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BELT CONVEYOR DRIVE GEARBOX PROBLEM CAUSED BY UNPAIRED GEARS- A CASE STUDY

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Abstract. *Belt conveyors for all kinds of materials are very important piece of equipment in mining and excavation industries. This paper presents a case study analysis of vibration on a belt conveyor driving unit. The analyzed belt conveyor is operating in copper production plant and it is conveying copper ore from mining site to process plant. In order to detect the possible defects in belt conveyor drive units, vibration measurements are conducted in all four drive units. Measurement points are set on bearing housings of electric motor and gearbox as defined by ISO 10816-1.*

Key words: *gearbox vibration analysis, gear tooth wear, unpaired gears, shaft misalignment*

INTRODUCTION

Belt conveyors for all kinds of materials are very important piece of equipment in mining and excavation industries. Continuous operation process in these industries demands continuous operation of belt conveyors in order to ensure planed capacities. Possible defects than can cause belt conveyor malfunction and shutdown are:

- Driving unit defect
- Conveyor belt defect
- Rollers defect
- Drums defect

A case study analysis of belt conveyor driving unit vibration has been presented in this paper. This paper is presenting a case study of belt conveyor driving unit vibration analysis. The analyzed belt conveyor is operating in copper production plant and it is conveying copper ore from a mining site to the process plant.

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Belt conveyor specifications:

- Length of conveyor: 1000[m]
- Width of conveyor belt: 2000[mm]
- Capacity: 1200[t/h]

Belt conveyor has two drums each powered by two 250[kW] electric motors with gearboxes (Figure 1). Three motors are always active and the fourth serves as a back-up.

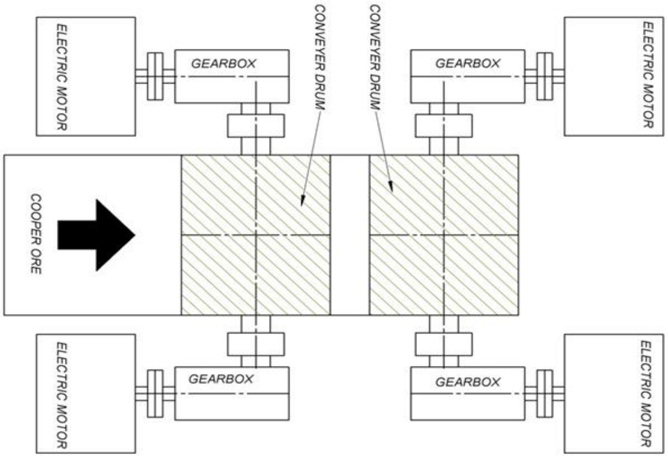

Fig. 1 Schematic display of the belt conveyor and the driving units

2. Belt Conveyor Drive Unit Design and Specifications

Belt conveyer consists of the following parts and sub-assemblies:

- Electric motor: Pem=250[kW], 6 poles, Nem= 980[rpm]
- Coupling: Hydrodynamic coupling type NKBS 500
- Gearbox: type RKHA2 500SS, i=22,4 ; Nin=980[rpm]; Nout=43,7 [rpm]

Gearbox is a two-stage gearbox with transmission ratio of i=22,4. The first stage are the pair of bevel gears; bevel gear pinion z=10; driven bevel gear z=41. The second stage are the pair of cylindrical gears with sloping teeth; pinion z=15; driven gear z=82 (Fig. 2).

