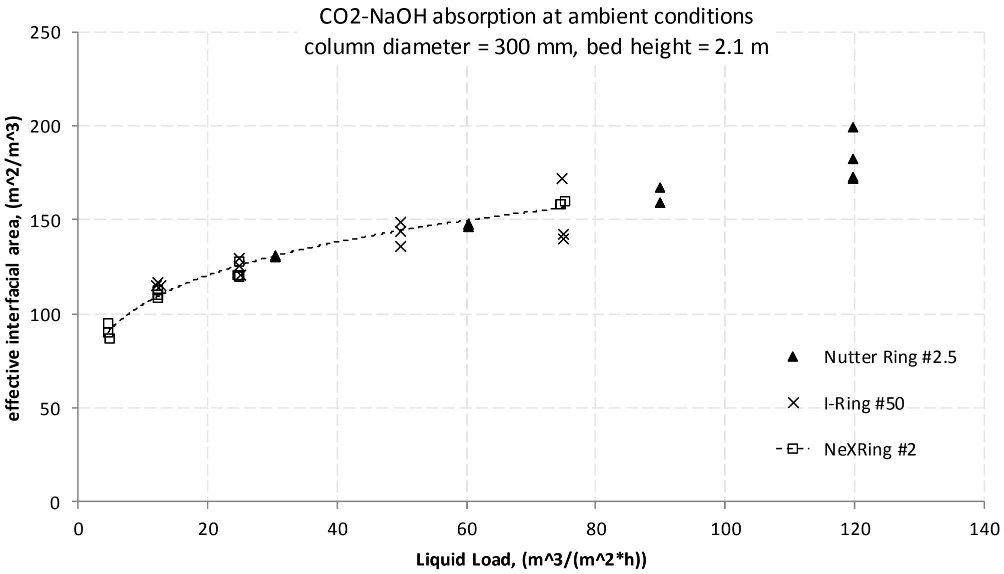


*Figure 3: Effective interfacial area measured in 3rd generation packings and in new NeXRing of similar size.*

For hydraulic testing, another test column is used with an inner diameter of 1000 mm. Due to such a big diameter, any wall effects are negligible and measured data can be scaled up linearly to bigger diameters (Olujic, 1999). The column is made out of translucent plastic, which allows only tests at ambient conditions but allows visual observation of the fluid phase behaviour inside the column. A blower circulates air and a pump circulates water through the column. Additionally to standard differential pressure transducers, the column is equipped with a radiometric gamma ray scan unit, which enables local hold-up measurements at different positions along the column axis. Furthermore, pressure drop and capacities are determined with that facility. A short description of the facility can be found in Duss et al. (2001).

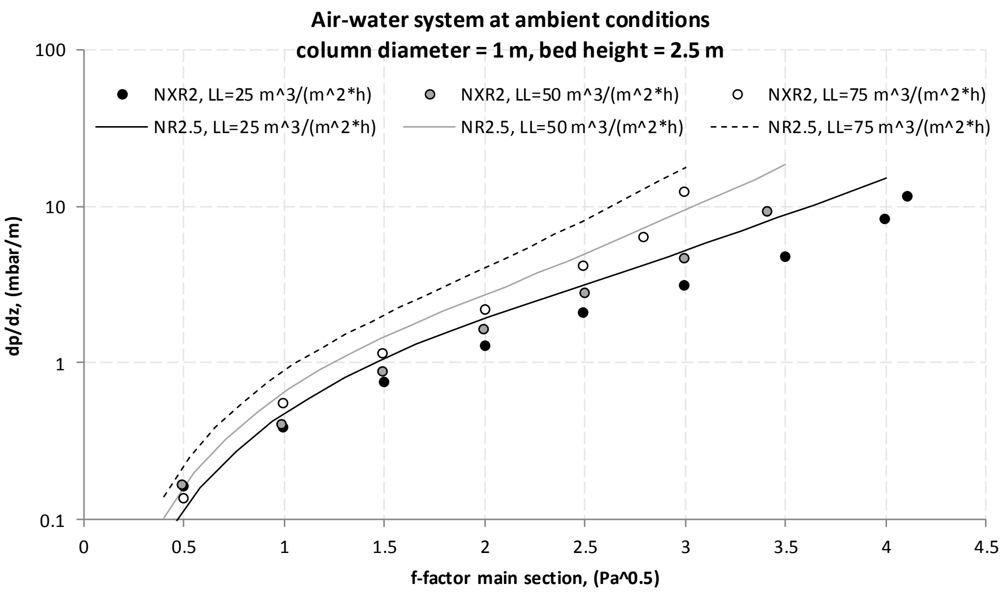


*Figure 4: Hydraulic comparison of NeXRing #2 (NXR2) and Nutter Ring #2.5 (NR2.5) at different liquid loads.*

