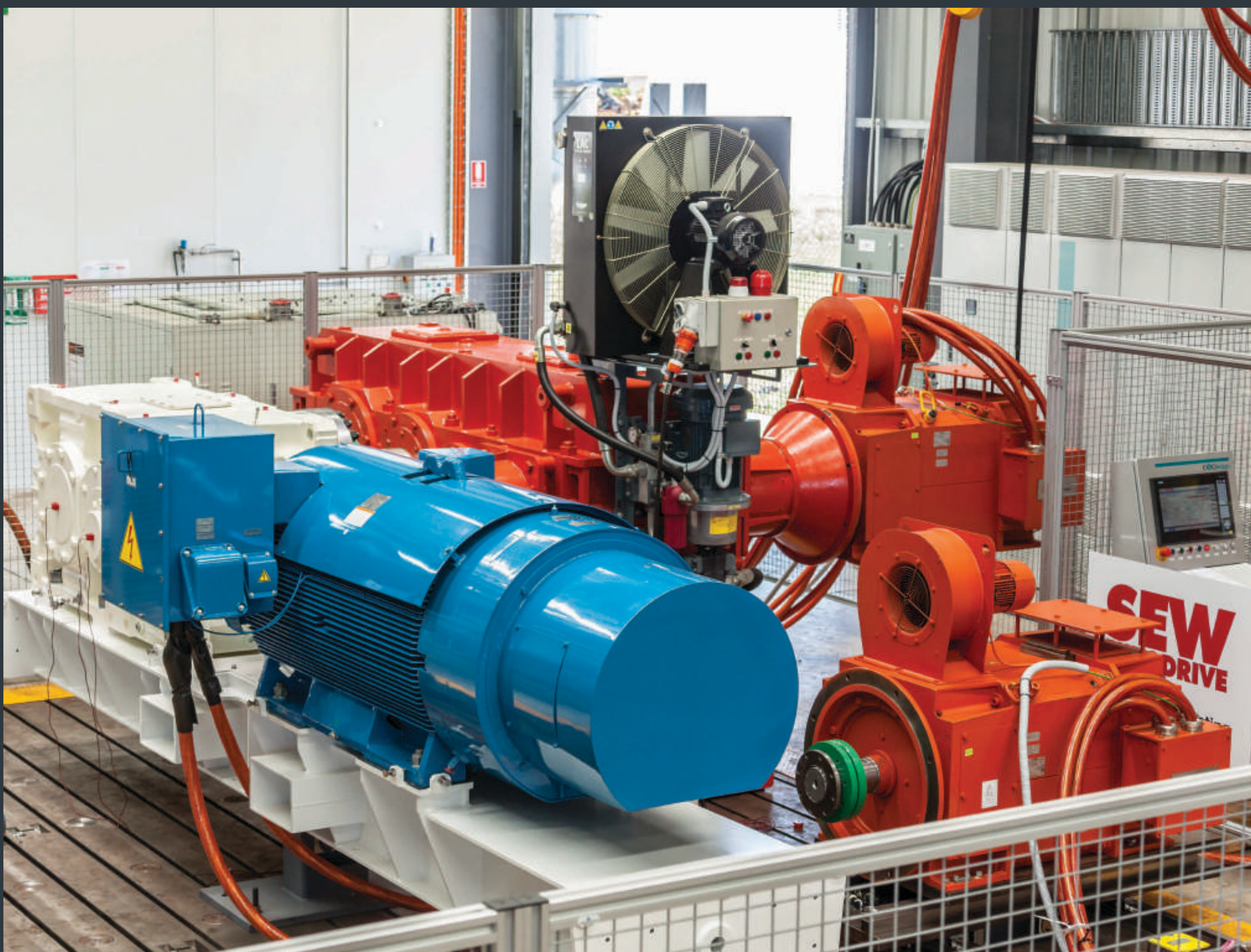
SEW EURODRIVE

Take a load off your mind



Gear units will naturally suffer wear-and-tear over time, and will require refurbishment at some time in their lifecycle. Ignoring gearbox issues can result in some serious unwanted outcomes, such as:

- Unscheduled downtime due to gear unit failure
- Excessive ongoing maintenance and short-term fixes
- Higher energy usage due to a decrease in gear unit efficiency

A gearbox overhaul can be an expensive exercise, especially when shutdown, removal and transportation costs are considered on top of the overhaul itself, so getting it right the first time is important.

