

Gearbox noise emission in stationary conditions for Production Quality Assurance

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VIBRATION MEASUREMENTS

A series of preliminary test on Gear Box Test Bench have been performed in order to understand the possibility to design an automatic diagnostic system for further implementation in a Gear Box Quality Control program.

The general idea was to use vibration measurements to detect faults in gear boxes instead of noise measurements since vibration measurements is less sensitive to environmental noise in the workshop.

Vibration measurements and Fourier Analysis of the signal where the investigation tools. An accelerometer has been positioned on the gear boxes (same position for all measurements) and the resulting signal it has been acquired and analyzed with 2 different systems. One of the system was again a NetdB-DAQ12 with dBFA software: a multi-purpose PC based analysis system for Noise and Vibration, used in this case to analyze data in Real Time and produce FFT spectra, stored on the PC Hard Disk. The other system was a much more sophisticated dB Sonic software for analyzing data acquired with the above mentioned dBFA-NetdB, and used as a secondary system to get more information, whether necessary or not, to achieve the criterion in distinguish between "Good" and "Bad".

The measurements have been performed to some "Good" and "Bad" gear boxes, judged by customer experience and usual means. From a set of measurements of "Good" ones it has been calculated the statistical average and the standard deviation in order to show some differences in the vibration energy contents.

GENERAL INTRODUCTION

In theory any vibration and noise phenomena can be correlated under certain circumstances, i.e. whether the mechanical vibration is the "origin" of the noise, in terms of absolute values it is necessary to consider the acoustic power (L_w) emitted by the machinery, make a correlation between the L_w and the Vibration level L_v and than recalculating the estimated Sound Pressure Level L_p at a certain distance.

The L_w of the source can be determined using ISO 374x standard by using L_p measurements around the source or (more appropriate in the gear boxes case), or Sound Intensity measurements according to ISO 9614/1/2. In both cases it is possible to determine the L_w of the source in 1/1 or 1/3 octaves and as dBA, dBLin values. Those L_w values are usable to certified the "product" in terms of noise emission.

To perform the L_w determination it has been used the NetdB-DAQ12 with the dBPower software, both from 01dB-Metravib advanced series of Sound and Vibration measurements system

From a sufficient number of L_w determination and Vibration measurements it become possible to achieve a good confidence in correlation between them and to the estimated L_p at a certain distance.

The gear boxes under test were taken from normal production with the following characteristics:

- pignon: 9 teeth
- crown: 35 teeth
- differential: 10 to 19

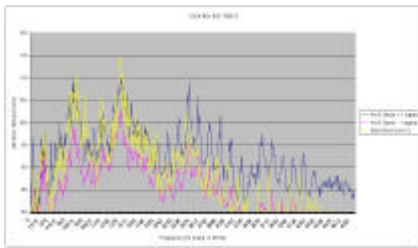
they have been tested in the conditions reported on the table "Frequency components in Hz".

		rotation components													
		1	2	3	4	5	6	7	8	9	18	27	36	45	54
rotation	load	tooth-mesh components													
rpm	%	1	2	3	4	5	6	7	8	9	18	27	36	45	54
1500	0	25	50	75	100	125	150	175	200	225	450	675	900	1125	1350
1500	50	25	50	75	100	125	150	175	200	225	450	675	900	1125	1350
2300	0	38,3	76,7	115	153	192	230	268	307	345	690	1035	1380	1725	2070
2300	50	38,3	76,7	115	153	192	230	268	307	345	690	1035	1380	1725	2070
3000	0	50	100	150	200	250	300	350	400	450	900	1350	1800	2250	2700
3000	50	50	100	150	200	250	300	350	400	450	900	1350	1800	2250	2700
3000	16	50	100	150	200	250	300	350	400	450	900	1350	1800	2250	2700

Frequency components in Hz

Some graphics will explain the vibration characteristics at different rpm and load, respectively for gearbox judged as "good" and as "bad".

