Materials of the future

- Next-generation materials for high-energy pumps
- New welding material for repairing turbines
- Carbon-fiber composite material for distillation
- Easy insertion of bone substitute materials
About Sulzer
Sulzer's core strengths are flow control and applicators. We specialize in pumping solutions and services for rotating equipment, as well as separation, mixing and application technology. Our customers benefit from a network of over 180 production and service sites around the world. Sulzer has been headquartered in Winterthur, Switzerland, since 1834. In 2017, we achieved sales of roughly CHF 3.0 billion with around 14’700 employees. Our shares are traded on the SIX Swiss Exchange (SIX: SUN).

Pumps Equipment
The Pumps Equipment division specializes in pumping solutions. Intensive research and development in fluid dynamics, process-oriented products and special materials as well as reliable service solutions help the company maintain its leading position in its focus market segments.

Rotating Equipment Services
The Rotating Equipment Services division provides cutting-edge maintenance and service solutions for rotating equipment dedicated to improving customers’ processes and business performance. When pumps, turbines, compressors, generators and motors are essential to operations, Sulzer offers technically advanced and innovative solutions.

Chemtech
The Chemtech division is represented in all important industrial countries and sets standards in the field of mass transfer and static mixing with its innovative solutions. The product offering ranges from process components to complete separation process plants. The customer support covers engineering services for separation and reaction technology and tower field services to perform tray and packing installation, tower maintenance, welding and plant turnaround projects.

Applicator Systems
Customers of the Applicator Systems division benefit from advanced solutions in the field of precise applications as well as two-component mixing and dispensing systems for adhesives, dental, healthcare and beauty applications. A global network ensures that local knowledge and competence help Sulzer to keep its leading position in its market segments.

Materials of the future

"Materials innovation can lead to market success of a product. That’s why Sulzer’s materials specialists investigate and check materials, coatings, and materials treatments to improve our products and production processes. Sulzer has broad experience in many different manufacturing processes and uses a wide variety of them. Our engineers analyze, assess and test thoroughly all new materials and production methods before they are used in full-scale production and different areas.

Read about the advantages of hot isostatic pressing (HIPing) of cast impellers used in water injection subsea pumps and not easy to exchange. To increase corrosion resistance, Sulzer implemented a carbon-fiber composite material for separation columns. Even for repairs, Sulzer makes use of the know-how of materials specialists to improve the longevity of refurbished turbines. Special plastic materials and processes are used to produce dental syringes which are filled with biocompatible bone material.

Thomas Kränzler, Head of Global Core Technology Materials of Sulzer Pumps Equipment, Winterthur, Switzerland

4  Next-generation materials for high-energy pumps

Stronger impellers for deep-water pumps

11 New welding material for repairing turbines

How to reduce stress corrosion cracking

16 Carbon-fiber composite material for distillation

How MellaCarbon internals were invented

19 Easy insertion of bone substitute materials

A dental syringe for tooth implants

22 News and events
Next-generation materials for high-energy pumps

Water injection pumps are used to extract oil and gas resources off-shore. The operating pressure of these pumps increases with reservoir depth. Impellers must withstand a pressure of 1’000 bar (100 MPa) and 60’000 load cycles per minute. To improve the reliability of pumps, Sulzer’s materials and processing specialists are constantly investigating which materials and process technologies are most suitable for use in the future.

There are invisible differences between pumps, but they influence the long-term availability of the pump. The material used for the pump impeller or pump casing has a big influence on its resistance to stress or corrosion. Every day, newly developed materials are available for additive manufacturing processes and allow manufacturers to go new ways in production.

Soon, the smart use of process technologies and materials will be one of the keys to offering competitive products for the market. The best material is not the only decisive factor — the most suitable material and process counts. In some cases, delivery time matters most — then a faster production process wins. For corrosive or aggressive pump fluids, improved material properties with coatings, or higher resistance to chemicals win the evaluation process.
Rising demands on water injection pumps

Exploring and extracting oil and gas resources from offshore reservoirs forces the oil and gas industry to stretch its limits. More and more water injection pumps are used in deep- or ultra-deepwater. The deeper the oil and gas resources are, the higher the fluid temperature of the pumped fluids is — a geothermal effect. Also, the deeper the pump is operating, the more corrosive substances in the injected water there are.

In the early 1970s, the discharge pressure of water injection pumps was around 350 bar (35 MPa). In 2001, Sulzer set a world record by installing four HPcp pumps in the Gulf of Mexico. These pumps operated with a discharge pressure of 605 bar (61 MPa). Anticipating the rising requirements, Sulzer launched a concept study in 2009 to develop an injection pump with an operating duty pressure of 800 bar (80 MPa). The customer feedback to this project set the development benchmark higher, and Sulzer developed a pump providing 1’000 bar (100 MPa) of operating pressure (Fig. 1).

