Feeder Loads Investigation

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Abstract

The current market climate of low commodity prices has prompted initiatives by resource companies to streamline operations by reducing costs. BHP Billiton Iron Ore's mineral processing assets are a significant component of business – by targeting machinery for improvement in this area, the potential for minimising the impact of poor market conditions can be improved. To reduce capital and operating costs of feeders, which control the flow of ore from hoppers to conveyor belts, an investigation was initiated to test the hypothesis that existing feeders are operating significantly below design loads. By analysing operational data from BHP Billiton Iron Ore's Port Hedland facilities and comparing the loads experienced by feeders in operation to design loads, the level of confidence in this hypothesis, as well as understanding of the loads experienced by feeders, was improved. The key finding of the study is that actual feeder loads are between 40% and 60% of design loads. Combined with historical data, this indicates that the accepted design method may be unnecessarily conservative. Further data analysis on a wide range of feeder-hopper systems shall enable the accepted method of feeder design to be improved, thereby reducing the capital and operational cost of feeders, their drive systems, and their supporting structures.

1. Introduction

In the 2014 – 2015 financial year, BHP Billiton Iron Ore (BHPBIO) achieved a reduction in iron ore production costs in Western Australia by 31%, to $16/tonne (BHP Billiton 2015). To stay competitive as a top 3 iron ore producer, BHPBIO must continue this trend: one way to achieve this is to eliminate unnecessary capital and operational costs on assets. A space with potential for future cost reduction is in the design, construction and operation of feeders at mineral processing facilities. In a mining industry context, feeders are used to control material flow by transporting ore from hoppers to conveyor belts at the desired rate. It has been suggested that loads on feeders operated by BHPBIO are lower than design loads (Allen 2013). By determining the extent of this phenomenon while improving understanding of feeder loads, an opportunity to reduce costs by downgrading the design loads for feeder systems is available.

The feeder systems in use at the client's mineral processing sites are currently designed using the University of Newcastle Research Associates (TUNRA) design method (Arnold 1982), which accounts for various forces that resist motion of the feeder, to evaluate the total power required by the feeder motor. This research was motivated by the hypothesis that in the TUNRA method, feeder design loads were being overestimated. An initial interpretation of this fact may lead to the belief that it is a positive result, as it produces a conservative design.

If the TUNRA method was to predict feeder loads with complete accuracy, the design of the hopper-feeder system would still be conservative due to the safety factors applied during design of the feeder drive system and the steel supporting structure. If, as the hypothesis for this research suggests, TUNRA loads overestimate the true feeder power requirements, an additional, redundant safety factor is applied during feeder design. This leads to an overconservative (and uneconomical) system which does not provide any benefit to reliability or safety of the equipment. By reducing the unnecesary conservatism in feeder design, capital and operational expenditure on feeders would be significantly reduced due to lower power requirements for the hydraulic drive system, and lower load requirements for steel supporting structures and equipment. Figure 1 shows the typical layout of a feeder-hopper system.

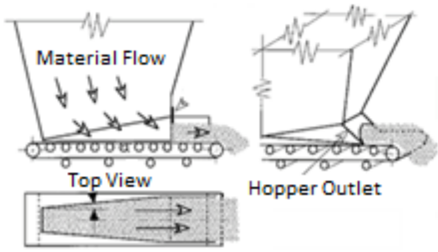


Figure 1 The typical layout of a feeder-hopper system (Roberts 1998)

1.1 State of the Art

The science of bulk solid handling was developed through extensive research over the 20th century; of particular relevance to this study are the works of A. W. Jenike in the 1960s and P.C Arnold and A. W. Roberts in the late 20th century. The dynamic behaviour of bulk material was studied in depth by Jenike (1961), who introduced the conditions for different flow classifications: mass-flow and funnel-flow. Mass-flow describes the condition whereby the entirety of the material within a bin is in contact with the outer walls of the bin, and is free flowing; funnel-flow refers to the case in which material gathers at sharp transitions within a bin and becomes stagnant. Mass-flow is optimal for feeding of bulk material, and hoppers are designed such that it occurs; if funnel-flow occurs, ore stagnates within the hopper. For this reason, mass-flow hoppers are used for mineral processing.

