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NOISE TESTING OF ELECTRICAL MOTORS ON THE ASSEMBLY LINES AND THE TEST RESULTS EVALUATION

Abstract: The noise measuring of electric motors is already well known and understandable, but when the motor producer wants to measure the motor noise directly on the motor assembly line (as out-going inspection) then come several troubles which must be fixed. The most important is to eliminate the background noise – the sound pressure on the work shop can be over 80 dB somewhere so then is practically impossible to do a motor noise measuring. It is necessary to use a noise-box to reduce the background noise – see Fig.2. Next trouble can be the test results evaluation – especially in case of special “noise requirements” with strict acceptance criteria. Here we have to count also with additional disturbances caused for example by using of bearings from different manufacturers.

1. Introduction of the test station

The main parts of the Test station are the noise box and measuring system SCS9002 as flexible and customizable PC Based product for end-of-production quality control based on dynamic acoustics measurements. The system has modular and expandable hardware architecture, based on a multichannel (up to four in standard version) analog & digital front-end, a data acquisition PC board, and a standard PC.

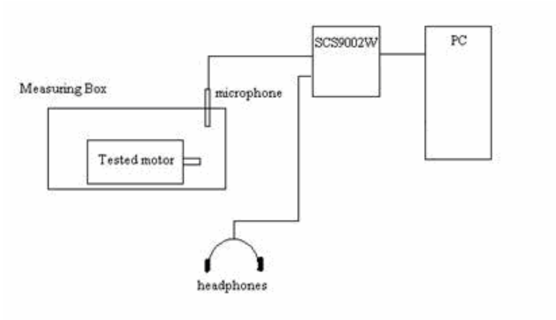

Fig.1. Main parts of the Test station

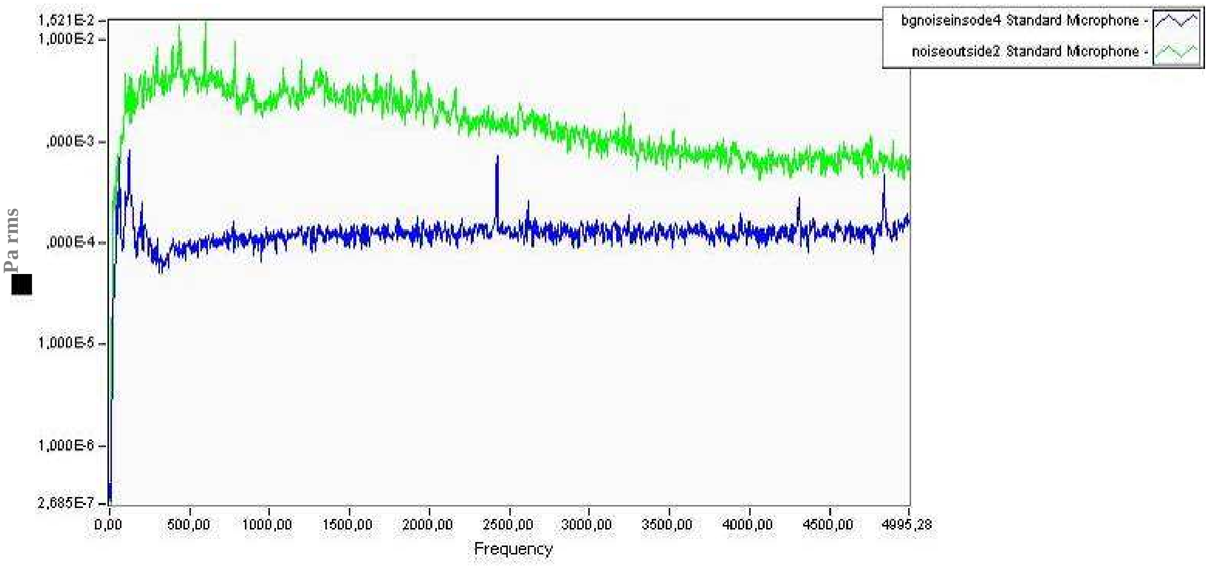

Fig. 2. FFT Spectrum inside (blue color) and outside (green color) of the measuring box

The measuring box wall thickness is 100 mm – sandwich acoustic board, surface treatment-komaxit and acoustical tiling from inside (see Fig.3).

