Photo: Fotolia / Anton Medvedkov

Oil-free compressed air is implemented e.g. in medical technology, in cosmetics manufacture and in the brewing industry.

Water injection – a secure process for oil-free compressed air

Implementation in medical technology, in cosmetics manufacture and in the brewing industry

Christian Rau

In many areas of industry, the compressed air quality required in manufacturing is increasingly that of class 1 as defined in DIN ISO 8573-1. Only by this means can it be ensured that the product does not come into contact with air containing oil and thus becomes contaminated. One method of producing compressed air securely and economically is water injection. This process is implemented e.g. in medical technology, in cosmetics manufacture and in the brewing industry.

Industry in Germany, and particularly the manufacturing and processing industries, can only secure major international market shares by producing outstanding products. A requirement for this is materials and processes of the highest quality. This also applies to the compressed air that is used during production. This energy source is being subjected to ever higher quality standards. Processes in, for example, medical applications, pharmaceuticals, cosmetics and the food industry are increasingly demanding oil-free compressed air.

The trend: generating compressed air without oil contact

In the past, oil-free compressed air was produced using oil injected compressor stages and subsequently passed through suitable filters. This method was elaborate and thus costly. Production processes today are increasingly sensitive – and their reliability must be maintained at a constantly high level. This increases demands on the means of production used. In recent years, there has been a notable tendency towards generating compressed air without any

oil contact. Meanwhile many manufacturers of high-value goods are specifying a compressed air quality of class 1 as per DIN ISO 8573-1 as an absolute requirement. This ensures that the product does not come into contact with air containing oil and thus become contaminated. Today, no manufacturer can afford production downtimes or the rejection of complete batches that arise, for example, owing to unsatisfactory maintenance of the compressed air system.

Where compressed air is generated using oil-injected screw compressors, the injected oil assumes three main functions. Doing without this medium is therefore not a simple matter. The first task of the oil is to cool the compressed air. This is because the compressing of the air and increased molecular friction result in a large quantity of heat that is conducted away via the oil. Secondly, the oil lubricates the moving metal parts and prevents damage to the surfaces. Finally, the oil forms a seal and prevents the compressed air flowing back into the zone in which the low-pressure air is present.

The alternative: water injection

The screw compressor is the compressor type most frequently employed in industry. Three possibilities exist for using this type to generate oil-free compressed air:

- Screw compressors with oil injection in the compression chamber, with downstream processing
- Screw compressors with a dry compression chamber
- Screw compressors with water injection in the compression chamber

The compressor systems for water and oil-injected screw compressors are based on similar-designs . They differ – to put it simply – only in the type of cooling medium, lubrication and sealing of the compressor stage. In the case of water-injected screw compressors, only water is introduced for cooling, sealing and lubrication within the compression process. This has significant advantages:

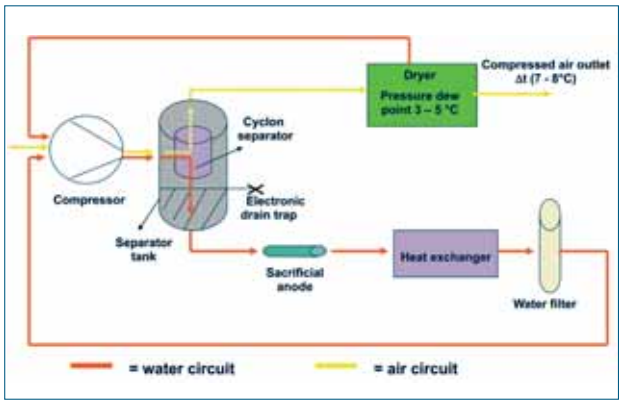
- Compared with oil, water has a larger capacity to remove heat and can be atomised more easily during injection. As a result, a low compression temperature of below +60° C can be achieved. This process comes very close to isothermal compression. It will thus also improve efficiency in the compression process significantly.
- No oil is present in the air circuit or in contact with the compressed air. The compressor therefore produces 100% oil-free compressed air immediately and without subsequent treatment – assuming that the intake air is oil-free to begin with.

