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| RESEARCH ARTICLE

Analyzing the Internal Part Condition on the Planetary Gear unit with Conditioning Monitoring Method at Cement Factory Horizontal Milling Station

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| ABSTRACT

Predictive maintenance is currently preferred over reactive maintenance because it's very effective in reducing the costs incurred for unplanned breakdown stalling of a machine or equipment while production is running. In a production process at a Cement factory, the Milling station process is very important and becomes the main process. So, if something goes wrong in this process, the production line can be stopped, and the losses due to this are very big. Condition monitoring is a significant part of predictive maintenance because the application of condition monitoring allows the scheduled maintenance and precautions to be taken to prevent further failures and possible unplanned downtimes at a later date. By measuring the value of the vibration level, we can know whether the bearings and gear teeth on the machine are suitable for use or not. Based on this analysis, we can conclude that there is no sign of defect both on bearing in each gear teeth and the gear teeth inside the gearbox.

| KEYWORDS

Condition Monitoring, Predictive Maintenance, Vibration, Cement, Breakdown

| ARTICLE INFORMATION

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1. Introduction

Maintenance is an important activity in the manufacturing industry. Schedule maintenance can reduce unplanned downtime, which can reduce productivity. Predictive Maintenance is currently preferred over reactive maintenance because it's very effective in reducing the costs incurred for unplanned breakdown stalling of a machine or equipment while production is running.

Condition monitoring is the process of monitoring the current condition in the machine, such as vibration, temperature and others. Condition monitoring is a major part of predictive maintenance because the application of condition monitoring allows the scheduled maintenance and precautions to be taken to prevent further failures and possible unplanned downtimes later. A way to be done Condition monitoring is to analyze the engine's vibration level in the form of vibration velocity amplitude value. Excessive vibration levels on the machine indicate machine component damage.

In the production process at the Cement factory, the Milling station process is very important and has become the main process. So, if something goes wrong in this process, the production line can be stopped, and the losses due to this are very big. In Its process, the Horizontal milling station uses a Planetary gear unit. So, the Maintenance team must always monitor the condition of the planetary gear unit so that the milling station can still run according to the schedule.

This research is to determine the condition of the bearings and gear teeth inside the planetary gear unit to predict the schedule for a part replacement to reduce unplanned shutdown.

2. Methodology

By measuring the value of the vibration level, we can know whether the bearings and gear teeth on the machine are suitable for use or not. Problems or the types of engine damage detected based on vibration signals are unbalanced, looseness, misalignment, and bearing damage. Identification of machine damage can also be identified using expert systems with the certainty factor method. This identification is made by looking at the symptoms caused by the machine and then analyzed through an application. Besides the vibration factor, machine damage also can be identified by the amount of electricity consumption.

This research uses a vibration measuring device to be carried out at the point where the bearings are installed and the friction between the gears in the axial and radial positions. See figure 1.

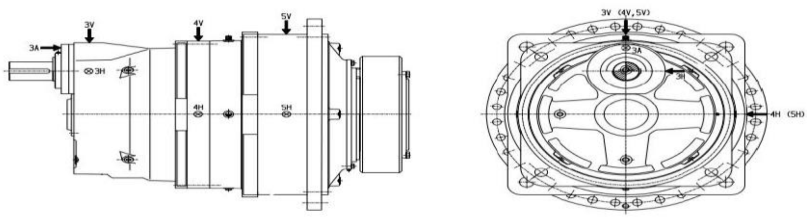


Figure 1. Measurement point

Vibration analysis is mainly based on comparing measured vibrations to theoretically calculated gearing and bearings excitation frequencies. The table with calculated excitation frequencies for the gear unit is shown in Figure 2.

