The relationship between **coal crushing and track condition on a heavy haul railway line**

Wikus van der Westhuizen
Engineer-in-Training
Transnet Freight Rail
Empangeni
wvandw@gmail.com

Prof Hannes Gräbe
Department of Civil Engineering
University of Pretoria
Transnet Freight Rail Chair in
Railway Engineering
hannes.grabe@up.ac.za

INTRODUCTION

South Africa is currently the seventh largest coal-producing country in the world, and annually roughly 70 million tons of coal (for export) are transported across the country by means of heavy haul train operations. Coal is used worldwide in a number of different applications, and each application demands a coal sample with very specific chemical, geological and physical properties. Chemical and geological properties of coal have been studied intensively over the last few decades, with physical properties – although important – rarely being included in these studies.

One of the important physical properties that determine the behaviour of a coal sample during the combustion process is the coal particle size. The physical size of coal particles within a specific sample will significantly influence the way in which the sample combusts, and burning profiles can change rapidly with only a slight change in coal particle size. Research has shown that a decrease in coal particle size will lower the burnout temperature of a sample, while producing more residue in the process. Not only does the burnout temperature of the sample decrease, but in some instances the peak temperature may also decrease when samples are crushed to a fine powder.

Since heavy haul train transportation remains the only viable option for transporting large quantities of coal, it is important to ensure that the physical coal quality is not affected during transportation cycles. It has been suggested that the geometry of the railway track could influence the physical properties and quality of the coal being transported, specifically the size of the coal particles. As a train progresses over certain sections of track, the train wagons and the coal inside the wagons experience intense vibration and acceleration forces due to imperfections in the track, as well as uneven vertical track profile. The intensity of the vibrations experienced on a certain section of track is dependent on the roughness of that specific section, and more coal particle breakdown can occur when a section of track has a high roughness value.

AIMS AND OBJECTIVES

The objectives of the study were as follows:

- To determine if coal crushing occurs inside train wagons during transportation cycles.
- If coal crushing does occur, to determine if a linear relationship exists between particle breakdown and applied acceleration forces.
- If coal crushing does occur, to determine which particle sizes experience the highest degree of degradation or crushing effects.

EXPERIMENTAL PROCEDURE

Two simple experiments were devised to study the relationship between vertical vehicle acceleration (instability) and the amount of coal particle breakdown achieved. The first experiment was carried out in the field, where an in-service Transnet Freight Rail (TFR) coal train was instrumented with accelerometers when travelling between Ermelo and Vryheid (roughly 210 km) so that the forces experienced by a typical CCR11 coal wagon could be recorded. A total of eight accelerometers were installed on four wagons, i.e. two devices per wagon. The devices were installed on small horizontal platforms on the back of Wagons 1 and 103, as well as on the front of Wagons 2 and 104. The wagons to be instrumented were not selected at random, but set up in order to measure acceleration at the front and in the middle of the train. Figures 1 and 2 show the setup used to measure acceleration on the train, as well as the placement of the instrumentation.

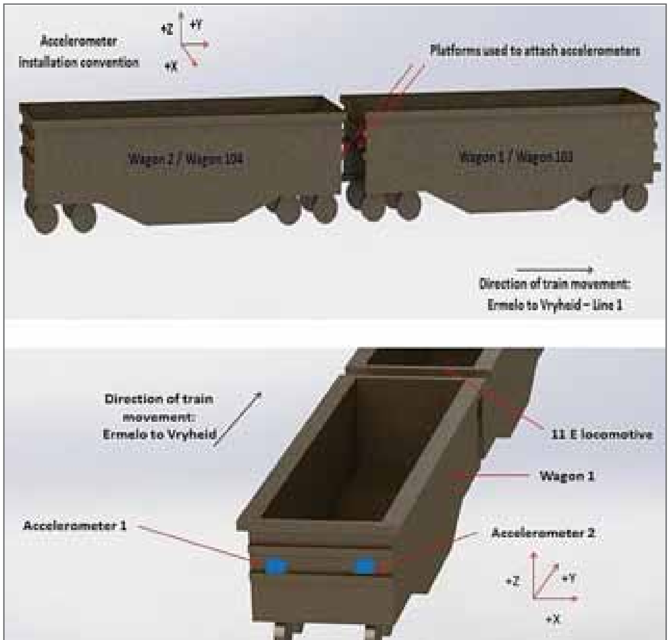

Figure 1: Instrumentation setup used on Transnet Train 4821 from Ermelo to Vryheid on 24 March 2014