How is it possible to achieve such a pressure increase? Partially, by adding pump stages, but mainly by defining a higher head per stage. These changes increase the mechanical stress on the materials used in the pumps. Usually, super-duplex stainless steel is used as the pump material for high-pressure pumps. But with a pressure of 1’000 bar (100 MPa), the mechanical limits of this steel are reached.

Besides smart engineering solutions, subsequent pump developments will require improved materials, which provide higher strength with the same or even improved corrosion resistance. However, these materials are not easy to find because material strength and corrosion resistance generally oppose each other.

A challenge is to find appropriate impeller materials, because these components cannot be executed like a pump casing in high-strength low-alloy steels clad with a corrosion- and wear-resistant stainless overlay. Beside strength and corrosion resistance, the fatigue resistance of the impeller material is the key to success, because these components are already nowadays exposed to a very high number of load cycles.
Load cycles in a pump

In a common diffuser-style pump, each impeller vane passes approximately ten diffuser vanes per revolution. Each pass causes a pressure peak on the impeller, which leads to a small elastic deformation of the part (Fig. 2).

If the pump spins at 6,000 rpm, the impeller will have 60,000 load cycles per minute. Just some comparison values: an average heart beats 90 times per minute and a car engine runs at 3,000 rpm. For the pump, a year (or 525,600 minutes) of continuous operation results in 31.5 billion (3.15 x 10^10) cycles (Fig. 3).

New materials needed

To meet the future demands of high-energy pumps, Sulzer is always looking ahead, and evaluates and tests new materials and process technologies. Aware that the pump material is of vital importance, Sulzer employs a dedicated team of 18 materials specialists in its Pumps Core Technology Materials department.

Thomas Kränzler states: “It is a challenge to find new potential impeller materials for the next generation of water injection pumps. Improving the mechanical and corrosion properties often influences the manufacturing methods or increases production costs disproportionately. Our evaluation is therefore not restricted to materials specialists. We cooperate closely with manufacturing specialists to select and qualify new materials.”
Materials selection
Modern materials selection is objective, a fact reflected in the quantified selection for an impeller material that is stronger than cast super-duplex stainless steel, but at least as corrosion-resistant. Quantifying the two critical material properties becomes easy in a database, but there are limits. Strength correlates well with the resistance to fatigue crack initiation. However, a need for correlations arises because there is more data for wrought rather than cast versions. To estimate and judge the resistance to pitting corrosion, the materials engineers use the pitting resistance equivalent number \((\text{PREN} = \text{Cr} + 3.3 \text{ Mo} + 16\text{N})\). PREN is an index made up of a linear combination of weight percentages of key chemical elements. Nevertheless, performance optimization using the two main properties across all database materials becomes clear in a graph. The circles in Fig. 4 represent the range of properties for a specific material, with super-duplex highlighted as No.1. Bubble positions show relative performance with equality given along a diagonal line and best performance toward the upper-right in this graph. The material with the most promising potential is a special nickel-based alloy (No. 2). The quantified material selection, therefore, reveals that there are only a limited number of alloys with better performance than super-duplex stainless steel, with only one offering most promise, a nickel-based alloy.

![Strength-corrosion factors of different materials](image)

**Fig. 4** Strength-corrosion selection chart.

Process selection
The selection of material processing is qualitative and simpler than material selection. Wrought or worked materials are known for relatively favorable mechanical properties, but only a single issue immediately disqualifies these. There is no further consideration of wrought materials because there are no tools to machine the complex cavities of a closed impeller. Likewise, joining of multiple wrought pieces introduces serious risks to fatigue resistance. The most
Next-generation materials for high-energy pumps

Vacuum investment casting

Vacuum investment casting is a three-dimensional replication process that involves a few steps before producing the metal impeller. First, a sacrificial pattern or copy of the impeller is 3D-printed from a low-melting-point plastic, and then this pattern is coated with multiple layers of ceramic slurry. After placing the coated pattern in a furnace, the plastic burns off and the ceramic slurry forms a rigid, yet brittle and empty, mold or container. That container is also sacrificial, for the molten metal to solidify, or invest, within. Third, the molten and reactive metal is poured into the warm ceramic mold under vacuum to avoid contamination. Finally, the metal inside solidifies, and the cast impeller is revealed by destroying the brittle ceramic mold. These basics of investment casting have ancient roots. Archaeologists claim that the use of beeswax patterns and clay molds is thousands of years old. The current process, vacuum investment casting, is contamination-resistant, and even incorporates modern methods such as the 3D-printed plastic patterns.

The table (Fig. 5) reviews these process pros and cons. Note that 3D printing using laser fusion essentially builds parts from multiple miniature castings. As a result, there are inevitable solidification discontinuities and residual stresses. Therefore, vacuum investment casting takes preference because of availability and competitive cost, and it is a proven production route for precipitation hardening nickel-based superalloys.