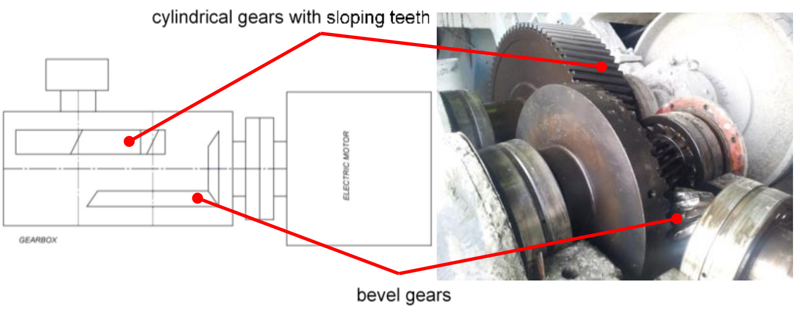

Fig. 2 Schematic display of driving unit and picture of two stage gearbox

In order to detect the possible defects on belt conveyor drive units, vibration measurements are conducted on all four drive units. Measurement points are set on bearing housings of electric motor and gearbox as defined by ISO 10816-1 standard and shown in Figure 3.

- L1 and L2 bearings (measurement points) on electric motor
- L3 and L4 bearings (measurement points) on gearbox input shaft
- L5 and L6 bearings (measurement points) on gearbox middle shaft
- L7 and L8 bearings (measurement points) on gearbox output shaft

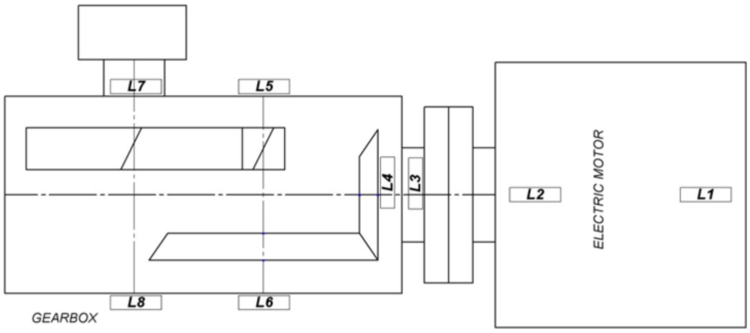

Fig. 3 Driving unit measurement points

Vibrations were measured at all points in all three directions, as it can be seen in Figure 4.

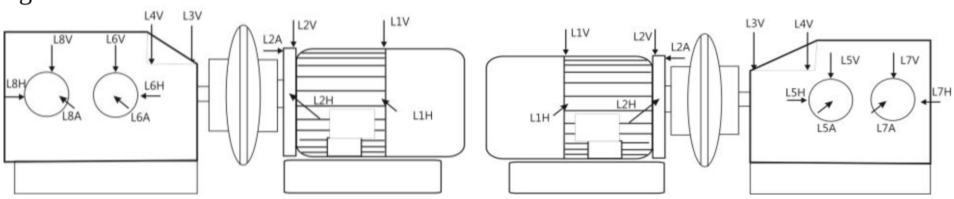

Fig. 4 Directions of vibration measurements

3. Potential Defects and Defect Frequencies

Each sub-assembly of driving unit carries potential defect and distinguishing defect frequencies. This means that defects can be divided in three groups:

1. Electric motor defects

When analyzing vibrations of electric motor, the attention should be focused on two defects: bearing defect and electric problems. Bearing problems are indicated by high amplitudes at characteristic frequencies for each bearing: BPFI, BPFO, FTF, BSF (Figure 5).

Table 1 Bearing types in electric motor

Measurement point	Bearing type
L1	6322
L2	NU322

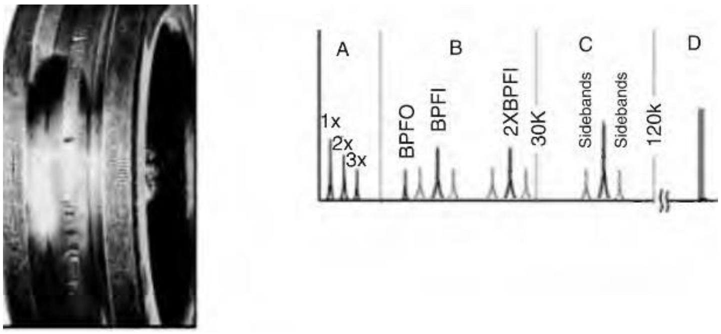

Fig. 5 Characteristic of frequency spectrum of bearing defect

Electric problems can be:
- Rotor defects
- Stator defects
- Phasing problem.

