Grease Noise in Ball Bearings
Noise generation in bearings and its effect, influence of the lubricating grease, grease noise tester, test procedure and requirements.

Author: Max Bichler, SKF QTC, Austria, Christian Roth, SKF QTC, Austria

SUMMARY

The essential customer needs of today, namely long bearing service life and low noise performance, demand the availability of a means to verify that the required cleanliness level and lubrication conditions are fulfilled. To fulfil these needs, a new equipment, the SKF BEQUIET+ tester has been developed to assess the quality of the lubricant with regard to cleanliness and damping characteristics. The test rig is recommended for application by lubricant manufacturers as a tool for their lubricant development as well as for production control, by bearing producers as a means to select the best lubricant on the market and for incoming batch control and by end-users to verify the lubrication quality in service.

1 INTRODUCTION

As underlined by SKF's Life Theory, the use of clean lubricants for rolling bearings is essential for obtaining a long bearing life. In the case of grease lubrication many factors can affect the degree of cleanliness during operation, but a clean grease for the initial lubrication as well as for re-lubrication will always be required. Also in applications where the bearing fatigue life is not at stake (e.g. because of very low loads), the need for clean greases can still be extremely important, for example contributing to low bearing noise which is required for many electric motor applications.

In field fan bearings are expected to run extremely quietly. It is clear that the electric motor manufacturers require bearings with the lowest possible vibration level and absence of disturbing noise. This calls for extreme cleanliness and low noise grease.

Bearings in automotive gearboxes are expected to run as long as the car lasts. Such bearings are exposed to foreign matter in the gear oil, often originated from the gears, which adversely affects the bearings. The particles being over-rolled damage the raceways producing "dents" and raising the stress level at their edges which promotes an ageing process leading to surface distress (noise increase) and finally to bearing fatigue failure.

2 NOISE GENERATION IN BEARINGS

2.1 Particle over-rolling. Since the film thickness which separates the mating surfaces in the rolling contact is very thin (usually below one micron) it is clear that any particles in size larger than the film thickness can disturb the smooth running.

Figure 1 shows a recording of the vibration peaks of an unclean lubricant. The vibration peaks are recorded by filtering the short duration effect of the over-rolling of particles from the total signal. The over-rolling of larger particles can lead to permanent dents of the raceways, see figure 2. The over-rolling of brittle particles create small damages of the bearing surface, see figure 3. If that occurs then the overall signal will increase in time, indicating that the original high bearing quality is actually lost by the use of a lubricant with insufficient cleanliness.
Experience has made it clear that particle over-rolling can be split into four distinct quality classes: dirty, noisy, clean and quiet. This classification can be defined as follows:

- # **dirty** i.e. the hardness and size of particles is such that over-rolling leads to a permanent damage giving increased overall noise and reduced bearing fatigue life;
- # **noisy** i.e. the hardness and size of over-rolled particles may damage the bearing surfaces which gives a noticeable increase in overall bearing noise but **not** to the degree that the bearing fatigue life is adversely affected;
- # **clean** i.e. the hardness and size of over-rolled particles will produce noticeable vibration peaks but there is **no** permanent damage of the bearing surfaces;
- # **quiet** i.e. highest degree of cleanliness due to a minimum of particles giving vibration peaks.

Lubricants of the class 'dirty' are rare in the delivery condition, but due to the application situation this condition may develop in operation. There are a few greases in the market, which due to their thickener type or solid additives fall into the class 'noisy'. Typical examples are some calcium-complex greases which contain large particles of calcium salts which produce small permanent dents, see Fig. 1. The majority of to-days greases fall in the class ´clean´.

Typical examples are polyurea greases where large agglomerates of the thickener can be present. These greases can produce then large vibration peaks, but since the hardness of these particles is low, the over-rolling will not give noticeable dents, see Fig. 4. Only a few greases can be classified as 'quiet'. Typical examples are Li-soap greases which are produced in a clean environment and by a process which filters out undue particles and produces a fine soap structure.

In each class, different levels can be distinguished to have a further grading in quality. The purpose of the **BeQuiet+** tester is to determine the grease quality in these levels in order to develop, improve or identify quiet greases.