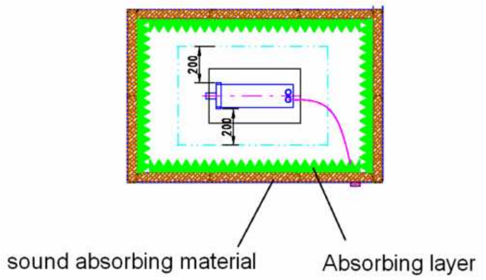

Fig.3. Construction of the noise box

The picture 1.3 shows noise absorption (sound reduction) of this solution and used materials – that means how the box is working in full frequency range.

2. Measurement

Note: all listed overall values of sound pressure have been calculated in accordance with standard ISO 1260 (1).
As first step it is necessary to do several measurements to see impact of microphone position (but at constant motor-microphone distance), motor speed, direction of rotation etc. to measured values.

Tab.1. Measured overall values of sound pressure at different microphone locations

Microphone location	Overall value of sound pressure LpA, dB
Back side	49,58
Front side	50,39
Left side	52,96
Right side	53,04
Up side	52,56

The Table 1 shows that most comparable and stable are results on left and right sides of the motor with difference 0,08dB.

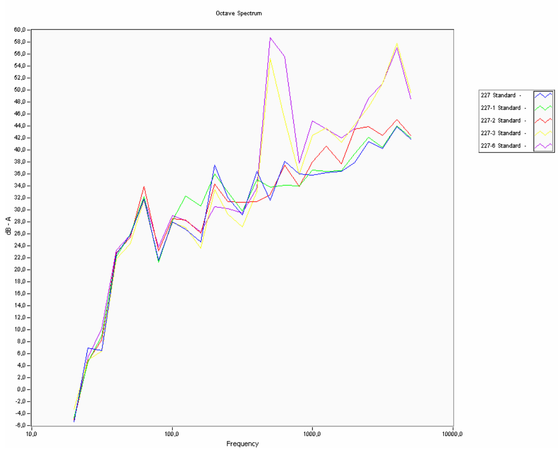

Fig. 4. 1/3 Octave Spectrum

The Figure 4 shows 1/3 Octave spectrum of the same motor measured at different speeds and shaft direction of rotation. The graph shows increasing of the noise level at 3000rpm motor speed – see table below for the graph lines assignment.

Tab.2. Assignment of the test speed to Fig.4

Color marking	Motor speed
227 Standard	0rpm
227-1 Standard	1000 rpm (CW)
227-2 Standard	2000 rpm (CW)
227-3 Standard	3000 rpm (CW)
227-6 Standard	-3000 rpm (CCW)

The measuring system SCS9002 is able to do (and store) all important sound measuring like FFT Spectrum, 1/3 Octave Spectrum, FFT Spectrum vs. Time etc. The measuring in 1/3 Octave seems to be more stable and fit for this kind of in-line measurement than FFT Spectrum.

2.1. “Quiet” and “Noise” samples comparison

With cooperation with customer we selected four motors for this test – one of them as “quiet” sample (serial number 227-3) and three as “noise” samples (serial numbers 225-3, 276-3 and 230-3). We needed these samples to be able to find most significant difference between “quiet” and “noise” motors – see Fig.5.

