GoodVibrations

News from KÖTTER Consulting Engineers

KÖTTER CONSULTING ENGINEERS

OCTOBER 2016 MACHINE DYNAMICS – FLUID MECHANICS – PULSATION STUDIES – TECHNICAL ACOUSTICS

Excellent young talents.

This year, we are particularly happy about the awards for two young engineers from KÖTTER. Henning Ledendecker achieved an outstanding second place in the EFRC Student Workshop with his homework on the design and sizing of a reciprocating compressor.

Patrick Tetenborg, an employee of KÖTTER and doctoral student at the TU Dortmund, made second place with his lecture on an adaptive pulsation damping plate developed by him that he held at EFRC-Conference in Düsseldorf. Both prizes were awarded at that event on 15 September as well.

We will present the latest results from current measurements of the new damping plate to you on 26/27 October at our 20th reciprocating compressor workshop as well. For more information on that event, see page 6 ...

Yours, Dr.-Ing. Johann Lenz

Content

Buzzing noise of a heat exchanger.

Sometimes, unusual sounds such as individual sounds or humming in certain operating conditions occur in tube bundle heat exchangers even after years of operation without problems. This is often due to a combination of different phenomena, such as vortex shedding, acoustic transverse or longitudinal modes, fluid-dynamic instabilities, thermo-acoustic effects or turbulence excitations that are particularly relevant in fluids.
Additionally, the influence of possible structure resonances may take effect, which then leads to noise as well as recurring damage such as cracking of tubes or other leaks. Detailed analysis is needed in order to specifically find the „cause“. This is the case in the following project example as well:

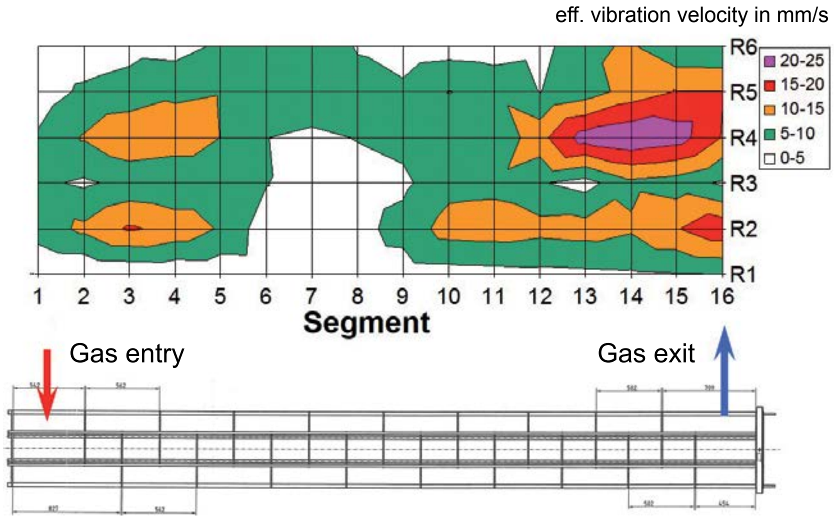

Fig. 1:
Measured vibration speed on the jacket surface of the heat exchanger

After conversion, an intense hum at a frequency of 245 Hz occurred on a lying heat exchanger. After the frequency had been found both in the air-borne sound and the jacket space downstream of the heat exchanger, a structure-born sound measurement of the jacket surface in operating condition subject to complaint was performed (see fig. 1).