In recent years, there has been a notable tendency towards generating compressed air without any oil contact.

- Water-injected screw compressors operate in single stages. This design allows the user to lower investment and service costs significantly. Additionally, these compressors require no synchronous transmission since the male rotor drives the female rotor directly.
- A compressor stage using water-injected screw compressors operates at four or five times lower speed than „dry-running“ compressors (3000–4000 rpm compared to 15,000–20,000 rpm). These low speeds contribute to longer bearing life and thus also to operational reliability.

Photos: ALMiG Kompressoren

Main components for water-injected compression:
Airend (1), speed controlled motor (2), integrated refrigerant dryer (3), water circulation (4), direct drive (5), frequency converter (6), microprocessor control (7)



Source: ALMiG Kompressoren

Scheme of the water- and air-circulation inside the LENTO

Water-injected screw compressors currently are available on the market up to an engin performance of approximately 100 kW. For very large quantities of compressed air, turbo compressors with a performance of approximately 300 kW and more are an efficient solution. The gap between water-injected screw compressors and turbo compressors is complemented by dry running screw compressors. The very high compression temperatures produced by this process make it necessary to run compression in two stages. This will be energetically more sensible than constructing ever larger water-injected screw compressors or yet smaller turbo compressors.

To develop an oil-free, water-injected screw compressor the corrosive and biological behaviour of the water has to be taken into account.

Design successfully implemented

To successfully implement this idea and develop an oil-free, water-injected screw compressor the corrosive and biological behaviour of the water has to be taken into account. All parts that come into contact with the water must be made of corrosion-proof materials. An internal water processing stage is also used.

The rotors of the compressor stage are made of a plastic compound and the housing is in an alloy of aluminium and bronze. These materials ensure long life and high performance. The maximum level of operational safety is assured by consistently separating the compression chamber from the storage tank. The bearings are greased and so enable a comparable compressor service life to that of an oil-injected screw compressor. The compression chamber is triply sealed to ensure absolute freedom from oil.

- Shaft seals on the rotor shafts prevent oil entering the compression chamber from the bearings.
- Mechanical, water-lubricated slip-ring seals provide additional isolation from grease.
- The lubricated bearing chamber is provided with vents. Excess grease can thus exit the chamber and not enter the compression chamber in the event of a natural drop in pressure. The maximum quantity of grease used is 12 g.

During installation the compressor is filled with ordinary tap water and from then on generates its own fresh water continuously. The compressed air is passed constantly through a built-in refrigerated air drier to remove moisture, which is returned as fresh water to the internal cooling circuit. This system has decisive advantages:

- No additional costs are incurred during operation for a cold water supply.
- The system can be operated independently of the availability of a water supply.
- The fresh water produced by the refrigerated air drier is free of calcium. No calcium can thus enter the system and compromise its operational reliability. To achieve the same effect using an external water supply, the water would have to be filtered.
- While the built-in refrigerated air drier was deployed primarily as the „water producer“, it also serves to cool the compressed air to a pressure dew point of 3 to 7° C. It is thus possible in many situations to do without an additional external refrigerated air drier. Should an external drier still be necessary, for example an adsorption drier, this can nevertheless be smaller and thus lower in cost as a result of the pre-dried intake air.

The system includes a large-area air/water heat exchanger together with slow-running fans. This re-cools the water after the compression

process and ensures a constantly optimal water temperature in the cooling circuit while also reducing the noise level. Because of the low compression end temperatures and the built-in refrigerated air drier, there is no need for an additional air/air heat exchanger for cooling the compressed air before it enters the air network, as would be the case for oil-injected compressors.

