



Review article

A review on numerical solutions to self-heating of coal stockpile: Mechanism, theoretical basis, and variable study

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HIGHLIGHTS

- Mechanistic analysis of low-temperature coal oxidation and self-heating of stockpiled coal.
- Detailed discussion on development of theoretical basis of the problem.
- Compilation of key parameters adopted by previous numerical solutions.
- In-depth investigation of impacts of various contributors on self-heating of coal stockpiles.
- Brief exploration on major challenges and perspectives of this subject.

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ABSTRACT

Self-heating or even spontaneous combustion of stockpiled coal, which is likely to outbreak under favourable circumstances during its transport, process, and storage, is a long-standing thermal dynamic hazard. This hazard is harmful in diverse aspects: causing loss of coal resource and caking property, raising safety concerns upon occurrence of open fire, and giving off noxious/greenhouse effect gases. Due to the complexity of involved physical process (e.g. heat and mass transport) and chemical process (e.g. coal oxidation), formulating an analytical solution to the problem with or even without a transient approach would be a daunting task and the problem is thus more often addressed numerically. So far many numerical models to self-heating of coal have been developed and to summarise these erratic findings, this work critically reviewed these numerical solutions since the last four decades. Mechanism of self-heating on coal mass and low temperature coal oxidation especially kinetic modelling of coal oxidation is firstly investigated to clarify the involved physical and chemical processes. On basis of the mechanistic understanding, theoretical derivations and progressive advances on governing equations like energy, mass, and momentum conservation are reviewed and compiled in details. Through parametric studies or sensitivity check these models produced fruitful but slightly inconsistent findings. Therefore to provide industry more unbiased and comprehensive guides, the present work examined the influences of various contributors including wind flow, stockpile dimensions, coal particle size, moisture content, and packing porosity on the self-heating behaviour of stockpiled coal. Last not the least, major challenges and perspectives this subject may have are briefly discussed.

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1. Introduction

Coal in all ranks, as a carbonaceous material, is able to be oxidised at low temperature with presence of oxygen rich air [1-19]. The interaction of coal with oxygen at low temperature is exothermic as a whole although some reaction sequences could be endothermic [15,20]. It is widely recognised that low temperature oxidation is the main source of heat leading to spontaneous ignition of stockpiled coal. Other exothermic processes like microbial metabolism, interaction of coal with water, and oxidation of pyrite can also contribute to self-heating of coal mass [21]. Among them an important one is that heat evolves as moisture physically bonds with dry coal particles and the process is termed as heat of

"wetting" in some literatures [21–23]. Phenomenon of self-heating on a coal stockpile is likely to outbreak if the heat generated by coal oxidation and other mechanisms is not adequately dissipated to the surroundings via conduction, convection, and radiation. The excessive heat is, to a considerable extent, stored in the coal by virtue of its poor thermal conductivity and results in a net increment of temperature and meanwhile the reaction rate of coal oxidation. Once the temperature of a coal mass reaches a critical value at which thermal runaway occurs, a fire ensues if not averted with appropriate remedies [24–26]. The hazard of self-heating of coal stockpile is likely to take place in long term storage of thermal power station, surface coal mining spoil piles, and transportation in cargo ship or train over large distances [26–30]. Spontaneous

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