Compressor technology in constant flux

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Compressor technology has seen constant development at least since the first industrial use of the steam engine approximately 300 years ago. In view of this time span, the question as to "quo vadis?" over the next few years seems to be a relative one. On the other hand, the driving force of applied research and development, the striving to reduce costs, has increased enormously, particularly in recent times. The global issues of energy efficiency and environmental protection are calling for new solutions, for which reason they are highly represented in the megatrends of compressor technology.

Increase in power densities

The increase in power density, or upgrading, is one example of this. In accordance with this, the theoretical mass flow of a displacer increases in proportion to the speed. At the same time, the negative effect of the existing gap decreases. Rotary displacers, with which the delivery rate is restricted decisively by gap flows, frequently exhibit as a result a disproportionately high increase in the delivery mass flow with speed. The attempts of manufacturers to increase speeds is therefore understandable. This trend is promoted by the development of HF motors.

Without the appropriate detailed engineering, however, this eagerness is soon harnessed for reasons of stability as the inertia forces of a compressor increase quadratically with the speed. Optimisation of all the moving parts in terms of weight and material is essential to push back the restricting limits. At the same time, the actual stress on the individual components must be determined numerically using modern FEM analysis methods and adjusted to the component-specific failure mechanisms.

Extension of the operating times

The basis for any operating time optimisation is a systematic weak point analysis. Building on this, a supporting coordinated status-oriented maintenance concept (ZOI) opens up the possibility of extending the operating times of compressors. Vital in this respect are monitoring systems which must be specifically tailored to the particular machine type. A number of additional measurable variables are already being integrated into these systems in addition to the process signals. The challenge for the future in this respect is analysis of the information, automated as far as possible, right through to providing a clear text message to the operator. At the same time, the ZOI requires a reliable forecast of the remaining wear reserve until the failure of the component in question.

Reduction in environmental impact

Approximately half of all compressors currently in use are screw compressors. The overwhelming majority of these machines (approximately 90 %) are oil-lubricated. Oil is injected into the working chamber of the compressors. Both the final temperature of the gas and the gap leakages in the machine can be minimised in this way. At the same time, the main rotor can activate the auxiliary rotor directly – i.e. with no other synchromesh gear required, which would otherwise be the case. However, the oil inserted must be separated from the gas again downstream of the machine. Depending on the quality of the separation process, it is generally the case that a residual amount of unwanted oil remains in the gas.

The tightening of environmental law as well as the process being subject to increased requirements have meant that manufacturers are experiencing increasing demand for dry-running compressors. Accordingly, the aim of future developments is to avoid having to use oil in the machines as far as possible. The screw compressors of the future will operate at high circumferential speeds (rpm) and will dispense with oil completely. Within the framework of various research projects, such a machine has already been developed and tested at TU Dortmund. It does not contain any synchromesh gears. The main rotor activates the auxiliary rotor directly, which for the first time is able to be dry running due to a novel rotor profile in association with a special rotor coating. Even at speeds of up to 30,000 rpm with an axial distance of 51 mm and a displacement volume of 286 cm^3 per main rotor rotation, this machine is breaking promising and environmentally-friendly new ground.

Another sensitive topic in the area of environmental protection is the avoidance of noise. Compressors cause non-steady-state flows, pulsations and vibrations, thus emitting media-borne, structure-borne and air-borne noise. The minimisation of these negative concomitant phenomena presents manufacturers and research institutions with unsolved questions time and time again. For example, while orifices were primarily used in the past for the attenuation of pulsations and acoustic pipe resonances, the requirement for energy efficiency is calling for alternatives. Options for the future in this respect are the minimisation of the flow irregularity, the optimisation of the fluid-structure interaction and the use of active attenuation systems.

Prospects from basic research – new fields of application

The basic understanding of non-steady-state effects also opens up new scope. For example, a profile in a non-steady-state flow can tolerate greater stress compared with the steady-state flow. As a result, flow machines in non-steady state can be subjected to greater stresses. Compressors can be charged with acoustic resonances. The result is an improvement of the delivery rate. The already mentioned understanding of the non-steady-state fluid-structure interaction offers further options from which more can be expected than only increased compressor efficiency. The interest of principle researchers in these topics is equally high. Industry can also see the potential and is investing in an appropriate infrastructure in the form of collaborations with universities and also in their own environment.

Oil-free, unsynchronised two-phase motor on a screw basis with media-lubricated bearings

Photo: TU Dortmund

Another market of the future will be the conversion of waste heat exergy into mechanical shaft power or electrical energy. Research in this respect is focusing on the economic design of small, decentralised systems. There are questions to be answered in the design of the cycles in terms of taking ecology into account (e.g. ORC or steam cycle) as well as the development of the expansion motor. An especially high exergetic exploitation of the waste heat can be expected from the use of a screw motor which – compared with turbines or reciprocating machines – permits expansion far into the wet steam area.

Even more fundamental basic research is looking at the use of waste heat using flash distillation in a two-phase motor (see photo), with which directly overheated pressure water is injected into an expansion motor where it becomes wet steam. In contrast to the conventional Clausius-Rankine processes, this is a wet steam process which no longer requires elaborate steam overheating. However, there is still some way to go before it is ready for the market. In particular, the non-steady-state filling of the working chamber in a double respect is the challenge for research. At the moment of injection, the overheated pressure water should vaporise as spontaneously as possible and at the same time completely fill the cyclically changing working chamber.

It is therefore the case that, in view of the aforementioned 300 years, anyone who expects compressor technology to be in a rather static state should think again. The current activities reveal very fundamental trends and developments which will continue to shape the ever-changing face of compressors in the future.

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