ISSN 1822-296 X (print)
ISSN 2351-7034 (on-line)

KAUNAS UNIVERSITY OF TECHNOLOGY
KLAIPĖDA UNIVERSITY
JSC LITHUANIAN RAILWAYS (AB "LIETUVOS GELEŽINKELIAI")
IFToMM NATIONAL COMMITTEE OF LITHUANIA
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OF LITHUANIAN ACADEMY OF SCIENCES
VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
PUBLIC ENTERPRISE ROAD AND TRANSPORT RESEARCH INSTITUTE

TRANSPORT MEANS 2018

PROCEEDINGS OF THE 22nd INTERNATIONAL SCIENTIFIC CONFERENCE

PART III

October 03 – 05, 2018
Trakai, Lithuania

KAUNAS • 2018

Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Vibro Acoustic Measurement at Sea: How Predictable Are Motor Failure by Means of Vibration Measurement?

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Abstract

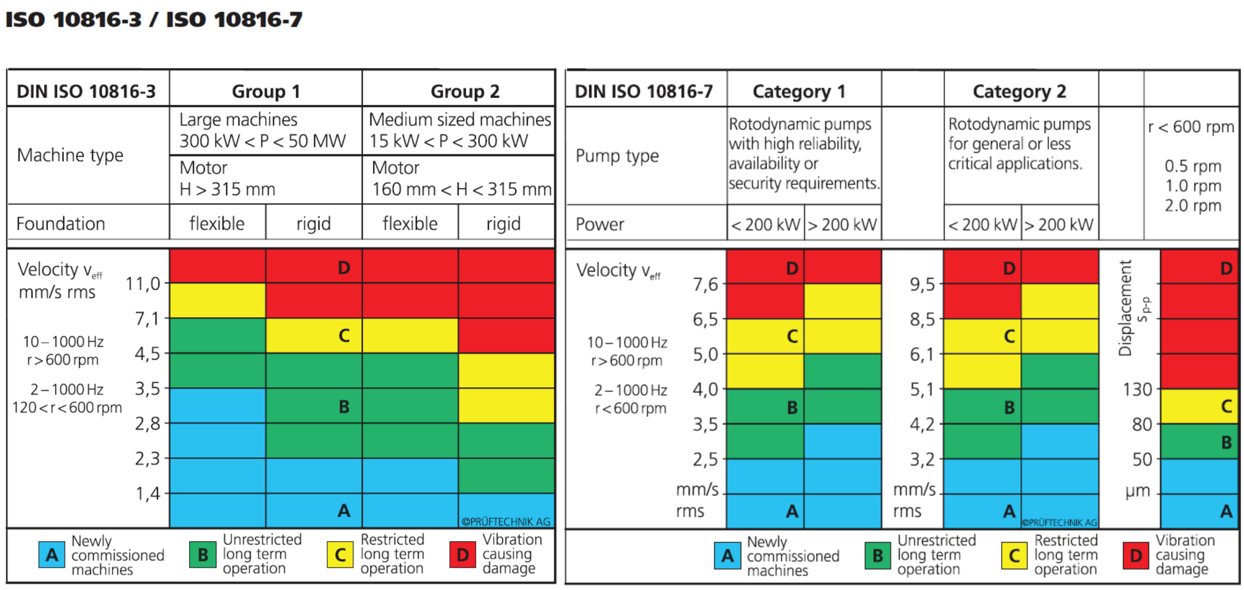
Vibration problems in induction motors can be frustrating and may lead to greatly reduced reliability. It can vary from a mere nuisance to an indication of imminent motor failure. With solid knowledge of motor fundamentals and proper diagnostic procedures of vibration analysis, it is possible to identify and pinpoint the root cause of the problem, and more significantly correct, or ascertain the impact of increased vibration on motor reliability and longevity.
Hereby below described research will monitor and analyse centrifugal pump and electric motor vibration signal evaluation as overall velocity, hi resolution velocity, shock pulse and bearing envelope measurements change for period more than one year. Task was based to discover how precise is our measurement techniques and how early we are warned about future damage to happen.
KEY WORDS: *vibration; vibscanner; bearing characteristic frequencies; vibration velocity; shock pulse measurement; vibration displacement; vibration acceleration*

1. Introduction

Vibration and its measurement is ongoing important and complex subject. Continually extended knowledge and experience based on progress in diagnostic and analytical tools or methods. For this reason, it is worthwhile periodically to present any new methods as well as to review prior knowledge. Vibration can occur at any time in the installation and root cause of it should be eliminated immediately to prevent further damage of equipment. The proper diagnostic test and measurement analyse will indicate true source of the problem as many work has been carried out in past to make it easy separate different causes. However, it is still unclear how fast we should react or how fast problem can evolve and are there any correspondence or it is merely a coincidence? This research outlines the current vibration amplitudes and frequencies as measured from the listed machinery. It highlights with concern or problem and is intended as an aid to maintenance and not a replacement for any scheduled maintenance procedures [2-5, 7-8].

