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RESEARCH ARTICLE

The effects of coal dust concentrations and particle sizes on the minimum auto-ignition temperature of a coal dust cloud

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Summary

Flash fires and explosions in areas containing an enriched combustible dust atmosphere are a major safety concern in industrial processing. An experimental study was conducted to analyse the effects of atmospheric coal dust particle sizes and concentrations on the minimum auto-ignition temperature (MAIT) of a dust cloud. Two different coal samples from Australian coal mines were used. The coal dust particles were prepared and sized in 3 ranges, of below 74 μm, 74 to 125 μm and 125 to 212 μm, by using a series of sieves and a sieve shaker. A humidifier was used to increase the moisture content of the particles to the required level. All the experiments were conducted in accordance with the ASTM E1491-06 method in a calibrated Goldbert-Greenwald furnace.

The results from this study indicate that coal dust properties, such as the chemical nature (H/C), concentration, particle size (D_{50}), and moisture content, impact on the MAIT. For coal dust concentrations less than 1000 g.m^{-3}, the MAIT decreases with increasing coal dust concentrations. On the other hand, for low concentrations of 100 to 15 g.m^{-3}, the MAIT becomes more reliable for particle size D_{50} rather than for volatile matters.

KEYWORDS

coal dust, coal ignition, flash fire, ventilation air methane, volatile matter

1 | INTRODUCTION

Coal dust explosions and flash fires are a major safety concern in coal mines and the extractive industries.[1,2] The losses and damages (such as lives and property) due to fire and explosion accidents caused by methane and coal dust in underground coal mines are substantial. The indirect effects of these accidents are even more considerable and cannot be expressed financially. Coal dust in cloud form is a homogenous, well-mixed fuel-air compound that can be ignited if provided with sufficient ignition energy.[3,4] The initial ignition can turn into an explosion and lead to a chain reaction. This rapid combustion process produces substantial pressure and liberates extensive heat. In addition, the shock wave developed by the coal-dust cloud explosion stirs up the settled coal dust on surfaces and provides the flame with more fuel. As such, the ultimate pressure and temperature increases dramatically, leading to massive destruction and damage.

Therefore, an understanding of dust explosion mechanisms is an important measure to avoid and mitigate these types of accidents.[5-7] To achieve this, all possible ignition sources must be reduced in underground coal mines. The coal dust, by itself, is capable of generating heat through a slow oxidation reaction. The self-heating may reach a point sufficient to ignite the coal dust. To prevent auto-ignition from occurring, the process temperature must always be kept significantly below the minimum auto-ignition temperature (MAIT). Additionally, the dust cloud properties also restrain and characterise the front flame in the mixture.[8] The ventilation air methane (VAM) capture duct is an interface between the coal underground mine exhaust fans and the thermal oxidation units, such as the flow reverse reactor or the VAM abatement unit. The aim of these thermal oxidation units, which are operated at temperatures of between 600°C and 1000°C, is to recover and decrease the fugitive methane emissions (VAM gases) from underground coal mines.[9,10] The VAM gases, however, are accompanied by coal particles present in the underground mine passageways. According to Spako,[11] the sizes of approximately 60% to 77% of the coal dust particles are below 212 μm, and approximately 26% to 39% of the coal dust particles are below 74 μm. Chen[12] examined the characteristics of the VAM gases. In 4 VAM systems in Australia, including the Hunter Valley, New South Wales, and the Bowen Basin, Queensland. He noted that the relative humidity in the VAM systems were above 75%, and in some cases, reached 100%. Exposure of the coal particles

to humid air increases the moisture content in the coal particles[13]; consequently, the moisture content of the coal particles in the VAM stream capture ducts is subject to change, depending on the humidity and temperature of the environment. Therefore, the presence of coal dust particles and high temperatures from the thermal oxidation units may turn VAM capture ducts a potential source for the auto-ignition of dust clouds.

