



## CASE HISTORY:

# Vibration Analysis On A Conveyor Drive Unit

BY MICHAEL S. JOHNSON, JR., PE

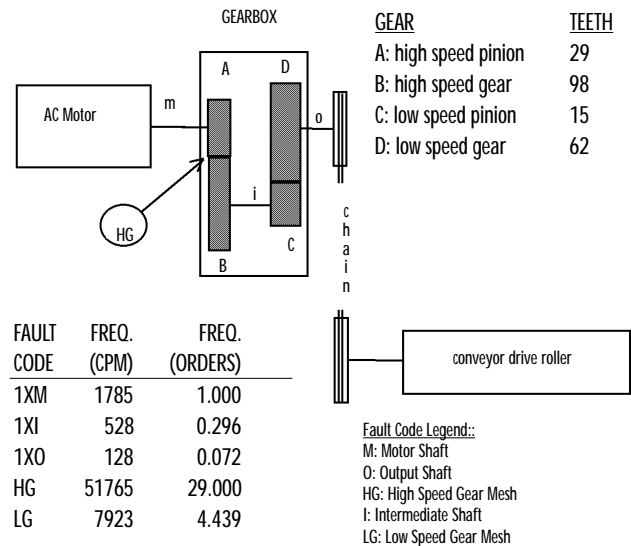
*The United States Postal Service processes large bundles, packages, and catalogues through 21 Bulk Mail Centers around the nation. These centers are filled with motors, conveyors, speed reducing gearboxes, and various other material handling equipment. This equipment operates 24 hours per day during peak demand periods. In an ongoing effort to increase machine reliability and reduce overall costs, the USPS Maintenance Technical Support Center in Norman, Oklahoma initiated a project to provide the BMC maintenance offices with vibration analysis equipment and training to help support the maintenance process. The following case history helps illustrate some of the benefit already gained through the use of this technology.*

### INTRODUCTION

A vibration monitoring program at the Cincinnati Bulk Mail Center (BMC) of the US Postal Service was started in October, 1996. The B-14 conveyor drive was classified as a critical drive for the movement of mail through the BMC. The vibration program identified a serious intermediate shaft looseness or impacting problem with the drive unit on B-14. The intermediate shaft vibration levels were monitored closely and trended for increased vibration. Through the Christmas season, the unit showed increased vibration levels indicating that the problem was getting worse. Once parts were available, a replacement to the gearbox was made during a scheduled maintenance period before catastrophic failure.

This case history displays some of the vibration data used in the diagnosis of the problem. A basic explanation of the internal configuration of the gearbox is included to help understand the machine. The driver is a 4 pole AC induction motor operating at a speed of about 1785 cpm. The motor /gearbox is close coupled and the double reduction

gearbox has two gear meshes that are identified as high speed gear mesh (HG) and low speed gear mesh (LG). The shaft rate frequencies and gear mesh frequencies were calculated using the gear teeth ratios. See Figure 1.



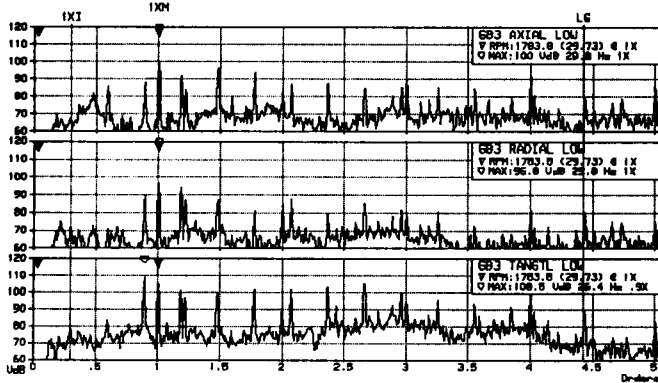
**Figure 1. Schematic of the B-14 conveyor drive and the primary forcing frequencies. The motor housing is bolted directly to the gearbox so that the prime mover is a close coupled unit. All shafts are in the horizontal plane.**

### VIBRATION SETUP

The BMC maintenance staff used a triaxial accelerometer sensor to collect vibration data in three axes (axial, radial, and tangential). The digital data collector was configured for 800 line vibration data using both the Fast Fourier Transform (FFT) and amplitude demodulation signal processing techniques. The FFT spectra were collected using two frequency ranges. The low range data covers a range from 0 to 150 Hz, and the high range data is from 0 to 1500 Hz. The demodulated spectra were collected using a frequency range from 0 to 300 Hz.