<table>
<thead>
<tr>
<th>Beneficial properties</th>
<th>Vacuum investment casting</th>
<th>Laser fusion (3D printing)*</th>
<th>Binder jetting (3D printing)*</th>
<th>Powder metallurgy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material properties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-directional</td>
<td>+</td>
<td>--</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Small crystal size</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Low residual stress</td>
<td>+/-</td>
<td>---</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>High density</td>
<td>--</td>
<td>-</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Uniform composition</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Material flexibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handles reactive alloys</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Alloy flexibility</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Multiple materials / cladding</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Design / dimension</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex shapes</td>
<td>+</td>
<td>+++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Large part size</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Near final shape</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Low shrinkage</td>
<td>--</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fine surface finish</td>
<td>+</td>
<td>+/-</td>
<td>+/-</td>
<td>+/-</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-cost starting materials</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Low labor intensity</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Less waste material (risers/supports)</td>
<td>--</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Process time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short production time</td>
<td>+</td>
<td>+++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Process without container</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Repeatability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single melt sequence</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Low entropy (steps)</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

* See details in STR 2/2018 – Additive Manufacturing

Fig. 5 Comparison of different processes for impeller production.
Heat treatment and reliability

Heat treatment tackles two specific factors in the statistical distribution of material strength, resulting in improved reliability with respect to the distribution of applied stress. Note that there is natural order for a scatter, or distribution, in strength and stress instead of single values. Hot isostatic pressing, as characterized in the table in Fig. 6, affects the scatter in the fatigue strength. The range of scattered fatigue strengths is narrower after applying hot isostatic pressing (HIP) which increases reliability (see Fig. 7). HIP is like a large pressure cooker. It takes place at 1'200 °C near the melting point of the metal and lasts for at least three hours. During HIP, inert argon is used to build 1'000 bar (100 MPa) pressures that close internal casting voids, which would otherwise degrade fatigue cracking resistance. This extreme pressure approaches the pressure in the Mariana Trench, which is the deepest-known natural part of the Earth’s oceans (approx. 11 km / 6.8 miles below sea level). A second heat treatment process improves reliability by increasing the average fatigue strength. With average applied stresses increasing from deeper oil fields, solution annealing and precipitation hardening under vacuum increases average material strength to reduce the chance of failure (see Fig. 8). There are added measures to control the strength distribution. Management of the internal or residual material stresses, which continues throughout the process, reduces strength variation. Since the alloy is compatible with slow cooling, Sulzer uses controlled inert gas cooling instead of quenching. Hot isostatic pressing and controlled precipitation hardening, therefore, improve reliability by resulting in a narrower distribution of material strength with a higher average.

<table>
<thead>
<tr>
<th>Advantages of HIP</th>
<th>Disadvantages of HIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relieve residual stress</td>
<td>Risk of large crystals and melting</td>
</tr>
<tr>
<td>Reduce variation in distribution of fatigue strength</td>
<td>Part shrinkage, if not dense enough before</td>
</tr>
<tr>
<td>Mitigate directional properties</td>
<td>Limited size of pressure vessel</td>
</tr>
<tr>
<td>Mitigate non-destructive testing limitations</td>
<td>Limited cooling rates</td>
</tr>
<tr>
<td>Mitigate early failure rates</td>
<td>Added cost</td>
</tr>
<tr>
<td>Densify material, close internal voids</td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 6 Advantages and disadvantages of hot isostatic pressing (HIP).](image)

![Fig. 7 Narrowing of scatter in strength from hot isostatic pressing and mitigation of internal material stress.](image)

![Fig. 8 Average increase in material strength by precipitation hardening (PH).](image)
Inspections and testing

Inspections of new processes and products are necessary to maintain reliability since no production process creates flawless parts. The goal is to limit or prevent faults from becoming defects.

During non-destructive testing, the prototype impeller castings showed promising results. The surfaces underwent visual, metrological, borescope and fluorescent liquid penetrant inspections for cracks and discontinuities. The complex volume of the castings makes interior inspections demanding. Only the accessible areas in the interiors of the impeller could be inspected using ultrasound. X-ray computed tomography, much like scanning a human body, complemented the ultrasonic inspections of the interior. An example of an acceptable X-ray computed tomography cross section is shown in Fig. 9. It shows how dense the material is after hot isostatic pressing.

Reliability makes use of empirical and material performance models. Quantifying impeller reliability depends heavily on materials science and engineering, fracture mechanics, and statistics due to the probabilistic physics of failure approach. For this, the fatigue and fracture mechanics properties are critical. Robust and adaptive Bayesian statistics will be applied to the results of the many ultrasonic fatigue crack initiation tests. Ultrasonic fatigue refers to an accelerated test, specifically using cyclic loading frequencies near 20 kHz instead of 20 Hz, to extend stress-life curves from the megacycle into the gigacycle domain. Note that gigacycle fatigue testing of steels has shattered earlier assumptions of infinite life and fatigue limits. Other tests measure flaw, damage and environmental tolerances. Therefore, testing and reliability physics are crucial to the development and design of the pump impeller.