Since the early 20th century, researches have investigated coal dust fires and explosions in coal mines. Several scholars investigated characteristics of coal dust explosions.[14-20] Other researchers investigated the lower explosion concentration, lower oxygen concentration and hybrid, and the ignition influence on the coal dust explosion. These investigations used a confined explosion chamber such 20 and 1000 L explosion chambers.[4,21-31] Other scholars investigated the minimum initiation energy of the coal dust,[32-35] and the MAIT of a coal dust layer.[36-41] The MAIT for a coal dust cloud, from a hot surface source, has been investigated in the past decades by many researchers. In a study conducted by Cao,[42] the MAIT of a coal dust cloud was investigated using a Godbert-Greenwald (GG) furnace. Cao observed that 740 g.m^{-3} of dust was the optimum concentration, where the MAIT had the lowest value, and that the MAIT increased with increasing particle size. Gummer (2003) built a large vertical scale apparatus (2 m long and 0.3 m in diameter) to investigate the MAIT for coal dust particles and showed that the MAIT increased significantly as the particle size increased.[43] The research outcomes of Torrent[44] showed that the MAIT for a dust cloud is a function of coal dust properties, such as volatile matter. He observed that the explosion is more rigorous for coal dusts with higher concentrations of volatiles. Sweis[45] obtained that there is a correlation between the MAIT and the coal dust concentration. He found that the MAIT increased with increasing concentrations from 200 to 1000 g.m^{-3}. In addition, the MAIT was inversely proportional to the particle size.

Hertzberg investigated the MAIT for a wide range of carbonaceous dusts, including coal dust (ie, Bituminous, Lignite, and Anthracite coals) using a 1.2 L furnace apparatus. By testing high-, low-, and medium-ranked coals, this study found that as the volatile matter percentage increased, the MAIT decreased. Moreover, he observed that the optimum concentration lies between 300 and 1200 g.m^{-3}. However, for concentrations below 300 g.m^{-3}, the MAIT was found to be inversely proportional to the concentration. Hensel (1984), as reported in Eckhoff,[46] compared the MAIT results of both GG and BAM furnaces for 21 different types of dust. The study concluded that the MAIT determined from a BAM furnace was lower than for the MAIT of a GG furnace. This was due to the horizontal geometry of the BAM furnace and the dust particles depositing on the surface of the furnace. In this case, the fuel gases and smouldering developed from the particles leads to the ignition of the mixture at a temperature lower than the actual MAIT.[46]

The effects of moisture on coal dust combustion have been highlighted by a number of researchers in the past. Küçük[13] investigated the influences of moisture content and particle size on spontaneous coal-dust bed combustion. He concluded that the moisture reduced the susceptibility of coal dust to spontaneous combustion; however, reducing the particle sizes works on increasing the susceptibility to coal dust combustion. The influence of moisture on self-heating has been illustrated by Beamish.[47,48] The outcomes show that moisture defers the self-heating for a specific time, depending on the amount of moisture in the coal sample. Yuan[20] did an experimental study to investigate the role of moisture on the coal dust explosion by using a 20 L explosion chamber. The conclusion was that the explosion sensitivity was reduced as the moisture content of the coal dust increased. Other studies investigated the influence of moisture on the heating rate and tendency for coal dust to spontaneously combust.[21-24]

In spite of the fact that there have been a number apparatus used to measure the MAIT of a dust cloud, the GG furnace (ASTM E1491) is recommended by the IEC standard for determination of the MAIT of dust clouds.[25,26] Despite the importance of the subject, there is little information available on MAIT of the coal dust present in VAMs in open literature.[10-12] The knowledge gap, important to increasing the level of safety in a VAM capture duct, can be addressed by investigating the MAIT and the probability of an explosions of coal dust in a VAM under set conditions. The conditions of interest include the lower coal dust cloud concentration required to initiate ignition and the influences of coal particle composition on the MAIT of coal dust clouds. To do this, a comprehensive set of experiments were conducted at the University of Newcastle, Australia, to investigate (1) the effects of particle size on the MAIT; (2) the impacts of the coal dust concentrations on the MAIT; (3) the effects of the coal dust properties on the MAIT; and (4) the effects of moisture on the MAIT.

2 | METHODOLOGY AND TECHNIQUE

The GG apparatus used in this study was used to determine the MAIT for the coal dust samples (see Figure 1). The set-up included a vertical tube furnace, compressed air storage, data logger, image and recording devices, thermocouples, and computer system. An analytical scale was used to measure the precise quantity of coal dust required for each experiment according to the experimental matrix. All the experiments were conducted according to the ASTM 1491 standard procedure.[49] Two different coal samples, collected from different mines, were examined.