Increased vibrations in the segments just before and at the gas outlet became evident. Comparison of the calculations to the vortex shedding frequency and the acoustic cross-modes that arise to the measuring results brought the decisive information regarding the cause-and-effect chain. The excitation takes place via vortex shedding at the tubes, which occurs in the area of the rear segments

Continued on page 2

KCE events 2016

- **Seminar Vibrations at Machines and Plants**
  25 October 2016
  Lecturer: Dipl.-Ing. Robert Missal
- **20th Workshop on Reciprocating Compressors**
  26 and 27 October 2016
  Specialist lectures – specialist exhibition – demonstrations – networking
- **Seminar Technical Acoustics**
  29 and 30 November 2016
  Lecturers: Dipl.-Ing. Robert Missal and Dipl.-Ing. Patrick Waning

More information and registration at:
www.koetter-consulting.com

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with an acoustic transverse mode and the natural structure frequency correlate (see fig. 2). Since the effective mechanisms are now known, targeted measures can be designed. In this case, installation of additional intermediate plates reduced the flow speed so that the "coincidence" between the excitation frequency and the acoustic natural frequencies no longer occurs and the system can be operated without the annoying single sound.

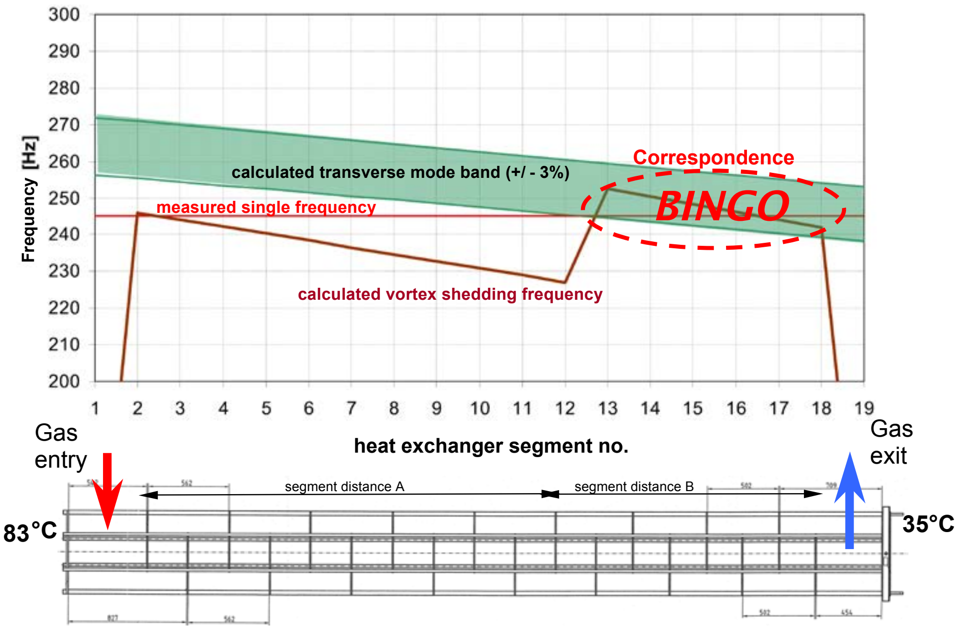
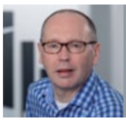


Fig. 2:
Comparison of calculation and measurement



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Modification and renewal of existing LDPE plants.

How can vibration-technical securing be successful if the data basis is unreliable?

The increase of capacity or the improvement of quality of LDPE (Low Density Polyethylenes) in existing production plants usually leads to larger conversion measures. The exchange of individual plant components, such as the inter- or aftercooler, once their service lives are reached can considerably impair vibration-technical behaviour of a plant. Changed pipe lengths lead to sudden high pipe vibrations, caused by pulsations inside the piping system. These are mostly caused by the plant's core, the high-pressure reciprocating compressors (hyper compressor), which compresses the ethylene at up to approx. 3000 bar.

Therefore, a theoretical pulsation study is usually performed in the scope of the planning work for vibration-technical securing in the scope of the planning work. This means that acoustic and structure-mechanical simulation is applied to calculate the expected pulsation and vibration situation for the conversion condition (revamp). Especially in older plants, however, there are often greater uncertainties regarding the input data that are needed for model formation, calculation of the study and evaluation of the results.