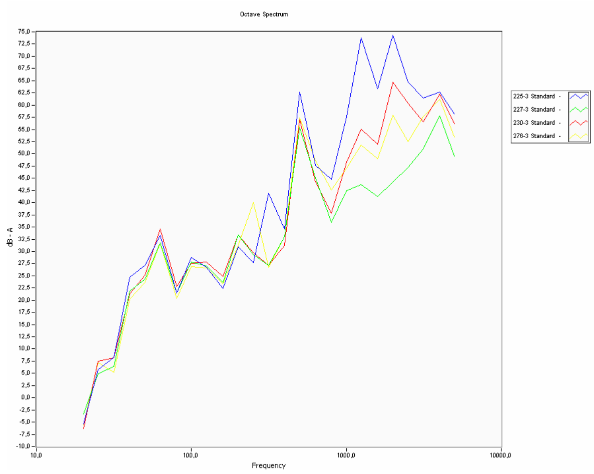

Fig. 5. 1/3 Octave Spectrum at 3000 rpm

The Tab.3 below shows overall values of measured sound pressure. The difference between “quiet” sample 227-3 and least “noise” sample “276-3” is not so significant (~4 dB) so we had to find another way how to recognize the "quiet" and "noise" motor – see Chapter 2.2.

Tab.3. Measured overall values of sound pressure

Motor marking	Overall value of sound pressure LpA, dB
227-3	61,16
225-3	77,92
230-3	68,59
276-3	65,63

2.2. The test results evaluation

- **Evaluation in accordance with EN 60034-9: It** seems to be simle and also usefull, but here is one main trouble. We are measuring acoustic pressure and the test limits listed in the standard are in sound power. It is really difficult to measure sound power – especially on the assembly line. For this kind of measuring is needed bigger "anechoic room" and also couple of microphones located around the measured motor. For our in-line quality control is better and simpler to measure acoustic pressure and if we want to use the standard EN 60034-9 then we have to re-calcutate the results to the sound power (1).

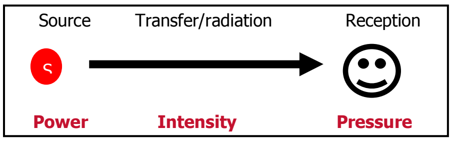

Fig.6: The acoustic problem

The formula how to re-calculate the acoustic pressure to the sound power:

$$L_W = L_P + 10\log\frac{S}{S_0} + C \qquad (1)$$

- **Our own test limit:** (usually on base of customer request) test acceptance criteria of max.overall value of acoustic pressure (power). These criteria can be more stricter as the standard (listed above) criteria.
- **Headphone:** with the headphone operator can also check the noise level. For example the well-trained operator can recognize some characteristic noise (like from bearings).
- **Create a mask:** we can create a mask and apply it to the measured graph (see Fig.7.). That means we can evaluate the measured results only at specific and more important frequencies.

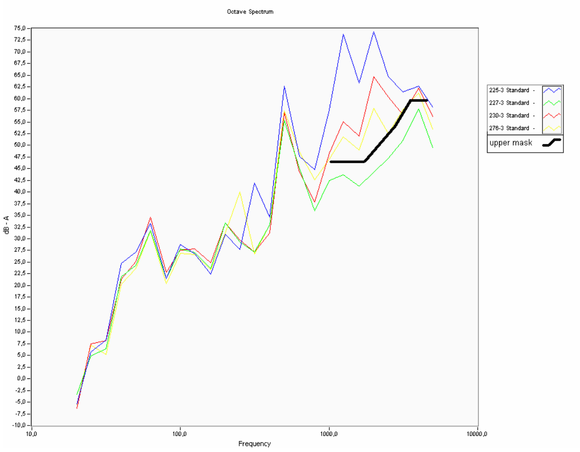

Fig.7. 1/3 Octave with applied mask

- **Focus to one most important frequency:** It is usually frequency around resonant frequency of the motor (see Fig.8.). We focused this area around 2 kHz and the result shows Fig.9.