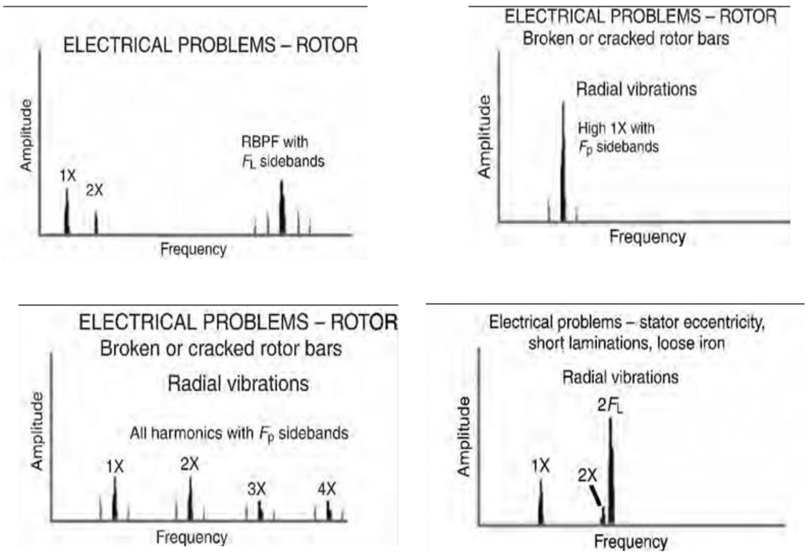

Fig. 6 Characteristic frequency spectrums of electrical problems [1]

Electrical problems are indicated by high amplitudes at characteristic frequencies, as shown in Table 2.

Table 2 Characteristic electric problems frequencies

Defect frequencies	
1x	16.4 Hz
F_L - line frequencies	50 Hz
Fs - slip frequencies	0.267 Hz
Fp – pole pass frequencies	1.6 Hz
P – No. of poles	6

2. Coupling defects

Two types of shaft misalignment can be diagnosed: parallel misalignment and angular misalignment. In many cases, both types of misalignment can be diagnosed on the same machine. Both parallel and angular misalignments are indicated by high amplitudes at 1x, 2x and 3x running speed (Figure 7).

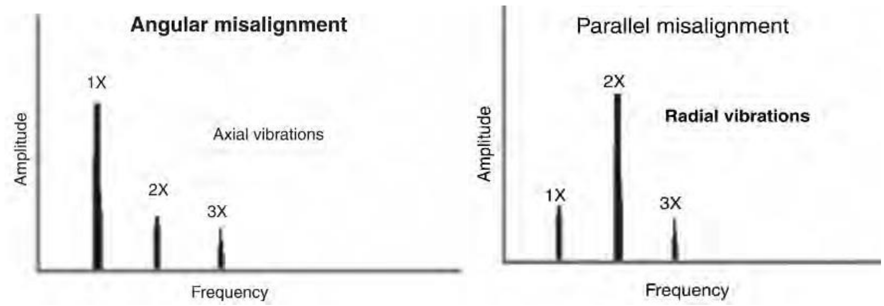

Fig. 7 Characteristic frequency spectrums of misalignment [1]

3. Gearbox defects

As for electric motor defects, the attention should be focused on two defects: bearing defect and gearing defects. Bearing problems are indicated by high amplitudes at characteristic frequencies for each bearing: BPFI, BPFO, FTF,BSF.

Table 3 Bearing types in gearbox

Measurement point	Bearing type
L3	**32324**
L4	**22328**
L5	**22332**
L6	**22332**
L7	**23052**
L8	**23052**

Gearing defects can be:

- Gear tooth wear
- Gear tooth load
- Gear eccentricity and backlash

- Gear misalignment
- Cracked or broken tooth.