2.2 Influence of the lubricating grease

Comparison of the damping characteristics of different lubricants should be made on the same bearing and being mounted in identical manner. When all these precautions are taken into account the selection of the lubricant with optimum damping characteristics can be successfully made.
Many factors within the lubricant are found to contribute to the damping characteristics. For oils the important factors are the viscosity, the base oil type and the applied additive types. A clear trend of increasing damping at increasing oil viscosity can often be found, see Fig. 5. For greases the damping characteristics can be quite erratic, probably because also the type of thickener and its microstructure will play a role. Moreover, additives influencing wettability and with strong surface attack can become dominant.

The importance of this damping effect has been the reason for the upgrade of the former BeQuiet instrument in order to enable lubricant manufacturers to develop lubricants with highest damping characteristics. For the bearing producers this new tool is equally important for selecting e.g. grease with highest damping characteristics.

3 GREASE NOISE TESTER "BE QUIET+"

To assess the particle over-rolling and damping characteristics of lubricants, SKF has developed the "**BeQuiet +**" test equipment (Picture 1).

The advantage of the BeQuiet class of equipment *vs* other equipment on the market, is the unique test **procedure** and degree of **automation**. In case of the BeQuiet + test equipment, the full automatic procedure consists of repetitive dosing of the lubricant to the test bearing and recording of the vibration level and peaks. The whole sequence, illustrated in Fig. 6, runs PC controlled by dedicated software. This procedure exclude that ingress of dirt particles from the environment can disturb the measurement results and makes it possible to use the **same** bearing for different tests without the necessity of dismounting. This can be advantageous for determination of the 'damaging' characteristics of dirty lubricants by following a sequence of testing reference lubricant, test lubricant and finally again the reference lubricant. Similar advantages will be found when comparing lubricants in terms of their damping characteristics. A logical consequence of the **BeQuiet+** test procedure is that the operating cost is reduced to a minimum, both in respect of bearing consumption as well as operator time.

3.1 Machine description

The machine is the semi-automatic equipment for laboratory use. There is a cabinet, which incorporates the PC, the loudspeaker, the keyboard, the screen and some room for tools, the calibration unit and a printer. The second cabinet incorporates the electrical installations, the pneumatics and the actual measuring unit. All important parts of the machine can be accessed from the front side.

The rig has the following main components:

- a high quality spindle rotating at 1800 rpm
- a special adapter to hold the test bearing, featuring grease inlet and outlet and an inlet for compressed air
- test bearing is a ball bearing type 608/QE4
- a pneumatic loading device for the test bearing with 30N
- a grease dosage unit comprising a linear actuator driven by a speed controlled servo-motor which acts on a disposable syringe containing the grease sample
- the QTC MEB 95 electronics with the SKF Peak Detection Algorithm to identify the vibration peaks and damping factors
- a special interface and program to carry out the measurements in a fully automatic way as well as to store the observed peak data and evaluate the results
- a printer/plotter
- network LAN

3.2 Functional description

The rig is able to measure the specific disturbances caused by over-rolling of particles, called vibration peaks. The key component of the rig is the proprietary SKF Peak Detection Algorithm, which enables these vibration peaks to be singled out from the total bearing vibration signal. The number of peaks detected and their intensity are used to assess the quiet running behaviour in a quantitative way. The user is then able to compare the result with a definable target.
In a further step a measurement for the "Grease Damping Characteristic" is also determined. The idea is to relate the bearing noise of the greased bearing in certain frequency bands to the bearing noise in reference conditions (slightly oiled).

3.3 Reliability and fast analysis

Efforts have been made to achieve a high degree of automation and to minimize the risks that other sources of contaminant

adversely affect the result. The key to this is the use of controlled grease dosages and peak measurements on a single test bearing of special low noise quality.
The entire process is controlled by dedicated software on a personal computer which also stores all peak data and vibration level and subsequently evaluates the results producing either tabular reports or line charts.
The **new BeQuiet+** equipment allows different measurement modes. Beside of the peak measurements also the "Grease Damping Characteristic" is identified. The bearing noise obtained in reference condition is related to the bearing noise in grease condition.