Outlook for the material evaluation

Destructive testing of prototype parts during the material selection and processing is indispensable. Determining mechanical and corrosion properties and characterizing the microstructure can only be achieved with destructive testing. Sacrificing many representative coupons and a few full-size impellers is part of the evaluation process. The test results of the new material and the new process with hot isostatic pressing are encouraging. Numerous metallographic cross sections without pores or microscopic shrinkage cavities confirm the quality of the casting and the effectiveness of HIP. Interim tensile tests show a strength improvement factor of 1.4 over cast super-duplex stainless steel.

Thomas Kränzler explains: “A multitude of further tests are still in progress. Because the material is currently not listed in any international materials standard, we must perform a full-blown material characterization, which comprises in addition to the standard material tests, the above-mentioned ultra-high-cycle fatigue (UHCF) testing and the determination of crack propagation. Another topic is the evaluation of resistance to general and localized corrosion as well as the resistance to environmentally induced cracking. The new statistical approach helps us to minimize the number of tests and shorten the project duration. As soon as all data are analyzed and the engineers of the material testing team are sure that the selected material is fit for the intended service, all Sulzer design teams around the globe get a release notice that the material can be used. This development helps Sulzer stay ahead in the field of high-energy water injection and enables Sulzer engineers to be on the safe side when they specify the materials for new pumps, even in other applications.”
New welding material for repairing turbines

Steam turbines are used across the world as a source of power for many different industries. Even with the best preventative maintenance procedures and techniques, problems can still arise. Resolving one of the more serious issues, that of stress corrosion cracking, can often be achieved in a straightforward manner by accurately identifying the causes and taking the appropriate corrective action. Sulzer’s new weld repair using 12% chromium steel can give renovated rotors an extended life over the original material.

Older steam turbines are prone to stress corrosion cracking of the turbine blades, disks and other components. Understanding the causes and potential solutions can help to minimize downtime and improve reliability. Sulzer’s “forensic” engineers not only evaluate the nature of the cracks but also calculate stress levels for the damaged parts with finite element analysis (FEA). In some cases, Sulzer went a step ahead and used a new weld repair method to increase the lifetime of the refurbished turbines tremendously.

Inspection methods for cracks
The sixth stage disk of an integral steam turbine rotor of a customer in India developed cracks in the root sections of the blade attachments. The turbine has an operating speed of 9’000 rpm, and the steam inlet temperature is 400 °C (750 °F). The equipment had been well maintained, and the service history was available to the maintenance engineers.
Usually, the root section of steam turbine disks and blades is subject to particularly high mechanical load. In this case, a total of seven roots with cracks were identified using a magnetic particle inspection process. The next step was to determine the cause of the cracks, and in-depth evaluations were carried out. First, four cracks were opened mechanically, and the fracture surfaces were examined using a scanning electron microscope (SEM). The SEM examination showed evidence of intergranular cracking.

Analyzing the material composition
Chemical analysis and testing of the mechanical properties of the components involved in the failure is very important. Optical emission spectroscopy was used to identify that the rotor was made of the low-alloy steel grade ASTM A470 Grade C. The mechanical properties were also tested, and only the tensile strength was found to be out of specification; in fact, the tensile strength was higher than the maximum value specified. Typically, this can lead to increased susceptibility to corrosion.

Further investigations were carried out using energy dispersive spectroscopy (EDS) to determine the chemical composition of the deposits at the fracture surface (Fig. 3). In addition to the elements that the engineers expected to find in the base metal alloy, the EDS identified sodium, magnesium, tin and chlorine. The most likely source of these elements is the steam used in the turbine.
Structural analysis
The stresses at the crack locations were estimated using finite element analysis (FEA). This involved creating a 3D CAD model of the disk with the blades fitted (Fig. 4a). The FEA (Fig. 4b) assessed the stress values experienced by the disk and the blade at the operating speed of the turbine (Fig. 5). In this case, the equivalent stresses in the disk at the short blade root exceeded 689 MPa (100 ksi). However, the maximum stress value is 786 MPa (114 ksi), which is less than the measured yield strength of the material, 862 MPa (125 ksi). This provided further evidence that the stress did not cause the cracks due to yield, but rather, that the stress corrosion cracking was the primary cause of the failure.

![Fig. 4](image1.png) Finite element analysis of a blade identified maximum stress levels at the operating speed.

![Fig. 5](image2.png) Design analysis of blades.