Gearing defects are indicated by high amplitudes at characteristic frequencies:

Table 4 Characteristic gearbox frequencies

Defect frequencies	Hz
1x – input shaft	16.09 Hz
2x - input shaft	32.18Hz
1x – middle shaft	3.92Hz
1x – output shaft	0.728 Hz
GMF 1/ ZP1 first stage gears	161.7 Hz
GMF 2/ ZP2 second stage gears	58,88 Hz

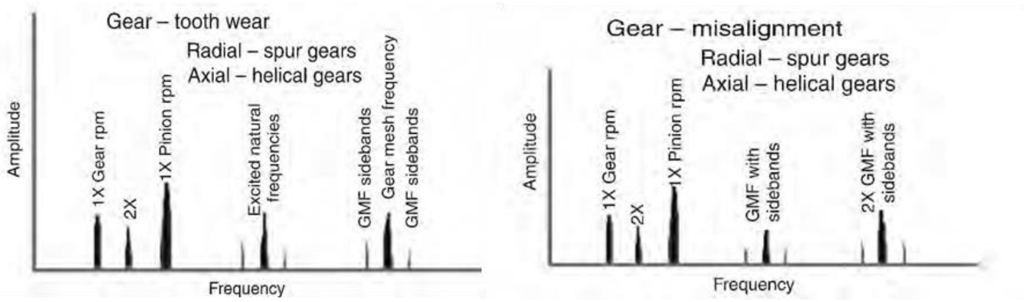

Fig. 8 Characteristic frequency spectrums of gearing defects [1]

4. Vibration Analysis and Results

Driving units 1 and 4 have the highest vibrations and most visible defects.

Driving unit 1 - When analyzing the frequency spectrum measured on electric motor, it is clear that both parallel and angular misalignment is present (Fig. 9 and Fig.10)

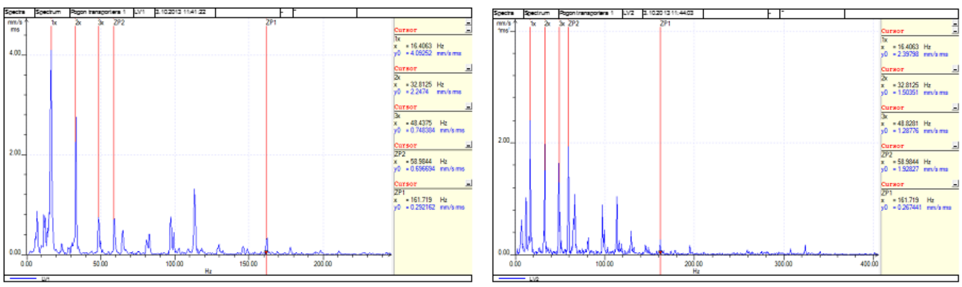

Fig. 9 Drive unit 1- LV1 and LV2 frequency spectrums–parallel misalignment

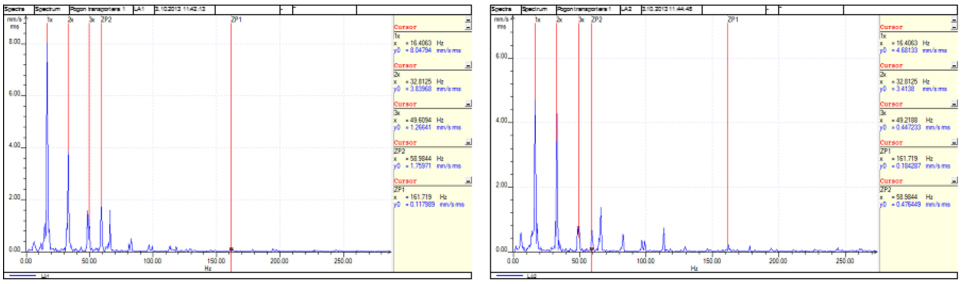

Fig. 10 Drive unit 1 - LA1 and LA2 frequency spectrums-angular misalignment

Table 5 Measured values of parameters LV1, LV2, LV3

	LV1 [mm/s]	LV2[mm/s]	LV3[mm/s]
1x - 16.4Hz	4.1	2.4	5.9
2x - 32.8Hz	2.2	1.5	2.2
3x - 49.2Hz	0.75	1.3	0.53