Measured pressure drops for NeXRing #2 at different liquid loads are shown in Figure 4 including comparison with Nutter Ring #2.5, which performs hydraulically very similar to I-Ring #50. The comparison shows that NeXRing #2 has about 35% less pressure drop leading to approx. 10% more capacity than Nutter Ring #2.5 when defining 100% capacity at 12 mbar/m pressure drop.

In Figure 5, another hydraulic comparison for rings of smaller size is shown: NeXRing #1.2 is compared to I-Ring #40 – from the Nutter Ring family no equivalent size is available for direct comparison. And again: NeXRing #1.2 has about 30 to 40% less pressure drop and about 15% more capacity than I-Ring #40 while both rings have comparable effective interfacial area and mass transfer characteristics. Those results are outstanding and propel the NeXRing to the class of 4$^{th}$ generation high performance rings.

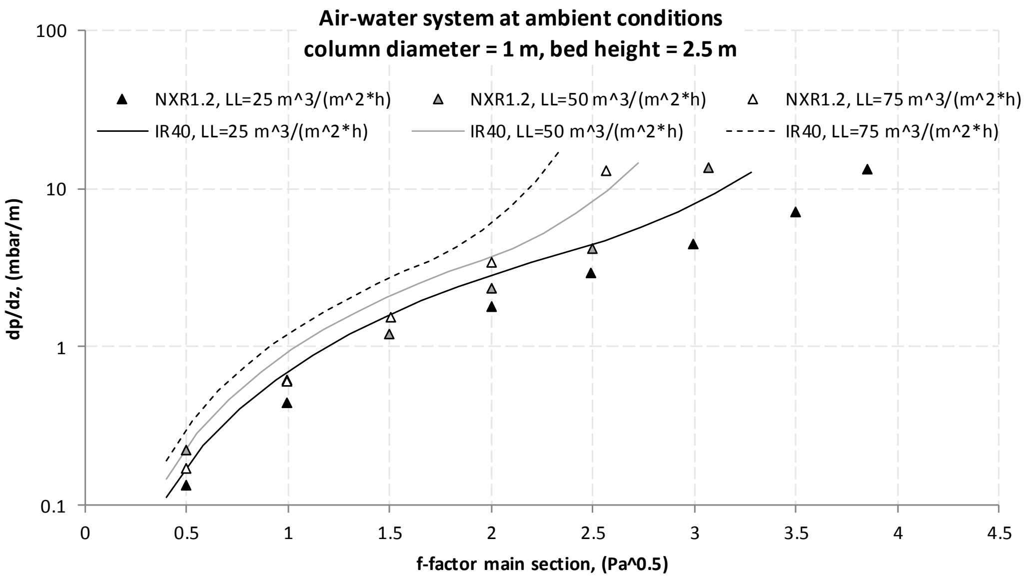


*Figure 5: Hydraulic comparison of NeXRing #1.2 (NXR1.2) and I-Ring #40 (IR40) at different liquid loads.*

## 4. Mechanical stability tests

Often mechanical strength of a packed bed is only worth a marginal note in publications. However, it is of high importance to install packings with sufficient mechanical stability in order to avoid collapsing of the packing beds, which could happen during installation or at high liquid loads with big hold-ups (Pilling 2009). Usually an improvement in mechanical stability is gained by using thicker sheet material, but that is strongly connected to higher costs (Duss & Menon, 2010); hence it is desirable to produce packing out of thin material and improve the mechanical stability by special design of the shape.

At Sulzer's test center, one facility exists for testing the mechanical stability: a small column section of 650 mm height and 1000 mm inner diameter contains the packing and all test equipment. As shown in Figure 6, the column consists of a reinforced head (A) and a reinforced bottom plate (H). The packing is installed between plates E and F. Force sensors above (D) and below the packing (G) measure how much force is loaded on the packing and is passed to the bottom, respectively.