Test sequence

1. **Blow-off:** clears the test bearing to make space for the next grease dose

2. **Dosage and pressure release:** takes care of the injection of a defined volume of grease from the dosage unit to the test bearing

3. **Running-in:** after each dosage the bearing is run-in for a defined period (default: 10 s) to distribute the grease in the bearing

4. **Peak reset:** zeroing of the Peak Detector for the next measurement

5. **Peak reading:** storage of highest peak value recorded during the test period (default: 3 s)

6. **More readings:** the program checks if the defined number of peak readings has been collected (default: 10 readings)

7. **More cycles**: the program checks if the defined number of dosages has been carried out (default: 10 dosages)

Upon completion of the test, the recorded peak readings are ranked by the program on a quality scale. The default scales are the SKF **BQ scale** and the **GN scale**.

4 GREASE QUALITY CLASSES:

The outcome of the Peak measurements of a greased 608/QE4 bearing are shown in µm/s and given in

% of the peaks ≤ 5 µm/s (5 µm/s was the limit of the previous BQ1 class)

% of the peaks ≤ 10 µm/s (10 µm/s was the limit of the previous BQ2 class)

% of the peaks ≤20 µm/s (20 µm/s was the limit of the previous BQ3 class)

% of the peaks ≤ 40 µm/s (40 µm/s was the limit of the previous BQ4 class)

The classification of grease noise is then set in GN classes (standing for **G**rease **N**oise)
in the following way:

GN0: > anything worse than GN1

GN1: > 95 % of all peaks are ≤ 40 µm/s

GN2: > 95 % of all peaks are ≤ 20 µm/s

GN3: > 95 % of all peaks are ≤ 10 µm/s

> 98 % of all peaks are ≤ 20 µm/s

100 % of all peaks are ≤ 40 µm/s

GN4: > 95 % of all peaks are ≤ 5 µm/s

> 98 % of all peaks are ≤10 µm/s

100 % of all peaks are ≤ 20 µm/s

In particular, the following assessments can thus be made with the test rig:

- determination of the quiet running classification of lubricants in terms of particle over-rolling

- determination of any permanent bearing damage due to particle over-rolling

- determination of the lubricant damping characteristics

- comparison of lubricants with regard to their damping characteristics

A logical consequence of the **BeQuiet+** test procedure is that the operating cost is reduced to a minimum, both in terms of bearing consumption as well as operator time.