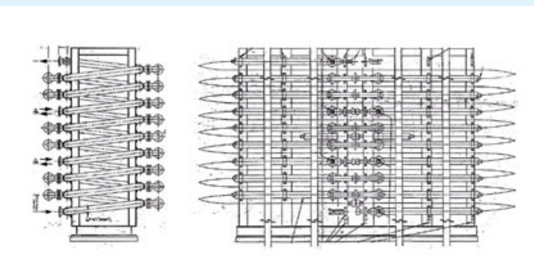

Fig. 1:
Schematic of the intercooler structure

Find a few examples of this below:

- Technical documentation for the compressors (primary and secondary compressor or hyper compressor)
- Sectional drawings of the cylinders and compressor valves
- „As built" condition of the piping system
- Contamination status (e.g. wax deposits) within the cylinders, pipes, etc.
- Which orifice plates are installed in which position?
- When operating several compressors in parallel: Does the phase of the crankshaft angle between the machines change?
- Is the pulsation level with a piping system in the current condition known, i.e. before the conversion?

There is a benefit of the legacy plants that you can use to close the knowledge gaps that become evident: They are already there. They are real! Therefore, it is possible to initially measure the real behaviour at operation of the system in the condition before conversion. The measured data can be used to adjust and reconcile the uncertain model and calculation parameters. This finally provides a reliable tool, i.e. a computer model that permits reliable forecasts for the vibration-technical behaviour for the converted condition of the plant. In particular, necessary acoustic (pulsations) or structure-mechanical measures can be included in the plans and developed at the same time.

OMA expands the KCE service range.

Resonances may cause inadmissibly high vibrations. In the planning phase or if there are any vibration problems, the natural frequencies therefore must be known precisely. For more precise and reliable determination of the natural frequencies – also under difficult conditions – KÖTTER Consulting Engineers (KCE) now also uses methods of Operational Modal Analysis (OMA).

Operational Modal Analysis (OMA) is a further development of the modal analysis. Natural frequencies, natural shapes and associated damping values of structures can be determined with both procedures. At experimental modal analysis, the structures are specifically excited with known (measured) excitations and the vibration response is measured. The ratio of response to excitation (transmission function) can be used to derive the required information. If the excitation is too small or not known due to external disturbances, modal analysis cannot be used. OMA is used in such cases. It was originally developed for very large structures such as buildings and bridges. Such structures usually do not technically permit targeted vibration excitation without any additional disturbances by, e.g., wind. These problems can be solved easily: only the vibration response is analysed and excitation takes place via the environment – or by the structure itself in operation. If the (unknown) excitation has certain properties, the response signal alone can be used to derive natural frequencies, natural shapes and dampenings. Current further developments and new algorithms now permit use of OMA in the areas of machines and plants as well, as the following project during measurement example of KCE shows quite impressively. In this project, OMA was used to examine increased vibrations in the coolant compression plant from figure 1. The examined plant comprised a fixed-speed asynchronous motor

Depending on the task, the pulsations in the piping system in the low pressure area (primary compressor) and in the high-pressure area (interim stage and end pressure of secondary compressor) are measured in a first step in the scope of measuring-technical examination. If the high-pressure lines do not contain the required pressure sensors, pulsation measurements can also take place indirectly via an application of strain gauges (DMS) coordinated by KÖTTER Consulting Engineers (KCE). The compression process of the hyper compressors (cylinder inner pressure of the secondary compressor) can also be recorded by DMS, e.g. at the expansion screws of the high-pressure cylinders.

The procedure recommended by KCE leads to six basic work steps (6-point approach):

1. Metrological registration of the current situation
2. Coordination of the model/parameter with the measurement results
3. Pulsation calculations
4. Structure-dynamic calculations
5. Review and design of reduction measures
6. Control measurement after recommissioning of the plant

This procedure has proven to be successful multiple times in the past already.

One example was an LDPE-plant in which frequent leaks occurred at the intercoolers of the hyper compressor water jackets. The operator observed some strong mechanical vibrations in some areas of the coolers. Excessive pulsations were suspected as the cause. Solutions for this problem were to be developed with a theoretical study. KCE was able to convince the operator to first carry out a metrological investigation of the situation on site.