PLANT: CINCINNATI BULK MAIL CENTER AREA: MAIL SORTING EQUIPMENT  
 MACHINE: BELT DRIVE B-14 (SRS)  
 LOCATION: GEARBOX BEARING (3AL)  
 LEGEND: 4 Oct 1996  
 FREQ: 29.81 Hz ORDER: 1 X LEVEL: 100 UdB  
 DATE: 4 Oct 1996/05:31:50



PLANT: Cincinnati BNC AREA: MAIL SORTING EQUIPMENT  
 MACHINE: BELT DRIVE B-14 (OK)  
 LOCATION: GEARBOX BEARING 3 (3TL)  
 FREQ: 0.813 Hz ORDER: .3 X LEVEL: 85.9 UdB  
 DATE: 26 Feb 1997/01:04:55 RPM: 1790  
 MID: 30 DELTA: 0.02/.3K

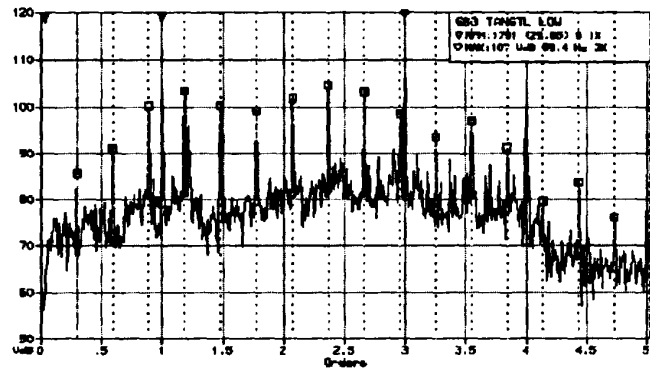


Figure 2. Low range vibration data from October 96 (on the left) and just before replacement in March 97 (right).  
 Note harmonic series at 1xI spacing.

### VIBRATION SPECTRAL DATA

The first vibration test was conducted on October 4, 1996. The prime mover was replaced in early March of 1997. Figure 2 shows the first and last set of data taken on the faulty machine. The tangential spectrum shows a strong 1xI harmonic series. Note that all prominent peaks in the spectra are harmonics of either 1xM or 1xI.

The spectra above are displayed in triaxial format. The upper spectrum is axial vibration, the middle spectrum is radial (vertical) vibration, and the lower spectrum is tangential (horizontal) vibration. The frequency scale is shown in units of Orders. The order 1.00 corresponds to the motor rotational rate (1xM). The order 0.296xM correspond to the intermediate shaft rate (1xI). The amplitude scale is displayed in units of Velocity decibels (VdB) using a velocity of  $10^{-8}$  meter/sec as a reference.

The replacement unit, while also a double reduction gearbox, came from a different manufacturer. The nameplate data was slightly different and had different gear tooth counts. Following the replacement of the unit, another vibration test was conducted. The spectra from this test are shown in Figure 3 to allow comparison of a fault free machine with the faulty machine. Note that the low speed gear mesh (LG) is lower frequency than the previous gearbox due to the differences in gear tooth count.

### VIBRATION DEMOD DATA

The demodulated spectra are shown in triaxial format in Figure 4a for the October 1996 data set. The February 1997

PLANT: CINCINNATI BULK MAIL CENTER AREA: MAIL SORTING EQUIPMENT  
 MACHINE: BELT DRIVE B-14 (SRS)  
 LOCATION: GEARBOX BEARING (3AL)  
 LEGEND: 11 Mar 1997  
 FREQ: 29.81 Hz ORDER: 1 X LEVEL: 93.6 UdB  
 DATE: 11 Mar 1997/05:07:11

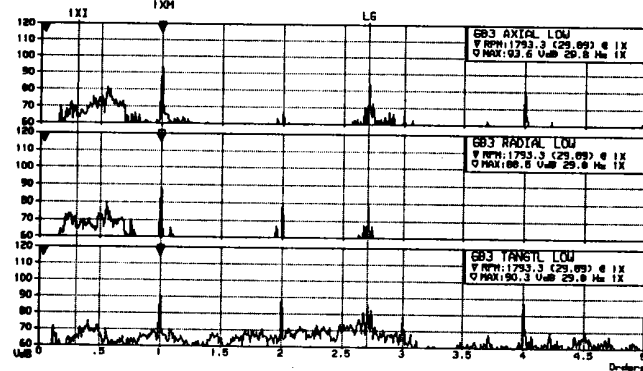


Figure 3. Low range vibration data after replacement of the drive unit. Note that 1xI harmonic series is not present in the fault free machine.

data is shown in Figure 4b. The harmonic spacing is clearly at a frequency that corresponds to 1xI. Note that the noise floor is higher for the February data while the amplitudes in the harmonic series are slightly lower.

Again for comparison purposes, the post repair demodulated spectra are shown in Figure 5. The amplitude scaling is slightly different from those spectra in Figure 4 due to a much lower noise floor.

### VIBRATION ANALYSIS

The first vibration test showed a significant intermediate shaft rate (1xI) harmonic series in the FFT spectra (Figure 2).