With water-injected screw compressors the processing of the water becomes particularly important. This is because water is active, both chemically and biologically. A multiple-stage security design prevents biological or chemical problems occurring in the first place:

- An integrated refrigerated air drier constantly produces more fresh water than is required by the process. Excess water is automatically passed to the water vessel and can be passed into the public waste water system without further processing. Because of the constant supply of process generated fresh water and the simultaneous removal of excess water from the cooling circuit, the water is constantly changed and its time idle in the system is minimised.
- An additional water filter cleans the water of suspended particles and solids.
- A sacrificial anode ensures that the metal parts carrying the water are not attacked by the water. This principle is widely recognised and trusted in many areas of technology.

Applications in sensitive production processes

For processes in medical technology, the pharma, cosmetics or comestible goods industry, oil-free compressed air is increasingly in demand.

Use in medical technology

For the fully automated production of measurement cuvettes and pipette tips, 95% of the

manufacturing area is subject to the clean-room technology criteria of GMP standard class 100,000. A manufacturing plant operating in three shifts will require compressed air in large quantities 24/7. This air can also come into contact with the end products. It must therefore be absolutely oil-free. This was previously achieved by compressing the air in speed-regulated oil-injected compressors and then processing it through micro filters and activated carbon filters. In the future, the additional processing of the air with activated carbon will be dispensed with, as medical technology demands quality and supply standards of a constantly high quality.

Use for cosmetics manufacture

The end products of the cosmetics industry come into contact with human skin. It follows that the highest product purity is required. The requirements for compressed air are therefore accordingly high:

- Maximum oil content: Class 1 (0.01 mg/m³)
- Pressure dew point: Class 5 (+7° C)
- Maximum residual particle content: Class 1 (particle size 0.1 µm, particle density 0.1 mg/m³)

Oilfree generation of compressed air inside a brewery: the LENTO with 55 kW driving power in air-cooled version

Despite the absolutely oil-free compression, the compressed air is passed through another activated carbon adsorber as a „policing filter“ before entering the air network. Here those oil particles are removed from the compressed air that may have entered the system through the inlet filter, for example from the exhaust systems of vehicles. Both compressors are connected to the process control systems of the building. In the event of a failure, a signal is immediately given at the reception area for further action to be taken. As the centrepiece of the compressed air supply, the screw compressors meet the clear specifications of this safety concept without problems.

The heart of the compressor: the airend made of corrosion-proof aluminium-bronze-alloy

Use in a brewery

In one of the strongest brewery groups in Germany, the management places highest priority on the quality and cleanliness of the compressed air, since this can come into contact with the beer. The product, made according to the centuries-old “Reinheitsgebot” (beer purity laws), stands for purity, quality and naturalness – a requirement that must also be assured through the process technology used.

At the Kulmbach brewery, the compressed air is used largely to control valves and as working air to power equipment. It is also used, however, to ventilate the gruit and for rinsing

tanks contaminated with carbonic acid. In these cases the compressed air is passed through an additional sterile filter to exclude any risk from contact with the end product. Additionally, in the winter months an adsorption drier is activated via the outdoor temperature in order to keep the overhead lines leading to the fermenting and storage cellars free of condensate and thus also ice-free even in extreme temperatures of down to -40° C. Decisive points for the choice of water-injected compressors were:

- The compressed air produced is cleaner than the fresh air drawn into the compressor, since foreign particles contained in the inlet air are effectively rinsed out by the cooling circuit water. This has been confirmed by several renowned and independent institutes in extensive series of tests. The water-injection process reduces the germs, bacteria and spores to a level below the limit of detection.
- Because of the low speeds and high quality materials, noise emissions compared to other technologies are low.

Thus also in the brewing industry water-injection compression has demonstrated itself as a secure and economical process for creating absolutely oil-free compressed air. In recent years, this procedure has matured into a process that can satisfy even the very high demands for compressed air in sensitive industries in terms of compressed air quality, safety and energy efficiency.

Author:
Christian Rau
Product Marketing
ALMiG Kompressoren GmbH, Köngen