Ensuring product quality through customized material tests

Classification of materials

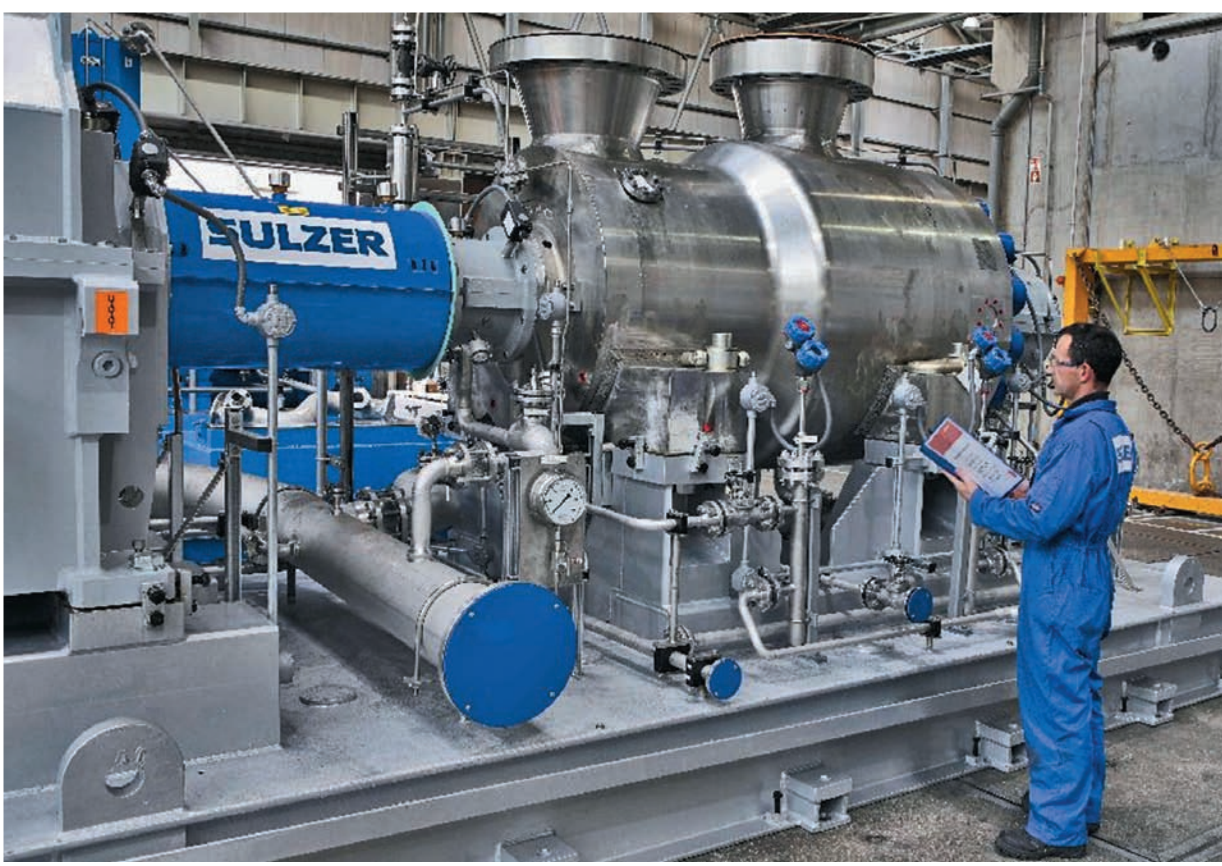
The exact wear behavior of a material cannot be predicted using only its simple physical and mechanical properties, such as hardness, modulus of elasticity, or tensile strength. Sulzer Innotec develops new testing methods that make the precise prediction of service life possible.