In many cases, because the gear unit will have been replaced with a spare, the refurbished unit may be placed in storage and not put into production for an extended period of time. The last thing the gearbox owner wants is to place a refurbished gear unit back into production and then find it is not up to the job. If there has been a long period of time between the overhaul and installation, it would be unfortunate to discover the unit has a defect that may lead to premature failure, when there had been plenty of time to fix the problem – especially since the installation generally occurs when it is critically needed.

Load testing before delivery back to site is critical to avoid unnecessary costs in the future. If a defect is identified during a load test it is generally relatively inexpensive to rectify the fault before delivery.

Local service for Queensland industry

Until recently there has not been a load testing facility in Queensland that can handle the load testing of large industrial gear units. Queensland industrial sites in the sugar and mining industries, and ports such as those at Mackay, Abbot Point and Gladstone, had no choice but to ship the units interstate – or to settle for refurbished drives that have not been load tested.

Now SEW-EURODRIVE has opened a state-of-the-art load testing facility at its plant in

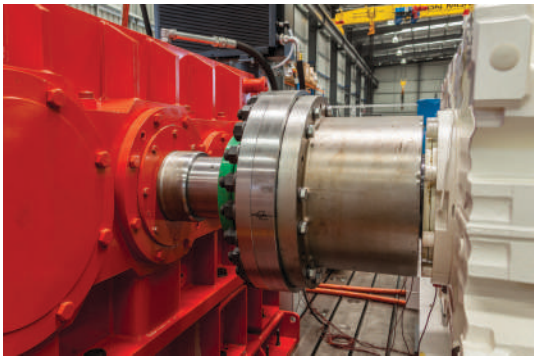


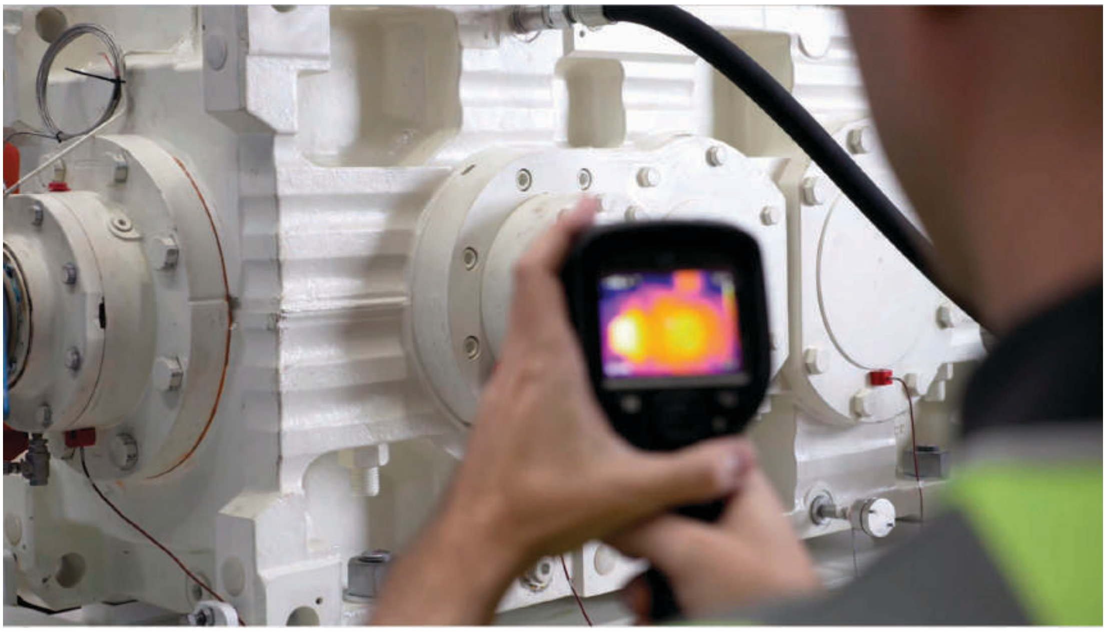
Figure 1

The GEARtest facility at SEW-EURODRIVE in Mackay.