Shaft speed	1001	rpm	i =	53,07	
Shafts	Sh1		Su1/Pl1/Ca1	Su2/Pl2/Ca2	
Number of teeth					
Pinion	31				
Gear	45				
Sun gear			19	17	
Planet gear			42	30	
Ring gear			104	79	
Rotation speed [rpm]					
Shaft	1001				
Shaft					
Sun gear			689,6	106,5	
Planet gear			263,8	49,67	
Planet Carrier			106,5	18,86	
Rotation frequency [Hz]					
Rot	16,68				
Rot					
RotSu			11,49	1,775	
RotPl			4,396	0,828	
RotCa			1,775	0,314	
Passing frequencies [Hz]					
PasSu			29,15	5,844	
PasPl			8,792	1,656	
PasRg			5,326	1,258	
Gear mesh frequency [Hz]					
	St1		Ps1	Ps2	
Gmf	517,2		184,6	24,84	
Motor bearings	Comment	FTF	BSF	BPO	BPI
MotDE	FAG	**6,540**	**36,67**	**52,27**	**81,20**
MotNDE	SKF	**6,990**	**49,87**	**69,84**	**97,00**
Shaft 1 Bearings, Pos. No.:	Comment	FTF	BSF	BPO	BPI
150	SKF	**7,191**	**57,19**	**151,1**	**199,2**
	FAG	**7,189**	**57,37**	**143,8**	**189,9**
151	SKF	**7,157**	**57,77**	**128,9**	**171,4**
Sun-Shaft 1 Bearings, Pos. No.:	Comment	FTF	BSF	BPO	BPI
550	SKF	**4,930**	**39,80**	**88,79**	**118,1**
551	SKF	**4,953**	**39,97**	**89,23**	**117,6**
	FAG	**4,873**	**36,06**	**87,72**	**119,1**
Planet 1 Bearings, Pos. No.:	Comment	FTF	BSF	BPO	BPI
348	SKF	**3,587**	**11,77**	**27,15**	**38,79**
	FAG	**3,543**	**10,55**	**24,75**	**36,79**
Planet 2 Bearings, Pos. No.:	Comment	FTF	BSF	BPO	BPI
248	FAG	**0,676**	**3,256**	**9,054**	**11,64**
Output shaft Bearings, Pos. No.:	Comment	FTF	BSF	BPO	BPI
255	FAG	**0,148**	**2,547**	**7,524**	**8,510**
256	FAG	**0,151**	**2,282**	**5,942**	**6,640**

1) Frequency component type

Rot	= Rotating frequency
Gmf	= Meshing frequency
Pas	= Passing frequency (for planetary stages)
BPI	=Inner ring defect frequency
BPO	=Outer ring defect frequency
BSf	=Rolling Element rotation frequency
FTF	=Fundamental train frequency (rotation frequency of cage)

2) Machine element

Ps1, Ps2…	1st (2nd…) Planetary stage (beginning from first rotating shaft)
St1, St2…	1st (2nd…) spur/helical/bevel gear stage
Sh1, Sh2…	1st (2nd…) shaft (beginning from first fast rotating shaft)
Su1, Su2…	Sun shaft, 1st (2nd…) planetary stage
Ca1, Ca2…	Carrier, 1st (2nd…) planetary stage
Pl1, Pl2…	Planets, 1st (2nd…) planetary stage
150,151…	Roller bearing, item position 150, 151…
MotDE, MotAx, MotNDe	Motor bearings, driven end radial bearing, axial bearing and non-driven end bearing

3) Harmonics

H1, H2…	= 1st (2nd…) harmonic

Figure 2. Calculated excitation frequencies

Condition monitoring methods are suitable for avoiding predictable faults in mechanical machines. We accomplish the condition evaluation based on the provided plant data and the noted measurement results. Methods of analysis and measuring, as well as diagnoses and prognoses, correspond to the present state of the art

Effective velocity vibration values are evaluated according to Standard DIN ISO 10816-3 in the frequency range between 10 Hz to 1000 Hz

Vibration velocity analyses detect faults in gears, couplings, or antifriction bearings. The measurement duration and frequency resolution is chosen to fit the gear unit type and operation conditions.

Envelope analyses identify initial roller bearing and/or gear problems that induce impulse-like vibrations. These impulses can be excited by antifriction bearing faults like pitting or spalling and gear defects.

Acceleration spectra are analyzed concerning wide resonance bands in the high-frequency range between about 3 and 8 kHz. When bearing faults get severe, these natural frequencies are excited.

3. Result and Discussion

Below are the basic data of the Planetary gear unit which had been measured in this research :

Nominal output torque of the gear unit: 506790 Nm
Nominal input speed of the gear unit: 1000rpm
Total gear unit ratio: 53.078
Built in: 2015
Nominal power of the motor: 1100 kW
Nominal speed of the motor: 1000 rpm
Date of commissioning: Sept. 2016
Total operating time: N/A
Ambient Temperature: 43°C
Input Speed: 1000 rpm
Absorbed motor power: 920 kW
Material feed: 28 tph

Then, look at the housing surface of the Planetary gear unit is still in the tolerance range. Shown in figure 3.