Picture 1: Test equipment BeQuiet+

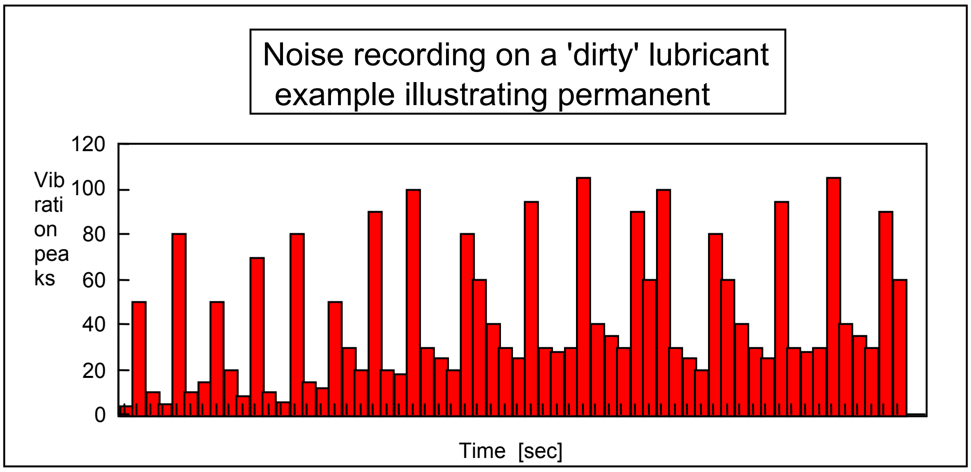

Figure 1: Noise recording on a "dirty" lubricant

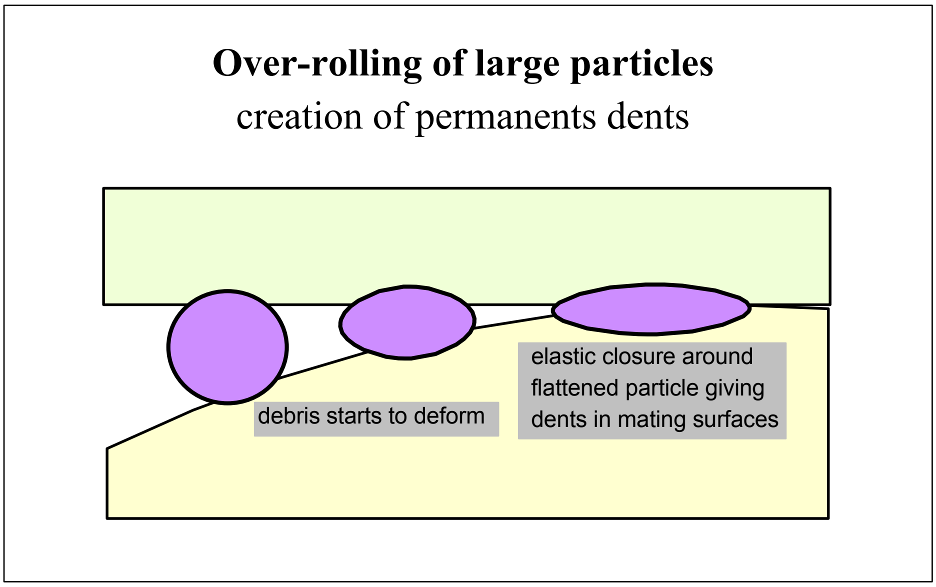

Figure 2: Over-rolling of large particles

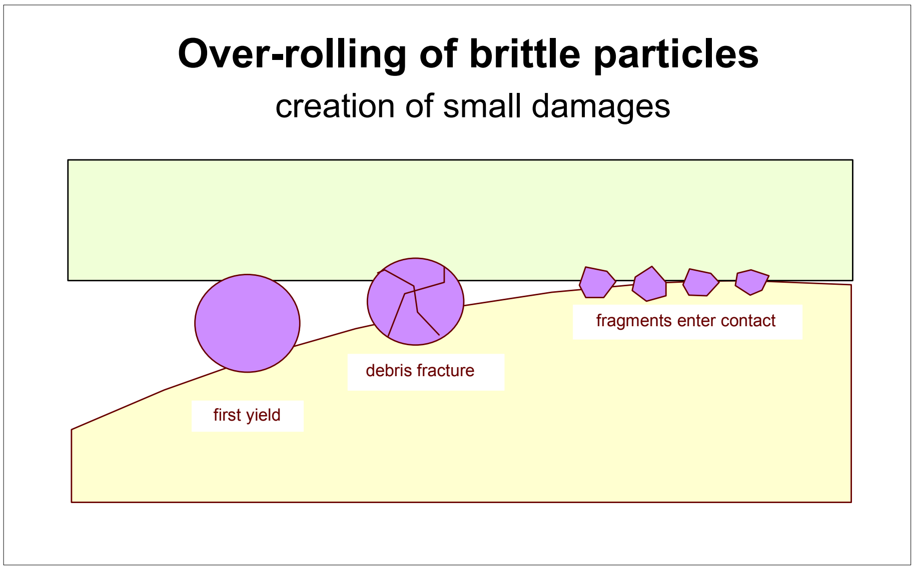

Figure 3: Over-rolling of brittle particles