The coal dust sample was placed into the coal dust injector and blown into the preset temperature tube furnace using compressed air. If no ignition was observed for that set point temperature, then

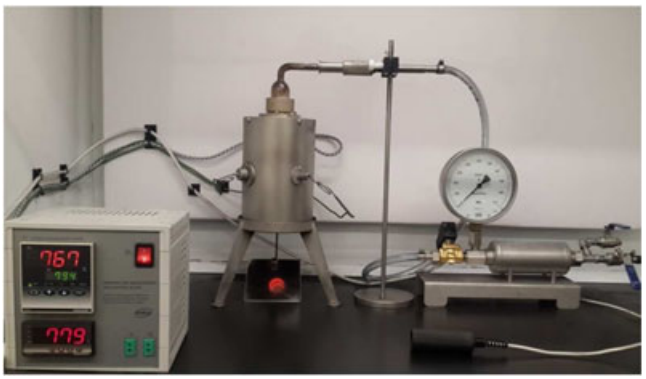


FIGURE 1 The Godbert-Greenwald apparatus (ASTM1241) [Colour figure can be viewed at wileyonlinelibrary.com]

the temperature was increased by 50°C until ignition was achieved. Upon achieving ignition, the temperature was then decreased in 20°C increments to identify more accurately the lowest temperature at which ignition still occurred. To establish the exact set point, each experiment was repeated 3 times. If ignition occurred, then the temperature of the experiment was considered to be the MAIT for the coal dust sample under the given conditions. In the case where no exact set temperature could be pinpointed, the MAIT was defined in a temperature range (between the temperature at which the ignition occurred and the highest temperature at which ignition did not occur). Two coal dust samples used were collected from 2 mines located in New South Wales, Australia. To avoid any further oxidation, the samples were kept in sealed containers and stored in a cool store. Optical micrographs at 20× magnification were obtained on a Zeiss optical microscope. The samples were filmed at room temperature, and the samples were analysed by smearing a small amount of the coal mixture F2 in between a glass slide and a coverslip (see Figure 2).

The properties of the sample were obtained by performing ultimate and proximate analyses as well as particle size distribution (see T1 Table 1).

3 | RESULTS AND DISCUSSION

3.1 | Coal dust particles below 74 μm

F3 Figure 3A,B presents the MAIT for the coal dust samples from mines A and B. In these figures, the MAIT for any given coal dust concentration (ranging from 100 to 1000 g.m^{-3}) is shown with hollow and solid symbols. The solid dots indicate where ignition occurred and the hollow dots indicate the nonignition temperatures for the given concentration. To define the MAIT accurately, 3 experiments were conducted for each concentration at any given temperature. The concentration at the set temperature was considered ignitable if ignition could be observed in at least 2 experiments. However, for cases with no emerging flame from the bottom of the furnace (ie, the internal ignition was observable by the mirror only), the concentration was considered as a nonignition.

The variations of the MAIT rely on the composition of the coal and the surrounding conditions. Since the conditions of the experiments are the same, ie, the test pressures and environment temperatures, the variations of ignition and nonignition temperatures, as shown in Figure 3, were a result of the particle size (D50) and the volatile matter content differences between samples A and B.

TABLE 1 Ultimate and particle size (D_{50}) analysis

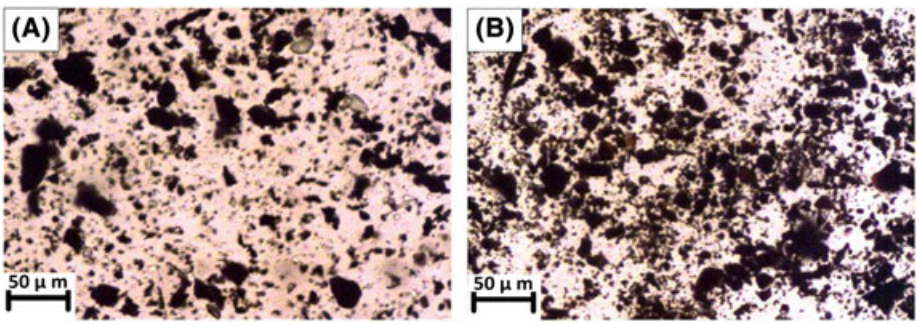
Mines samples	Moisture%	Ash%	Volatile Matter%	D_{50}(μm)
Mine A	4.1	20.6	27.5	21.8
Mine B	1.1	10.3	31.7	29.91

