International Journal of Mining Science and Technology 25 (2015) 261–266

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

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

A comparison of the energy consumption and carbon emissions for different modes of transportation in open-cut coal mines

Liu Fuming [a,b,*], Cai Qingxiang [a], Chen Shuzhao [a,b], Zhou Wei [a,b]

[a] School of Mines, China University of Mining & Technology, Xuzhou 221116, China
[b] State Key Laboratory of Coal Resources and Safe Mining, China University of Mining & Technology, Xuzhou 221116, China

ARTICLE INFO

Article history:
Received 9 July 2014
Received in revised form 10 August 2014
Accepted 15 October 2014
Available online 13 March 2015

Keywords:
Open-cut coal mine
Mode of transportation
Energy efficiency
Carbon emission calculation

ABSTRACT

Transportation accounts for 80% of open-cut coal mine carbon emissions. With regard to the energy consumption and carbon emissions of transportation within an open-cut mine, this paper systematically compared the work and energy consumption of a truck and belt conveyor on a theoretical basis, and constructed a model to calculate the energy consumption of open-cut mine transportation. Life cycle carbon emission factors and power consumption calculation model were established through a Process Analysis–Life Cycle Analysis (PA–LCA). The following results were obtained: (1) the energy consumption of truck transportation was four to twelve times higher than that of the belt conveyor; (2) the CO_2 emissions from truck transportation were three to ten times higher than those of the belt conveyor; (3) with the increase in the slope angle for transportation, the ratio of truck to belt conveyor for both energy consumption and carbon emissions gradually decreased; (4) based on 2013 prices in China, the energy cost of transportation using a belt conveyor in open-cut coal mines could save 0.6–2.4 Yuan/(t km) compared to truck transportation.

1. Introduction

Climate change is an issue that has received worldwide attention, and establishing an effective response to climate change is a challenge at all levels of government planning in China [1]. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, the key contributor to climate change is the increase in carbon emissions from energy consumption [2]. Coal, is an important raw material and source of energy in China, and has a significant strategic position in the national economy. In 2011, China became the biggest primary energy consumer in the world, with 70% of the energy consumed being generated from coal [3]. Therefore, coal production and consumption are the main sources of greenhouse gas emissions in China. The Life-Cycle Assessment (LCA) method is a versatile technique for assessing the environmental impacts associated with all stages of a product's life from-cradle-to-grave, including carbon emissions. It has been broadly applied in many studies, including as a carbon emission accounting method at the regional level [4,5], in highly energy-consuming industries such as metallurgy and the cement industry [6–9], in power production and associated transportation [10–13], and in basic energy production chains [14–16]. Since 2003, China's surface coal mining industry has undergone rapid development. The total annual output of coal from open-cut mines in 2012 was 450 million t, which accounted for approximately 12.3% of the total national coal production. As the total quantity of coal excavated through surface mining is over three billion t, and the average haulage distance within a surface coal mine is about 2.5–4 km, the annual transportation volume of China's open-cut mine industry is 7.5–12 billion t km [17,18]. Therefore, improving the transportation efficiency, and reducing the carbon emissions associated with surface coal mines is critical to the development of a low carbon surface mining industry. Existing domestic and international studies of the carbon emissions during transportation at open-cut coal mines have mainly focused on how to reduce the haulage distance by improving the management of truck transportation, thus achieving emission reductions [19–23]. However, there have been no fundamental changes in the mode of transportation used, and the effects of emission reductions achieved so far have not been significant. In this study, by analyzing the principles of truck and belt conveyor operation, a model was established to determine the energy efficiency and carbon emissions of the two modes of transportation through the application of LCA. The energy consumption and volume of carbon emissions of the two modes of transportation in an open-cut coal mine were then

* Corresponding author. Tel.: +86 15862180487.
E-mail address: fumingliuok@126.com (F. Liu).

http://dx.doi.org/10.1016/j.ijmst.2015.02.015
2095-2686/

compared via the proposed model. A flowchart to show the research procedure adopted is shown in Fig. 1. This study provides a sound scientific basis for the selection of low carbon mining technology, and a theoretical method for calculating carbon emissions from surface mines.