One essential result of the measurements was that the noticeable cooler vibrations were not due to excessive pulsations in the area of the intercoolers, see fig. 2. Instead, local structural-mechanical resonances at the cooler were causing the damage to the water jackets. The critical resonances were essentially due to aging of the cooler structure. Therefore, possible solutions were revision of the existing cooler structure or complete exchange of the coolers. The operator finally decided to replace the intercoolers. For the new coolers, the pulsation-technical effects and the structure-dynamical properties for the entire cooler setup were reviewed in the scope of a study. Since recommissioning, the plant has been running without any vibration problems.

This example shows that a solution can be found, especially in existing plants, if individual properties and interrelations of every plant are uncovered in the first step of the described 6-point approach – carrying out a metrological registration of the situation on site.

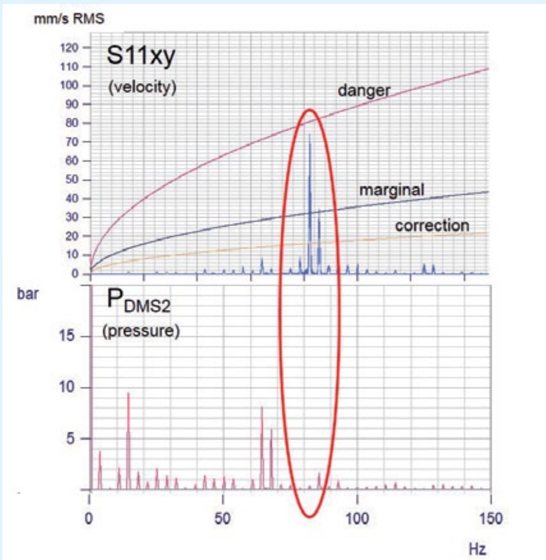

Fig. 2:
Frequency ranges of the measurements, above: Vibration speed at a position on the pipe of the intercooler,below: Pulsation (dynamic pressure) before exiting from the cooler

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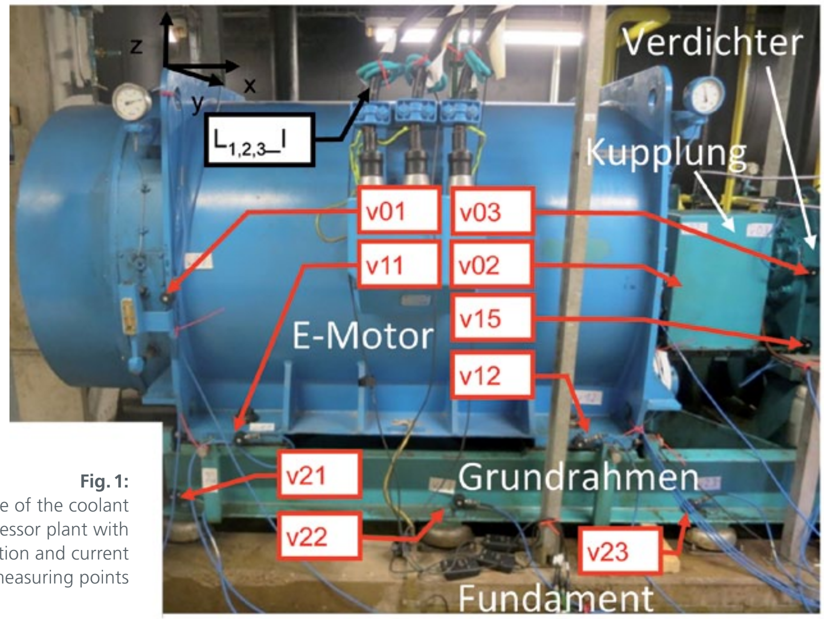

Fig. 1:
Drive of the coolant compressor plant with vibration and current measuring points

(6 kV, 50 Hz, 520 kW), coupling and screw-type compressor. These were set up with vibration insulation on a shared basic frame. The staff complained about increased vibrations in operation. The cause-effect mechanism for the noticeable vibrations was not known. Therefore, the customer charged KCE with an objective vibration-technical examination of the units and the substructure. As part of the examination, a natural frequency determination by impact tests with a modal hammer took place. These measurements were carried out with the plant standing still. However, the adjacent system of the same build was in operation in parallel.