The mine B sample ignited at a lower temperature than the mine A sample. This can be seen in Figure 3. for sample B (Figure 3B), the solid dots of the range of concentrations from 1000 g.m^{-3} to 600 g.m^{-3} are located at a temperature of approximately 580°C; while for sample A (Figure 3A), the solid dots are located at a temperature of approximately 610°C. In both cases, the samples are more difficult to ignite at lower concentrations.

The results show that the MAIT significantly decreases as the coal dust concentration increases. This phenomenon is more distinct for mine B in when compared with mine A. The MAIT for mine B decreases from 775°C to 675°C as the coal dust concentration increases from 100 g.m^{-3} to 1000 g.m^{-3}. A similar pattern was observed for mine A for concentrations of up to 300 g.m^{-3}. However, for larger concentrations (>600 g.m^{-3}) the MAIT remains approximately constant and does not change with concentration. For example, the MAIT for concentrations above 300 g.m^{-3} for the mine A sample remained at nearly 605°C.

Figure 4 shows the variations of the MAIT with the various con- F4 centrations for the dust clouds. There are 2 distinct areas: the first area shows that the MAIT decreases as the concentration increases, while the shaded area shows that the MAIT is relatively constant with increasing concentrations. The lowest MAIT for both samples lies in the area between 750 and 1000 g.m^{-3} (the shaded area). This region can be considered as the region in which the coal dust concentration is at its optimum level. Cao et al also observed a similar behaviour for the MAIT in their study. The gap in the MAIT between both samples at the optimum concentration is due to the role of volatile matter.[15,30] The coal particles have a lower MAIT when the volatile matter content is higher. The curve of the MAIT as concentration decreases shows that the dust cloud needs higher temperatures to be ignited as the concentrations decrease.

The gap between the MAITs of mine samples A and B are approximately constant, with a difference of 30°C within the area of optimum concentrations. The sustainability of the auto-ignition largely depends



Q6 **FIGURE 2** Micrographs of coal samples with 20× magnification: A, mine sample A; B, mine sample B [Colour figure can be viewed at wileyonlinelibrary.com]

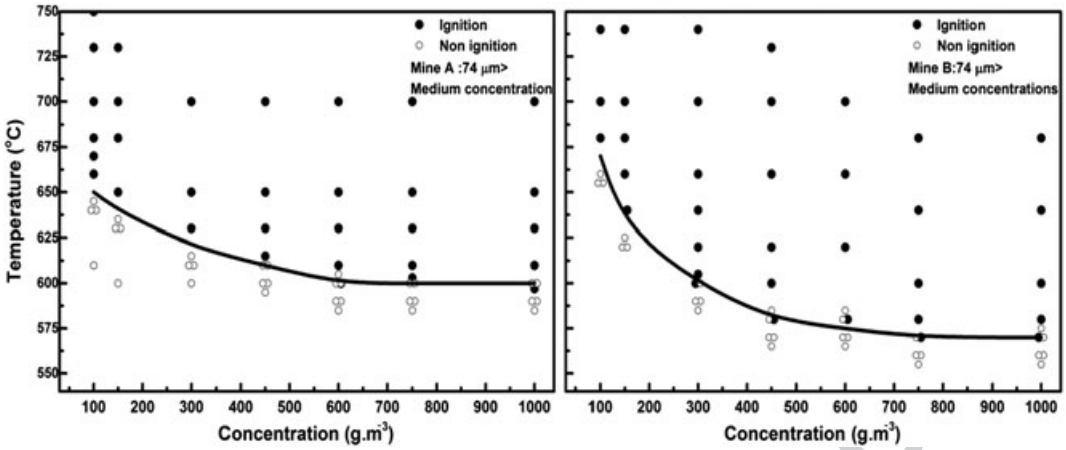


FIGURE 3 Ignition/nonignition tests for medium concentrations of mine samples A and B