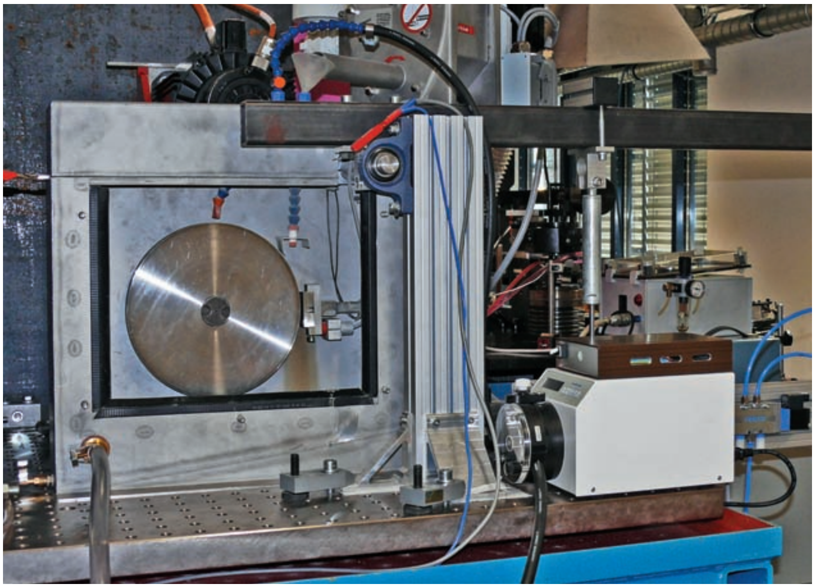
Sulzer Innotec has a wide range of different testing methods for the characterization of materials and coatings. In addition to standard tests, customized methods are increasingly being used to test materials under near-service conditions with a range of stresses close to the actual range that will be encountered in the application.

Materials as the key to success

Hydroabrasive wear and corrosion are significant factors in the lifetime of pump components. In many cases, the service life of a pump can be significantly extended through the selection of special materials and coatings 1. To make a determination, it is necessary to have detailed information about the corrosive and abrasive characteristics of the liquid being pumped and a thorough understanding of the behavior of the material under the respective conditions. For modern pump materials and coatings, however, this data often cannot be found either in open literature or in publicly accessible databases, but has to be determined in application-specific test methods. Since the

1 Sulzer builds the most powerful water injection pumps in the world. The pumps help optimize the pressure in oil fields over their full productive life cycle. Highly loaded parts of these pumps are coated for protection against corrosion, erosion, and cavitation.



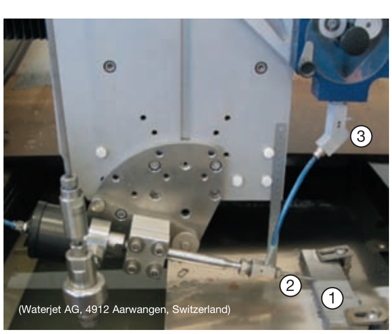


2 Block-on-ring test bench for testing slide friction wear and three-body abrasion.

correct choice of materials can substantially affect not only the technical performance, but also the commercial success of a pump, the generation of reliable materials data remains one of the central tasks of Sulzer Innotec today.

Sulzer Innotec works closely with the specialists from Sulzer Pumps and Sulzer Metco to select the materials and coatings to be tested as well as the tests to be performed. They determine whether these tests exist already, can be adapted from existing tests, or need to be developed from scratch. This approach has a long tradition at Sulzer. In the 1980s and 1990s, highly complex test benches such as SAPHYR, EROCOR, and TRIPAL were developed. These made a considerable contribution to the understanding of the wear processes in pumps and also to the development of extremely resistant protective coatings (SUMEPUMP™). Some of these facilities are still in use today.

3 Water jet erosion test equipment.



1 Material probe
2 High-pressure jet
3 Powder-dosing unit for abrasive material

Wide range of stresses

Unlike loads in many other applications in mechanical engineering, the conditions in pumps cannot be clearly defined in many cases. Instead of a single main load factor, a wide range of different loads arise that interact with one another to some extent, and, in the worst case, can even mutually reinforce each other. One example of this phenomenon is erosion-corrosion, in which either the erosive degradation of the protective oxide film brings about an increase in the corrosion or, on the other hand, increased wear results from the build-up of soft hydroxide coatings caused by the corrosion.