Table 6 Measured values of parameters LA1, LA2

	LA1 [mm/s]	LA2[mm/s]
1x - 16.4Hz	8,0	4,7
2x - 32.8Hz	3,8	3,4
3x - 49.2Hz	1,3	0,44

Frequency spectrums measured on gearbox indicate that higher vibration levels are caused by first stage gears misalignment. This is determined by high amplitudes of first stage gear mesh frequencies harmonics – GMF1, GMF2 and GMF3.

Table 7 Measured values of parameters LH3, LV3, LH4

	LH3 [mm/s]	LV3 [mm/s]	LH4 [mm/s]
1xGMF1 - 161.7Hz	1.15	3.26	0,75
2xGMF1 - 323.8Hz	1.1	2,84	2,44
3xGMF1 - 485.5Hz	2.8	1,15	2,35
1xGMF2– 58.88Hz	0.2	0.4	0.3

Table 8 Measured values of parameters LH5, LH6, LH7

	LH5 [mm/s]	LH6 [mm/s]	LH7 [mm/s]
1xGMF1 - 161.7Hz	0.7	0.8	0.8
2xGMF1 - 323.8Hz	1.2	0.4	0.6
3xGMF1 - 485.5Hz	1.0	1.1	0.4
1xGMF2 - 58.88Hz	0.2	0.4	0.3

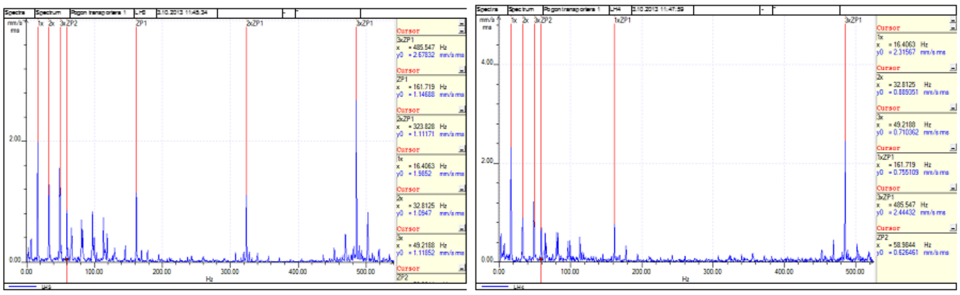

Fig. 11 Drive unit 1-LH3, LH4 gearbox input shaft-frequency spectrums first stage gears misalignment

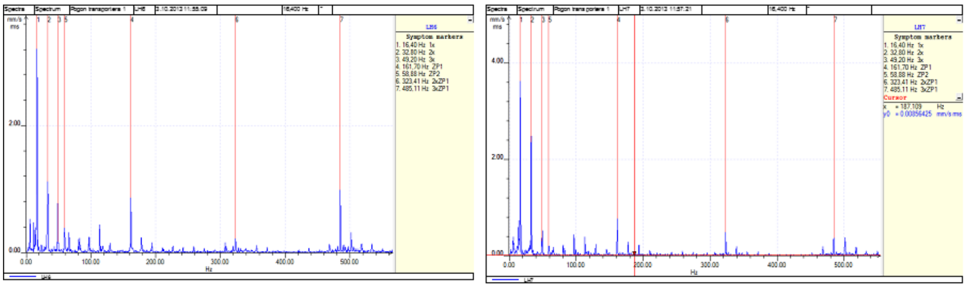

Fig.12 Drive unit 1–LH6, LH7 gearbox middle and output shaft–frequency spectrums first stage gears misalignment

Second stage gears are working properly which is indicated by low amplitudes of GMF2.

Driving unit 4 - When analyzing the frequency spectrum measured on electric motor it is clear that both parallel and angular misalignments are present as in the drive unit 1, as shown on Figure 13 and Figure 14.