Figure 2: GCDC (Gulf Coast Data Concepts) x 16 accelerometers used for three axis measurements

Figure 3: Vibration table and setup used to simulate vehicle acceleration at the University of Pretoria

Once these acceleration forces had been recorded, the extreme values, as well as continuous acceleration frequencies (bandwidths), were identified and used in the second experiment. Here similar magnitude forces to those measured on the train were applied to coal samples in a controlled environment at the University of Pretoria's Civil Engineering laboratory. Steel moulds accelerated on a vibration table were used in order to simulate the effect of applied acceleration on coal wagons due to high track roughness. Each mould contained either fine (< 2 mm particles), intermediately-sized (particles 2 mm – 13.5 mm) or coarse-sized coal samples (particles > 13.5 mm), which were taken from a representative coal sample collected at the Ermelo train marshalling yard. Three tests were conducted in the laboratory, during which all three particle size categories were accelerated simultaneously, but separately, each test at a different frequency, namely 60 Hz, 40 Hz and 20 Hz respectively. A standard sieve analysis was conducted on each sample before and after the vibration test to monitor the change in particle size. These three tests each simulated a constant acceleration force of 2.1 g, 3.3 g and 7.8 g respectively. The laboratory setup and steel moulds containing different particle sizes are shown in Figure 3.

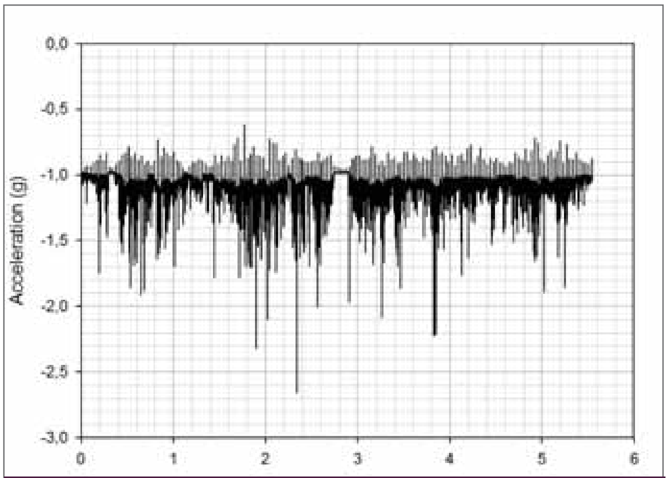

Figure 4: Vehicle accelerations measured from accelerometer 5 (left rail) on the train

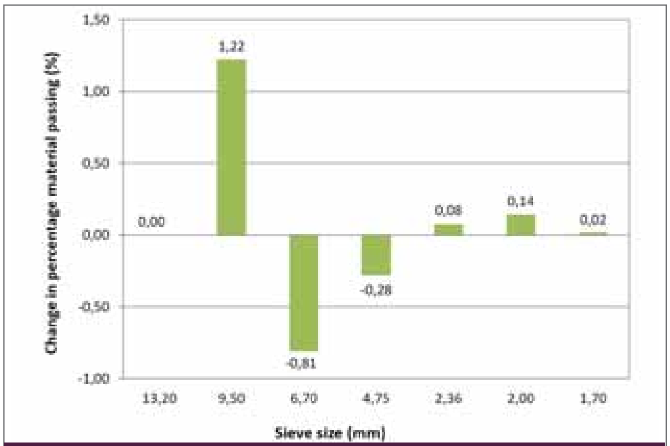

Figure 5: The change in percentage of material passing specific sieve sizes, indicating particle breakdown

