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A comprehensive investigation of loading variance influence on fuel consumption and gas emissions in mine haulage operation

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ABSTRACT

The data collected from haul truck payload management systems at various surface mines show that the payload variance is significant and must be considered in analysing the mine productivity, diesel energy consumption, greenhouse gas emissions and associated costs. The aim of this study is to determine the energy and cost saving opportunities for truck haulage operations associated with the payload variance in surface mines. The results indicate that there is a non-linear relationship between the payload variance and the fuel consumption, greenhouse gas emissions and associated costs. A correlation model, which is independent of haul road conditions, has been developed between the payload variance and the cost saving using the data from an Australian surface coal mine. The results of analysis for this particular mine show that a significant saving of fuel and greenhouse gas emissions costs is possible if the standard deviation of payload is reduced from the maximum to minimum value.

1. Introduction

Mining industry consumes a large amount of energy in various operations such as exploration, extraction, transportation and processing [1]. A considerable amount of this energy can be saved by better managing the operations [2–5]. The mining method and equipment used mainly determine the type of energy source in any mining operation [6]. In surface mining operations, haul trucks use diesel as the source of energy [7–10]. Haul trucks are generally used in combination with other equipment such as excavators, diggers and loaders, according to the production capacity and site layout. Haul trucks use a great amount of fuel in surface mining operation; hence, mining industry is encouraged to conduct a number of research projects on the energy efficiency of haul trucks [11–13].

There are many kinds of factors that affect the rate of fuel consumption for haul trucks such as payload, truck velocity, haul road condition, road design, traffic layout, fuel quality, weather condition and driver skill [14–18]. A review of the literature indicates that the understanding of energy efficiency of a haul truck is not limited to the analysis of vehicle-specific parameters; and mining companies can often find greater energy saving opportunities by expanding the analysis to include other effective factors such as payload distribution and payload variance [17,19–21].

Loading process in truck and shovel operations is a stochastic process [20]. An analysis of the haul truck payload data obtained from a number of mine sites around the world shows that the payload distribution can be estimated by a normal distribution function with a satisfactory error; and the variance associated with haul truck payloads is typically large [19–21]. The payload variance depends on a number of parameters such as the particle size distribution, the swell factors, the material density, truck-shovel matching, number of shovel passes and the bucket fill factor [19,20,22]. Many attempts have been made to reduce the payload variance by using the latest developed technologies such as truck on-board payload measurement system, direct connection between this system and the shovel control system and on-line fleet monitoring system [19,20].

The payload variance not only affects the production rate and fuel consumption, but it is also an important parameter in the analysis of gas emissions and cost. Many research studies have already been conducted on the measurement of the haul truck gas emissions in the mining industry [23–27]. In addition, several numbers of economic models have been presented to predict the cost of diesel and gas emissions [28].

In this paper, the effects of payload variance on fuel consumption for a mostly used haul truck in Australia surface coal mines (CAT 793D) are investigated. A model is presented to estimate the effect of payload variance on the gas emissions and the total cost associated with fuel consumption and gas emissions. The corresponding energy saving opportunities to the reduction of payload variance is also investigated.

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