Belt Feeder Head Load Investigation

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Abstract

A recent increase in the number of belt feeder downtime events at the Client's sites and a changing economic environment has prompted the need for a better understanding of belt feeder resistance loads occurring at site. A better understanding of the loads actually occurring at site will be used to make recommendations on how the current design process could be improved. The Bruff and TUNRA methods currently used for belt feeder design were reviewed and used to predict the pressure of the belt feeder hydraulic drive system for a range of initial fill bin levels. Trials were then carried out at one of the Client's iron ore sites to verify these design predictions over a range of bin levels. The results of the trial indicate that the current design methods significantly over-predict belt feed resistance. These prediction methods also fail to predict the relationship between initial start-up pull out force and initial fill bin level. The results suggest that an arched stress field is partially formed in the hopper during the filling process resulting in significantly lower initial pull-out forces. This implies that a smaller drive system could have been used for this particular application, potentially resulting in significantly reduced installation costs. The results do not, however, provide enough evidence to be able to confidently state that the pull-out force on a belt feeder in a different application would also be significantly less than the TUNRA prediction. Further trials need to be done, and the results from this project have shown that further investigation is warranted.

1. Introduction

Belt feeders are used extensively throughout the Client's iron ore operations to control the volumetric flow of iron ore in the material handling process. The changing economic environment has seen the focus of the industry shift from rapid growth projects to increasing the output of existing facilities through improved utilisation. A recent increase in the number of belt feeder process downtime events has prompted the need for a better understanding of belt feeder drive resistance occurring at site.

The belt feeder drive systems are currently designed based on theoretical predictions of belt feeder resistance. To date, the actual feeder resistances at the Client's site have not been measured in a controlled trial to verify the theoretical predictions. As a result it is not fully understood if the current drive systems are sized optimally for the given operating conditions. Downtime events on equipment and infrastructure result in increased maintenance and repair costs as well as lost production tonnes, with these lost production tonnes translating to significant loss of revenue. A better understanding of the belt feeder resistance occurring at site is needed to ensure that the most appropriate drive system is utilised for each application. The initial capital costs of different drive systems vary significantly. Therefore, the ability to accurately predict drive resistance has the potential to significantly reduce initial costs.

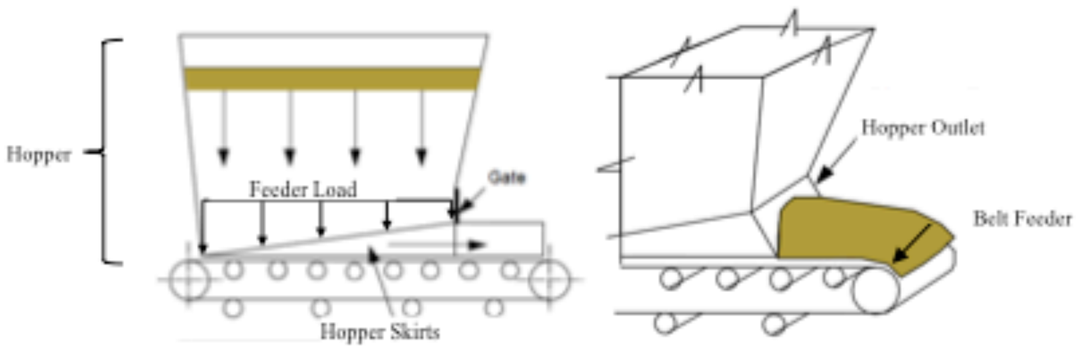

Figure 1 Belt feeder layout consisting of hopper and conveyor belt (Roberts 2001)

1.1 Belt feeder drive resistance prediction for belt feeder design: State of the Art

In order to accurately predict feeder resistance, the vertical load on the feeder at the hopper outlet, illustrated in Figure 1, must first be predicted to some degree of accuracy. There are a number of methods that can be used to predict the feeder load using varying levels of detail. It is widely known that the stress field established in the hopper greatly influences the feeder load. Different methods account for the different stress fields to varying levels of accuracy. The belt feeders installed at the Client's site were designed using the Bruff and TUNRA prediction methods. Therefore, the review will focus on these methods.

Early prediction methods, such as the Bruff and Johanson methods were empirical based approximations derived from observations of poorly designed funnel flow hoppers. As a result they often failed to accurately predict the feeder load for a mass flow hopper (Arnold, Roberts et al. 1982). With a better prediction method needed, focus shifted to developing theoretical methods. Following work done by Jenike (1964) to develop a better understanding of flow patterns and stress fields in hoppers, McLean and Arnold (1979) developed a prediction method based on Jenike's radial stress theory in which the feeder load was expressed in terms of a non-dimensional surcharge factor.