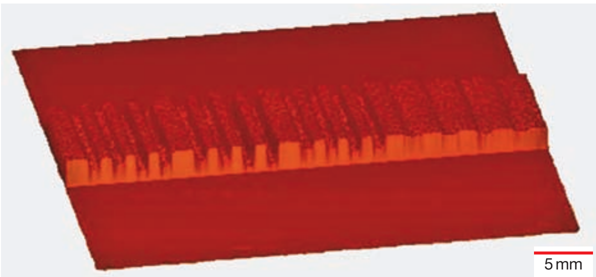
In general, it can be assumed that wear through abrasion, erosion-corrosion, and cavitation will increase with the flow speed, solid content, and corrosion potential of the pumped liquid. However, it is difficult to state specific limits for individual materials because wear during operation depends on additional factors, such as the size, shape, and hardness of the solid particles. In addition, the application range of pumps is very wide with regard to abrasive materials and concentrations, stretching from relatively clean river water in drinking water supply systems up to highly loaded slurries in the fertilizer industry. To further increase complexity, the wear mechanism is also decisively influenced by the structure and design of the pump.

For this reason, the best test bench is always the pump itself. Because wear tests at the customer's premises are only to be recommended in exceptional cases and the operation of pump test benches is cost- and time-intensive, various laboratory tests have been developed for evaluating the wear behavior of materials under defined conditions.

Wear tests

Because the wear behavior of a material cannot be predicted with the help of its simple physical and mechanical properties, such as hardness, modulus of elasticity, or tensile strength, it is necessary to carry out special wear tests.

These tests can be divided into two categories: phenomenological tests and application specific tests. The former are used to determine the basic wear behavior of a material under clearly defined loads, while the latter are designed for components and specific applications. The results of such component tests can often be directly utilized. The disadvantages here are the high costs and the low transferability of the results to other applications. The general rule is that the closer the test is to reality, the higher the costs will be. In addition to the investment costs



4 Three-dimensional pictures of erosion damage caused by water jet.

for the test bench and the operational costs, the manufacture of the often very complex test samples contributes significantly to the expense. Therefore, one of the main tasks in the definition of wear tests in industrial research is to find the right compromise between purely academic laboratory tests and extremely expensive component tests.

Test methods at Sulzer Innotec

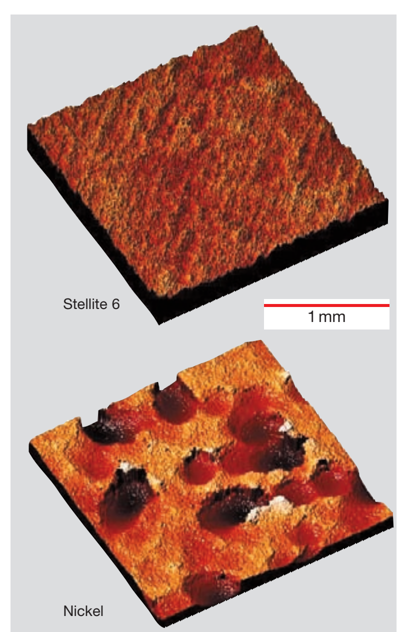
Sulzer Innotec places a very high value on the fact that the wear test method should lie as close as possible to the actual service conditions of the subsequent application, whilst at the same time allowing material screenings to be carried out on a wide range of different materials. As it is not possible to characterize the wear behavior of a material using a single test, the results of different tests are grouped together in a material fact sheet and are then weighted by the material specialists according to the relevant application.

A material fact sheet contains the purely material data, but also, information about the microstructure, hardness, and porosity of the material, as well as the results of the wear tests. Material characteristics are currently determined using the following test methods:

- Sliding abrasion: The two-body block-on-ring test 2 evaluates the wear behavior of friction pairings subject to sliding friction, for example, such as can arise between the shaft and the bushing when starting up or shutting down pumps. When carrying out the test, a test block is pressed against a rotating, water-cooled disk with a defined standard force, and the resulting frictional force is measured using strain gauges. The standard force is increased until a greater increase of the sliding friction indicates the transition to heavy wear.
- Abrasion: In the three-body block-on-ring test, in a similar manner to the one in previous test, a test block is pressed onto a rotating metal disk with a defined force, which, in this case, is also impacted by water-sand slurry. It is thereby possible to simulate realistically the so-called three-body wear caused by liquid containing sand in the narrow passages of the pump.
- Erosion: In the water jet erosion test 3, a finely focused high-pressure water jet containing abrasive material is directed over the material at different angles, and the wear volumes for each angle are then determined 4. The erosion behavior of the materials is then calculated from these values, which can vary strongly with the angle depending on the brittleness of the material.
- Cavitation: In the cavitation test 5, the material is subjected to high-frequency ultrasonic vibrations in a water bath. Thereby, very fine water vapor bubbles

