The hydrogen economy is complex. The methods of production are just as numerous as the possible applications. All processes require the use of compressors. Source: Shutterstock.com

Hydrogen: a vital building block for a green future

Angelina Stohp, Michael B. Schmitz, Alexander Maier

Hydrogen is the ideal fuel of the future thanks to its high energy density. Until it can be produced using electrolysers and green electricity on a large scale, thereby becoming „green“ itself, it will primarily be obtained using the steam reforming process. Compressors also play a crucial role in this form of hydrogen production. But producers have to overcome major challenges depending on the ambient conditions, as is shown by the example of a unit designed for use in Taiwan.

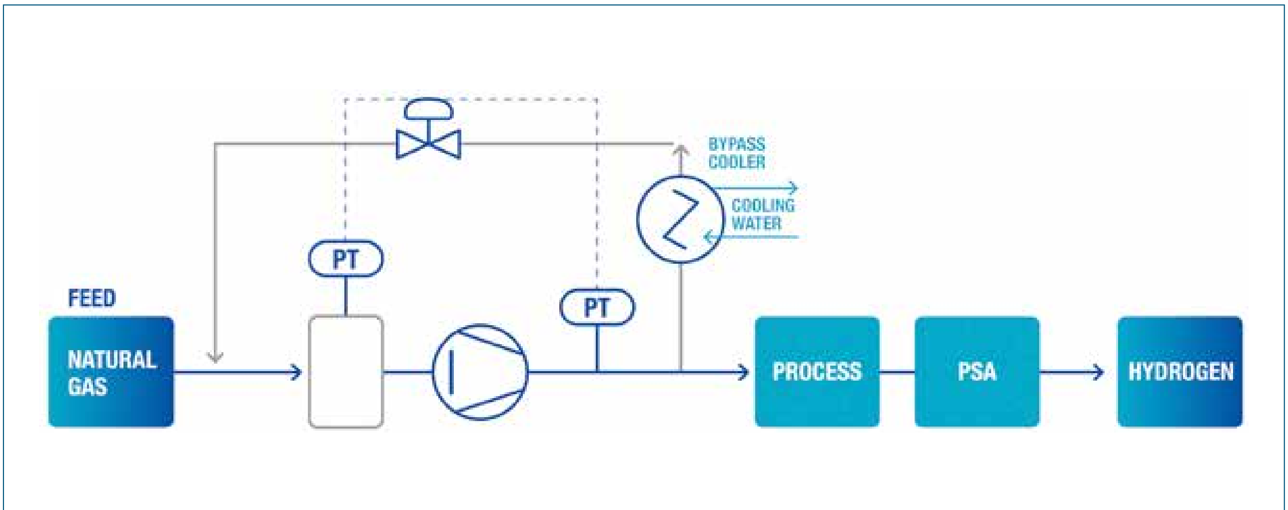
The most economical and therefore also the most common method of generating hydrogen used today is steam reforming of natural gas, LPG or naphtha. This process produces high-purity hydrogen, which is of great importance for many industrial sectors. Ninety-five percent of the world's hydrogen demands are covered by steam-reformed hydrogen. According to calculations of the International Energy Agency (IEA), 196 million tons of hydrogen are produced from natural gas every year. This is known as grey hydrogen and still currently dominates the industry because producing green hydrogen is presently more than twice as expensive as producing grey hydrogen. Green hydrogen is produced by electrolysis using only electricity from renewable energies. However, experts assume that the price of green hydrogen will at least halve by 2050 as a result of technological progress, mass production and falling electricity prices.

Compressor units play an important role in the production of hydrogen as well as in its subsequent use. With a growing hydrogen market, the demand for compressors is inevitably also on the rise. And their use in this process is certainly of great consequence. This is shown by the example of a large, new production facility in Taiwan that obtains hydrogen from natural gas using the steam reforming process.

One major challenge in this project is the environment, as the compressor is set up outside. In Taiwan, temperatures can rise to 40°C in summer and at times drop to almost 0°C in winter. The humidity is very high all year round due to the subtropical location. The humidity and extreme temperature fluctuations make it difficult to determine the correct paint specifications. Each individual component of the compressor that is in contact with the environment requires a specified coating thickness to ensure that it is permanently protected against corrosion and can withstand the temperatures that occur. The material from which the parts are made and the surface temperature reached are also significant factors.

