KÖTTER CONSULTING ENGINEERS

MACHINE DYNAMICS

Minus 170° C ... and it works!

For the production of carbon monoxide in a new plant an industrial enterprise uses a multi-stage centrifugal pump with submersible motor (with vertical shaft) for the methane wash of the CO-product to obtain the liquid methane at approx. -170°C. After commissioning of the plant, multiple damages occurred at the bearings of the centrifugal pumps (machine down-time: approx. 6 weeks) so that the operator switched over to pumps of another manufacturer with radial plain bearings for the fluid and oil lubricated axial bearings for the non-fluid.

However, after one week of operation, a first damage appeared together with noise development. The machine was reviewed and taken into operation again. After a short time, the pump lost again its pumping power so that it had to be removed from operation again. The operator assumed that rotordynamic effects caused the breakdown of the centrifugal pump.

The vibration and rotordynamic situation during pump operation should be evaluated after re-commissioning. KCE was asked to work out a concept and to carry out an investigation. The concept based on the following three steps:

1. Selection of appropriate sensors for low temperature applications
2. Metrological definition of a reference state for centrifugal pumps under test-bench conditions
3. Control of the machine during re-commissioning with fluid methane at -170°C

In a first step, after selecting appropriate sensors, the velocity sensors and their necessary encapsulation were checked in the laboratory on their suitability by using liquid nitrogen.

To estimate the basic vibration situation during operation of the centrifugal pumps and to determine a reference state, measurements at a test-bench of the manufacturer during operation with water were carried out in a second step. Here, also the relevant structural-mechanical natural frequencies of the centrifugal pump were determined.

During re-commissioning the measured vibrations showed a normal vibration behavior after start. At that point of time, the quality of the measurement signals was comparable with that at the test-bench. After approx. 15 hours of operation, together with the beginning of a loss in pump power - and therewith a new damage – a subsynchronous rotational frequency component could be determined in the vibration signals. This component mainly appeared at the measuring level at the inducer of the hydraulic unit. When the broadband vibration level increased, the first mechanical bending natural frequency of the hydraulic unit was excited as well. In total, the guideline values were significantly exceeded at the measuring points at the hydraulic unit within the pump can. However, the vibration level kept the guideline values at the measuring points outside the pump can.

The measured values confirmed that primarily an arising rotor instability was responsible for the damage. A decentering effect of the forces in the bearing and/or sealing gap led to a destabilisation of the rotor and therefore to vibrations which appeared as subsynchronous rotational components in the signals. As reduction measures KCE recommended the following modifications:

a) Increasing the load capacity of the radial bearings
b) Reducing the peripheral speed of the fluid within the sealing gap
c) Reviewing the design of the inducer, possibly working without inducer

When the manufacturer reviewed the centrifugal pump, especially the load capacity of the slide bearings at the beginning of the hydraulic unit was improved and for this application the centrifugal pump could work without inducer.

Now, the centrifugal pump works without any problems despite of -170°C!The case study described is a good example that increased vibrations can also occur in an untypical form of appearance, depending on the individual situation. The example makes clear how important it is for the analysis of the situation on-site to consider all appearances and possible causes. Thus, costly delays during the commissioning process can be avoided.

Last preparations of the sensors at the centrifugal pump before re-commissioning

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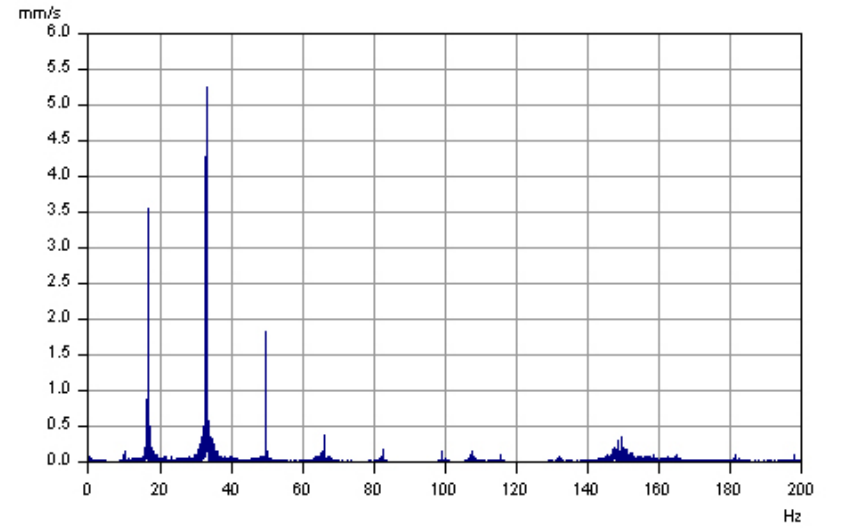

Frequency spectrum of vibration velocity after approx. 15 hours of operation – measuring position at the entrance of the hydraulic unit

Installation of the centrifugal pump for a test run at the test-bench

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