Mackay, providing a load testing service for Queensland.

Capabilities

The load testing facility – the first of its kind in Queensland – has been built in collaboration with the Melbourne-based CNC Design, a specialist in large machine automation systems. CNC Design has extensive experience in load testers for both industrial and wind turbine gear units in Australia and USA.The facility is capable of load testing up to a power level of 500 kW and 600 kNm of torque. Simpler spin testing and partial load testing up to 1.5 MW are also available. In addition to load testing gear units, in most cases SEW-EURODRIVE will be able to load test the entire gearbox, motor and swing-base assembly. This can be done as a shaft-mounted assembly that closely replicates site mounting. Motors up to 6.6 kV can also be load tested. GEARTest, as it is known, is a back-to-back setup to test the gear units up to 100% full load with minimum energy consumption. The drive motor is connected to the gearbox undergoing the test, and the output shaft of the gearbox is in turn connected to a special-purpose



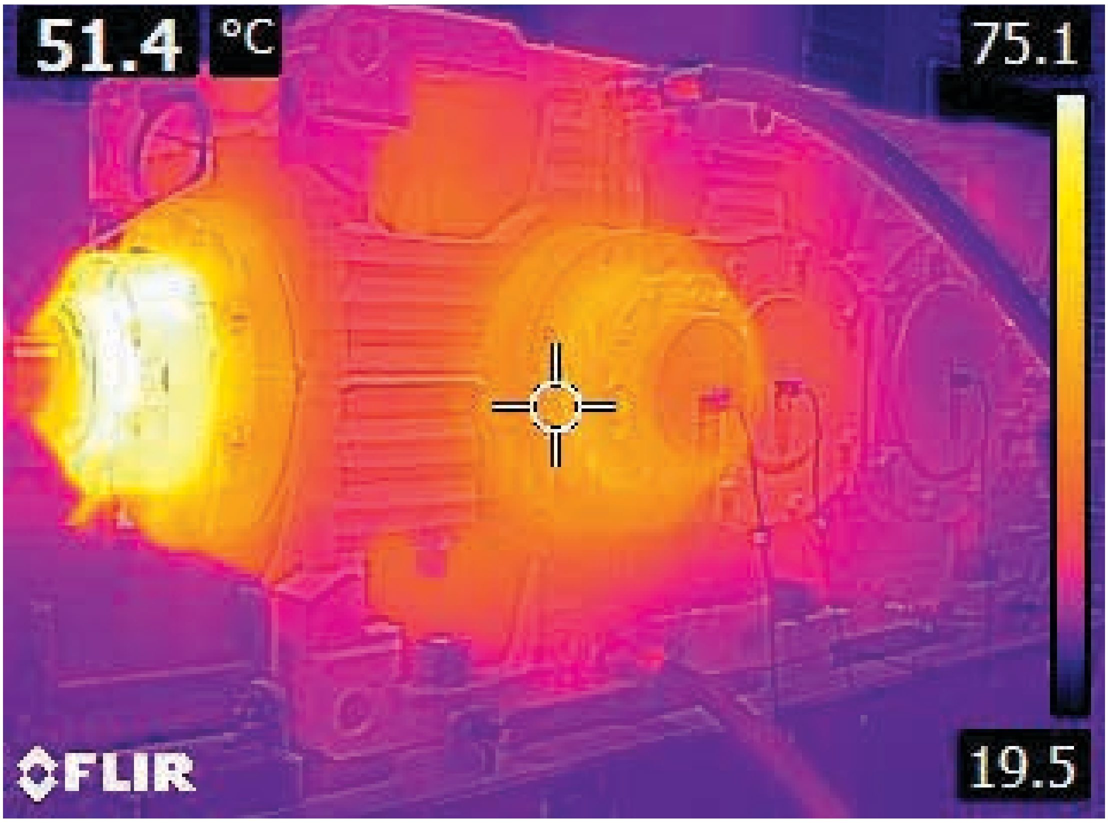


Figure 2

Thermal image of a gearbox under test

SEW-EURODRIVE speed-matching test gearbox unit, itself driving another motor acting as a generator. The test rig is controlled by an advanced motion control system, so the load cases and test sequences are flexible and can be adjusted to the specific test plan for each gear system.

