

Water injection pumps for the oil industry

Pushing the boundaries of centrifugal pump design

In offshore oil production, high-pressure pumps are used to inject water into the reservoir to increase oil recovery. Sulzer has developed a new centrifugal pump for ultrahigh-pressure applications up to 1000 bar.

Crude oil is one of the most important primary fossil energy sources, and all of its products (fuels, plastics, chemicals, etc.) are basic requirements of modern life. Crude oil is located underground and must be extracted by drilling wells. The pressure in the oil reservoir is typically increased by injecting water (or other fluids) to force the crude oil to the surface. This method uses multistage centrifugal injection pumps and improves the overall recovery ratio. Because active oil reservoirs are most often found offshore in deepwater, the pressure requirements for pumps have increased significantly during the last several years. Such pressures can be provided by pumps located at the bottom

of the sea (subsea) or by equipment installed on a production platform (topside). Sulzer provides solutions for both applications. In the following, the topside pump developments are described.

1000 bar pump development

Sulzer started as early as 2009 with concept studies to develop an injection pump that delivered 800 bar (11 600 psi) of operating duty pressure. The outcome of these studies was presented to major oil and gas companies. In a second development step and based on client feedback, Sulzer pursued the same concept to develop a pump that provided 1000 bar (14 500 psi) of operating pressure in 2011. The main design approach

follows the well-established Sulzer HPcp pump line in back-to-back or opposed impeller arrangement to achieve an internal load balance (Fig. 1).

Pressure of 1000 bar can be expressed as a weight of about 1000 kg acting on each square centimeter of a pressurized area, or about 14 500 pounds per square inch. This means that exceptionally high loads stress the materials and components involved. Because the pumped medium is typically seawater, the materials need to be highly resistant to corrosion as well. It is only possible to use duplex stainless steels or low-alloy steels with applied weld overlays on all wetted surfaces. The high pressure classes require certain barrel case thicknesses to provide the

High-pressure water injection pumps improve the recovery ratio of deepwater oil wells.



needed mechanical strength. However, the design and the thickness of the barrel cases are limited by the applicable manufacturing methods.

Dealing with constraints

A pump which has a rated operating point of 1000 bar must withstand higher pressures (e.g. during shut-off). This raises the maximum allowable working pressure to 1320 bar (19 140 psi). In order to qualify the integrity of the case, factory pressure testing is even up to 1890 bar (27 400 psi). Since it is not possible to manufacture duplex material cases for such high pressures with the technologies currently available, Sulzer adapted the pump case design. The adapted case geometry is optimized for the local internal pressure, which increases through the pump.

For that reason, the pump design and the pressure test arrangement follow a three-pressure-chamber concept. The

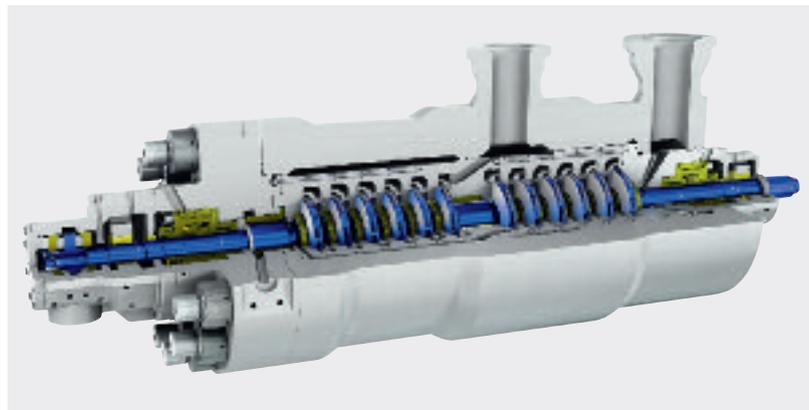
Sulzer investigated sealing solutions for extreme deepwater conditions.

design chosen accommodates not only the mechanical integrity during operation but also the available manufacturing methods for the components.

In addition, Sulzer has applied the latest design methods to ensure mechanical integrity. Pump case designs usually follow commonly available pressure vessel standards. In this project, Sulzer applied the latest editions of the two preferred standards to guarantee a validated design approach:

- ASME Boiler & Pressure Vessel Code (Section XIII) Division 2
- EN13445-3 Design-by-Analysis Method

These codes provide procedures to design and simulate such pressure cases with finite elements. The simulations can predict the mechanical behavior of a pump during pressure test, design, and operating conditions. The pump case structure, which is designed with modern 3D CAD tools, is divided into a finite number of small elements. Each element is assigned the properties of the steels used. When the pressures and external



1 The new 1000 bar pump is based on the established Sulzer HPCp pump line.
More information: www.sulzer.com/HPCp-pump

loads are applied to these elements, they deform the elements and create internal stresses. Generally, these stresses need to be within the elastic regions of the material throughout the entire pump. Certain material limits, which are also given by the referenced codes, are applied to validate the design against the simulated loads. Fig. 2 illustrates a

typical full-size simulation of a pressurized pressure case of a multistage centrifugal pump. These simulations verify all pressure-retaining components involved (such as bolting, nozzles, and cases). Highly loaded areas are identified and optimized to reduce local stress regions of the parts.

In addition to ensuring the mechanical integrity of the pump, Sulzer must confirm that the deformation of the parts remains within a certain limit. It is especially important to check the clearance between rotor and stator, which is reduced due to the high pressure at operation, to avoid a contact between the rotor and stator.

Furthermore, the static seals have to be tight. Therefore, Sulzer investigated the alternative static sealing solutions that are available and qualified in the oil and gas industry for such extreme conditions. Sulzer tested these seals on internal design test rigs to the highest pressures, simulating similar material deformations and confirming tightness. These tests established internal evaluation criteria for future designs.

Additionally, all standard design procedures of these engineered pumps were followed and checked against validated external and internal standards:

- Shaft stress analyses
- Impeller fatigue analysis
- Rotor-dynamic analyses
- General risk assessment and mitigation measures

With this innovation at the edge of modern pump design, Sulzer can now offer even better solutions to meet the challenging requirements of the oil and gas industry.

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2 Finite element analysis validates the mechanical behavior of the pump case.