Evaluating the root cause
For stress corrosion cracking to occur, three conditions must be present:
- The alloy must be susceptible to stress corrosion cracking (1)
- The stress intensity factor must be above the threshold value (2)
- A corrosive environment must be present (3)

In this case, the higher tensile strength levels made the disk alloy more susceptible to corrosion (1). The location of the high-stress region (2) within the disk corresponded perfectly with the crack initiation and propagation locations found during the magnetic particle inspection (MPI). Finally, the presence of chlorine at the fracture site indicated a corrosive environment (3), which led to the cause of the failure being confirmed as stress corrosion cracking.

Reducing stress corrosion cracking
To avoid stress corrosion cracking, it is necessary to remove or reduce at least one of the prerequisite conditions. Modern steam turbine components use the latest alloys as well as different blade root designs. In this case, redesigning the blade root to reduce the peak stress levels would not be feasible because the current bulb (ball) root design is very compact and does not allow for much improvement in the stress profile. Here, protective coatings applied to the surface of the disk can provide robust protection against corrosive elements attempting to attack the base material of the rotor.

Another feasible solution for the owner of the turbine is to address the presence of corrosive agents in the steam. Conducting a complete analysis of the steam being used in this machine would allow the chemicals to be identified and would indicate subsequent actions that could be taken to improve the quality of the water treatment at the plant.
Investigation team at work

Another customer in the United States had a similar failure in one of their steam turbines. Cracks in the turbine’s sixth stage disk root section were investigated using procedures similar to the ones described above. Again, the engineers of Sulzer’s “failure investigation team” executed the chemical, mechanical, fractographic and design analyses. Apart from some minor variations in the chemical composition of the rotor, the measured impact strength value (Charpy impact test) did not meet the specified requirement for the alloy, and it was considerably below the limits acceptable for the subject alloy when used in turbine rotor applications.

Further investigation using an SEM showed that the entire fracture surface exhibited intergranular structure. An assessment using optical microscopy of a polished section that also indicated branched cracking supported this finding. In addition, an EDS analysis found heavy oxide on the fracture surface. All these findings confirmed that the failure had been caused by stress corrosion cracking.

After a polished sample of the fracture surface had been chemically etched, it became clear that the microstructure was not fully tempered martensite. This finding, combined with the low impact strength values, indicated that the forging had not been properly heat-treated, and the combination of these factors may have accelerated the crack propagation in the disk (Fig. 6).

How Sulzer developed a new weld repair

Getting to the root cause of the failure of a steam turbine component can take considerable effort and may require a suite of technical evaluations. However, this time will pay off generously as the performance and reliability of the turbine will be improved. The findings from a failure analysis may also be useful, and can be applied for similar components of different turbines.

The following section discusses a new weld repair process that can mitigate the stress corrosion cracking in turbine rotors. Though this repair process was not applied in the two above-mentioned cases, it would have been applicable to the two rotors as well.

Driven by steam from the inside of the earth

Geothermal steam turbines work with steam that may contain very corrosive components. These components vary unpredictably because of the nature of the geothermal steam. In practice, very substantial damage can occur over time due to corrosion and erosion, which can cause the areas exposed to the steam to be “washed away.”
Sulzer’s new repair service

Original equipment manufacturers often propose replacing the rotors. However, the Rotating Equipment Services team saw a market opportunity to set itself apart by repairing the rotors by welding. Welding is less costly and can reduce the waiting time for clients. In this process, an area of damaged material is removed, and a large mass of weld material is deposited to restore it to the original form. After welding is completed, the part is machined to make the geometry of the renovated rotor identical to the original. This process can be much quicker than ordering a replacement part because the long lead time for new forgings can be avoided. Both the customer and Sulzer profit by employing weld repair processes.

Longer turbine lifetime with chromium

There was some concern within the Sulzer team about the weld material used at that time — a low-alloy weld wire for turbine rotor material, which is likely to suffer corrosion cracking when exposed to a hostile environment. The team eventually came up with the 12% chromium stainless steel (12Cr) weld wire option, which provides even better corrosion resistance than the original rotor materials in many cases.

The 12Cr weld has greater corrosion resistance than typical low-alloy steel rotor alloys. This means that, in some cases, the 12Cr weld can give the renovated rotor an improved life over the original material.

Applying a 12% chromium weld onto the various low-alloy rotor steel base materials is quite a difficult feat. Nevertheless, a welding process was developed successfully by the Sulzer engineering and operations teams (Fig. 7) and has already been implemented in the repair of rotors shipped to customers on-site.

The idea of using chromium in the welding process arose in 2013 when Sulzer in Indonesia received a geothermal steam turbine rotor repair project from a customer in the Philippines. The steam turbine showed cracks and stress corrosion. Our customer then requested improvements to avoid any recurrence in the future. The implementation of this new material for repair processes won the Sulzer Innovation Award in 2018.