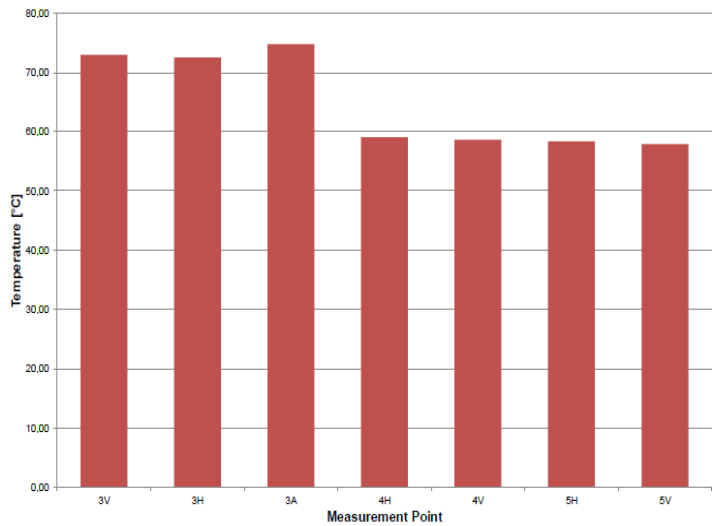


Figure 3. Temperature measurement

The vibration level based on the measurement