Assetivo

Case Studies

Case Study: Condition Monitoring Prevents Downtime - Skip Hoist Bearing Issue

Executive Summary

This report represents a condition monitoring case study of a blast furnace skip hoist that is utilised to transport raw materials to the top of a typical ironworks blast furnace. This production critical equipment suffered an increasing overall vibration velocity trend in a short number of weeks. The trend highlighted that the motor drive end bearing – a 6238 C3 deep groove ball bearing – had a defect. The defect was successfully highlighted using a combination of online and handheld vibration data collection and vibration analysis. The removal and inspection successfully revealed flaking and denting in the outer race load zone, though root cause is unknown. The motor replacement brought overall vibration back down to historical levels. The report recommendations were to derive a new lubrication routine, take regular grease samples for analysis and ensure motor shafts are rotated when in storage to avoid false brinelling.

Introduction

The Blast Furnace is the driving force for the site's steelmaking activities and therefore its reliability and availability is critical to the entire process from raw materials movements, to the conversion of iron to steel, and finally finished strips of steel coil ready for shipment. Critical to the ironmaking process is the delivery of raw materials to the top of the blast furnace and this is achieved by a skip hoist that pulls two skip cars in opposite directions on rail track on a steep incline. This case study details a high vibration issue on a drive end bearing on one of the skip hoist's two DC motor drives that had the potential to severely affect iron production if not remedied. The motors provide a dual drive to the hoist via their individual reduction gearboxes driving a larger reduction gearbox coupled to the hoist drum via couplings and supported by anti-friction bearings. The fault was initially indicated by the Skip Hoist's online vibration monitoring system; this is just one of several predictive maintenance tools used by the site's condition monitoring team with others including lubrication sampling, acoustic emissions, and infrared thermography. The company utilises condition monitoring and tribology methodologies as part of its reliability and professional asset management strategy with the aim of achieving world-class levels of overall equipment effectiveness.

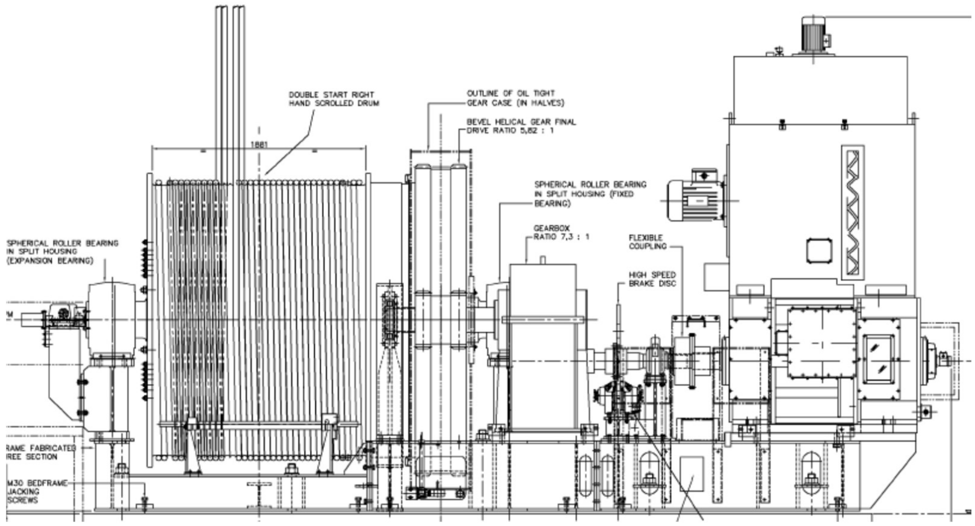

Figure 1: Side elevation of the Blast Furnace skip hoist unit

Introduction

The Skip Hoist has an Iconet online vibration monitoring system installed that monitors vibration 24 hours per day from several positions on the unit. Though not every traditional vibration data collection point is measured due to costs and infrastructure issues, the following points are monitored: motor drive ends, drive gearboxes' axial and vertical, outrigger verticals and axials, and the main gearbox bearings at axial and vertical as shown in **Figure 2**.