Table 1

Vibration standard(s) used [9]



By returning to the root of defect indication, we can assume that noise of electric motor bearing defect heard by human ear can be set as critical and imminent when motor failure can occur. At this point immediate electric motor overhaul are required (in our case, critical measurement dated: 19.01.2018). Here we compare first fixed measurement above alarm point setting Table 1 [9] (as per ISO 10816-3 and ISO 10816-7) within one year time period until audible intelligible sound was registered.

2. Methodology

Test Object

Centrifugal pump electric motor (Fig. 1): Nom. Rev – 3515rpm, Real rev. – 3565rpm, Current – 33.5Amp, Power – 21.4kW, bearing in use: 2 X SKF 6309 2ZC3 (Single row deep groove, two side metal shield, radial clearance larger than normal), 45mm I.D, 100mm O.D

Fig. 1 Test object

Vibration main Source

Bearing SKF 6309 2ZC3 (Single row deep Groove, Two sided metal shielded, Radial clearance larger than normal) (Table 2).

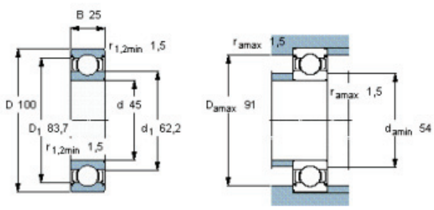
Table 2

SKF bearing reference data [10]

Deep groove ball bearings, single row, SKF Energy Efficient (E2) bearings

SKF

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed ratings Reference speed	Limiting speed	Mass	Designation
d	D	B	C	C_0	P_u				
mm			kN		kN	r/min		kg	-
45	100	25	52,7	31,5	1,34	17000	8700	0,83	E2.6309-2Z/C3



Calculation factors
k_r 0,03
f_0 13

Measuring equipment

Vibscanner VIB 5.400Ex; S.N.51541/2016. Manufacturer: Pruftechnik AG (Fig. 2).

Fig. 2 Vibscanner VIB 5.400Ex

Fig. 3 Omnitrend 2.91.advert

For measured data analyse manufacturer: Pruftechnik AG software: Omnitrend 2.91.was used (Fig. 3).
Centrifugal pump electric motor condition has been analysed at period as per below Table 3.

Table 3

Measurement periods

No.	Date	Motor working hours	Condition
1.	05.01.2017	45126	First measurement (First time alarm limit reached)
2.	30.07.2017	47225	Middle measurement
3.	19.01.2018	48960	Acoustic noise identified measurement (critical condition)
4.	22.02.2018	49224	After overhaul measurement. New bearing installed.

Motor first 60Month / 20.000Hrs overhaul with bearing renewal carried out 22.11.2011 at 19913wHrs.

OMNITREND calculates roller bearing characteristic frequencies from the bearing geometric data that are entered in the Frequency Editor. The geometric data can be found in the manufacturer catalog. Structure and content of a file with bearing characteristic frequencies see below (Table 4).

Table 4

Bearing SKF 6309 frequency data [10]

Manufacturer	Bearing No	Inner race speed	Inner race pass (Hz)	outer race pass (Hz)	Roll. elem. pass (Hz)	Cage rotation (Hz)
SKF	6309	1000	82,767	50,567	65,017	6,317

By utilizing the proper data collection and analysis techniques, the true source of vibration can be discovered. This includes, but is not limited to: Electric imbalance; Mechanical unbalance – motor coupling, or drive; Mechanical effects – base, driven equipment, misalignment, ect.; Resonance, critical speed ect.. In our case source of vibration is electric motor top bearing defect.

This paper provides analytical approach for understanding and analyse of vibration data within period and early discovery of problem.

Define measurement points (Fig. 4).