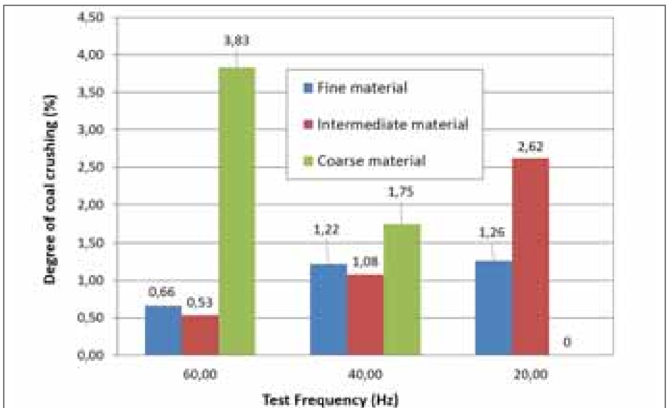

Figure 6: The degree of coal crushing based on particle size and test frequency

DISCUSSION OF RESULTS

The results obtained from the field experiment showed that the track section between Ermelo and Vryheid railway stations is maintained fairly well, since only isolated acceleration spikes were recorded at specific track locations. Although acceleration forces were recorded in three different directions – lateral, longitudinal and vertical – only the vertical accelerations were analysed. Data analysis becomes tedious when recording acceleration at 400 Hz for a long period of time, and it was found that the vertical acceleration component induces the breakdown effect of the particles, with lateral and longitudinal acceleration having little effect. Figure 4 shows the vertical acceleration component recorded by Accelerometer 5 on Wagon 103.

A statistical analysis of the data showed that 60% of the acceleration forces experienced by the coal wagons was within the range of 1 g – 1.2 g, with 30% of the forces in the range of 1.2 g – 1.4 g. Only 10% of the track distance produced vertical acceleration of wagons in excess of 1.4 g. It should be noted that vehicle acceleration measurements are dependent on vehicle characteristics such as suspension, vehicle speed, wheel condition and vehicle mass.

The sieve analysis provided interesting results: At higher levels of acceleration, all particle size categories showed significant levels of particle breakdown. It proved a difficult task to accelerate the coal samples at the precise level of acceleration recorded on the train, hence fixed frequency levels were selected and the samples were accelerated at 2.1 g, 3.3 g and 8 g respectively. Figure 5 shows the change in the percentage of intermediately-sized material passing specified sieve sizes after the vibration test had been completed. In this specific particle size category, particles 9.5 mm in diameter were crushed to sizes of between 6.7 mm and 4.75 mm. Smaller particles of roughly 2 mm were broken down to sizes smaller than 1.7 mm and ended up in the fine particle size category. The compiled results for all particle size categories subjected to various acceleration forces are shown in Figure 6.

CONCLUSIONS

In conclusion, the following statements can be made in accordance with the aims and objectives set out earlier:

- Based on the research conducted, it was proved that a definite degree of coal crushing occurs inside wagons during transportation. The degree of coal crushing was determined as 0.5% – 3.8%, depending on the applied acceleration. The duration of the applied acceleration forces, as well as the magnitude of these forces, has an effect on the amount of coal crushing which occurs inside the wagons.
- A nonlinear relationship exists between coal crushing and track condition. Results from laboratory experiments show that there is a decrease in the amount of coal crushing at intermediate levels of particle acceleration compared to lower levels of particle acceleration. This is followed by a sharp increase in particle breakdown beyond this point.
- The fine material in a coal sample will achieve the largest degree of particle breakdown at high to mid-range frequencies. The intermediately-sized particles will also experience significant crushing effects, but these effects are not as severe as for the fine material. The coarse particles in a sample may or may not experience particle breakdown, depending on the shape and size of the particle, as well as on the applied acceleration level.

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