Method of analysis

The system uses a Fast Fourier Transform (FFT) Spectrum analysis of vibration to identify any potential bearing, gear, or shaft defects. The load test loads the bearings and gearing in such a way as to avoid gear mesh backlash that can cause errors in the vibration analysis. The analysis of the vibration readings and the subsequent reporting is always conducted by an independent third party company. The test protocol will take the gearbox through various tests (with loaded gear teeth) that will detect potential misalignment, including misalignment caused by load, speed or temperature, while temperature logging as well as thermal imaging are used to evaluate gearbox thermal performance. Noise levels can also be checked for compliance with noise requirements.

Benefits

Generally, most gearbox repairers only spin test the overhauled gearboxes and most potential problems will only be revealed after the unit is back in operation. By providing a load test, SEW-EURODRIVE can provide reassurance that the overhauled gear unit (or drive train) is fit for its intended purpose, since the test will more closely replicate site conditions. In addition, some of the testing performed at the SEW-EURODRIVE Mackay testing facility, such as thermal tests, cannot be done on site, since thermal cameras often cannot be taken underground at a mine site, for example. Maintenance and service personnel are able to visit the facility to witness the load test phase, ensuring complete transparency.

A controlled environment enhances flaw detection

A load test provides a controlled environment in which vibration frequencies of interest can be elevated and captured. To elevate frequencies the active profile of the tooth is loaded, eliminating clearances such as those induced by backlash and end float, and the frequency response of all rotating elements during motion is measured. Gear mesh frequencies (GMF) and bearing defect frequencies are a primary focus when reviewing vibration spectra noting they are all separable and identifiable within the signal as they are all represented by a specific frequency. Loading the tooth flank also transfers force through the shaft to all other rotating elements such as shafts, keys, bearings, etc. enabling small surface abnormalities and defects to be detected and their impact measured. Defects that are often identified during load testing are difficult (and often impossible) to observe via no-load spin testing, as the parts are not stressed and defect frequencies are often lost in noise. Most of the defects that can be detected this way cannot be observed by the naked eye but have the potential to develop over time, leading to premature failure and unplanned stoppages. Load testing helps to mitigate risk, providing the customer with reassurance that the equipment is fit-for-purpose and ready for redeployment into service.

Visual inspection

Another part of the testing regime at the SEW-EURODRIVE test facility is a visual inspection of the gear meshing contact pattern. Prior to testing, each gear is accessed via inspection ports and dye applied (dye can be red or blue) to the teeth that are visible from the port. The test is performed once the dye has dried.

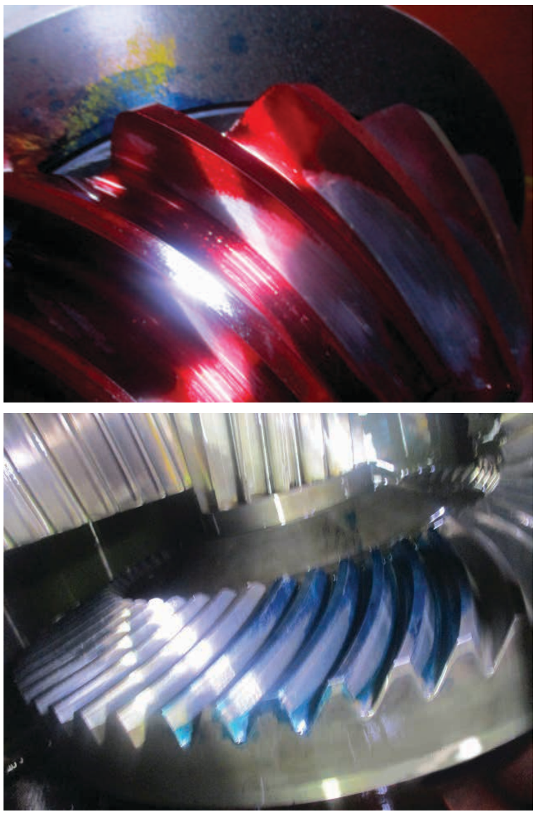


Figure 3

Visual inspection revealing an uneven dye pattern that exposes uneven gear meshing.