P.C. Arnold (1982) was motivated by the need to develop reliable feeder design equations, and wrote a seminal paper that outlined the TUNRA method that was used by RCR Tomlinson (contracted by BHPBIO) to design the feeders analysed in this thesis. The TUNRA method builds on the theoretical work performed by Jenike (1961) to construct a series of equations based on stress fields and friction within a hopper-feeder interface to define the total load on a feeder.

The sources of load, or "resistance" include the vertical force on the feeder due to the pressure exerted by material in the hopper and the friction between the material on the feeder and the hopper skirtplates, amongst others (Arnold 1982). Once these forces have been calculated, their sum is taken as the total feeder load. The motor torque required to drive the feeder can then be determined and the feeder and supporting structure can be designed to support the load.

The conventional approach to feeder design until the 1980s was to assume hydrostatic pressure acted on the feeder (Manjunath & Roberts 1986). However, this method was flawed – it was proven to overestimate feeder loads, due to the lack of consideration towards the arched stress pattern which forms within the lower region of the hopper during material flow.

The ore in the hopper effectively supports its own weight, therefore the total head load on the feeder is lower than hydrostatic. A contemporary summary of the TUNRA method, taking all recent developments into account (including research on stress fields within the hopper-feeder system) was used for the purpose of this study (Roberts 2001).

1.2 Objectives

Considering the hypothesis that actual feeder loads are lower than those predicted during design, the objective of this study is to determine the extent of the discrepancy, and ascertain whether it is systematic, or isolated to specific feeders at a given facility.

If the discrepancy is systematic, it is possible that through extensive research and data analysis, a "load-reduction factor" may be applied to feeder design. For example, if it is found that operational feeder loads are 50% of those designed for, it would be justifiable to reduce the design loads by any amount up to 50% without impacting safety or reliability.

A group of apron feeders at BHPBIO's port facilities in Port Hedland were analysed during this study. The feeders are used to transfer ore from Car Dumper hoppers – the dump hoppers which receive material released from incoming train cars – to a main conveyor belt. A total of seven feeders were analysed: AF11, AF12, AF21, AF22, AF23, AF41 and AF42.

2. Process

Two primary objectives had to be completed for the research objectives to be satisfied: the operating loads on the feeders under consideration had to be measured accurately, and they had to be predicted using the TUNRA Method.

2.1 Measuring Feeder Loads

The instrumentation available at the car dumper apron feeders at BHPBIO's Port Hedland facilities is extensive, allowing multiple parameters such as material flowrate and bin level to be measured. The feeders use hydraulic drive systems, and the hydraulic pressure at any time can be measured, at intervals of five seconds, using the Citect software package.

The hydraulic motors driving each feeder are Bosch Rexroth Hägglunds MB1600 and CB840 series drive systems. By using the motor specifications outlined in the manufacturer catalogue (Bosch Rexroth 2012), the operating motor torque can be calculated at any time. The load on the feeder at that time can then be determined, by dividing the motor torque by the radius of the feeder pulley.

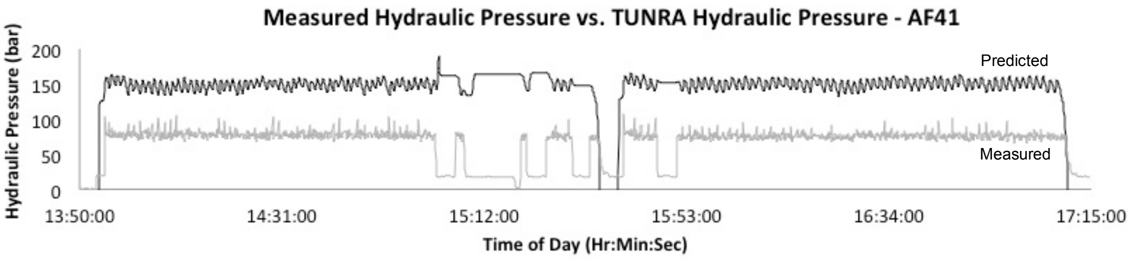
2.2 Predicting Feeder Loads

To obtain feeder load trends that could be compared with those measured on site, Microsoft Excel was used to predict the load at each time step over which data was collected. Using the TUNRA method (Roberts 2001), calculations were made using the geometry of each hopper-feeder system. Predictions were made for loads during initial fill and flow conditions by using the amount of material in the hopper (as a function of height), and the material flow rate as variable inputs. The hopper and feeder dimensions, along with standard ore material properties, were used as static parameters in the calculation. Ore material properties such as friction angle were measured by TUNRA, and bulk density was assumed to be 2400kg/m^3 based on the Process Design Criteria for the Port Hedland facilities (BHP Billiton 2013).

