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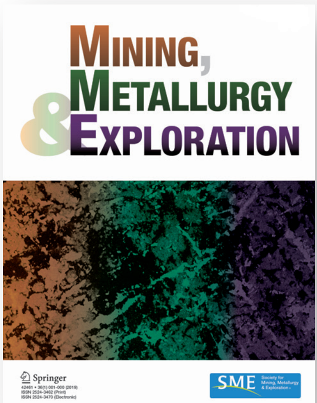

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Collection on Mine Ventilation

Hot surface ignition of liquid fuels under ventilation

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Special Extended Abstract

Mine equipment fires remain as one of the most concerning safety issues in the mining industry, and most equipment fires were caused by hot surface ignitions. Detailed experimental investigations were conducted at the National Institute for Occupational Safety and Health's (NIOSH) Pittsburgh Mining Research Division on hot surface ignition of liquid fuels under ventilation in a mining environment. Three types of metal surface materials (stainless steel, cast iron and carbon steel), three types of liquids (diesel fuel, hydraulic fluid and engine oil) and four air ventilation speeds (0, 0.5, 1.5 and 3 m/s) were used to study the hot surface ignition probability under these conditions. Visual observation and thermocouples attached on the metal surface were used to indicate the hot surface ignition from the measured temperatures. Results show that the type of metal has a noticeable effect on the hot surface ignition, while ventilation speed has a mixed influence on ignition. Different types of liquid fuels also show different ranges of ignition temperatures. Results from this work can be used to help understand equipment mine fires and develop mitigation strategies.

Background

Hot surface ignition is one of the main reasons for mine fires [1,2,3]. In this work, a series of experiments were designed to investigate the hot surface ignition of combustible liquids on a metal plate in an experimental wind tunnel. Several types of liquids fuels (diesel fuel, hydraulic fluid and engine oil) and metal plates (stainless steel, cast iron and carbon steel) were used to study their respective effects. The ignition probability for each type of liquid fuel and metal

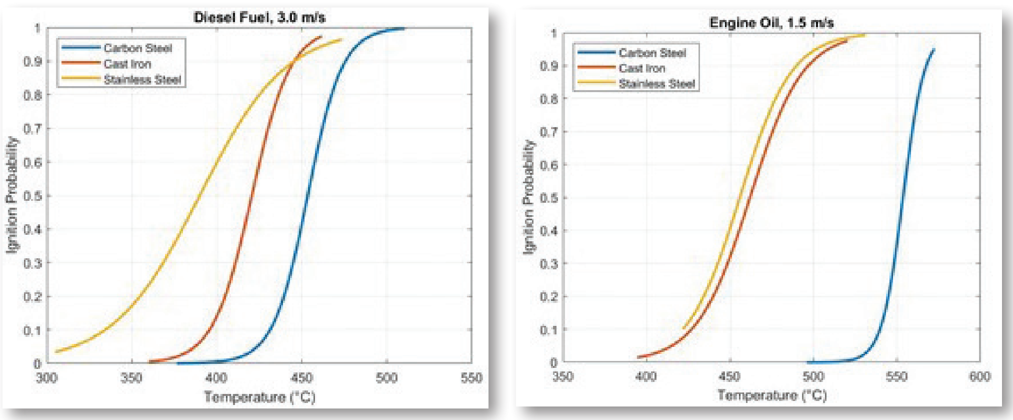

Fig. 1 The effect of metal type on ignition probability.

plate under different temperatures were also investigated. Results from this work will shed light on the ignition behavior of liquid fuels in a typical mining environment where hot surface and ventilation coexist. Data from this work can be used to develop more effective fire-suppression techniques for mine fires.

Method

Four electrical heaters were placed under a metal plate, measuring 22 cm by 22 cm, in a spatially uniform manner to heat the plate to the required temperatures. Nine K-type thermocouples, 0.8 mm in diameter, were attached to the surface of the metal plate to monitor the temperature of the plate. A small oil dispenser was positioned 25 cm above the metal plate, with a valve to control the liquid dripping rate. The liquid valve was set to drop to the hot metal surface at a rate of two drops per second, and the volume of each drop was about 0.045 mL. For each test, there were roughly 10 drops onto the metal surface or until ignition occurred. After each test, a minimum of a 30-second interval was allowed for the metal plate to regain thermal equilibrium. For each temperature setting, at least 10 tests were conducted, and the numbers of "ignition" and "no ignition" tests were recorded. A camera was positioned in front of the setup to capture the ignition or no ignition of the test. Every test was repeated at least twice to ensure repeatability. A total of about 3,000 tests were conducted.