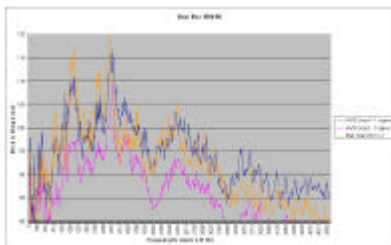
By looking at the graphics below: the yellow curves is the Gearbox classified as Bad n.3 and that the vibration level exceed the + 1 sigma reference (blue curve) in the 3rd and 6th harmonic of gear box tooth-meshing frequency, while the 5th harmonic it shows up only sometimes in the spectrum. Red curve is the - 1 sigma reference.



It is interesting to note that the load applied change the vibration spectrum and a lot of energy in fractional harmonics disappear, i.e. rotation is actually more stable and measurements more repeatable, meaning that test conditions shall be as "loaded".

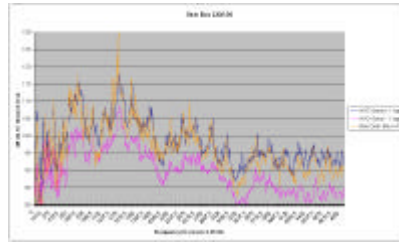
The fault identification was not the goal of this preliminary investigation but it could be interesting to understand that the energy within the 3rd harmonic of the tooth-meshing component is normally indicating a bad contact while energy at higher harmonics is more related to the teeth generation quality, i.e. the Glyson machinery conditions.

In the load conditions of 1500-50 (Graph below) it can be seen that there is a more stable rotation condition due to the load applied, the difference in peaks frequency components (not the level but the frequency value) is almost insignificant.



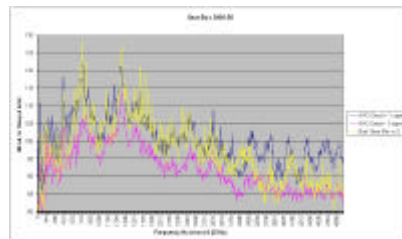
In the 2300-50 test conditions some side-bands rise up in the spectrum; side bands

are usually positioned around tooth-meshing frequency with delta-F corresponding to rotation frequency.



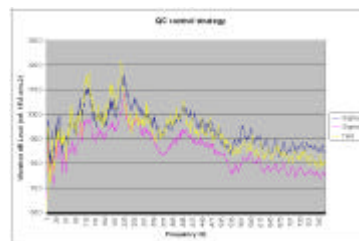
At the 3000 RPM with 0, 50 and 16 load conditions there are a lot of side-bands activities, indicating bad gear conditions, probably as a distributed fault.

Side bands activities become more visible in the 3000-50 load conditions (Graph below) and in the overdrive test conditions.



Upon the full measurement set it has been developed an algorithm and in order to test it we estimated the average spectrum and the std-dev of a measurements set referred to gearbox judged as "good", all in a given RPM and load conditions. Several test have been conducted with satisfactory results, QC mask, as reference spectra (blue as +1 sigma and red as - 1sigma), are plotted on graph below overlaid with a test sample, resulting as "bad".

CONCLUSION



The detection of quality level and Quality assurance in Gear Boxes production can be rather easily achieved using vibration analysis comparison between Good and

Bad products.

The "window" of acceptability (Reference mask) can be optimized and narrowed, once more data become available from a consistent set of measurements on several Gear Boxes, directly from production line.

From frequency analysis of the vibration signal it is also possible to detect faults typology and look directly to the source in order to correct the problem.

Combining vibration analysis results with noise and vibration measurements performed in a vehicle on the road, one can understand the real noise contribution of the Gear Box to the overall level in the car, so it is possible to study the Gear Box structure and the elements manufacturing to achieve a better result.

Among all advantages of implementing such kind of system for the Production total quality control there is also the real possibility of improving the general quality to meet car manufacturers expectations.

INTRUMENTS SETUP & WORK AKNOWLEDGE

The investigation have been conducted using the brand new NetdB-DAQ12 Front-end with internal HD and WiFi connection, and the dBFA software for Noise and Vibration analysis, while for specific analysis and algorithm search it has been adopted the dBSONIC Sound Quality software.

Aknowledge goes to engineers of our partner SCS, which actively collaborate to the research.



NetdB