International Journal of Mining Science and Technology 26 (2016) 745–752

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

A discrete-event model to simulate the effect of truck bunching due to payload variance on cycle time, hauled mine materials and fuel consumption

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ARTICLE INFO

Article history:
Received 29 November 2015
Received in revised form 13 January 2016
Accepted 28 March 2016
Available online 8 June 2016

Keywords:
Discrete-event model
Simulation
Truck bunching
Payload variance
Cycle time
Fuel consumption

ABSTRACT

Data collected from truck payload management systems at various surface mines shows that the payload variance is significant and must be considered in analysing the mine productivity, energy consumption, greenhouse gas emissions and associated cost. Payload variance causes significant differences in gross vehicle weights. Heavily loaded trucks travel slower up ramps than lightly loaded trucks. Faster trucks are slowed by the presence of slower trucks, resulting in 'bunching', production losses and increasing fuel consumptions. This paper simulates the truck bunching phenomena in large surface mines to improve truck and shovel systems' efficiency and minimise fuel consumption. The study concentrated on completing a practical simulation model based on a discrete event method which is most commonly used in this field of research in other industries. The simulation model has been validated by a dataset collected from a large surface mine in Arizona state, USA. The results have shown that there is a good agreement between the actual and estimated values of investigated parameters.

1. Introduction

Improving the efficiency of haulage systems is one of the great challenges in mining engineering and is the subject of many research projects undertaken in both study and industry [1–9]. For mining, it is important that haulage systems are designed to be as efficient as possible, in order to minimise haulage cost, improve profitability and increase the total mine value. Haulage system inefficiency is typically derived from inadequate engineering, which results in poor haul road design, machinery standby and downtime, and circuit traffic [10–12]. According to the literature, haulage costs can be some of the largest in a mining system [13,14]. In various case studies it was found that material transportation represents 50% of the operating costs of a surface mine [15].

The main effective parameters on material transport when a truck and shovel system is used in surface mines are mine planning, road condition, truck and shovel matching, swell factors, shovel and truck driver's ability, weather condition, payload distribution and payload variance [16–19]. Based on the literature among all above mentioned parameters, truck payload variance is one of the most important parameters in this field [7,20,21]. The payload variance not only affects the production rate, but also it is an important parameter in the analysis of fuel consumption. The main source of the payload variance in truck and shovel mine operation is the loading process. Loading is a stochastic process and excavator performance is dependent on factors such as swell factor, material density and particle size distribution [22]. Variation of these factors causes variation of bucket and consequently truck payloads, affecting productivity. Reducing truck payload variance in surface mining operations improves productivity by reducing bunching effects and machine wear from overloaded trucks [23]. In large surface mines having long ramps, bi-directional traffic and restrictions on haul road widths negate the possibility of overtaking. Overloaded trucks are slower up ramp in comparison to under-loaded trucks. Thus, faster trucks can be delayed behind slower trucks in a phenomenon known as truck bunching [20]. This is a source of considerable productivity loss for truck haulage systems in large surface mines.

There are some investigations about the payload variance simulation and the effect of this event on other mining operational parameters. A project completed by Hewavisenthi, is about using a Monte-Carlo simulation to investigate the effect of bulk density, fill factor, bucket size and number of loading passes on the long term payload distribution of earthmoving systems [21]. The focus of their study is on simulation of payload distribution and variance in large surface mines. A study conducted by Knights and Paton

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http://dx.doi.org/10.1016/j.ijmst.2016.05.047
2095-2686/