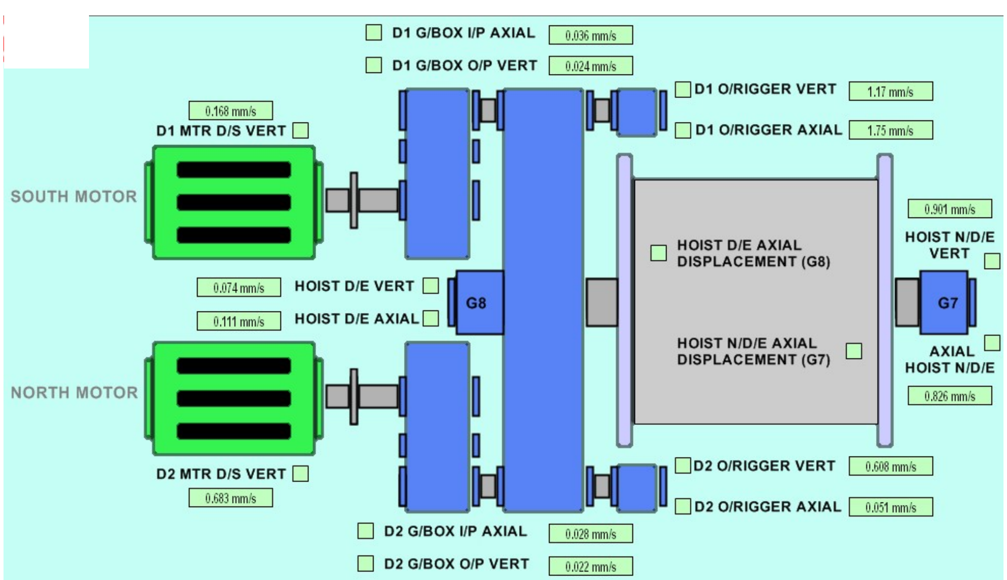

Figure 2: online system user screen and accelerometer positions

As a further confirmation of machinery health, monthly handheld data is collected from the same accelerometer transducers via a switchbox near the skip hoist. This takes place as a back up to the online system's data and as check that sensors and cables are still functional. Other predictive methodologies such as lubrication samples, thermography routes and acoustic emissions measurements are not part of the skip hoist's scheduled maintenance plan at present.

The Problem

The Skip Hoist had been running smoothly for several years without any serious interruptions to production. In early November 2012, a step change in the overall velocity RMS reading (mm/s) was noticed on the drive motor 1 drive-end bearing via a vertically mounted accelerometer. The trend had always been under 1 mm/s RMS for several years. At first the trend oscillated between values of 1.6 to 3 mm/s between November and December 2012 – as seen in Figure 3. Then in early January 2013 the trend became more erratic with values oscillating between 2 and 5.5 mm/s – values considerably above historical trends and a clear sign of an anomaly in the system. The motor drive end bearing was greased in mid-November 2012 but it had little or no effect on vibration levels as shown in **Figure 3**.