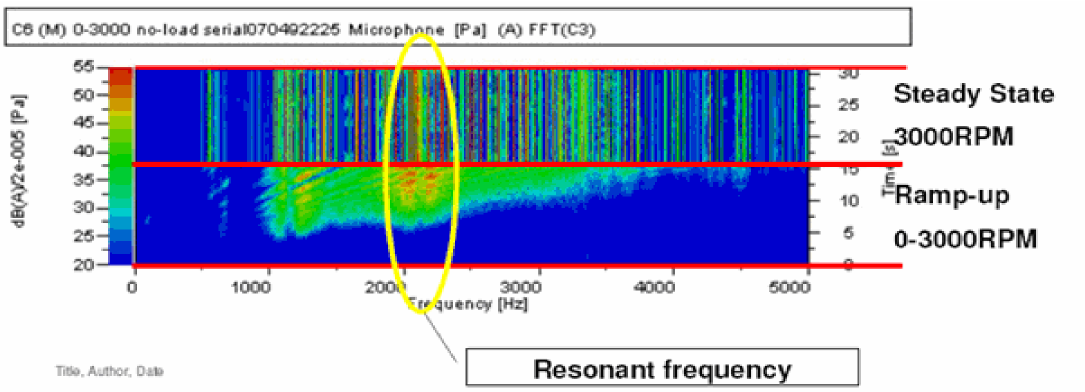

Fig.8. FFT vs. time with marked Resonant Freq

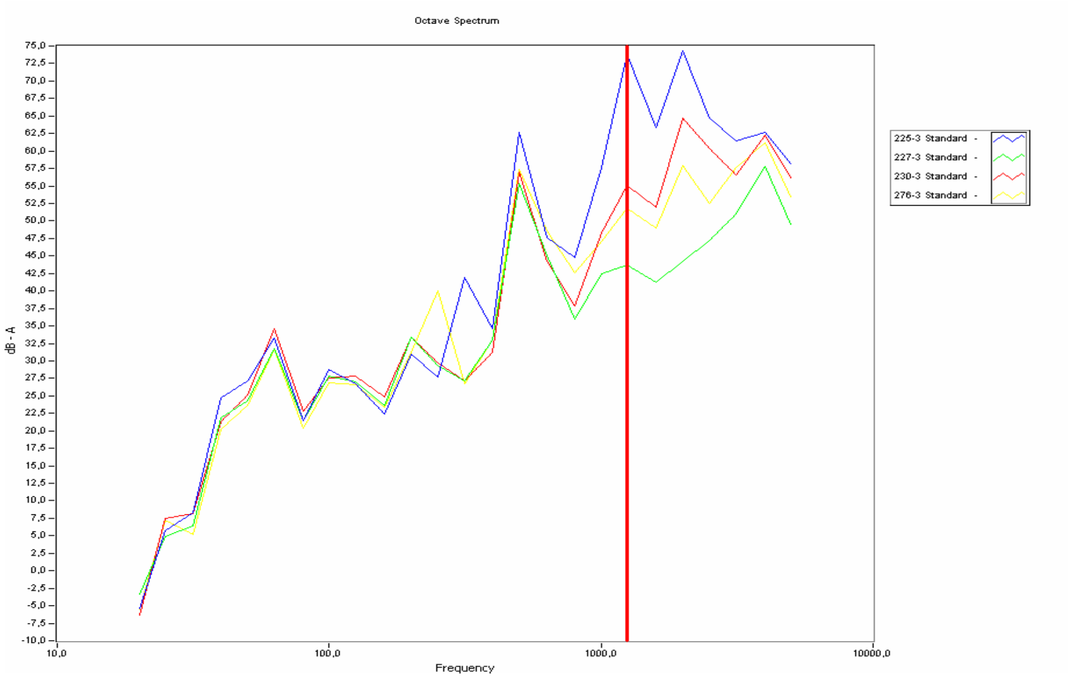

Fig. 9. 1/3 Octave Spectrum with marked frequency 2kHz

The Tab.4 below shows values of measured sound pressure at 2 kHz. The difference between "quiet" sample 227-3 and least "noise" sample "276-3" is most significant (over 13dB) than overall values in Tab.3. On base of these values (44,2 dB for "quiet" and 57,9 dB for least "noise" sample) we determined the noise limit as average value = **51,1 dB**