Analysis of the impact tests showed that several natural frequencies of the plant were in the range up to 100 Hz. In particular the frequency range at approx. 50 Hz stood out. The data quality (coherence) was low, since the adjacent plant impaired the measurement in this frequency range, but the transmission function showed a clear peak in direct proximity of the 49.9 Hz rotation frequency of the plant. To determine whether this was a natural frequency, the recorded data were subjected to expanded analysis by OMA.

For the OMA, the data of all impact tests with different excitation positions and directions were combined. Use of reference sensors made it possible to assign the individual sensor data to the correct phases. In the next step, signal influences of interferences with harmonic excitation ranges (e.g. rotary frequencies of e-motors, grid disturbances) were removed from the data. Two different calculation algorithms were used for vibration: Enhanced Frequency Domain Decomposition (EFDD) and Curvefit Frequency Domain Decomposition (CFDD). The additional provisions of the natural modes make it possible to prove by the Modal Assurance Criterion (MAC) that the modes are linearly independent. Complete linear independence makes MAC = 0, which means a natural frequency.

Table 1 shows that the different calculation procedures only had small deviations in the determined natural frequencies. Additionally, the MAC values of the CFDD calculation are presented as examples. It becomes clear that all secondary diagonal values are near zero and that the modes are therefore all linearly independent. This makes the values of table 1 valid natural frequencies. The OMA results showed that the noticeable frequency at 49.8 Hz actual was a natural frequency of the structure that was in direct proximity to the rotation or main excitation frequency.

Figure 2 schematically shows the associated natural shape of the plant: an overlaid bend/torsion at the compressor-side basic frame.

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Mode	EFDD	CFDD	Natural shape
	Natural frequency in Hz		
1	2.1	2.1	Bend of the basic frame
2	3.5	3.5	Bend of the basic frame
3	7.8	7.8	Rigid mode, swinging
4	14.6	14.6	Vertical rigid body mode
5	25.4	25.4	Rigid mode, swinging
6	38.0	38.0	Torsion mode
7	49.9	49.8	Bend/torsion of the basic frame
8	79.1	79.1	Bend of the basic frame

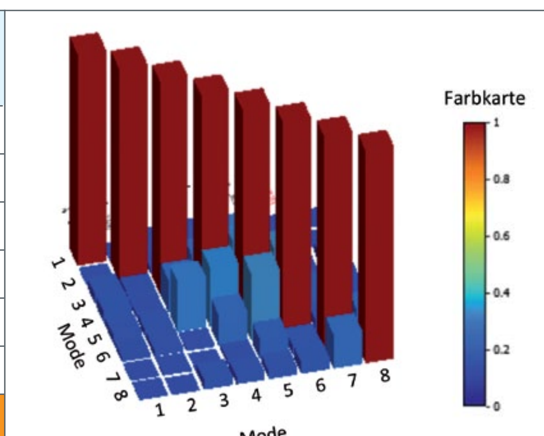

Table 1:
Natural frequencies of the plant and 3D illustration of the MAC matrix at the example of the CFDD results

Continued from page 4

In this example project, OMA permitted successful determination of natural frequencies in spite of detrimental measuring conditions, which made it possible to develop fitting reduction measures.

You cannot shut your system down? Adjacent units impair your vibrations? We will gladly develop solution approaches for your vibration problems as well. Call us or meet us at the 7th International Operational Modal Analysis Conference IOMAC 2017 in Ingolstadt.