Special local regulations and standards are further obstacles. For example, all motors installed in the compressor must be certified in advance by the Taiwanese Industrial Technology Research Institute (ITRI). This means that the ITRI has to declare individual approvals for these motors before they can be handed over for subsequent assembly.

A further important task is ensuring that the system is protected against explosion. The surroundings of this aggregate system were classified as explosion zone 2. We carried out risk assessments on this basis and in collaboration with the customer to identify any residual risks. We designed and evaluated the explosion protection of the compressor unit in accordance with the international explosion protection standard IECEx to mitigate any relevant hazards.



Source: Mehrer

Fig. 1: Simplified diagram of the hydrogen production process

Source: Mehrer

Fig. 2: Compressor unit on delivery

In a unit of this kind, the volume flow is controlled with the aid of a bypass. This means it is possible to return almost 0 to 100 percent of the delivery rate to the inlet of the compressor unit or, conversely, to regulate the delivery rate at the outlet of the compressor unit from almost 0 to 100 percent. This wide control range cannot be achieved using more energy-efficient speed control units because the compressor valves limit the dynamic performance. Alternatively, the two methods can be effectively combined, depending on the application. In this case, we chose the more robust bypass control method along with a constant-speed compressor.

Variables of the compressor unit

We derived the necessary technical properties of the compressor unit from the aforementioned environmental conditions and system requirements so that we could begin the development process.

The pressure ratio of $\prod_v = 2.3$ is low for reciprocating compressors, so single-stage compression was sufficient. We selected the compressor block and its speed to suit the required delivery rate.

Operating conditions and component selection

During compression, the compressed gas reaches a temperature of 121°C before it is passed on to the subsequent sections for further processing. The heated gas is cooled using water coolers. The gaseous water condenses and is removed in a separator. We generated a simple simulation using the DWSIM chemical process simulator to make an initial assessment of the operating behaviour. According to an initial estimate, a temperature of just 55°C produces around 0.7 kilograms of condensate per hour that must be removed.

Table of requirements

		Unit
Gas type	Steam saturated mixture according to specifications	Vol %
Gas suction pressure	8.8	bar (abs.)
Gas suction temperature	40	Celsius
Gas final pressure	20.2	bar (abs.)
Delivery rate	1850	Nm^3/h
Controllability	0.3–1.0	(/)

Source: Mehrer

Fig. 3: Table of requirements

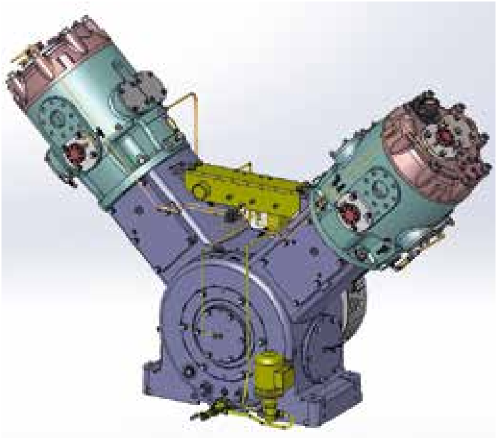


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Fig. 4: Single-stage V-type reciprocating compressor

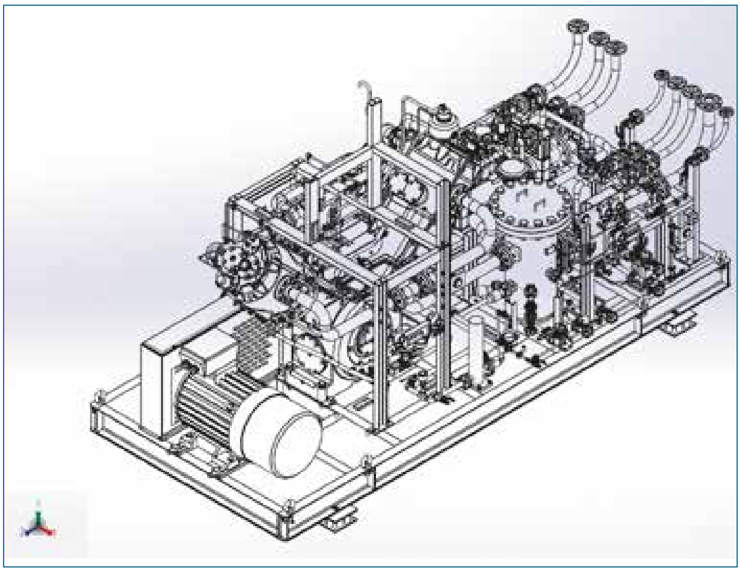
Based on these observations, we then created the process diagram (P&ID) and defined the required components and their properties.