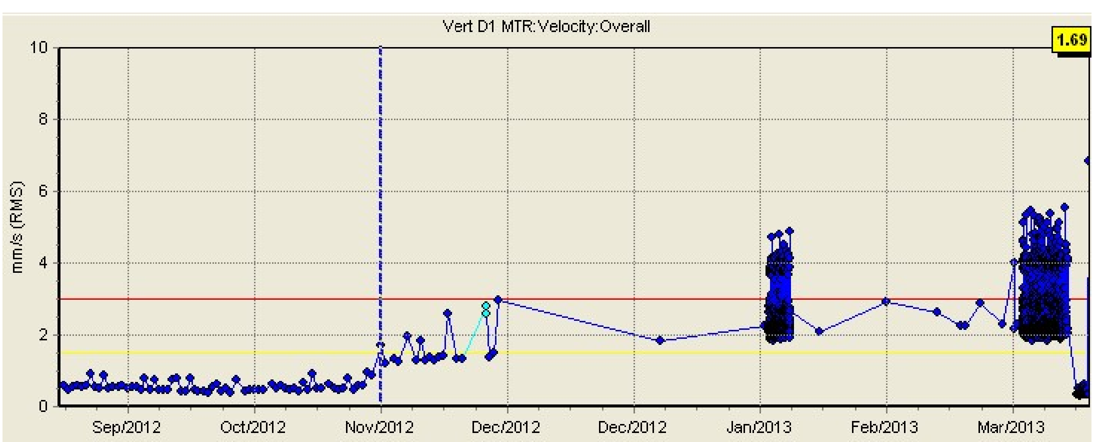

Figure 3: Online system six-month trend

Despite the fact that the skip hoist has redundancy built-in because of the dual drive motors, the possibility of losing one motor to a catastrophic failure would place the blast furnace operations at high risk of total loss of production – approximately £70,000+ per hour - if the second drive was lost for any reason. Given that an estimate for motor drive changeover is 16 to 24 hours, there was the distinct possibility of at least a £1.12M to £1.68M in lost production costs if both motors were to fail.

Analysis

On a recommendation from the Plant Condition Monitoring team, the decision was taken by management to remove and replace the motor. The removal, replacement and production restart took place between 5th and 7th April 2013 during a planned maintenance stop. The motor was then sent to a local refurbishment company to be stripped and inspected.

During the vibration monitoring program initial set up, the bearing details – in this instance an SKF 6238 C3 deep groove ball bearing – were inputted into analysis software. The specific details relating to bearing geometry that aid in the analysis process are as follows: ball spin frequency (BSF), fundamental train (cage) frequency (FTF), ball pass frequency outer ring (BPFO), and ball pass frequency inner ring (BPFI) all measured in hertz (Hz). These non-synchronous frequencies - as they appear in the spectra and time waveforms - help the analyst determine the exact nature of the fault, whereas the relative amplitudes in velocity or acceleration help determine the severity.

On closer inspection of the time waveform from hand-held data (see **Figure 4**) it was clear that impacting was present, and repetitive and periodic in nature. The analysis software allowed all fault frequencies (including running speeds, line frequencies, and fan blade and gear mesh frequencies) to be overlaid on the time waveform. After trying several bearing frequencies, a perfect match was found in the BPFO, i.e. an anomaly was present in the outer race of the bearing.