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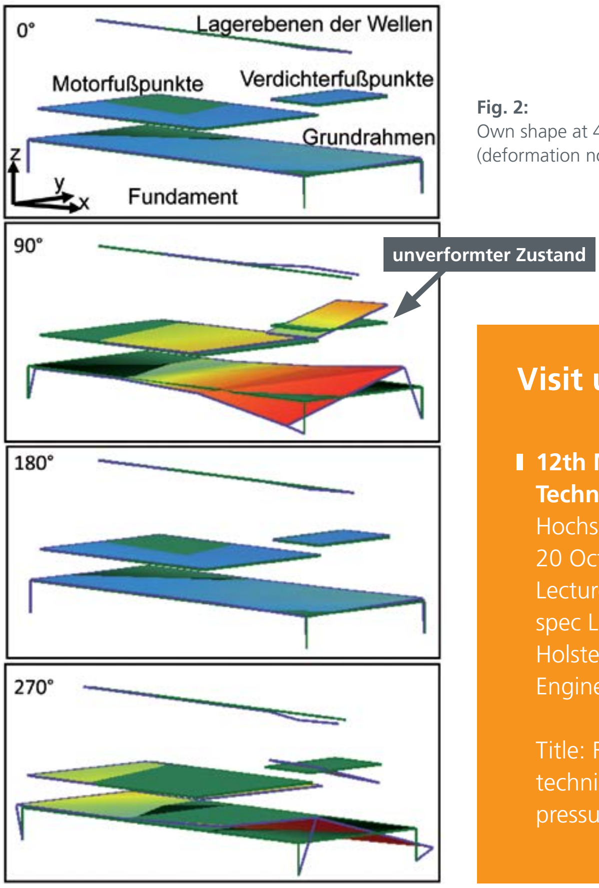


Fig. 2:
Own shape at 49.8 Hz as still images (deformation not to scale)

Visit us at the

- **12th Meeting for Technical Diagnostics**
  Hochschule Merseburg
  20 October 2016, 11:05 AM
  Lecture of Mirko Graf, Innospec Leuna GmbH and Joachim Holstein, KÖTTER Consulting Engineers Berlin GmbH

  Title: Removal of vibration-technical problems in a high-pressure polymerisation system

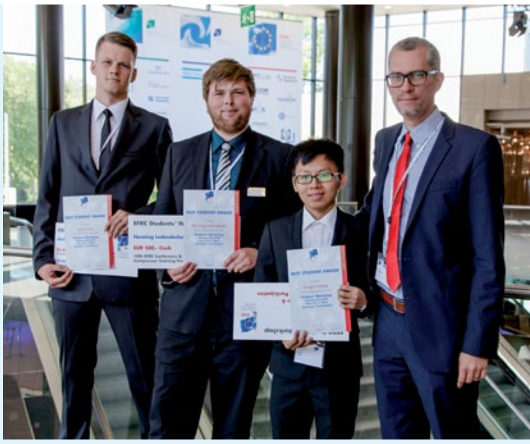
Henning Ledendecker receives award from EFRC.

The European Forum for Reciprocating Compressors (EFRC) offers a 4-day Student Workshop on the subject of reciprocating compressors every other year that students from European universities can apply for.

This year, 25 selected students from across Europe participated in the workshop. Among them our colleague Henning Ledendecker, who completed his dual course of studies as a mechanical engineer at the university of Osnabrück (site Lingen) in cooperation with KÖTTER Consulting Engineers (KCE) in Rheine. At the moment, he is working on his Master's studies in engineering at the TU Dortmund. He continues to work for KCE in the scope of various projects.

This year's Student Workshop comprised various lectures and company tours among manufacturers and operators of reciprocating compressors in Germany and in Switzerland. The final homework enabled all participants to prove their specialist knowledge: The task demanded design and dimensioning of a reciprocating compressor for specified framework conditions. The procedure had to be explained in addition to the calculations. Henning Ledendecker made an outstanding second place in this! The prizes were awarded at the 10th EFRC Conference in Düsseldorf on 15 September. It was attended by several hundred participants – all of them specialists from the reciprocating compressor industry.