McLean and Arnold's prediction method was improved by Arnold, Roberts et al. (1982) to better account for the stress redistribution occurring at the hopper-feeder interface and was considered the best prediction method for many years. However, the method did not take into account the effect of surcharge pressure or the aspect ratio of the hopper outlet, for flow conditions. Roberts (1989) developed the theory further to capture these influences, although the effect on the predicted value was minimal. This method, known as the TUNRA method, has been widely accepted as the most accurate method for predicting the feeder load for some time now and has become standard practice in industry. However, while more accurate than earlier empirical methods, it is still a very conservative method, often over-predicting the feeder load. Earlier empirical methods such as the Bruff method are also still used in industry today, although not as a sole prediction method.

Historical data from the Client's site has previously been compared to TUNRA predictions by the equipment supplier. The historical data, illustrated in Figure 2 , suggests that the initial pull out force is closer to the predicted flow pull out force, with the recorded flow pressure significantly less than predicted. This was expected, as the use of the knife gates during filling would have caused an arched stress field to form prior to initial start-up; thus, the initial pull out conditions were not the same as those assumed for the TUNRA prediction.

1.2 Project Objectives

The first objective of the project was to review existing methods for predicting belt feeder resistance, including those used in industry today. This included an investigation into the stress fields that develop in storage bins and the theories that are used to explain them. As part of this the original design calculations for the belt feeders at site were reviewed with regards to the methods used and assumptions made. The second objective of the project was to develop a Microsoft Excel spreadsheet to predict the belt feeder resistance for a range of conditions using the Bruff Method and the two variations of the TUNRA Method used in the original calculations.

The third objective of the project was to collect data on actual belt feeder resistance from one of the Client's large-scale iron ore operations for a range of operating conditions and compare the actual belt feeder resistance data to predicted resistance in order to verify design methods and assumptions. The final objective of the project was to provide recommendations on possible areas of improvement to current design methods based on data analysis and to identify any areas that require further investigation.

2. Methods

The original design calculations were critically reviewed with respect to the methods used and the assumptions made. From the review of literature and the original design calculations, an Excel spreadsheet was created to predict the torque and corresponding hydraulic pressure requirements for initial start-up and flow operating conditions for a range of bin levels. Predictions were made using the Bruff method as well as the TUNRA method for both mass flow and expanded flow conditions. The procedures used for both of the TUNRA predictions are outlined in detail by Roberts (2001). The Bruff method procedure is outlined by Arnold, Roberts et al. (1982).

The inputs for the predictions were the bin, hopper and belt feeder dimensions, the level of ore in the bin as well as the ore's material properties. The dimensions of the bin, hopper and belt feeder were taken from technical drawings of the equipment. The material properties used in the calculations were obtained from TUNRA material flow properties reports.

TUNRA predictions were done for mass and expanded flow patterns. The pressure predictions, illustrated in Figure 2, show that the assumed flow pattern in the top section of the hopper has little influence on the initial pressure prediction and no influence on the flow pressure prediction.

For the mass flow TUNRA prediction, each section of the hopper was considered as a separate mass flow hopper, with the outlet pressure of each hopper section being used as the surcharge pressure of the hopper section directly below it. For the expanded flow TUNRA prediction, the hopper sections above the knife gates were considered as a single expanded flow hopper, with the outlet pressure being used as the surcharge pressure for the mass flow hopper below the knife gates. For both predictions it was assumed that a peaked stress field existed in the knife gate section. A skirt plate contact area ratio was used in calculating the hopper skirt plate resistance in order to reflect the semi-load bearing nature of the skirts installed.

The aim of the trial was to verify the design predictions of belt feeder resistance by recording the operating pressure of the belt feeder hydraulic drive motor during initial start-up and flow conditions. The procedure for the trial was to completely empty the selected hopper and stop the belt feeder, keeping the knife gates open at all times. The hopper was then filled to a predetermined level with the belt feeder stopped. The belt feeder was then started and set to run at constant speed until the bin was empty of ore.

The hydraulic pressure of the belt feeder drive system was monitored using the Citech software program and recorded in Microsoft Excel at two second intervals for the duration of the trial. This recorded hydraulic pressure was used to calculate the torque and thus the drive resistance of the belt feeder at different bin levels. This procedure was repeated at five different bin levels for one belt feeder and at two different bin levels for an identical feeder.

Weightometer data recorded during the trial was used to give a more accurate indication of the bulk density of the ore being processed through the plant during the trial. This calculated bulk density was then used in feeder resistance calculations to give a better indication of the accuracy of the predictions.