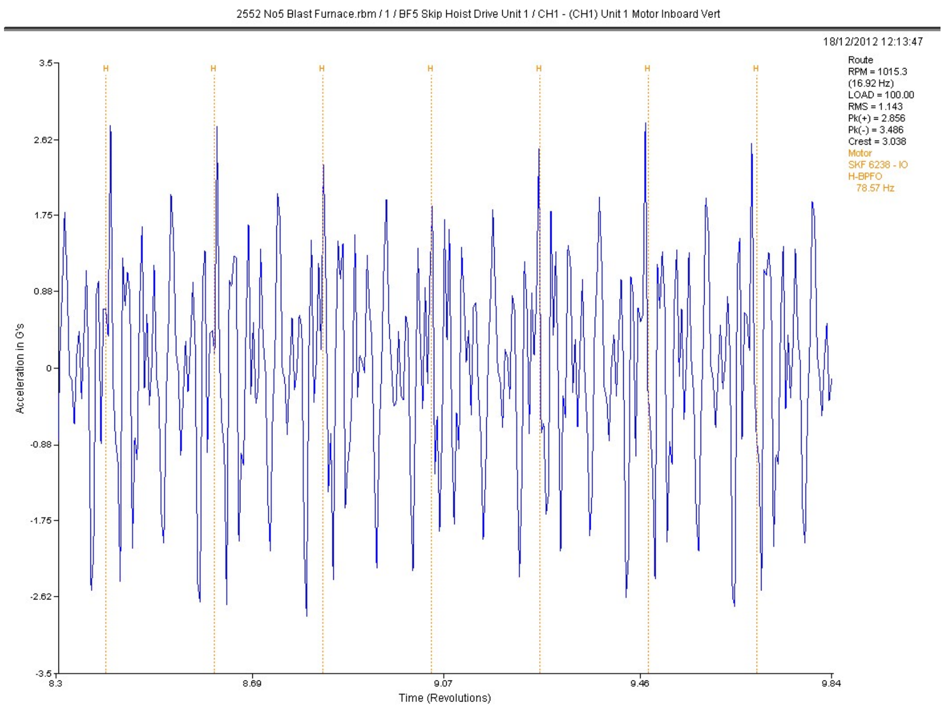

Figure 4: Acceleration time waveform taken on 18/12/2012

As further evidence that the anomaly is on the fixed outer race and *not* the rotating inner race, it is seen in **Figure 4** that the severity of the impacts is reasonably steady with no significant evidence of amplitude modulation that is common on inner race faults that move in and out of the load zone.

The analysis software carried out a Fast Fourier Transform to obtain a frequency spectrum as shown in **Figure 5**. In this instance it displayed the overall velocity RMS vibration levels in mm/s and the discrete frequency components that the overall level consisted of. Immediately it can be seen that there are several harmonics - a classic spectra symptom of impacting and non-linearities – dominating the spectrum up to an approximate frequency span (Fmax) of 1000Hz or 50 orders of running speed. On overlaying the known bearing fault frequencies again, the BPFO was a clear match for the impacting present starting from 4.6 orders of running speed up to eleven perfectly aligned harmonics. Again the lack of sidebands around the harmonics indicated that the fault probably was not an inner race fault.