The force itself comes from a pneumatically driven rescue pillow (B), which is commonly used by rescue teams to lift up heavy loads. That pillow SQ-24 from ResQTec®, Netherlands, is able to lift maximum 25 tons to a height of 300 mm, which is sufficient to compress even very strong packing structures. With a pressure reducing valve, the force inside the pillow can be controlled. Furthermore a laser distance sensor OptoNCDT 2200 from Micro-Epsilon AG, Switzerland, is used to determine the deflection of the packed bed. With that equipment it is possible to yield a stress-strain curve and calculate the maximum allowable force to the packed bed (Ausner & Keller, 2012) even for very large rings of 3 or more inches.

With that test setup, all NeXRings and rings from other generations were tested for their maximum allowable force. A comparison of the required force to achieve 5 % of bed compression is shown in Table 2 for several 2-inch rings with 0.4 mm sheet thickness (stainless steel at room temperature). The NeXRing has the second best stability after the I-Ring, which is the strongest ring in that comparison due to its saddle shape.

*Table 2: Maximum allowable force for different 2" rings in 0.4 mm stainless steel*

| Raschig ring | Pall ring | Nutter ring | I-Ring | NeXRing |
|---|---|---|---|---|
| 10 kN/m$^2$ | 12 kN/m$^2$ | 14 kN/m$^2$ | 25 kN/m$^2$ | 18 kN/m$^2$ |

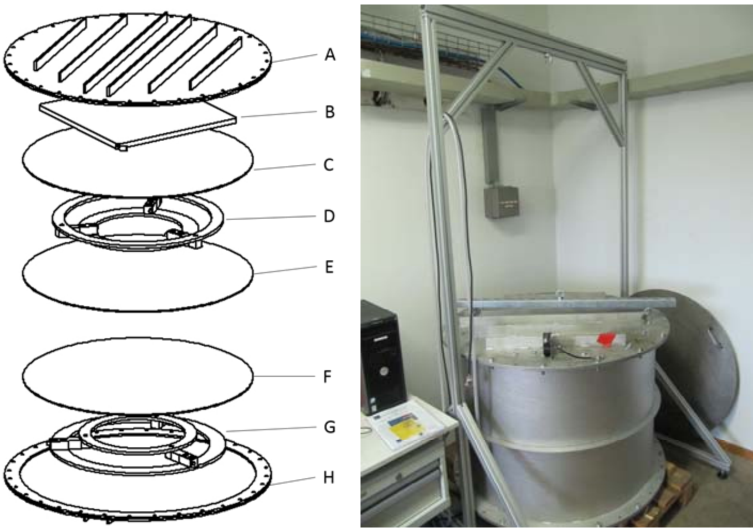


*Figure 6: Setup for mechanical stability testing. Left: exploded view of equipment inside column. Right: complete test rig including gallows frame for lifting up the top.*

## 5. Distillation tests

Even if the main application for random packings is the absorption at higher liquid loads, there are also distillation applications where random packings are applied, preferably at intermediate pressure. Beyond that, independent testing institutions like Fractionation Research Inc. (FRI) in Stillwater, Oklahoma, perform distillation benchmark tests and therefore provide an interesting opportunity to explore the NeXRing performance in distillation application.
All NeXRing sizes were tested in Sulzer's P1000 distillation column with 1000 mm inner diameter. That column is operated under total reflux conditions at atmospheric pressure and vacuum. In Figure 7, test results of NeXRing #1.2 and NeXRing #2 are shown for atmospheric distillation with the standard binary mixture containing chlorobenzene and ethylbenzene. The comparison to Nutter Rings (NR) and I-Rings (IR) shows equivalent baseline efficiencies and more capacity on both NeXRings. Measured gain in capacity is in the range of 7 to 13 % for both NeXRings compared to I-Rings of equivalent size.