is shown in figure 4 below.

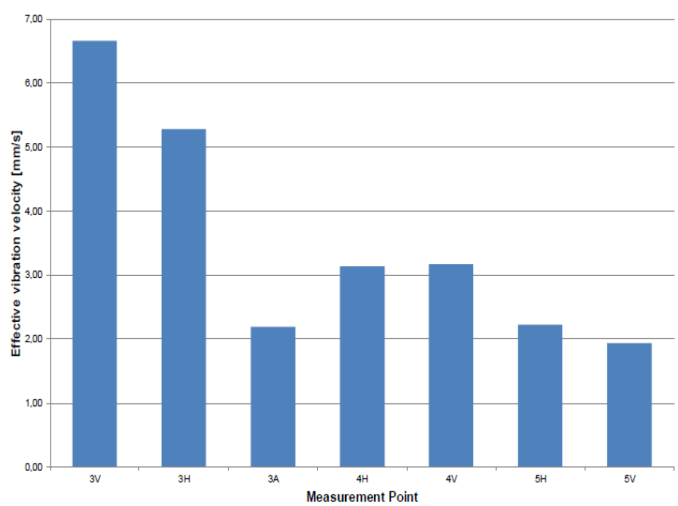
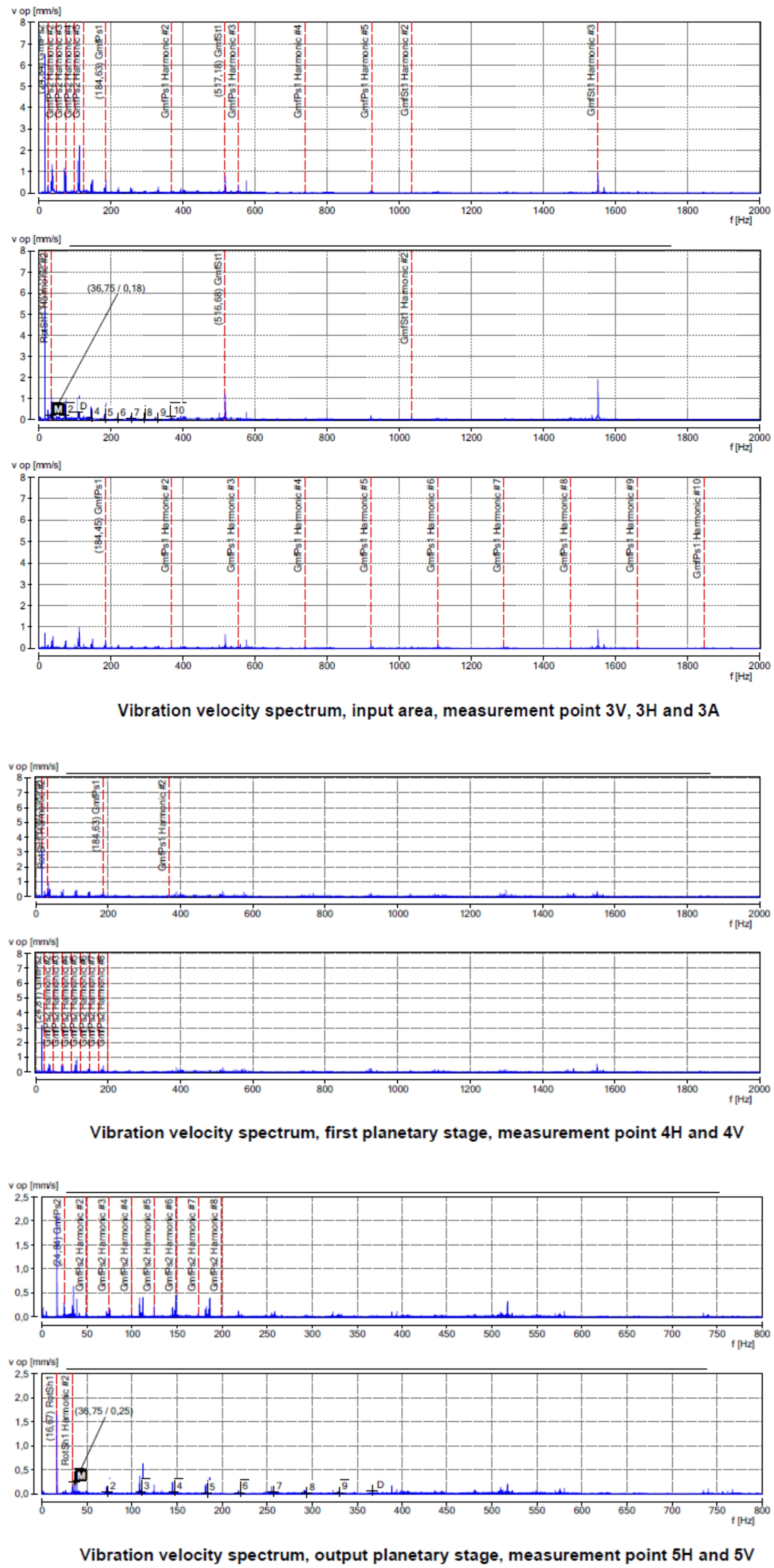