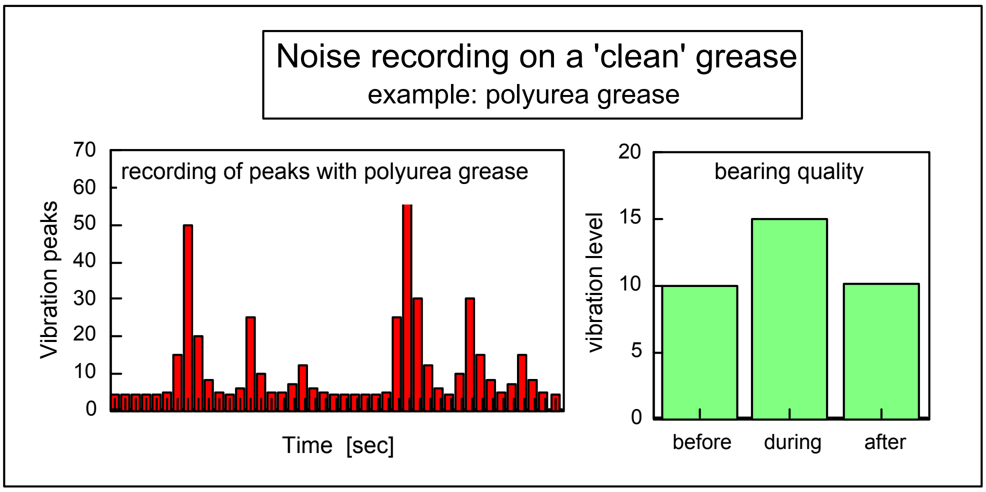

Figure 4: Noise recording on a "clean" grease

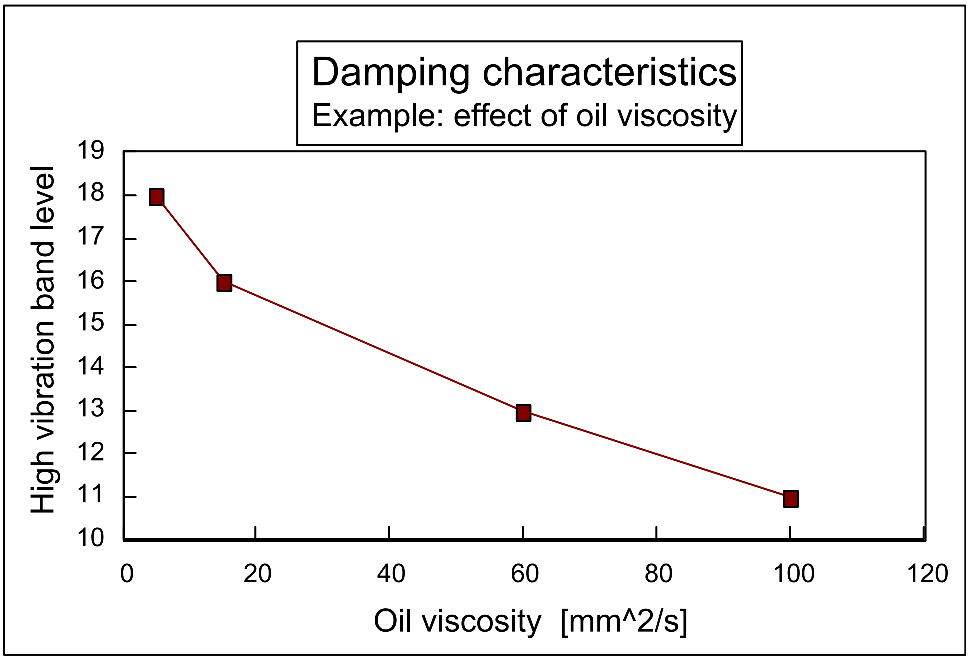

Figure 5: Effect of oil viscosity on damping characteristics

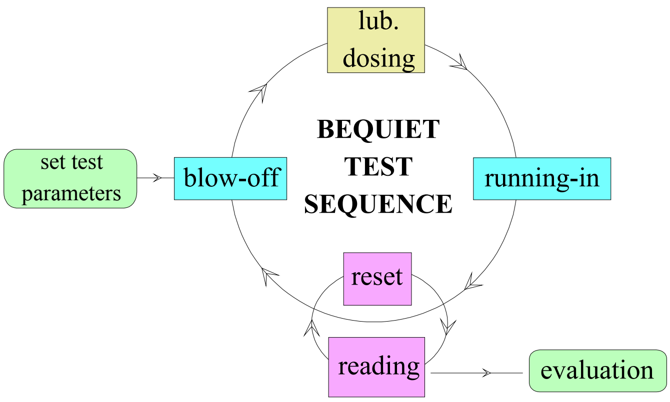

Figure 6: Sequence of BeQuiet + Testing