After the test, the teeth are inspected again, to see how the dye has been worn from the teeth. Correctly meshed gears should show an even erosion of the dye, while misaligned gears (Figure 3) will exhibit an uneven dye pattern.

How Spectrum analysis helps detect problems

Various vibration sensors placed on the machinery under test will generate individual vibration waveforms that are converted to the frequency domain using a Fast Fourier Transform (FFT). The resultant frequency spectra will show clear Spectrum artefacts should a defect be present.There are a wide range of defects that can be detected using FFT spectra, including:

- Mechanical looseness
- Misalignment
- Gear tooth defects
- Bearing defects

Examples are shown below.

Mechanical looseness

If there is mechanical looseness or an improper fit between parts in the system under test, a long string of rotating frequency harmonics or 1/2 rotating frequency harmonics at abnormally high amplitudes may be seen in the spectrum (see Figure 4). These harmonics may be random and unorganised. For example, looseness may display peaks at 2x, 3x, 4x, 5x, 6x, etc. of the fundamental rotating frequency, or at 3x, 3.5x, 4x, 5.5x, 6x, etc. Figure 4 shows an example of a vibration signature associated with loose components. Typically, looseness is identified by abnormally high running speed amplitude followed by multiples or 1/2 multiples. Harmonic peaks may decrease in amplitude as they increase in frequency. In other words, if there are a series of three or more synchronous or 1/2 synchronous multiples of running speed (range 2x to 10x), and their magnitudes are greater than 20% of the fundamental running speed, there may be mechanical looseness.

Misalignment

Misalignment is created when shafts, couplings and bearings are not properly aligned along their centrelines. The two types of misalignment are angular and parallel, or a combination of both:

- Angular misalignment occurs when two shafts are joined at a coupling in a manner that induces a bending force on the shaft.
- Parallel misalignment occurs when the shaft centrelines are parallel but displaced or offset.

A cocked bearing (aligned improperly in the housing) can also generate considerable axial vibration. Phase measurements from the axial position are necessary to help differentiate the difference between the two.

Common causes of misalignment that may be detected in a test bed are:

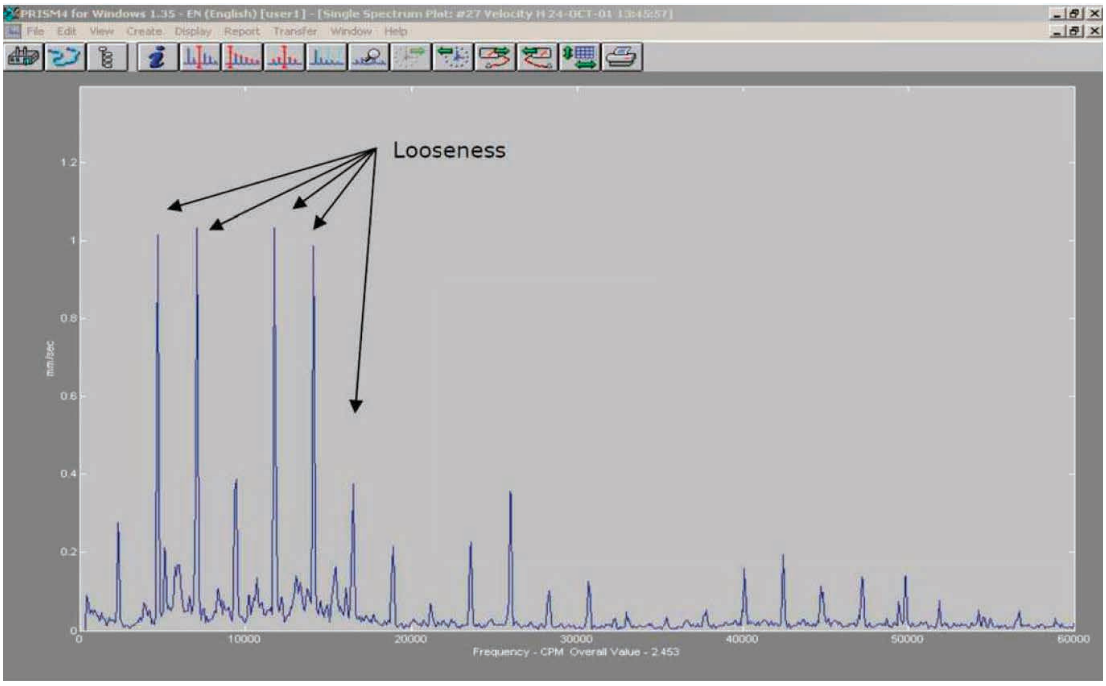


Figure 4

Spectrum indicating possible component looseness (Source: SKF USA Inc.).

- Cold alignment: Most machines are aligned cold and heat as they operate. Thermal expansion can have an impact on various components causing them to grow misaligned.
- Mechanical damage: bent shafts or excessive runouts.
- Installation error: Alignment of components is not correctly achieved when rebuilding.

Misalignment usually causes the bearing to carry a higher load than its design specification, which may cause bearing failure due to early fatigue.

When analysing an FTT spectrum where misalignment is indicated, a higher than normal 1x amplitude divided by 2x amplitude may occur. The indication of amplitude can vary from 30% of the 1x amplitude to 100-200% of the 1x amplitude. An example of this is seen in Figure 5. The 2x amplitude (0.90 mm/sec) is almost twice that of 1x (0.45 mm/sec).

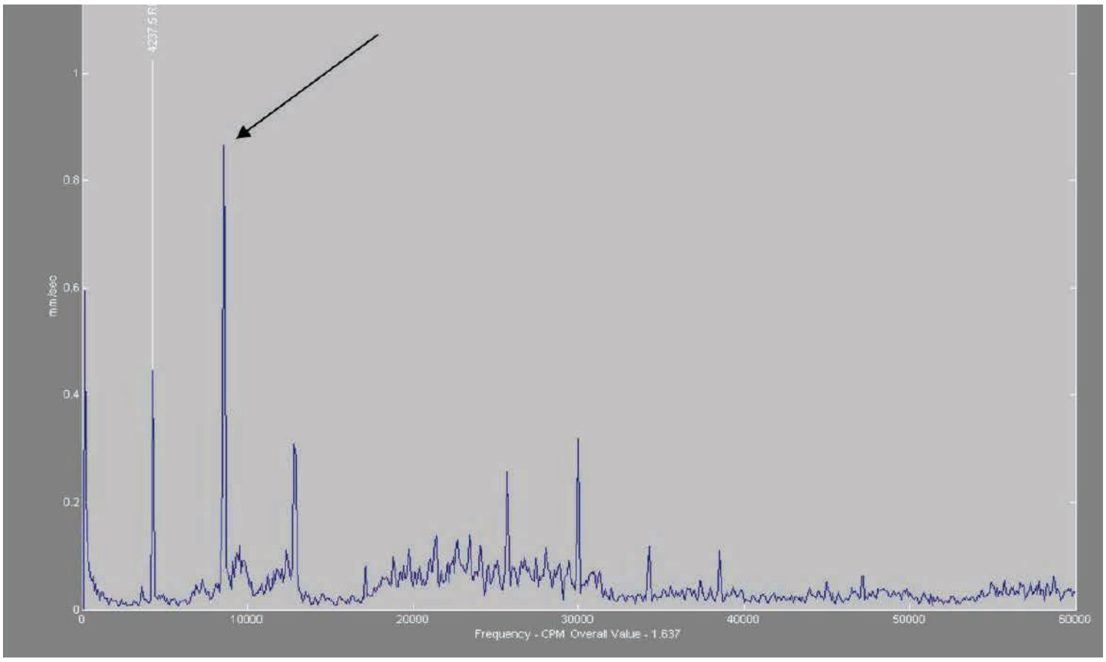


Figure 5

FFT spectrum showing severe misalignment (the second peak in the spectrum at ~8,500 rpm (141 Hz) indicates severe misalignment, as it is almost twice the amplitude of the running speed; the peak marked with the white marker is running speed (4,237.5 rpm, or 71Hz) (Source: SKF USA Inc.).