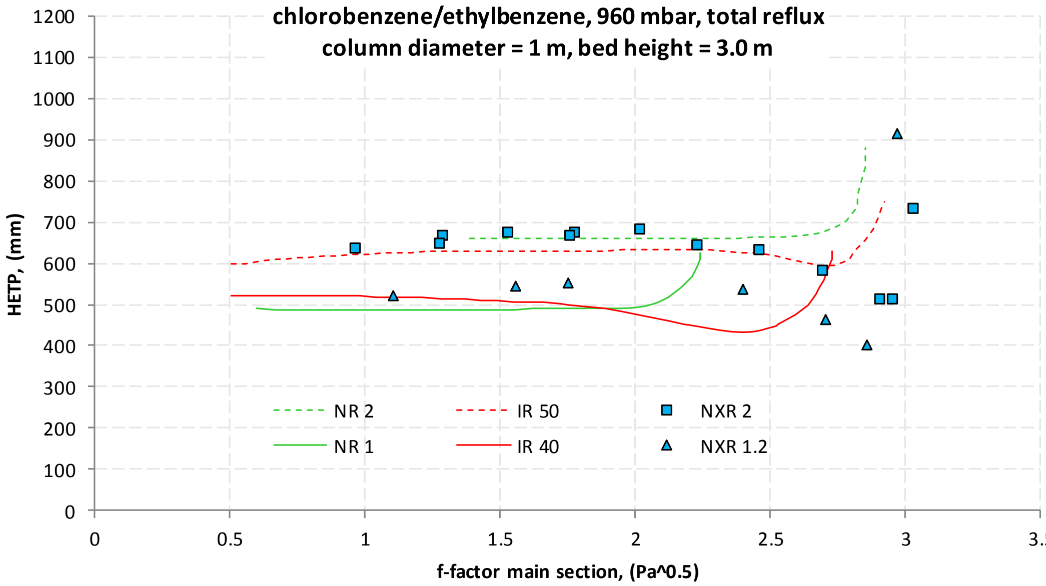


*Figure 7: Distillation results of NeXRing #1.2 and NeXRing #2 at atmospheric pressure and total reflux.*

Finally, the NeXRing #1.2 was tested in FRI's high pressure column with 1.22 m column diameter. The test systems were o-/p-xylene at atmospheric pressure and iso-/n-butane at 6.9 and 11.4 bara. Figure 8 shows the results of total reflux runs, compared to atmospheric test results obtained in Sulzer's P1000. With increasing column pressure the efficiency rises and capacity reduces because of the higher liquid loads inside the column.

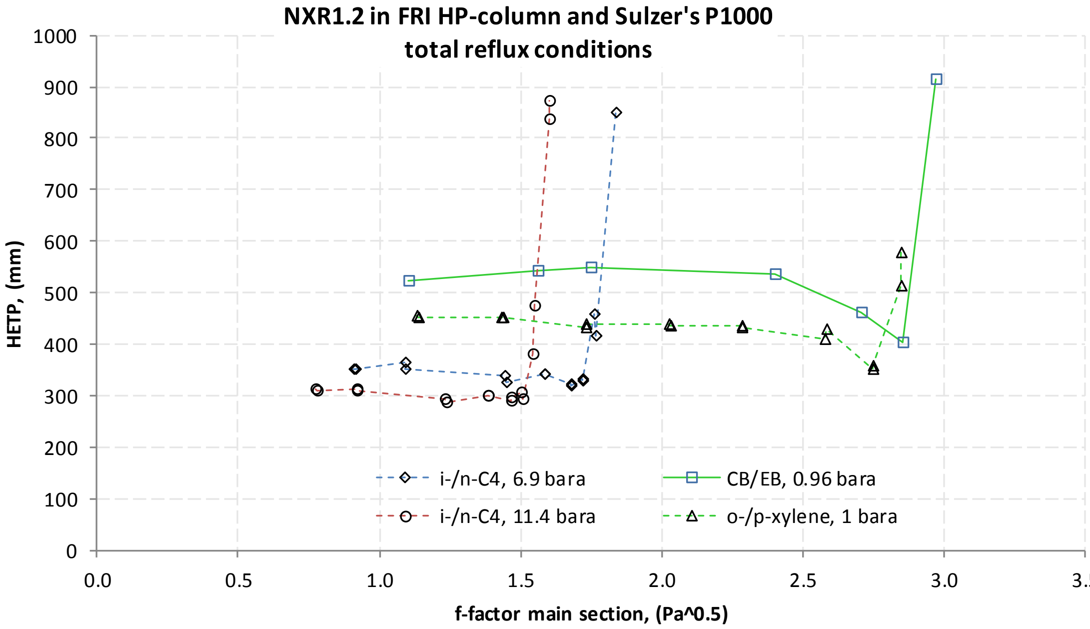


*Figure 8: Test results of NeXRing #1.2 in FRI's HP-column (Category 1 test, 2017) and Sulzer's P1000.*

## 6. Conclusions

It is shown for two different sizes that NeXRing is a great replacement for standard 3rd generation rings as Nutter or I-Rings. In $CO_2$ absorption and total reflux distillation tests, the NeXRing showed equivalent separation efficiency, but significantly lower pressure drop and up to 15 % higher capacity compared to the standard rings. Regarding mechanical stability, the NeXRing is the second best after the I-Ring and allows the installation of very high packed beds. Distillation tests at FRI complete the development process of NeXRings.

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