Hepy Hanipa, Head of Turbo Services SEA, Purwakarta, Indonesia
Carbon products are used whenever other materials such as steel, aluminum, copper or plastic fail due to their limited material properties such as temperature and corrosion resistance. Launched in 2017, the MellaCarbon internals for separation columns allow customers to build higher-capacity plants which can be operated at lower cost.

Innovation is not limited to design changes. Customers can benefit tremendously when known parts are executed in a new material or composite. Sulzer Chemtech is a leader in providing internals for distillation separation columns. The column "internals" or "packings" are commonly made from metal, plastic or graphite.

MellaCarbon — the corrosion-resistant material

Sulzer has developed a new range of internals from corrosion-resistant carbon fiber composite (CFC) material for separation columns. Introduced in 2017 under the existing brand MellaCarbon, the new internals are as resistant as the known graphite internals, but they are lighter, stronger and stiffer. They withstand higher temperatures than any plastic material and cost less than special metals. An innovative connection system allows the easy production of larger diameters, enabling customers to build bigger columns with a much higher capacity.

Features of carbon and carbon fiber composites

Carbon fibers are obtained by the thermal decomposition of plastic fibers, which are first oxidized in air at 180 to 300 °C under tension. Heating the fibers under nitrogen to 1'600 °C produces amorphous carbon. Further heating up to 3'000 °C gives the fibers a crystalline structure. The individual carbon fibers have a diameter of 5 – 8 micrometers. At the same weight, the fiber strength is far superior to the strength of steel. The density of carbon is 1.8 g/cm³, while aluminum has a density of 2.7 g/cm³, and steel 7.8 g/cm³.

Further advantages of carbon are its good electrical and thermal conductivity. Carbon fiber composites (CFC) are widely used. In CFC production, the fibers are used as multifils (threads with several individual fibers), which are further processed into ribbons or fabrics. They are then impregnated with plastic monomers (epoxy resins, thermoplastics) and polymerized. The process results in lightweight, stable and molded products that are highly resistant to tension, bending and corrosion.
Cooperation with SGL

The new carbon-fiber-based internals family was jointly developed with the SGL Group. SGL is a market leader for the production of carbon and carbon composite materials. About 70% of the SGL Group staff is employed in Europe. The entire global research and development activities take place at the Technology and Innovation Center in Meitingen, Germany. The main headquarters is in Wiesbaden, Germany.

The key to the innovation is that the team was able to build on and improve a well-known Sulzer product. Sulzer provided the design, testing and installation knowledge. SGL provided the manufacturing know-how with the carbon fiber composite material and the first customers to purchase early prototypes. For over three years, the Sulzer team worked tirelessly with SGL to design and manufacture the first usable products made from the new material. This process involved rigorous testing in the Sulzer lab and test rig to understand how the material behaves. Fig. 1 shows the testing device for the flow measurement in Meitingen, Germany.

Advantages of the new material

The state-of-the-art carbon fiber composite material called SIGRABOND® provides an innovative and economical solution for Sulzer customers and their demanding applications. With the new design, the weight of the grids can be reduced by an incredible 90%, while the open area of redistribution can be increased by 60%. The design (Fig. 2) allows Sulzer to build column internals for customers with a diameter of over one meter that can be installed easily via a manway. The new carbon fiber composite material allowed SGL and Sulzer to expand into new markets and reach new customers with structured packing and internals. The team has submitted two patent applications so far to protect the manufacturing and functionality of the new development.

Ralph Spuller, SGL project manager for the cooperation project, Meitingen, Germany.

The SGL Group, a worldwide manufacturer of carbon-made products, was glad to expand its cooperation in the field of column internals based on SGL’s carbon fiber composite materials (CFC). The new column internals, introduced by Sulzer under the brand name MellaCarbon, are as corrosion-resistant as graphite liquid distributors used to date, but they are at the same time lighter, stronger, stiffer and more temperature-resistant than plastics. At the same time, they can be offered/produced at lower cost than special metals.
An innovative idea born in Sulzer’s kitchen

In one of the first meetings, it was not clear how much liquid would diffuse through walls made of carbon fiber composite material. So, the kitchen sink close to the meeting room was used as a testing device. The team, consisting of five people, filled a test trough with water and placed it on the table in the meeting room for the day.

By the end of the day, everyone in the meeting room was convinced of the material’s promising strengths because very little liquid got through the walls compared with the flow through the distributor. To convince the management of the capabilities of the carbon fiber composite material, the innovation team made a model distributor permanently available below the tap of the team’s kitchen to showcase the distribution effects. This was a long-term feasibility study.

Learning by cleaning

“I knew about the electrical conductivity of carbon fibers (Fig. 3), but it was just university knowledge. When I started my career as a development engineer, I was asked to run a test with carbon fibers and check how the stiff fibers behave on a warping creel. The test ran well, although some fibers split off during the test.