In this step, we calculated the materials, pipe diameters, valve characteristics, cooling water volumes and control parameters and made initial estimates of the expected pressure pulsations and mechanical vibration properties. We defined control parameters for all operating points. The design also takes national and customer-specific standards and regulations into account. This makes the P&ID the central document for all technical and operational steps.

Hydrogen is an essential component of a sustainable energy future.

Compressor unit construction

Immediately after determining the essential components of the compressor unit, such as the inlet filter, compressor block, drive motor, cooler and separator, we arranged the components in the available installation space. For this compressor unit, it made sense to install all components on a single frame so that only the interfaces for gas, cooling water, control air, electric motor supply and sensors had to be connected in the final application.



Source: Mehrer

Fig. 5: 3D CAD model of the delivered unit

Digital twin

Drawings will soon be obsolete in the design process. Today, 3D models are increasingly taking over as the Single Source of Truth accessed by all other areas, such as purchasing, assembly and service. The goal is to create a digital twin whose digital master corresponds as exactly as possible to the machine being designed. The as-built status and the finalised parts list for the unit are recorded after assembly. This data set then forms the entire digital master representing the beginning of the machine's life cycle. Any further changes that occur during the life cycle are added to the data set. This means that the data set is always kept up to date with the system in question.

With a growing hydrogen market, the demand for compressors is also on the rise.

Validation and acceptance test

During the final acceptance test, the overall performance of the unit was tested mechanically and electrotechnically at various operating points. As a rule, the tests were carried out under reduced operating conditions, maintaining the correct speed and operating pressures but using air as the medium. For this purpose, we exchanged and replaced the compressor valves with corresponding test valves suitable for the molar mass of air. We compared the test results with our calculations to evaluate the performance of the unit. In addition to the thermodynamic performance tests, vibration measurements were made at representative points on the compressor unit. The vibration speed is used as the relevant variable for compressor units. To evaluate sound emissions, the acoustic power is calculated from the sound pressures measured at 10 defined points in space.

After passing the tests, the compressor was delivered to the customer in Taiwan. In the manufacturing process used at the Taiwanese site, the feed gas is taken in at a pressure of 8 bar and mixed with hydrogen. The compressor compresses the gas mixture to 20 bar and transfers it to a heat exchanger for desulfurisation. Bypass control of the volume flow was adapted on site to the actual conditions. We also verified that inerting (or flushing) mode was working correctly. In this mode, the entire unit is automatically flushed with nitrogen to prevent any flammable mixture from forming in the unit. This ensures that the entire unit can be switched on and off safely, for example during maintenance work.

Prospects

Today, hydrogen is an essential component of a sustainable energy future. Hydrogen technologies have advanced noticeably in recent years. So we can predict that steam reforming, which is still the predominant method used today, will be increasingly replaced by electrolysis hydrogen production.

With an increasing proportion of green hydrogen production, dry-compressing reciprocating compressors will continue to gain in importance. In particular, service life and leak-tightness requirements call for constantly improving technical solutions for a continuously growing market with ever greater unit sales. If hydrogen is generated directly, i.e. without the detour of steam reforming, the customer-specific project planning efforts described in this article will increasingly be replaced by standardised series solutions. Even then, compressors will play a central role: they compress the hydrogen after electrolysis to increase its energy density and save storage space for subsequent processes. For a green future with lower CO_2 emissions.

Authors:
Angelina Stohp,
Marketing & PR Manager
Michael B. Schmitz,
Head of Design & Project Engineering
Alexander Maier,
Project Leader Large Packages
Mehrer Compression GmbH,
Balingen, Germany