Results

Figure 1 shows typical test results on the effect of metal type on hot surface ignition probability. It can be seen that carbon steel requires a higher ignition temperature than the stainless steel and cast iron. Cast iron and stainless steel have a similar influence on the ignition temperature.

The indication from this study regarding mine fire prevention and protection is that carbon steel might be a better choice compared to the other two metals for mining equipment that has the potential for a hot surface ignition. For the same external conditions, such as temperature and ventilation speed, as for the other two metals, carbon steel will result in a higher ignition temperature for the three liquid fuels in the testing.

Table 1 shows the highest temperatures for no ignition

Table 1 — Highest temperature for no ignition and lowest temperature for ignition.

Fuel type	Ventilation speed (m/s)	Metal type					
		Cast iron		Stainless steel		Carbon steel	
		Temperature (°C)					
		Lowest for ignition	Highest for no ignition	Lowest for ignition	Highest for no ignition	Lowest for ignition	Highest for no ignition
Engine oil	0	482	528	467	536	558	595
	0.5	426	467	438	505	550	562
	1.5	417	481	421	441	497	519
	3.0	447	476	344	459	461	482
Diesel fuel	0	466	515	441	482	565	577
	0.5	418	466	435	477	528	564
	1.5	414	457	405	441	460	467
	3.0	379	422	391	446	442	471
Hydraulic fluid	0	502	547	510	532	563	596
	0.5	449	478	466	500	550	556
	1.5	452	494	410	477	492	526
	3.0	454	466	402	453	465	498

and the lowest temperatures for ignition. These two temperature ranges provide the overlap range of the ignition temperatures. The tables presented could form a database for mine fire ignition conditions and provide guidelines for better fire protection designs.

Conclusion

Three types of metal (carbon steel, stainless steel and cast iron), three types of liquid fuel (diesel, engine oil and hydraulic fluid) and four ventilation speeds (0, 0.5, 1.5 and 3.0 m/s) were chosen to study the hot surface ignition of mine equipment. Logistic regression data analysis was applied to obtain the ignition probability curves and then compare the influence of each parameter on the ignition. Test results show that under the same circumstances, ignition probability of diesel fuel is higher than engine oil and hydraulic fluid. Ignition on carbon steel is less likely than stainless steel and cast iron, which makes it a better choice for mining equipment for the prevention of hot surface ignition. Ventilation speed has a mixed influence on the ignition of liquid fuels due to the competing mechanism between cooling and oxygen supply. The experimental results demonstrate the probabilistic nature of hot surface ignition of common liquid fuels. Results from this work can help prevent mine fire ignitions and provide a dataset for better mine fire protection designs for mine equipment manufacturers. ■

Disclaimer

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Study on oxidation kinetics and mechanism of copper slag under nonisothermal conditions

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Special Extended Abstract

Copper slag is mainly used in cutting tools, abrasives, asphalt pavement, road construction, and in the production of concrete as an alternative to sand and cement [1]. As a renewable resource, only about 15-20 percent of the slag is used for these applications, and the dumping or disposal of surplus unused slag results in waste of a certain amount of usable metal in the feedstock [2]. In this work, the oxidation behavior of copper smelting slag under nonisothermal condition is studied using data obtained by the thermogravimetric (TG) method, and the kinetics parameters and reaction mechanism of oxidation are determined. It provides a theoretical basis for the comprehensive recovery of iron resources in slag and the selection of reasonable slag-making conditions.

Background

Copper is the third most extensively used metal after iron and aluminum, with 80 percent of it produced by the pyrometallurgical process [3], which also produces a large amount of copper slag. The high output of copper slag is a major problem of pyrometallurgical copper smelting. Copper slag is a complex polymetallic material containing iron, silicon, zinc, copper, lead, aluminum and other precious metals and their oxides. During the matte smelting process, two different liquid phases are formed — copper-rich matte (sulfide) and molten slag (oxide) — with most of the valuable elements entering the slag. Normally, a ton of copper produces about 2.2 tons of copper slag.

Only about 15-20 percent of copper slag is reused in cutting tools, abrasives, asphalt pavement, road construction, and the production of concrete as an alternative to sand and cement [4,5]. The surplus unused slag is dumped or disposed, resulting in waste [6].

Knowledge of basic kinetic data for metallurgical slag can aid in the smooth progress of the smelting process, temperature control, interface reactions and the removal of inclusions. If the oxidation behavior of copper slag can be studied, the kinetic data in the process of copper slag oxidation can be determined and the oxidation mechanism of copper slag can be elucidated. The theoretical basis data can be provided for optimization of the copper slag treatment process and estimation of the real-time material properties.

Materials and methods

The copper slag, sourced from Yunnan Copper Co. Ltd., is separated in an electric furnace after smelting in an ISASMELT furnace. It is a glassy material made up of copper