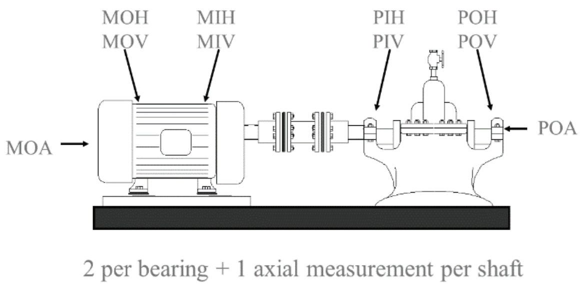


Fig. 4 Measurement point location [9]

Housing vibration obtained with magnetically mounted accelerometer. Vibration measurements obtained with the motor operating under the following conditions: Loaded, Coupled, Full voltage, all conditions stabilized (i.e. normal operation conditions: constant speed, stable discharge pressure of media).

Before we can proceed to the measurements the Database structure to be set as per example below used for our tests (Fig. 5).

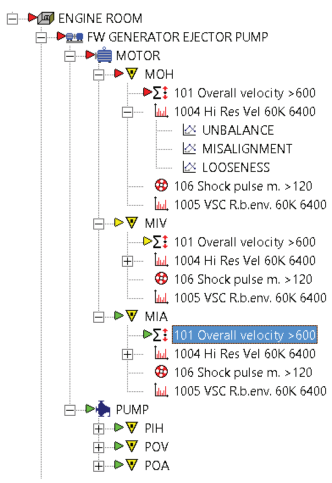


Fig. 5 Pruftechnik AG Omnitrend database structure set for task [9]

When database measurement is setup, it is very important to define right values. At Omnitrend it can be chose as per below list (Fig. 6).

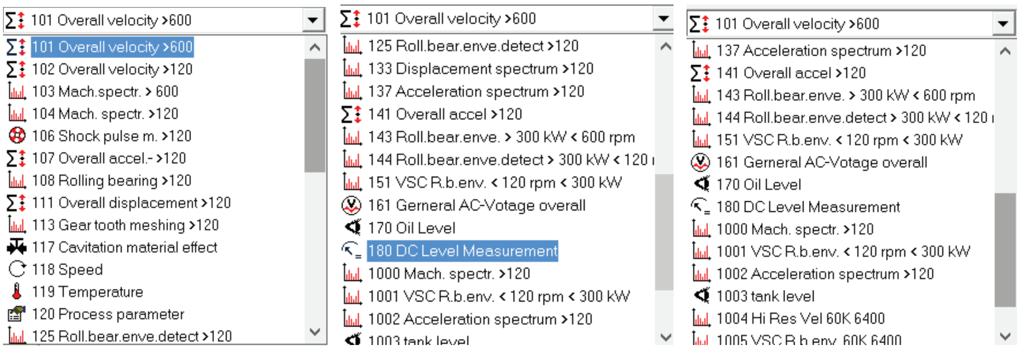


Fig. 6 Omnitrend available task list [9]

3. Measurement and Results

Task chosen and values measured for the measuring point (MOH – motor outer horizontal) giving highest signal values indicating the worst bearing condition:

1. 101. Overall velocity >600 (indicate if we got problem);
2. 1004. Hi Resolution velocity 60K6400: Unbalance / Misalignment / Looseness (give answer what problem is);
3. 106. Shock pulse m.>120 (indicate if we have problem with bearing);
4. 1005.VSC R.b.env. 60K6400. “Acceleration enveloping” is globally recognised as an immensely powerful method to detect bearing wear and bearing damage (answer what is the bearing problem).

Now that the mechanical source of vibration is understood, it is time to establish a systematic approach to measurements.

Vibration can be measured in units of displacement (peak to peak, mils), units of velocity (zero to peak, mils per second), or units of acceleration (zero to peak, g’s). Acceleration emphasizes high frequencies, displacement emphasizes low frequencies, and a velocity gives equal emphasis to all frequencies. This relationship better illustrated in Fig. 7 where comparison of vibration amplitudes are expressed in acceleration, velocity, and displacement.

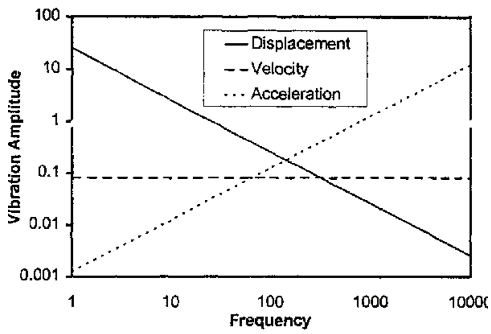


Fig. 7 Comparison of vibration amplitudes [6]

Data trend collected and extracted from vibscanner as per below.