Mr Ledendecker at KCE was able to intensely deal with reciprocating compressors. Avoiding or calming pulsation and vibration problems that are caused by piston compressors forms one of the focus points of our company.



We congratulate Henning Ledendecker (2nd from the left.) to his outstanding 2nd place

KÖTTER Consulting Engineers also is a member at EFRC, a European network of companies and organisations working in the area of reciprocating compressors. The members' target is to support operators, manufacturers and scientists by driving science exchange, work on standards and directives, research and technology in the area of reciprocating compressors. The Student Workshop is to introduce students to the reciprocating compressor industry and to raise their interest in working in that area at a later time.

Anniversary event:

20th workshop on reciprocating compressors.

On 26 and 27 October 2016, we invite to the 20th reciprocating compressor workshop in Rheine! The outstanding specialist lectures of selected lecturers from the last two decades have essentially contributed to the event's success. Today, it is the most important German-speaking conference on the subject of reciprocating compressors. The exchange of experience between manufacturers and operators or between industry, economy and science are still at the focus.

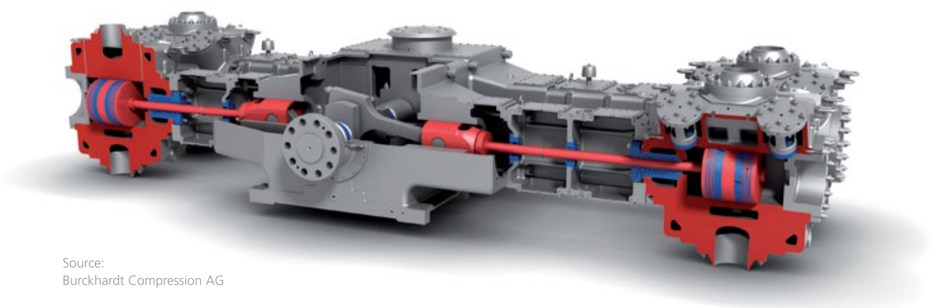
The lectures are, among others, about technical innovations, field experience with reciprocating compressors or options of monitoring. Economic and legal challenges are dealt with as well, however.

The audience particularly loves the experiments on sound and vibration technology that are presented in the breaks. A supporting technical exhibition offers further options for learning about current developments.

In addition to participants from the German-speaking area, visitors from other European countries such as the Czech Republic, Italy, Denmark, the Netherlands, Belgium, etc. also often join us in Rheine. The traditional workshop evening event that will be held in a rustic ambiance of the "Hausbrauerei Isendorf" in Emsdetten this year will once again find its highlight in the appearance of a surprise guest.

The workshop will be preceded by the day seminar „Vibration in Machinery and Plants: recording – assessment – restoration" managed by Dipl.-Ing. Robert Missal, KÖTTER Consulting Engineers, on 25 October.

All information on the event and the current lecture range can be found on our website under www.koetter-consulting.com.



Source:
Burckhardt Compression AG

For more information on us and other interesting projects, see online at www.koetter-consulting.com

Get-Together-Days 2016.

KÖTTER group keeps growing closer. A new corporate design and a new website.

In the scope of various changes, all members of the sites of Rheine and Berlin met for mutual exchange in Rheine for the first „Get-Together-Days 2016".

The close cooperation between the two affiliated companies in Rheine and Berlin and the international alignment of KÖTTER group was reflected in the company name's change from KÖTTER Beratende Ingenieure Berlin GmbH to KÖTTER Consulting Engineers Berlin GmbH.

Additionally, a new, shared corporate design was introduced that will present THE BIG PICTURE to the outside from now on.

This is also the background for the planned relaunch of a shared website. We will tell you as soon as the new website is online!

The closer networking between the sites enables our customers to profit from our know-how and experience even more strongly.
Your usual contacts continue to be available to answer any questions on sound and vibration engineering.

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