PLANT: CINCINNATI BULK MAIL CENTER AREA: MAIL SORTING EQUIPMENT  
 MACHINE: BELT DRIVE B-14 (SRS)  
 LOCATION: GEARBOX BEARING (3AD) DATE: 4 Oct 1996/05:32:37  
 LEGEND: 4 Oct 1996  
 FREQ: 29.63 Hz ORDER: 1 X LEVEL: 32.7 dBuW

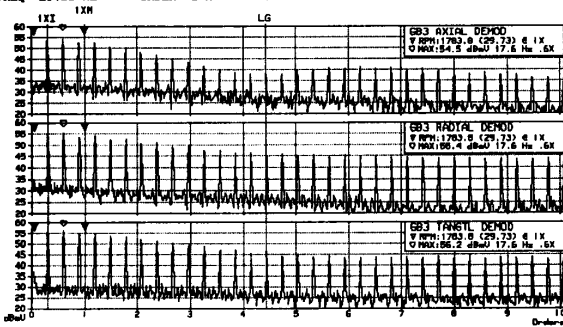


Figure 4a. Demodulated spectra, October 96

PLANT: CINCINNATI BULK MAIL CENTER AREA: MAIL SORTING EQUIPMENT  
 MACHINE: BELT DRIVE B-14 (SRS)  
 LOCATION: GEARBOX BEARING (3AD) DATE: 26 Feb 1997/01:05:34  
 LEGEND: 26 Feb 1997  
 FREQ: 29.63 Hz ORDER: .99 X LEVEL: 35.1 dBuW

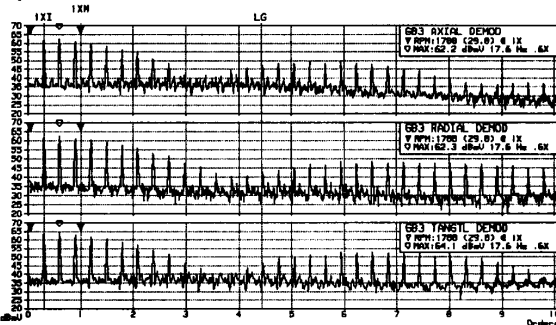


Figure 4b. Demodulated spectra, February 97.  
 The amplitude scaling is slightly different from Figure 4a.

PLANT: CINCINNATI BULK MAIL CENTER AREA: MAIL SORTING EQUIPMENT  
 MACHINE: BELT DRIVE B-14 (SRS)  
 LOCATION: GEARBOX BEARING (3AD) DATE: 11 Mar 1997/05:07:51  
 LEGEND: 11 Mar 1997  
 FREQ: 30 Hz ORDER: 1 X LEVEL: 34.2 dBuW

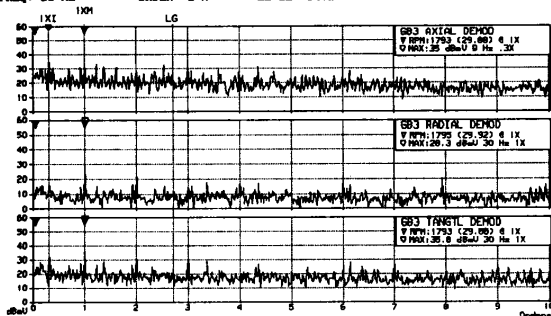


Figure 5. Demodulated spectra, March 97. Note the amplitude scale is different from the data shown in Figure 4.



The strong 1xI harmonic series in the demodulated spectra (*Figure 4*) confirms the intermediate shaft problem and actually shows the fault much more clearly. The shaft rate harmonic series with high amplitudes indicates a looseness or impacting problem with the intermediate shaft or one of the components on the shaft. The BMC maintenance technicians continued to monitor the machine on a monthly basis until a replacement was available and the conveyor could be taken out of service. Each monthly survey showed the strong 1xI harmonic series up to the point of replacement.


When the unit was replaced, the BMC maintenance technicians disassembled the defective gearbox and found a broken tooth on the low speed pinion. The broken tooth was causing an impact each time it meshed with the gear on the output shaft. The tooth next to the broken tooth also had a severe crack and came off when handled by the analyst. The photographs show the intermediate shaft on the left and the broken teeth on the right.



## BENEFITS

Represented in this case history are two obvious benefits to any facility with critical machinery in an industry where down time creates a hardship. First, the BMC technicians were able to identify a significant problem on a critical unit and continue to evaluate the risk of continued operation over the five months they needed to run it.

Second, they were able to anticipate the parts required for repair, order them, and schedule the repair before failure occurred.

Third, if left to run until complete failure, the low speed pinion would have continued its self- destruction and catastrophic failure would have probably been the result. Catastrophic failure usually causes collateral damage (which results in significantly more down time and repair costs) and typically happens at the worst possible time. 

*Michael Johnson is a Senior Mechanical Engineer with the DLI Engineering Division of PredictDLI. He has six years experience as a Naval Nuclear Propulsion Officer and six years as a senior application engineer for the DLI Expert Automated Diagnostic System. He is a registered Professional Engineer with experience in marine, semiconductor, manufacturing, power education, and facilities engineering.*

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