Path of Location : NMM\Stena Perros\1 MONTHLY\ENGINE ROOM\FW GENERATOR EJECTOR PUMP\MOTOR\MOH\101 Overall velocity >600

Date	Time Zero-Peak	Peak-Peak	RMS
04.01.2017	18:09:5821,16 mm/s	42,31 mm/s	8,46 mm/s
05.01.2017	13:31:0416,58 mm/s	33,16 mm/s	9,68 mm/s
05.01.2017	19:36:2214,95 mm/s	29,89 mm/s	9,19 mm/s
30.07.2017	10:22:4414,07 mm/s	28,14 mm/s	7,42 mm/s
19.01.2018	17:47:0830,43 mm/s	60,86 mm/s	14,85 mm/s
22.02.2018	17:20:387,71 mm/s	15,41 mm/s	2,79 mm/s

PUMP\MOTOR\MOH\1004 Hi Res Vel 60K 6400\UNBALANCE\MISALIGNMENT\LOOSENESS

Date	Time Meas. Value UNBALANCE	Meas. Value MISALIGNMENT	Meas. Value LOOSENESS
04.01.2017	18:10:300,96 mm/s	18:10:300,12 mm/s	18:10:301,56 mm/s
05.01.2017	13:31:320,87 mm/s	13:31:320,20 mm/s	13:31:320,04 mm/s
05.01.2017	19:36:500,89 mm/s	19:36:500,21 mm/s	19:36:500,04 mm/s
30.07.2017	10:23:100,94 mm/s	10:23:100,34 mm/s	10:23:100,03 mm/s
19.01.2018	17:47:340,63 mm/s	17:47:340,12 mm/s	17:47:340,42 mm/s
22.02.2018	17:21:101,05 mm/s	17:21:100,23 mm/s	17:21:100,16 mm/s

For more easy data visual analyse displayed graphs used as per below:
Where possible I have made spectral graphs on the same vertical and horizontal scales (Figs. 8-11).

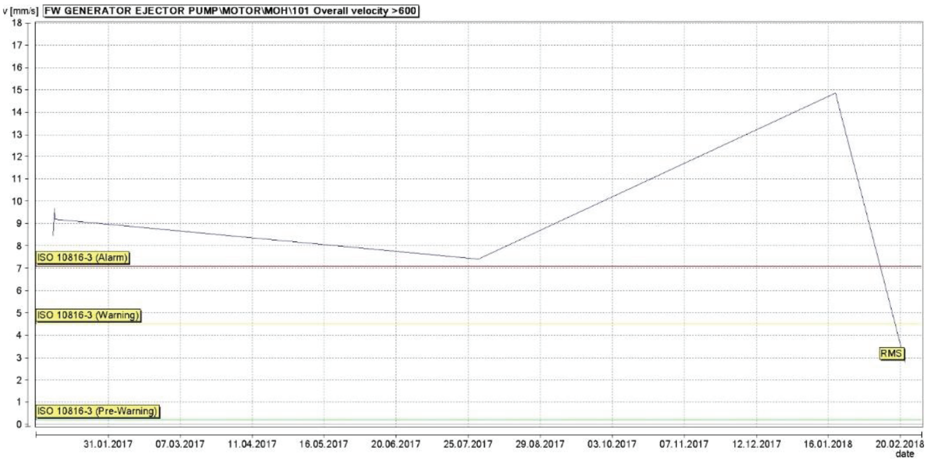


Fig. 8 MOTOR\MOH\101 Overall velocity > 600

Here we can see that all Overall velocity readings before motor overhaul are above ISO 10816-3 Alarm zone [Table 1, [9]] at $v > 7$mm/s. After motor overhaul it is in 2,79 mm/s zone.

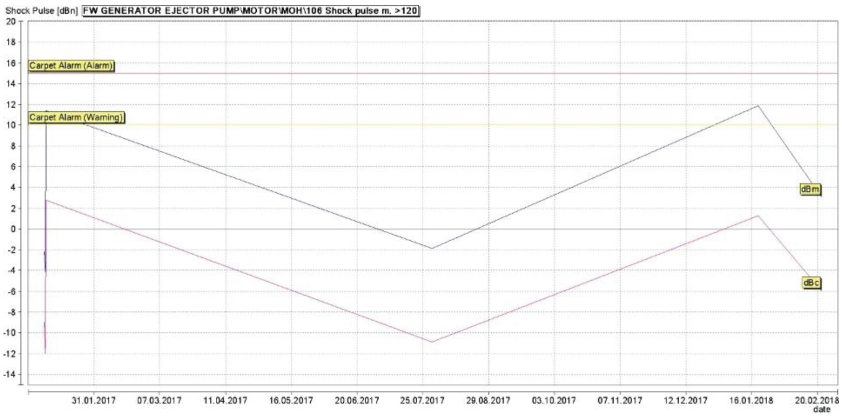


Fig. 9 MOTOR\MOH\106 Shock pulse *m*. > 120

Fig. 9 Shock pulse *m*. > 120 indicate that on 19.01.2018 carpet and max values have increased to above the alarm thresholds what means that there is clear problem with outer end bearing. Further this problem are analysed by 1005 VSC R.b.env. 60K6400 data collection.