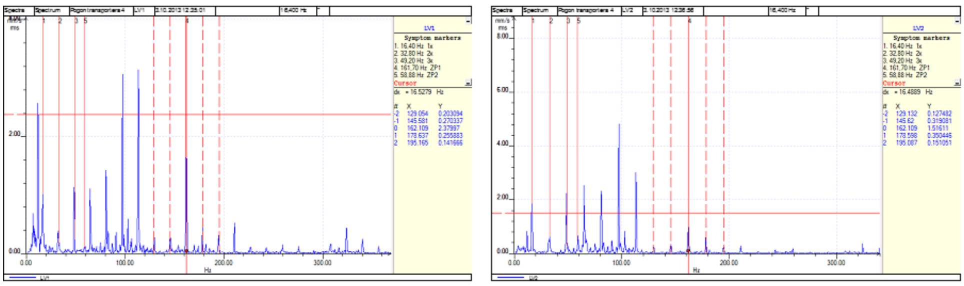

Fig. 13 Drive unit 4 - LV1 and LV2 frequency spectrums – parallel misalignment

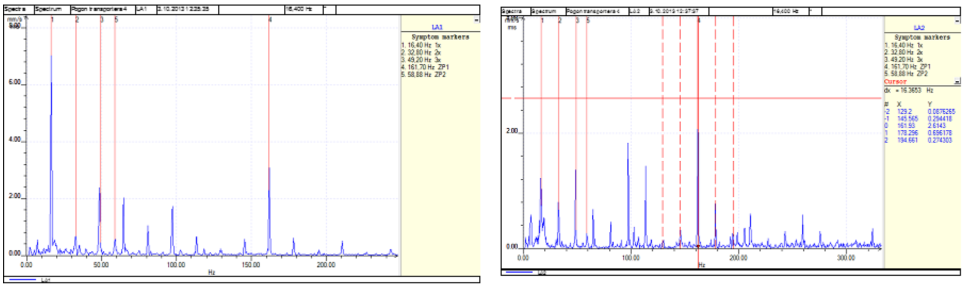

Fig. 14 Drive unit 4 - LA1 and LA2 frequency spectrums - angular misalignment

Table 9 Measured values of parametersLV1, LV2, LV3

	LV1 [mm/s]	LV2[mm/s]	LV3[mm/s]
1x - 16.4Hz	1.1	1.9	4.3
2x - 32.8Hz	0.2	0.5	0.4
3x - 49.2Hz	1.2	2.4	1.8

Table 10 Measured values of parameters LA1 and LA2

	LA1 [mm/s]	LA2[mm/s]
1x - 16.4Hz	6,8	1,2
2x - 32.8Hz	0,8	0,8
3x - 49.2Hz	2,3	1,6

Frequency spectrums measured on gearbox indicate that higher vibration levels are caused by first stage gears tooth wear. This is determined by high amplitudes of first stage gear mesh frequencies harmonics – GMF1, GMF2 and GMF3 and surrounding sidebands.

Table 11 Measured values of parameters LH3, LV3, LH4

	LH3 [mm/s]	LV3 [mm/s]	LH4 [mm/s]
1xGMF1 - 161.7Hz	4.5	4.2	2.4
1xGMF sidebands	3.8	2,6	4,4
2xGMF1 - 323.8Hz	2.1	3.9	1.6
1xGMF2 – 58.88Hz	0.3	0.5	0.4

Table 12 Measured values of parameters LH5, LH6, LH7

	LH5 [mm/s]	LH6 [mm/s]	LH7 [mm/s]
1xGMF1 - 161.7Hz	3.2	6.4	4.6
1xGMF sidebands	1,2	0,8	2,1
2xGMF1 - 323.8Hz	2.1	1.1	0.4
1xGMF2 – 58.88Hz	0.6	0.5	0.3