The next morning, my colleague started up the warping machine in the test center. A firework sound shook him and me awake. Electric arcs were visible. We wondered what on earth had happened! The split-off microfibers in the air had spread around the room, and some had landed on the electrical boards of the test machine. The conductivity of the fibers had led to short-circuits on the boards. Later, I learned that when using carbon fibers, the electrical cabinets should be operated under negative pressure to avoid the intrusion of the microfibers. It took a whole week to clean up the entire test center, and I promised myself to take adequate precautions if I ever worked with carbon fibers again.”

Nadia Qaud, Textile engineer and Editor-in-Chief of the Sulzer Technical Review, Winterthur, Switzerland.

From model to market launch

With SGL, Sulzer found a perfect partner with experience in this special area of material technology and with the required know-how to manufacture the carbon fiber composite products. Once the contractual basis was defined, the path was clear for an efficient cooperation between SGL’s materials experts and Sulzer’s engineering specialists.

Johannes Rauber, Senior Application Manager of Sulzer Chemtech, explains: “To make this kind of R&D partnership successful, open and dynamic communication between the teams and individual specialists of both companies was decisive. We already had many ideas for technical solutions, and after settling the cooperation contract, an open discussion developed that allowed us to overcome the biggest technical challenges quickly.”

This development, which won a Sulzer innovation award, helps customers to extend the lifetime of their column internals. The market success since the launch of MellaCarbon speaks for itself.
Easy insertion of bone substitute materials

Biomaterials and components used on or in the human body are called biocompatible and they should not provoke any adverse response. For dental implants, bone substitute materials made of synthetic, human or animal raw materials are used. Medmix now offers a special syringe solution made of biocompatible plastic that allows bone replacement material to be inserted intuitively, safely and hygienically into a bone defect.

Medmix Systems AG, based in Rotkreuz, Switzerland, is a leading provider of mixing and application systems for the global healthcare industry, developing and marketing unique, efficient and easy-to-use application solutions for biomaterials. Many renowned companies in the fields of orthopedics, oral surgery and tissue treatment have been working with Medmix for decades, and appreciate the state-of-the-art development process. Through the acquisition of Medmix, Sulzer’s Applicator Systems division has expanded its portfolio of dispensing and mixing solutions. Medmix’s products are mainly used in the medical and clinical fields.

Significant increase in dental implants
A dental implant is a component made of foreign material that is inserted into the jawbone. After a defective tooth is removed, these implants take over the function of an artificial tooth root, to which various tooth prostheses can be fixed. Dental prostheses include single teeth, bridges or crowns.
The implants are usually inserted into the jawbone with a screw thread. Before the implant is inserted into the jaw, a bone substitute material is inserted into the cavity intended for the implant. Over a period of 3 to 6 months, the implant grows together with the surrounding bone. Due to the incorporation of the implant into the bone (osseointegration), the implant is connected to the bone in an extremely load-bearing manner.

Dental syringe with bone substitute material
In June 2018, Medmix launched its dental syringe, which is designed to make it easier for dentists to handle bone substitute materials. With the syringe, the bone replacement material can be stored in a sterile manner until it is used, hydrogenated if needed, and later inserted into the jawbone. Dentists appreciate the simple handling of the syringe. Whether the bone replacement material is in the form of granulate or paste, both can be inserted precisely and reliably.

Ergonomic handling
The unique design of the syringe allows one-handed operation. The curved shape in the front part of the syringe gives the dentist a much better view of the bone defect to be treated. This ensures accurate placement of the bone substitute material.
The dental syringe is available in two configurations. One with a filter tip for the hydrogenation of granular bone replacement materials and the other with a simple sealing cap for bone substitute materials in paste form (Figs. 2 and 3).

**Fig. 2** Dental syringe with filter tip for granular bone substitute materials.

**Fig. 3** Dental syringe with simple sealing cap for bone substitute materials in paste form.

**Package and shell in one**

Dentists are not the only ones who appreciate efficient processes. It is also better for the patient if the procedure is completed as quickly as possible. Thanks to the analysis, observation skills and creativity of our development engineers, Medmix's new products can be used with fewer hand movements and make the dentists’ processes faster. Upon request, the Medmix dental syringe can be delivered with a blister shell, which can also be used by the dentist as a handling kit for the hydrogenation of granular bone substitute materials (Fig. 4).

**Fig. 4** Easy handling thanks to the integrated reservoir for blood, for example, for moistening the granular bone substitute material.

**Biocompatibility and sterility**

The syringes are manufactured and packaged in an environment that is low in particles and germs (clean room ISO 8). The selected plastics meet the requirements of the USP VI regulation (approval for pharmaceutical use) and are suitable for use on and in humans. Furthermore, the selected plastics allow sterilization using gamma rays without limiting the performance of the syringe.