2. Methods and data

2.1. Carbon emission calculation model

The Process Analysis–Life Cycle Analysis (PA–LCA) is the most commonly used technique for estimating a carbon footprint. The Process Analysis (PA) method, when applied to a traditional LCA, is a bottom-up approach that describes the impact of a product on the environment during the whole process from production to disposal [24]. The PA–LCA uses the PA as the basic starting point. In this stage, a life cycle list is compiled by listing of all of the components of the life cycle, and then input and output data are obtained to calculate the life cycle carbon emissions (i.e., the carbon footprint) of the object under assessment. The determination of a carbon footprint enables carbon emissions to be investigated from the perspective of a life cycle analysis, thereby allowing a scientific and rational carbon reduction plan to be developed.

$$C_E = \frac{C_e}{\eta_i} EF_i \quad (1)$$

$$EF_i = \sum EF_{ij} \quad (2)$$

where C_E is the volume of carbon emissions, kg/kW h; C_e is the energy efficiency of transportation kW h/(t km); i refers to different types of energy (here it is diesel fuel and electric energy); j refers to the energy production chain; η_i is the energy exchange efficiency; and EF is an emission factor.

2.2. Energy efficiency calculation model

Surface mining is accomplished by undertaking work to extract materials, and using dedicated equipment to transport the extracted materials. In each stage of the mining operation energy is consumed, with haulage accounting for most energy consumption. The modes of transportation typically used in open-cut mines are mainly truck transportation, belt conveyor transportation, and a combination of the two modes. With regard to the differences between mines, a unified energy efficiency model was established to calculate the energy efficiency of different modes of transportation in open-cut mines. This can be used to assess the differences in energy demand between the different modes of transportation, and the carbon emissions associated with each level of energy activity. The calculation used in the model is as follows:

$$C_e = \sum_{i=1}^{n} M_i \cdot (A_i \cdot f_{Ai} \cdot f_{MAi} \cdot q_{Ai} + H_i \cdot f_{MHi} \cdot q_{Hi}) \quad (3)$$

where C_e is the transportation energy efficiency in an open-cut mine, J; M_i is the material volume, t; A_i is the horizontal length of the material transportation path in an open-cut mine, m; f_{MAi} is the effective load factor for horizontal transportation; f_{Ai} is the delivery distance factor; H_i is the average hoisting height of materials, m; q_{Ai} is the energy needed for horizontal transportation, J, considering the resistance $c_{R,i}$ and 95% of drive mechanical energy efficiency; f_{MHi} is the effective enhancement load factor; and q_{Hi} is the energy needed in elevation transportation, J.

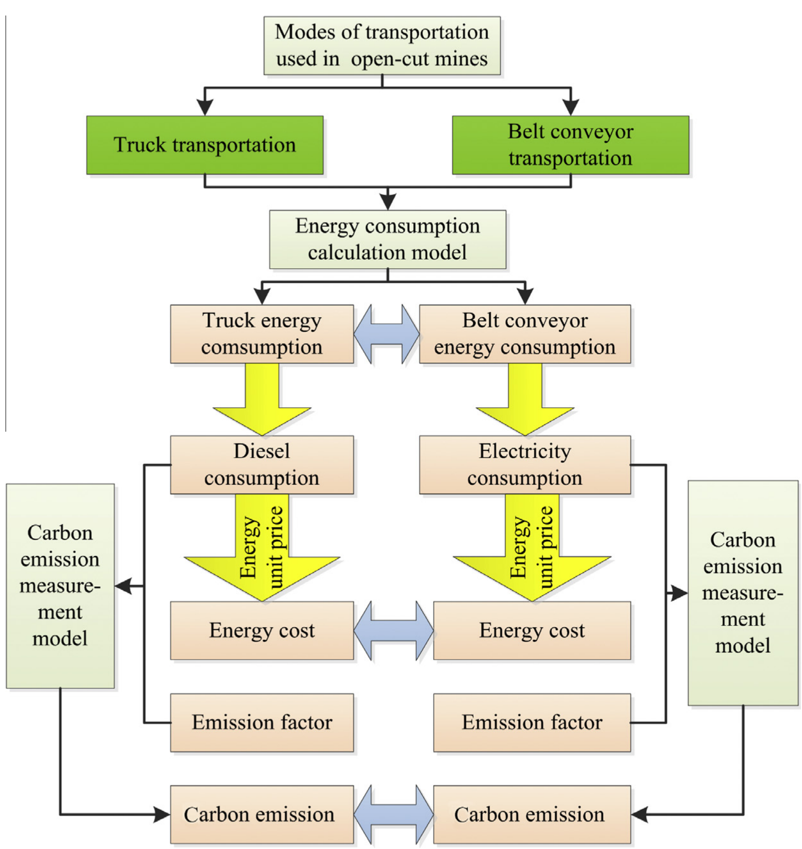

Fig. 1. A flowchart to show the procedure followed in the research.