Figure 4. Vibration Level on Housing

This is the result of spectrum Vibration velocity, as shown in figure 5. The maximum peaks are visible at the rotation frequency of the input shaft with levels up to 6.5 mm/s (0-p) but without distinctive harmonics. The reason is residual unbalance of the motor and/ or the input coupling. The absolute levels are tolerable for this kind of construction with a soft steel-frame foundation. The gear mesh frequencies of all gear stages are visible, partly with slight harmonics. Because no irregular side band modulations are present, the condition of the planetary gear stages can be assumed as faultless. Eyecatching is some harmonics of 36.8 Hz with side bands spaced apart with 1.8 Hz.



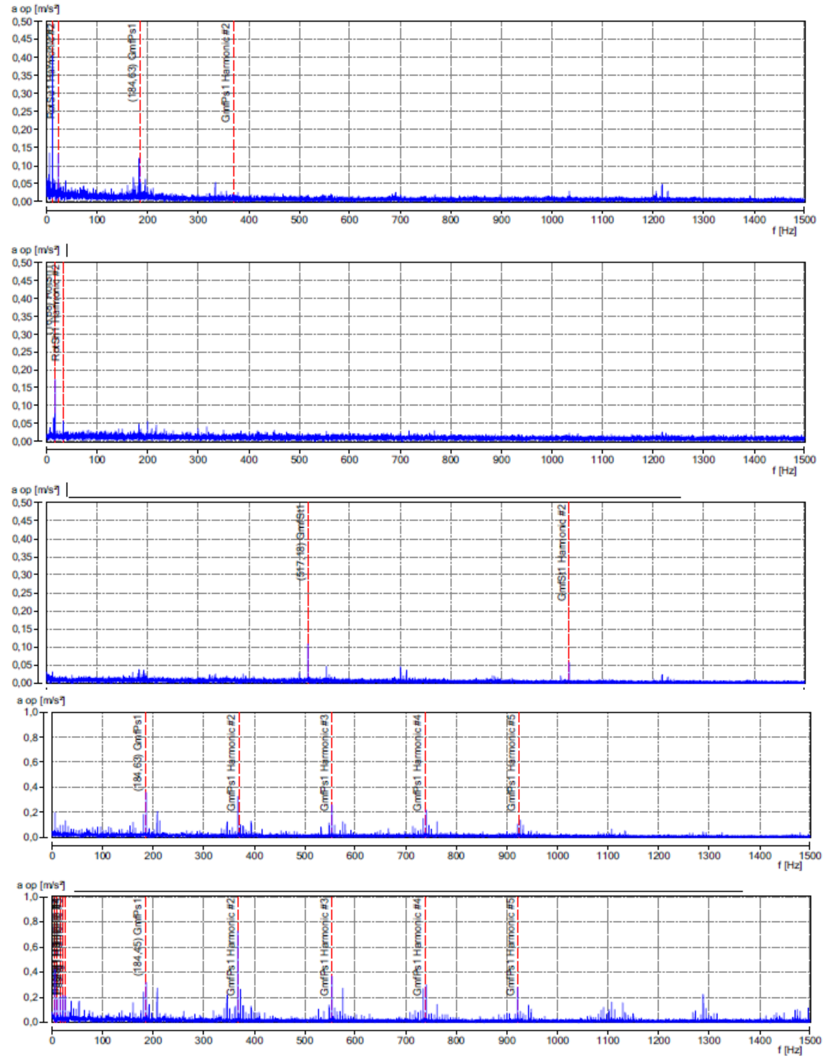
Vibration velocity spectrum, input area, measurement point 3V, 3H and 3A

Vibration velocity spectrum, first planetary stage, measurement point 4H and 4V

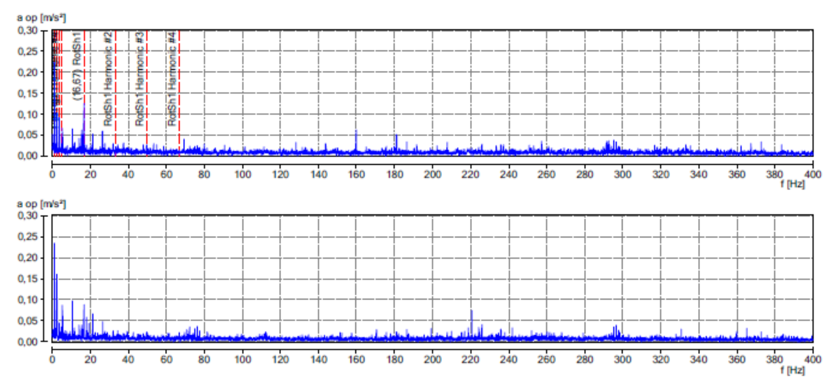
Vibration velocity spectrum, output planetary stage, measurement point 5H and 5V

Figure 5. Vibration velocity spectrum

Then, we look at the curve from the Envelope spectrum shown in Figure 6 below. The gear mesh frequency of the planetary and input stages are visible at the input shaft measurement points. The modulation pattern shows peaks at the passing frequencies of the ring gears of both planetary gear stages. The output stage only shows low levels. Because the present modulations of the ring gear passing frequency are considered regular modulations, it can be said that there are no suspect irregularities at the planetary stages.



Envelope spectrum, first planetary stage, measurement point 4H and 4V



Envelope spectrum, output planetary stage, measurement point 5H and 5V

Figure 6. Envelope spectrum

The last analysis using the acceleration spectrum is shown in Figure 7. High peaks are present at harmonics of the input gear stage meshing frequency. The third harmonic shows high vibration levels. This is not necessarily an indication of irregularities at the stage. The vibration behavior should be tested again after six months of operation. Bearing irregularities are not suspected, as no high-frequency range resonances are visible.