Tab.4. Measured overall values of sound pressure – assignment to Fig.5

Motor marking	Overall value of sound pressure LpA, dB
227-3	44,2
225-3	74,4
230-3	64,7
276-3	57,9

2.2.1. Impact of minor design changes

For this test "impact of bearing supplier change to the measured values" we selected three independent bearing producers (marked as "A", "B" and "C"). We produced 102 motors with these bearing samples (34 samples with bearings from supplier "A" inside the motor, 34 samples with bearings from supplier "B" and 34 samples with supplier "C").

Each Figure (Fig.10-12) shows measured values of sound pressure LpA at 2 kHz (blue points) and also the investigated noise limit at 2 kHz (51,1 dB) for better imagination. Measured values show some differences between each supplier – where the supplier "A" is the worst one (6 samples over the limit) then supplier "B" (2 samples over the limit) and the best was supplier "C" with 0 samples over the limit.

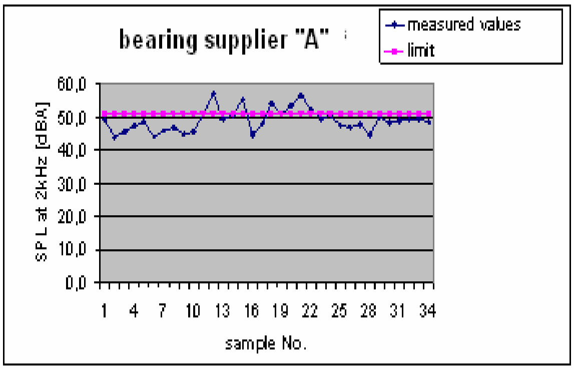

Fig. 10. Measured values with bearings from supplier "A"

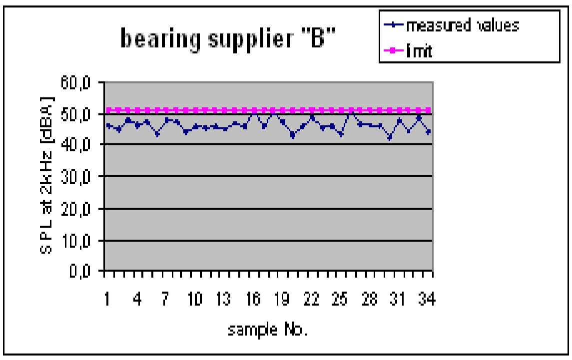

Fig. 11. Measured values with bearings from supplier "B"

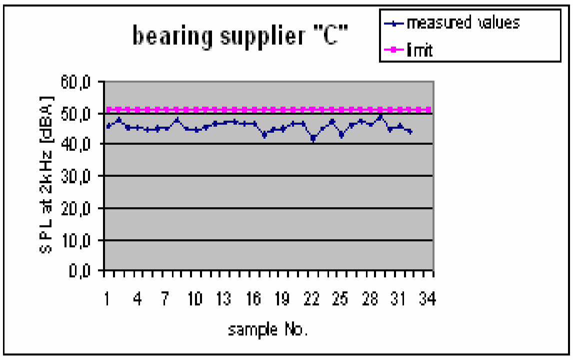

Fig. 12. Measured values with bearings from supplier "C"

3. Conclusions

On base of finished measurements and showed graphs we can say that it is possible to do the noise measuring directly on the assembly line (with background noise over 80 dBA). But it is necessary to provide a good measuring methods, instrumentation and a box with really good sound reduction in full range of the frequencies (usually it is problem to cover also frequencies in range 0-100 Hz).

It is also necessary to use fit motor speed (sometimes a lower speed can be practically the same as background noise at 0rpm) and good method of the test results evaluation. To provide really precise acceptance criteria it is necessary to do several measurements of reference samples – and this reference measurement has to be repeated after each design change (for example like bearing supplier change).

Acknowledgement

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