Gear teeth

There are two key elements to consider in order to understand how gear mesh issues arise:

- Gear mesh frequency (GMF)
- Sidebands of the GMF

By monitoring these two elements, it is possible to establish how the gear affects the system and the significance of the problem.

Gear mesh frequency

Gear mesh frequency equals the number of teeth on the gear multiplied by the speed of the shaft to which the gear is attached. For example, for 50 teeth at 1,180 rpm, the GMF would be 59,000 teeth contacts per minute, or 983.3 Hz. In addition to evaluating GMF, it is important to use the proper span (F_{max}) regarding frequency range to observe the GMF at higher frequencies in the same vibration signature. To achieve this span, GMF should be multiplied by a factor of 3.25. For example, using the above GMF, F_{max} = 3.25 × GMF = 3.1958 kHz. If the GMF is not known, then an F_{max} of 200 times the running speed is used. The factor of 3.25 relates to a gear characteristic that wear problems do not necessarily occur at the fundamental gear mesh frequency (GMF), but may occur at 2x or 3x GMF (second or third harmonic). In fact, one of the most common frequencies at which gear mesh is detected is the third harmonic. This is attributed to the three motions of gear interaction: engaged sliding, rolling and disengaged sliding. Hence, three pulses per revolution.

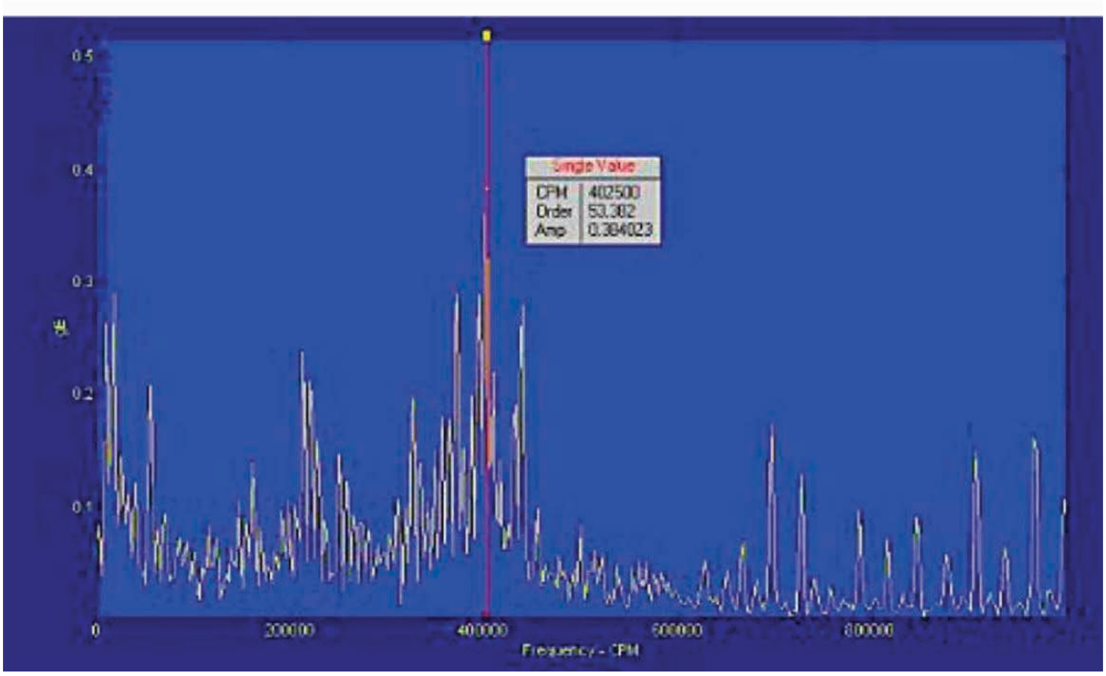


Figure 6

Spectrum with gear mesh frequency at 402,500 rpm, marked with the overlay. The shaft is turning at 7,595 rpm with 53 teeth on the gear (Source: SKF USA Inc.).

Gear mesh frequency sidebands

If one or both interfacing gears have worn teeth, the spectrum exhibits sidebands around the GMF. These sidebands are spaced at a distance equal to the shaft speed. When the amplitude and number of the sidebands increases, there is likely a problem with the gearbox components. An example is shown in Figures 6 and 7. In the Figure 6 spectrum, the GMF is shown as a peak at 402,500, since the shaft is rotating at 7,595 rpm and there are 53 teeth on the gear.