3. Results and Discussion

The system pressure recorded during the trial was significantly less than the pressure predicted by the TUNRA and Bruff methods as illustrated in Figure 2. The flow pressures recorded were around 41% less than the TUNRA predicted flow pressure, while the initial pressures recorded varied from 45% less to 60% less than predicted. It was expected that the recorded pressures would be lower than those predicted, given the conservative nature of the TUNRA method. However, it was not expected that the discrepancy would be so great.

The TUNRA method also failed to accurately predict the relationship between feeder resistance and initial fill bin level. Whilst the recorded flow pressures were effectively 41% less than the TUNRA prediction for all bin levels, the difference in *initial* pressure varied substantially for different bin levels. The recorded initial pressure stayed relatively constant across all bin levels, rather than increasing as predicted by the TUNRA method.

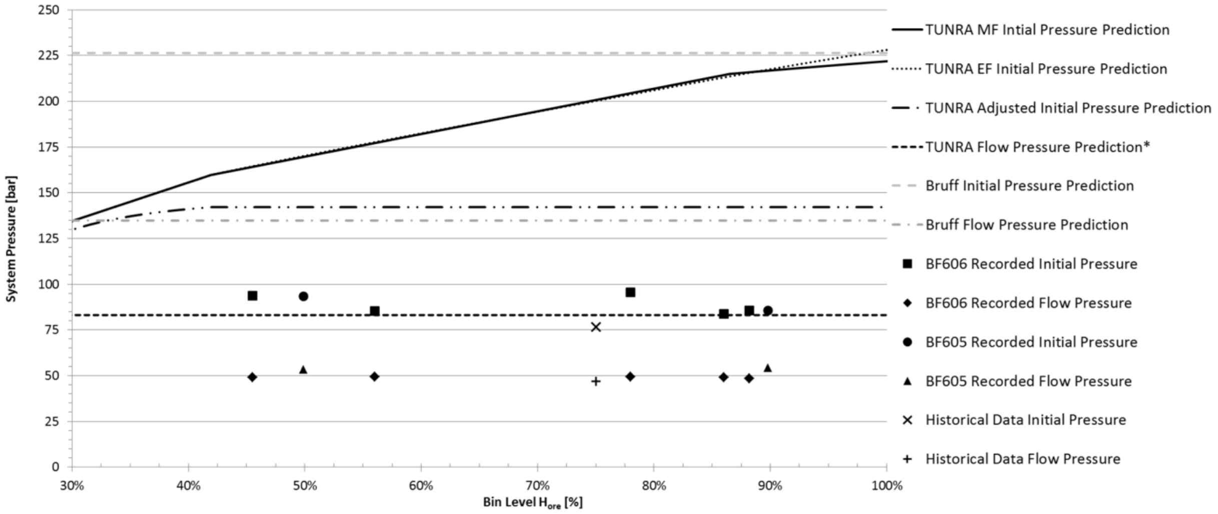

Figure 2 **Predicted and recorded system operating pressure for initial and flow conditions. Data recorded from two identical belt feeders, BF605 and BF606. Historical data recovered from Client database. *Flow pressure predicted by TUNRA is the same for mass (MF) and expanded flow (EF)**

The results suggest that an arched stress field partially forms in the hopper during filling, resulting in the initial pressure being far less than predicted, and independent of the surcharge pressure above a certain bin level. The initial pressures recorded were comparable to historical data of initial pull-out during which the knife gates were used, which supports the hypothesis that an arched stress field is formed during filling. The likely explanation for this occurrence is that, as the level of ore in the bin increases, the weight of the ore above compresses the ore in the lower section of the hopper. This causes the ore in the upper section of the hopper to move down the hopper, resulting in the formation of an arched stress field in the upper section. The resulting surcharge pressure for initial fill at that point will then be equal to the flow condition surcharge pressure and independent of bin level. An arched stress field would only form in the lower section of the hopper once flow has been initiated, resulting in the reduction in feeder resistance under flow conditions observed in the recorded data as illustrated in Figure 3. This situation is illustrated in Figure 4, for the ore below the knife gates being compressed. The pressure prediction corresponding to this situation is illustrated in Figure 2 as TUNRA Adjusted.