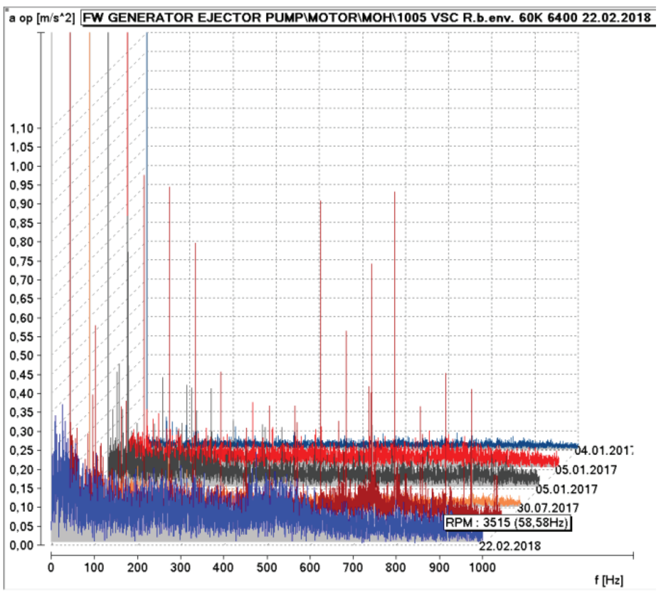


Fig. 10 MOTOR\MOH\1005 VSC R.b.env. 60K6400 for all dates - 3D graph

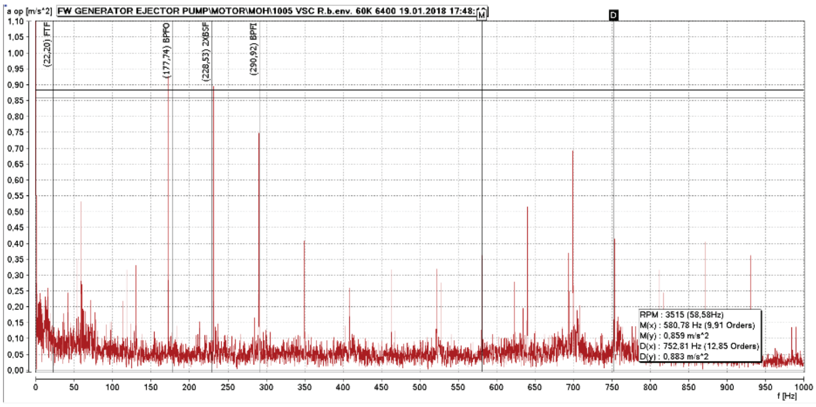


Fig. 11 MOTOR\MOH\1005 VSC R.b.env. 60K6400 analyse based on19.01.2018 collected data

At Fig. 11 1005 VSC R.b.env. 60K6400 reference lines added for FTF – Fundamental train frequency (22.20Hz), BPFO – Ball pass frequency outer race (177.74Hz), 2xBSF – Ball spin frequency (228.53Hz), BPFI – Ball pass frequency inner race (290.92Hz). BPFI max value pike is exactly align as per SKF6309 bearing data [10]. These visual markers help us identify particular cause of vibration at particular frequency.

4. Conclusion

Vibration problems can vary however this example highlights early prediction possibility for future breakdown of equipment. From other point industry still need more precise timing when evaluate condition and remaining time period till imminent breakdown of equipment. That means that different vibration sources should be evaluated by different algorithms.

It was observed, that, at constant real time electric motor condition monitoring it is possible to prolong installation work period per 50% if compare with time based maintenance. The factor limiting the vibration limits at these levels is the motor bearings. The obtained results show that real trip limits can be safely set at 10% above the Industry alarm limits.

As additional advice for industry I would like to point that sound measurements [1] can provide valuable clues about a motor and overall equipment condition. Future sound monitoring technique improvement as on database set online sound monitoring and analyse (comparison between noise change) systems can be used as alarm trigger for future alarm and monitoring systems in different industries.

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