Figure 7 shows a gearbox spectrum with potential issues. The GMF is the main peak at 378,157, while each sideband is separated from the peak by intervals of 7,513 rpm, which is the nominal shaft speed in this case.

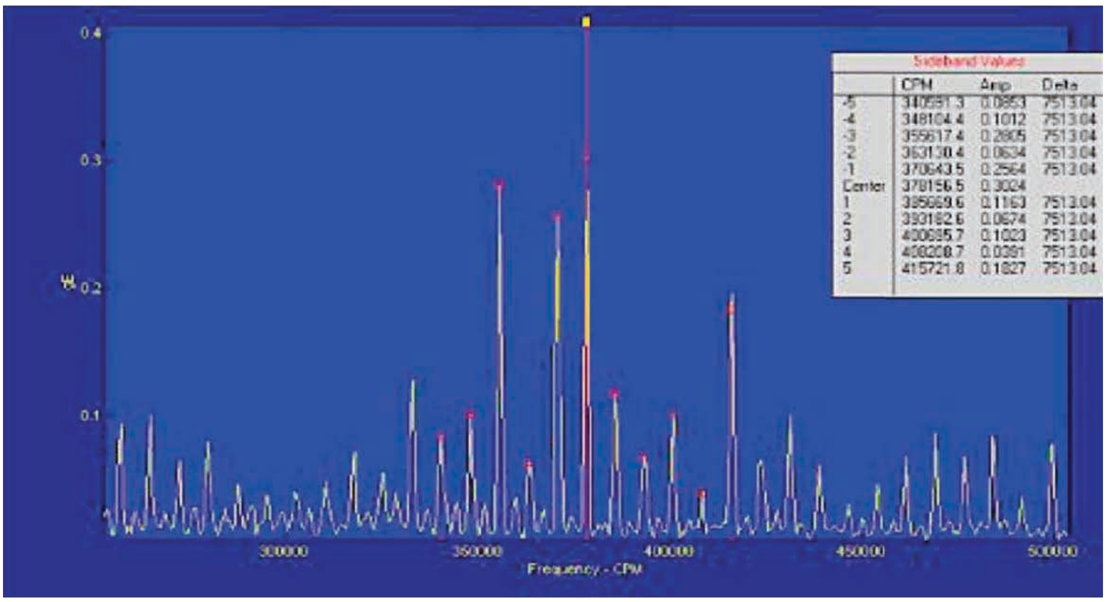


Figure 7

Spectrum containing gear mesh frequency at 378,157 rpm, marked with sideband markers. Sidebands are spaced at 7 513 RPM, which is the nominal speed of the shaft on which the gear is riding (Source: SKF USA Inc.),

Reference

Mais J 2002, Spectrum Analysis, SKF USA Inc., < http://www.skf.com/binary/ tcm:12-113997/CM5118%20 EN%20Spectrum%20Analysis.pdf>

If you want to know more please visit : https://www.sew-eurodrive.com.au/services/load_tester/load_testing.html

Company background:

The SEW-EURODRIVE group is a global designer and developer of mechanical power transmission systems and motor control electronics, headquartered in Bruchsal, Germany. Its broad spectrum of integrated solutions includes geared motors and gear units, high torque industrial gear units, high-efficiency motors, electronic frequency inverters and servo drive systems, decentralised drive systems, plus engineered solutions and after-sales technical support/training.

The Australian division of SEW-EURODRIVE is headquartered in Melbourne and is supported by a network of offices in Sydney, Brisbane, Mackay, Townsville, Perth and Adelaide. A comprehensive service and technical support centre is located in Melbourne, and is complemented by production, service and assembly facilities in all mainland states. SEW-EURODRIVE offers a full 24 hour emergency breakdown service on its products to put customer's minds at ease. SEW-EURODRIVE can also tailor a training program to equip customers' with a comprehensive set of skills to get the most out of motor and drive technologies and applications. The company's customer base includes large-scale corporations and smaller entrepreneurial enterprises across Australia.

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