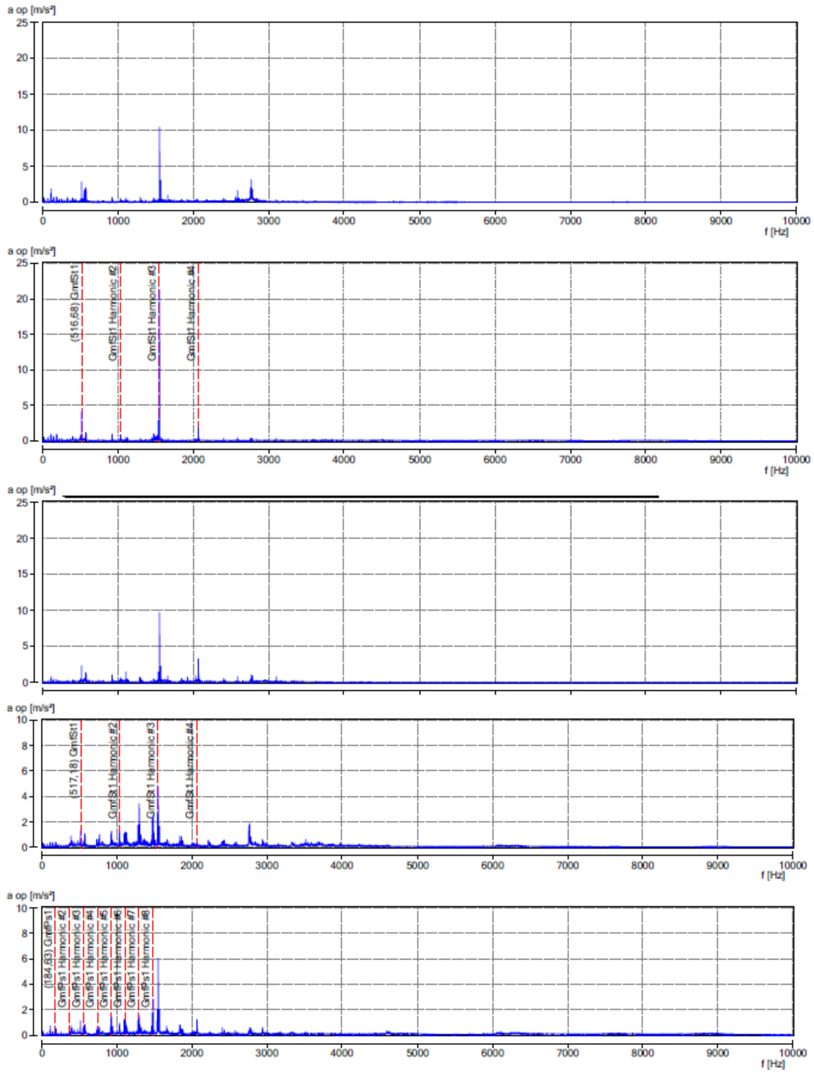
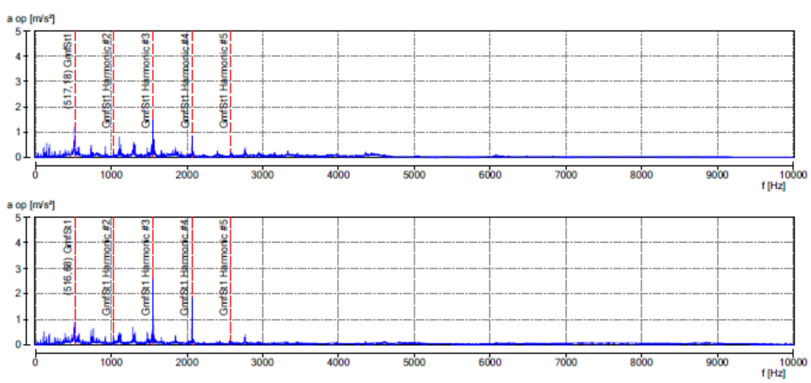


Fig. 11: Acceleration spectrum, first planetary stage, measurement point 4H and 4V



Acceleration spectrum, output planetary stage, measurement point 5H and 5V

Figure 7. Acceleration spectrum

4. Conclusion

This research determined the condition of the bearings and gear teeth inside the planetary gear unit to predict the schedule for a part replacement to reduce unplanned shutdown. Based on the Vibration Velocity, Envelope and Acceleration Spectrum signal analysis, we can get the conclusion below:

1. There is no sign of bearing damage in each gear teeth on the Planetary geat unit.
2. There is no sign of damage from the gear teeth, even though there is high vibration in the input shaft, but still in the tolerance range.

For the next six months of operation, this planetary shall operate well with the same condition as the measurement was done.

Successive measurements should trace the development of these vibrations after six months of operation.

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