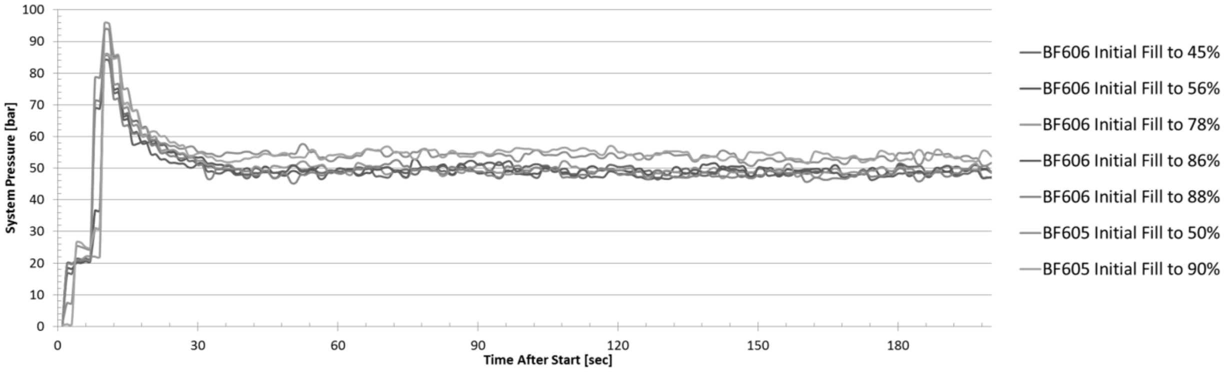

Figure 3 Hydraulic drive system pressure recorded during trial for 200 seconds after starting belt feeder for range of initial fill bin levels. Pressure curves are very similar for different bin levels, suggesting pressure is independent of initial fill bin level.

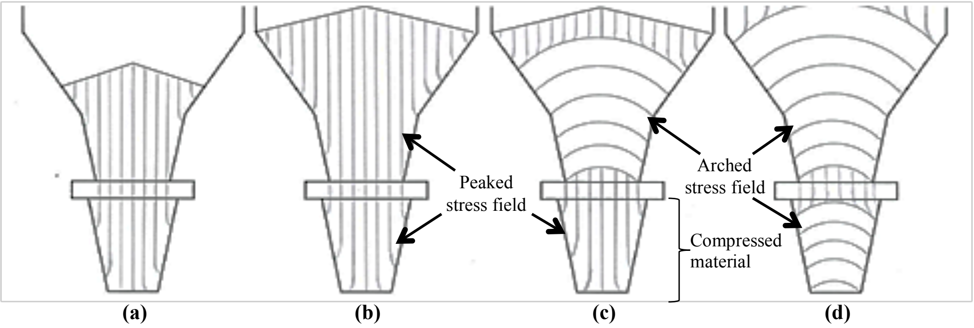

Figure 4 (a) Peaked stress field for initial filling conditions at low levels. (b) Peaked stress field throughout entire hopper for initial fill conditions as assumed by TUNRA. (c) Arched stress field partially formed in the upper section of hopper due to compression of material in lower section of hopper. (d) Arched stress field in both upper and lower sections of the hopper for flow conditions.

The point in the hopper at which the arched stress field begins to form is difficult to determine from the data recorded. An estimate of the height could be made based on the TUNRA predictions and the maximum initial pressure reached, however this too would be difficult due to the overly conservative predictions reached using TUNRA. The TUNRA method uses an exponent intended to account for material compressibility and feeder deflection in the calculation of outlet pressure. However using different values of this exponent still failed to accurately predict the initial pressure values recorded.

This would suggest that the current application of the TUNRA method does not accurately capture the feeder loads occurring at site for initial fill conditions. However, one must be careful in interpreting the results of this trial. Time constraints and technical difficulties meant that fewer trials were conducted with data recorded at a lower resolution than intended.

Whilst it is evident that the current prediction methods significantly overstate the actual belt feeder resistance occurring at site, it would be dangerous to assume that the prediction methods are just overly conservative. The inability of the TUNRA method to predict not only the value of system pressure but also the relationship between system pressure and initial fill bin height indicates that the current application of this method is not suitable for predicting belt feeder resistance. The similarities between the trial data and historical data indicate that the assumption made by TUNRA that a peaked stress field exists throughout the hopper for fill conditions is incorrect and constitutes a major source of error in the TUNRA predictions.

4. Conclusions and Future Work

The results indicate that the TUNRA and Bruff prediction methods currently used in the design of belt feeders installed at site significantly overestimate the belt feeder resistance for this particular application. Consequently, much smaller drive systems than those installed could be used whilst maintaining current performance capacity for this particular application. The cost benefit of using a smaller, more appropriately sized drive system has the potential to be significant, in particular where electromechanical drives can be used instead of larger hydraulic drives.

While the results from this trial alone are not enough to develop a better prediction method, they do indicate that a more accurate method is needed. The results also fail to explain the cause of the unexpected process downtime events occurring at site. Additional trials are required to give a more complete data set from which further conclusions can be drawn. These trials should include data collection from belt feeders processing a range of ore types to investigate the possibility of mechanical cohesion within the ore causing the unexpected downtime events. Data should also be collected over a lower range of bin levels to find the height at which initial pressure becomes constant.

6. References

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