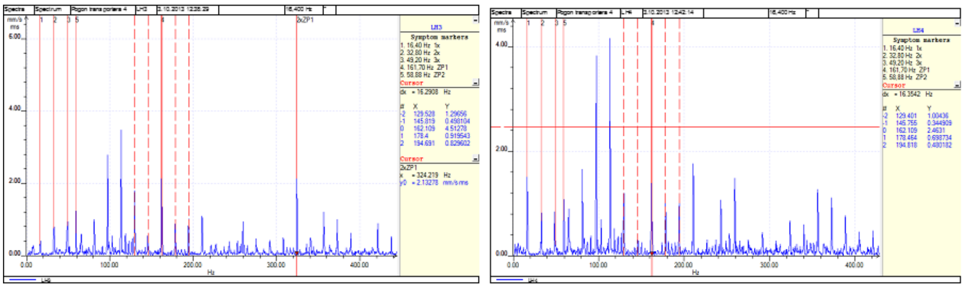

Fig. 15 Drive unit 4 - LH3, LH4 gearbox input shaft - frequency spectrums first stage gears misalignment + gear tooth wear

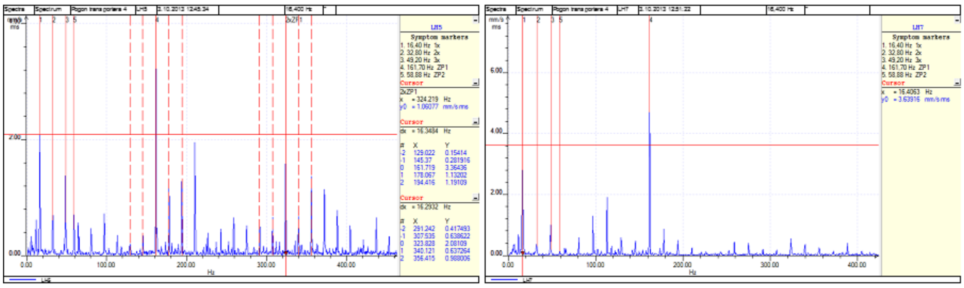

Fig. 16 Drive unit 4 – LH5, LH7 gearbox middle and output shaft - frequency spectrums first stage gears misalignment

Second stage gears are working properly which is indicated by low amplitudes of GMF2.

Fig. 17 Drive unit 4 – First stage gears wear

5. CONCLUSION

Excessive vibrations on drive units 1 are mainly caused by shaft misalignment between electric motors and corresponding gearboxes. Gear misalignment on drive unit 1 gearbox is noticeable but it could be fixed relatively easily.

The situation with drive unit 4 gearbox is much more complex. Due to unfortunate chain of events, the gearbox had been working with unpaired set of first stage gears for a while. Unpaired gears means that gear teeth are not fitted to one another, causing the load to be transferred from one gear to another with very small gear tooth surface. This small contact surface has resulted in very large contact pressure causing gear tooth wear.

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PROBLEM KOJI NASTAJE USLED NEUPARENOSTI ZUPČANIKA NA POGONSKOJ JEDINICI TRAKASTOG TRANSPORTERA- STUDIJA SLUČAJA

Trakasti transporteri se koriste za različite vrste materijala, i predstavljaju veoma važan deo opreme posebno u rudarstvu i industriji iskopavanja. Ovaj rad predstavlja analizu studije slučaja izmerenog nivoa vibracija za pogonsku jedinicu trakastog transportera. Analizirani trakasti transporter radi u kopovskom proizvodnom pogonu i to u procesu prenošenja rude iz rudarske stranice do mesta obrade rude unutar fabrike. Kako bi se otkrili mogući nedostaci na pogonskim jedinicama transportera, sprovodi se merenje vibracija na sve četiri pogonske jedinice. Merne tačke su postavljene na kućištu ležaja elektromotora i prenosnika snage, kao što je definisano od strane standarda ISO 10816-1.

Ključne reči*: analiza vibracija na prenosiku snage, brzina trošenje zuba, neuparenost zupčanika, nesaosnost vratila.*