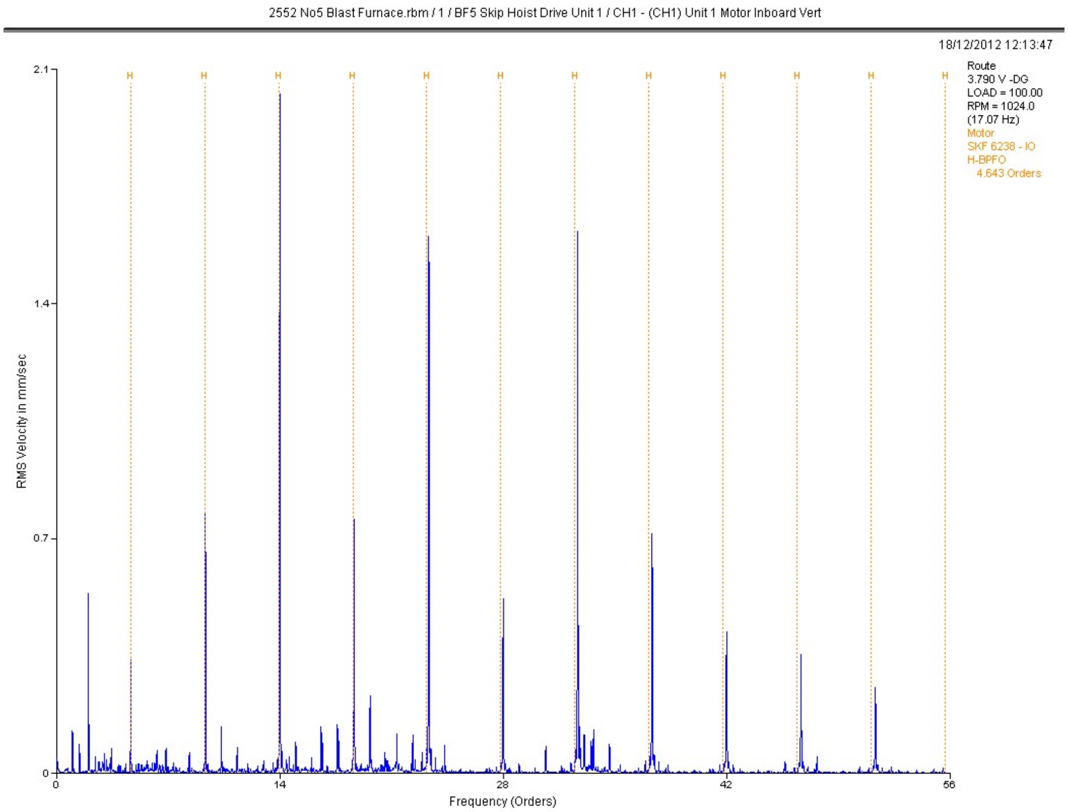

Figure 5: Overall velocity spectrum taken on 18/12/2012

On inspection of the bearing it was found that the outer race had indeed suffered flaking damage (also known as spalling) as seen in **Figure 6**. This damage typically results from rolling fatigue of the smooth bearing raceway and causes metal to eventually break away from the surface. There is also evidence of randomly spaced denting which may come from the flakes being rolled and forced into the surface by the balls in motion. The running traces on the inner and outer races indicated normal radial loading with no indication of misalignment, bore ovality or thrust loading. To find the origin of the flaking would require testing of the grease and a study of the metallographic structure of the bearing materials – both of which were not possible in this case study.

Figure 6: Drive end bearing during strip & load zone damage on outer raceway

On a planned maintenance stop the replacement motor was installed, and then run up and put into full production. Vibration data was collected and analysed and as can be seen in **Figure 7**, overall vibration levels had dropped significantly to historical levels.

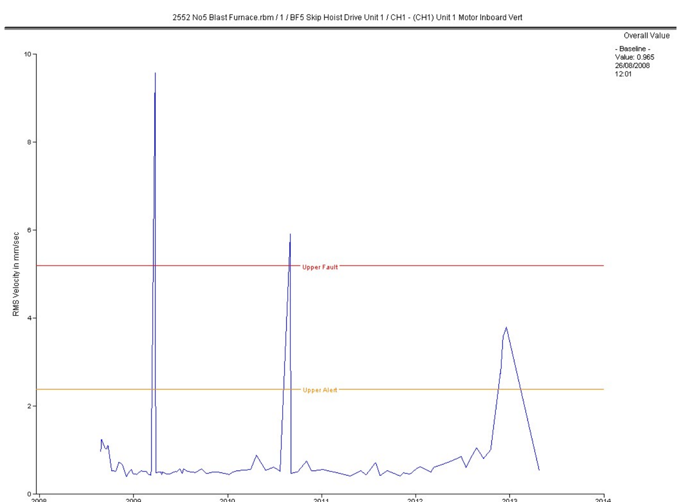

Figure 7: Trend of overall vibration levels showing drop in vibration

The time waveform and frequency spectra had also returned to stable, historical levels well within fault and alarm levels as shown in **Figures 8** and **9**.