Total hydraulic system pressure was calculated using the TUNRA method for each time step at which data was collected. Using the feeder and hopper parameters that were measured at each time step of the TUNRA prediction allowed an intuitive comparison to be made between measured and predicted loads.

3. Results and Discussion

The results of this study confirmed the hypothesis that actual feeder load was lower than that designed for. The degree to which operational feeder load was exceeded by predicted load, however, varies according to the hopper-feeder system. In order to compare between measured and predicted feeder loads, each were plotted over time, for 18 hours from 06:00 on 01/04/2015. This allowed both visual and mathematical confirmation of the discrepancy between measured and TUNRA loads.



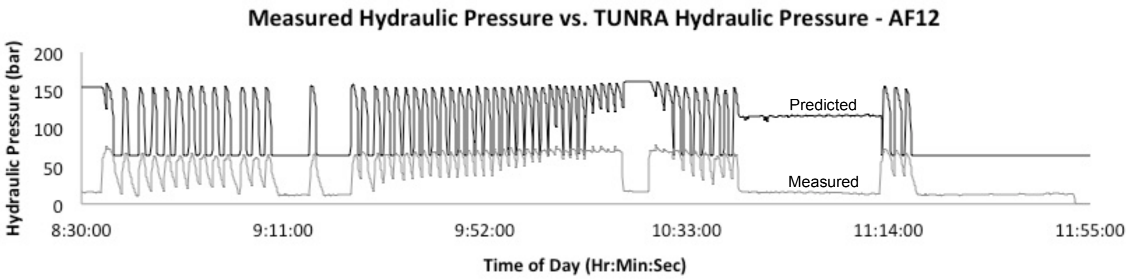


Figure 2 Plots comparing predicted hydraulic system pressure (dark line) to measured hydraulic system pressure on AF41 and AF12.

Figure 2 shows that the general behaviour of TUNRA-predicted hydraulic pressure behaves similarly to the measured pressure. During periods where the feeder is not operating (flat sections of the recorded pressure trend), the predicted pressure increases to a constant value. This is due to the influence of bin level on predicted load. The TUNRA method does not differentiate between periods during which a feeder is on standby and when it is in operation – however, when a feeder is on standby, the load is minimal. Therefore, predicted loads during periods for which a feeder is on standby are inaccurate. The plot of predicted pressure is therefore irrelevant when the feeder is on standby.

Figure 2 depicts trends for single apron feeders. To obtain results that are useful in determining the systematic discrepancy between design and measured loads, the trends for multiple feeders were analysed, and plots of the difference were constructed. Figure 3 shows the ratio of measured load to TUNRA load for feeders AF21 and AF12. Figure 4 shows the ratio for all feeders, plotted using linear regression. Periods during which feeders were on standby were eliminated for the purpose of visual analysis.