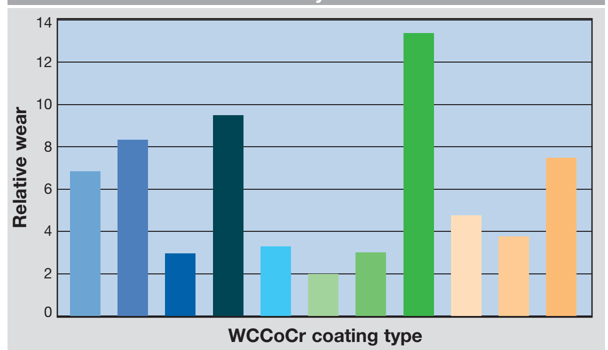
5 Cavitation test rig.

6 Clear differences can be seen in the surface structures of Stellite 6 and nickel after the cavitation test.



7 Oscillating test bench for the determination of adhesive and sliding abrasion under reversing conditions.

9 Results from the three-body wear test



Differences in the three-body wear of thermally sprayed protective coatings of the same metallurgical composition.

arise, whose implosion create shockwaves in the material; these, in turn, lead to a strong degradation of the surface. The determination of the wear volume and the change in surface roughness 6 allows conclusions to be drawn about the toughness of the material. Furthermore, areas of poor bonding at the interface between the substrate and the coating become visible.

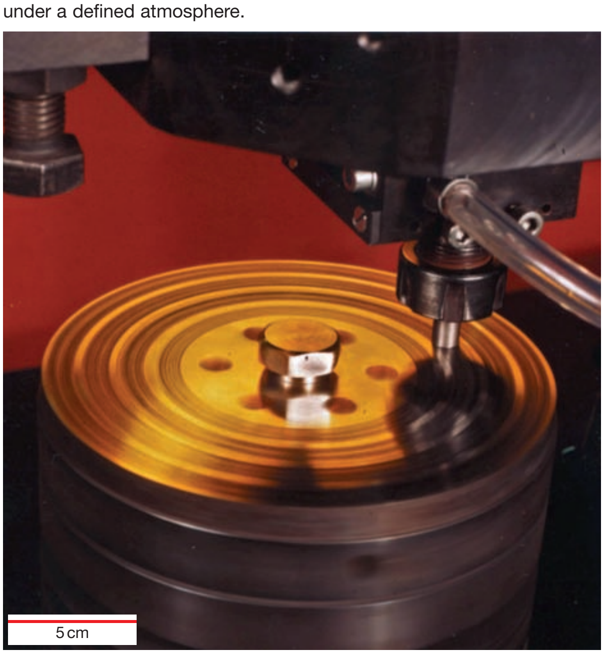
In addition, the corrosion behavior of the materials is tested, for which both aging tests and ultramodern electrochemical methods are used. Further tests are performed depending on the material and the area of application. Charpy impact tests are carried out on heat-treated components, while coated materials are routinely subjected to a thermal-shock test and a pull-off adhesion test, for which the coated sample is glued between two stamps and stressed in a tensile-testing machine until the test body fails at either the glued joint or the interface between the substrate and the coating.

Special applications occasionally require additional test methods, such as: HELI erosion (erosion through dry sand), fretting (wear due to micro-oscillation), two-body abrasion (wear of the test body against an abrasive belt), oscillating test bench (adhesive and sliding wear under reversing stresses 7, or various pin-disk test rigs 8 that can also be operated under defined corrosive atmosphere.

Expert systems for material data

The tests described above are well established at Sulzer, standard methods for both material development and for quality assurance, in particular, in the area of coatings 9 and they make an important contribution to the understanding of material behavior and wear processes in pumps. The midterm goal is to set up a database to combine the material data collected with the expertise and the experience of the pump engineers and to establish thereby an expert system that will permit even better service life predictions for new applications and materials in the future.

8 Pin-disk arrangement for the determination of sliding and static friction coefficients. Operation is possible both with lubricant and under a defined atmosphere.



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