**Dispensing systems for biomaterials**

Bone substitute materials and biomaterials and their appropriate handling are becoming increasingly important in the health sector. Absolute reliability and quality in production must be guaranteed to ensure the safety of both the dentist and the patient. Medmix is an ISO 13485:2016 certified company and an experienced partner in this field. Medmix’s customers receive support in the legal admission of products by providing the required product documentation.
The HST 30 is the newest addition to the HST™ line of high-speed turbocompressors. It offers more flow and pressure at a significantly higher efficiency than its predecessors. This translates into big energy savings by low-pressure air compression in water treatment and industrial processes.

Typical application areas for HST 30 are aeration of water, wastewater or other liquids, flotation by air, supplying air to combustion processes or desulfurization. To find out how to save energy and money with HST 30, please visit sulzer.com/hst30. Detailed research on compressors was done in cooperation with a Finnish university to achieve this energy reduction. To learn more about the research, read the Sulzer Whitepaper 5/2018.
Virtual reality showroom for column internals

A picture says more than a thousand words. A detailed 3D image creates even more clarity. That’s why Sulzer has developed the Sulzer VR Column Internals app as a virtual showroom for its column internals solutions.

Using only the app, without virtual reality glasses, you can move from display to display as in a live exhibit. Visit eight interactive product displays to get the latest information on Sulzer’s column internals range. Download the free app by clicking or scanning the QR codes for iOS or Android.

Sulzer’s electromechanical services expanded

Sulzer acquired Brithinee Electric, a leading independent electromechanical service provider in Colton, CA, United States. Last year, Brithinee recorded annual sales of about USD 10 million with a workforce of 46 employees.

Through this acquisition, Sulzer expands its electromechanical services business into Southern California and extends its ability to serve the Californian wind, cement and water markets with established offerings and customers. Founded in 1963, Brithinee offers electromechanical repair services, remanufacturing, redesign, upgrades, and modifications, as well as custom electric control panel systems.
Getting the vision of opinion leaders

Collecting market needs and developing new ideas is the basis for a market driven company. Sulzer Mixpac has an international network of dentists called opinion leaders, and has collected ideas from four regions around the globe to further develop and expand the portfolio.

In 2018, an international team of 20 dentists shared their knowledge with Sulzer, and being part of the process. They provided insights into a dentist’s needs and daily challenges. To emphasize the value of their input, Sulzer has created a Dental Competence Center. The dentists — each with different expertise and know-how — involved in this center hold lectures, conduct market analysis, or lead workshops at dental trade fairs.

International or local needs and trends?
To differentiate between global and regional needs or trends, the product managers at Sulzer Mixpac conduct international market analysis and make use of the input of all opinion leaders around the globe. In the last six months, Sulzer Mixpac has organized four events to meet opinion leaders in different regions: USA, Brazil, China and Europe. During these events, the dentists discussed key topics in their region and future trends of the dental industry. The successful events provided new ideas, which our product development team now transfers into new product concepts and future products.
Webinars and upcoming events
If you missed our webinar on “Challenges of Maintaining Rotating Equipment for Onshore and Offshore Platforms” you can find it online. Click [www.irdirect.com/templates/sulzer/20181004/followup.htm](http://www.irdirect.com/templates/sulzer/20181004/followup.htm) to see our webinar list and the recordings.

Click [www.ccj-online.com/sulzer-coatings-webinar/](http://www.ccj-online.com/sulzer-coatings-webinar/) to see the webinar “Keep Aging Gas Turbines Competitive with Coatings and Material Upgrades”.

Sulzer takes part in events, exhibitions and conferences around the globe. Please check our event calendar to stay informed. For more details please visit [www.sulzer.com/events](http://www.sulzer.com/events).

And the winner is …
Lee Manson who is currently working as an electrical design engineer at EDF Energy in Glasgow, UK — although employed by the recruitment company Rullion. He won our contest and will receive an Apple Watch Nike+ soon.

EDF Energy is an energy company in the UK, supplying around 5 million accounts with electricity or gas. They produce around one-fifth (20%) of the nation’s electricity. EDF Energy employs over 13’500 people across the UK — from Torness in Scotland right down to Exeter in Southern England. As the largest producer of low-carbon electricity by volume in Great Britain, EDF Energy believes in a decarbonized future and is committed to support the Paris Agreement on Climate Change.

News ticker
+++ Sulzer Mixpac continues successful enforcement of Candy Color™ trademarks. +++ Sulzer’s BLUE BOX™ IoT Advanced Analytics has won the Gold Certificate Industry 4.0 at the Swiss Digital Economy Awards in the category Highest Digital Quality. +++ Sulzer will be a distributor for Nidec Industrial Solutions. Nidec manufactures custom-made drives for industrial applications, mainly for the United States and Canada. +++