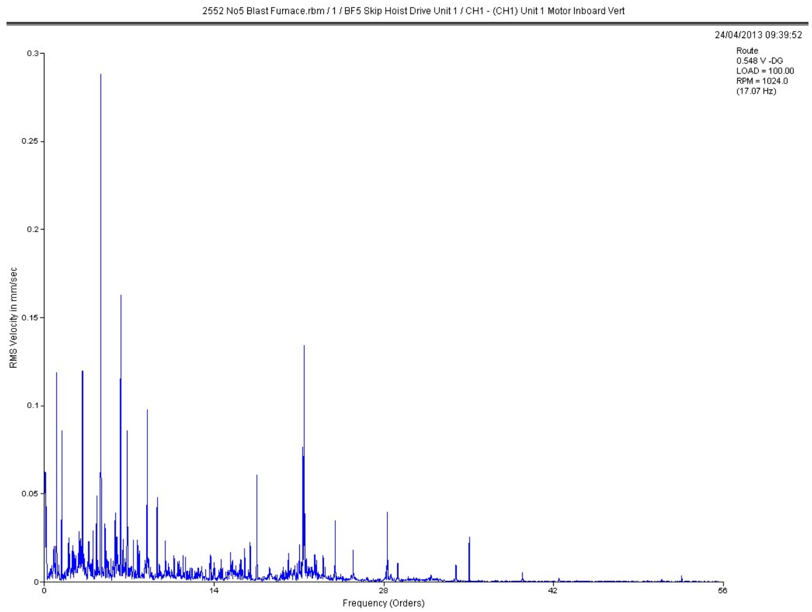

Figure 8: Frequency spectrum of drive end bearing after motor change

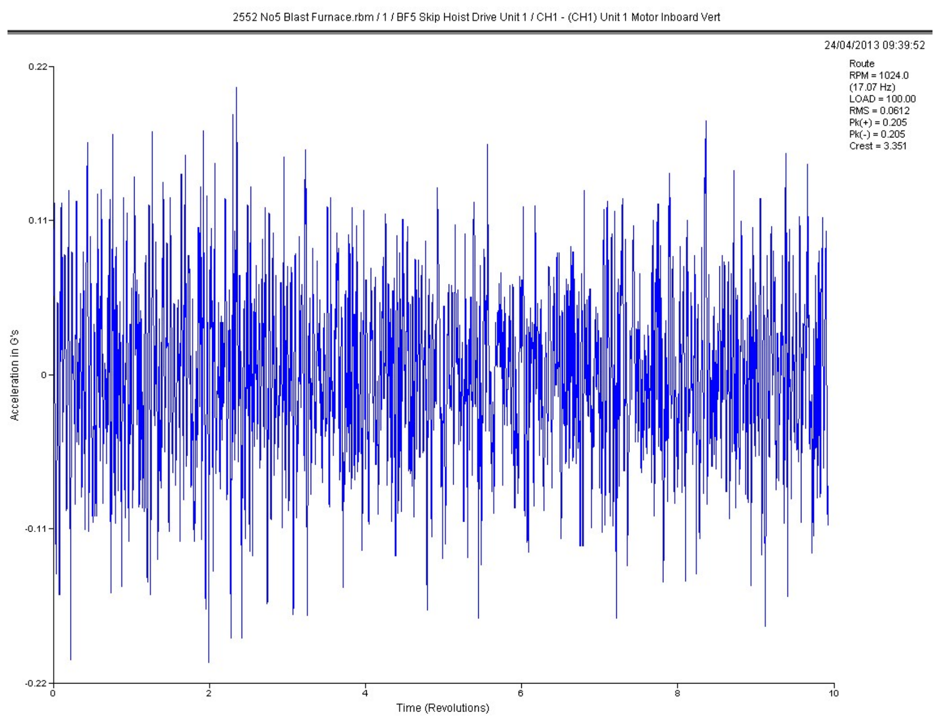

Figure 9: Acceleration time waveform of drive end bearing after motor change

Conclusion

The permanent online vibration monitoring of the skip hoist motor revealed a gradual increase in vibration velocity RMS at motor 1's drive-end deep groove ball bearing. When this increase was sustained above historical levels handheld data was collected and analysed. The vibration analysis revealed a suspected defect on the outer race of the bearing and the motor was removed from production for replacement and inspection. The bearing inspection successfully revealed an outer race flaking defect in the load zone of the bearing along with randomly spaced denting, though the root cause of the defect could not be determined. The new motor was put into production and vibration levels immediately returned to normal.

Recommendations

It is recommended that a new maintenance plan is developed (and old one reviewed) for the Skip Hoist to include lubrication routines, grease samples to be taken at fixed intervals for laboratory analysis, and a new procedure put in place to ensure motors in storage have their shafts rotated at fixed intervals to avoid any possibility of false brinelling.