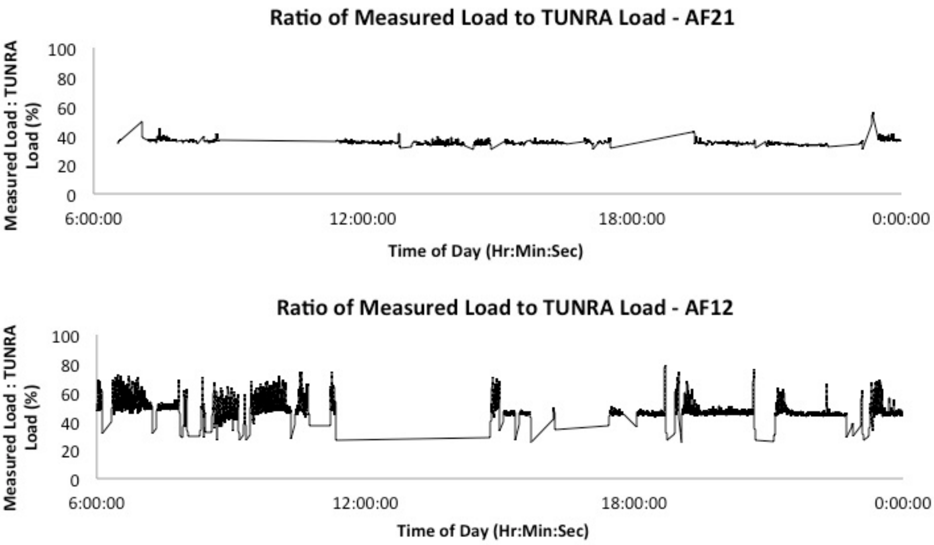


Figure 3 **Ratio of measured feeder load to feeder load predicted using the TUNRA method, for both AF21 and AF12, from 06:00 to 24:00 on 01/04/2015**

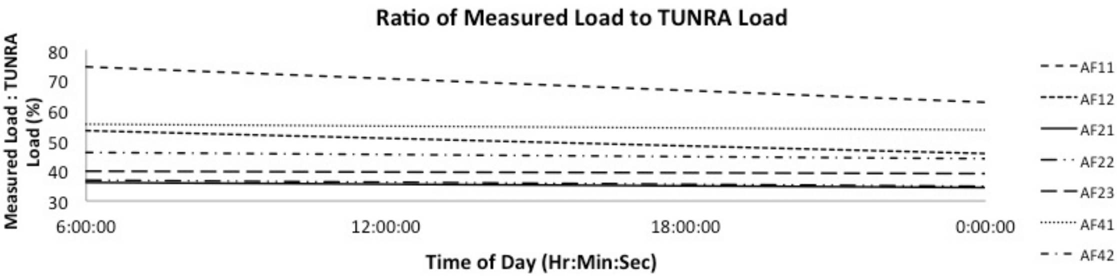


Figure 4 **Linear regression plot of the ratio between measured feeder load and load predicted using the TUNRA method. Plots from top to bottom: AF11, AF41, AF12, AF42, AF23, AF22, AF21**

Figures 3 and 4 show that depending on the feeder, predicted load can fluctuate significantly. While AF21 is relatively steady, operating at approximately 40% of design load, AF12, due to the higher variation in bin level over time, oscillates at approximately 50%. The reason for this oscillation is the high dependancy of the TUNRA method on bin level (The bin level of AF12 fluctuates to a higher degree than AF21). Figure 2 shows that while the discrepancy between measured and TUNRA loads changes, when the load is at a maximum, the difference is high. This value should therefore be used for design. Figure 3 shows that this value for AF12 is approximately 50%. The plot of linear regression is therefore an overestimation of the ratio for AF12 (and AF11, which is similar), and an accurate estimate for more steady feeders such as AF21. However, it still shows that operating loads are consistently lower than design loads.

4. Conclusions and Future Work

It is clear that measured feeder loads are between approximately 35% and 60% of predicted loads for all apron feeders analysed. This data, combined with the work of Allen (2013), who showed that the belt feeders at Yandi operated at approximately 41% of TUNRA-predicted flow loads, demonstrates that the TUNRA method for feeder design systematically overestimates the operating loads of feeders. Although the exact ratio between measured and predicted loads for all hopper-feeder systems cannot be predicted, it can be stated with certainty that the TUNRA method systematically overestimates the load on a feeder.

This study has been limited in some respects by the lack of accurate ore density data, as well as by the inability to measure initial fill conditions due to the 5 second timestep for data measurement. However, initial fill condition loading has been analysed previously (Allen 2013), finding that the ratio of measured load to predicted load was between 45% and 60%, and a conservative assumption was made for ore density. By continuing the study of hopper-feeder systems using the calculation templates developed during this research, a greater degree of confidence in the systematic discrepancy between TUNRA-predicted and measured feeder loads for both initial fill and flow conditions may be achieved. Following this, future work should determine a “load-reduction factor” that may be applied to TUNRA calculations, minimising excess costs while preserving safety and reliability.

5. Acknowledgements

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6. References

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