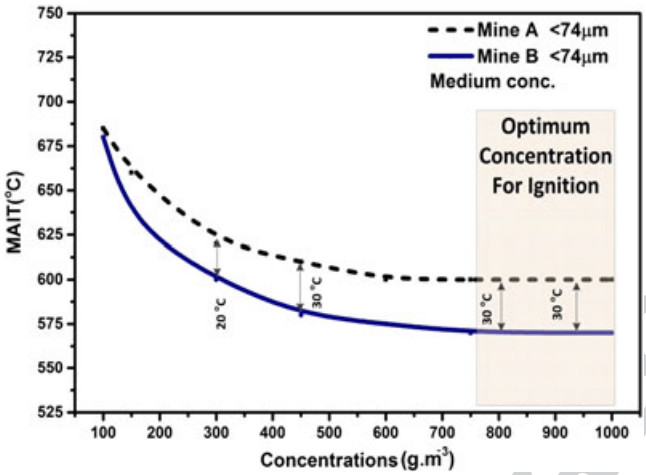


FIGURE 4 The minimum auto-ignition temperature (MAIT) of the dust cloud for high concentrations [Colour figure can be viewed at wileyonlinelibrary.com]

on the liberation of the volatile matter from the coal particles inside the furnace. This process is called homogenous ignition and often occurs when there is sufficient coal dust and volatile matter in the cloud.[50] Once homogenous ignition occurs, it generates sufficient heat to sustain the reaction by igniting the char (solid composition of coal particles). The ignition of the solid particles of coal dust is called heterogeneous ignition. As seen in Figure 4, the gap reduces from 30°C to 10°C as the concentration reduces from 750 g.m^{-3} to 200 g.m^{-3}. While the gap starts to reduce at decreasing coal dust concentrations, reaching a minimum of 5°C at 100 g.m^{-3}, the dust cloud needs more energy to ignite. Therefore, it can be concluded that the MAIT for the optimum concentration is highly dependent on the devolatilized gases from the coal particles and that homogenous ignition is the dominant mode of reaction.

The domination of the homogenous reaction over the heterogeneous reaction changes according to temperature and particles size. However, there is also an area called the hetero-homogenous reaction. In this specific region, both of the reactions (ie, a homogeneous reaction and the oxidation of the active site and/or fixed carbon on the surface of particles) take place together.[51] From these findings, it can be concluded that the MAIT rise, shown in Figure 3, is mainly controlled by the homogenous reaction and depends on the chemical composition more than physical composition for samples A and B. The MAITs (at optimum concentration for ignition) of mines A and B are in good agreement with the data from the literature review, as shown in Table 2.

3.2 | Coal dust particles below 212 μm

Approximately 60% ± 10% of coal particles in the VAM stream are below 212 μm. Out of this, around 40% ± 10% are below 74 μm, so it is essential to have a better understanding of the impact of coal particle size on the MAIT. To determine this, particles ranging from below 74 μm, 74 to 125 μm, and 125 to 212 μm were investigated Figure 5 shows the MAITs of sample B for high concentrations (ie, 100-1000 g.m^{-3}) for the particle size ranges <74 μm, 74 to 125 μm, and 125 to 212 μm from mine B.

This figure indicates that the MAIT significantly decreases as the particle size decreases. The MAITs for higher concentrations (>550 g.m^{-3}) were nearly constant and followed an even trend. However, for lower concentrations (ie, 100 g.m^{-3}) there were significant differences in the MAITs between fine and coarse particles. For a concentration of 1000 g.m^{-3}, there was a difference of 15°C between the MAITs for particles sized >74 μm and <74 μm. This difference increased at a concentration of 100 g.m^{-3} to a value of 80°C for the

TABLE 2 The minimum auto-ignition temperatures (MAITs) of coal dust clouds in the literature for particles below 74 μm

	D_{50}(μm)	MAIT(°C)	Reference
Bituminous coal (Petchora)	38	590	Eckhoff[46]
Bituminous coal (high volatile)	4	510	Eckhoff[46]
Activated carbon	46	630	Eckhoff[46]
Pittsburgh seam	<74	585	Khalil[52]
Pittsburgh seam	<74	600	ASTM E1491[49]

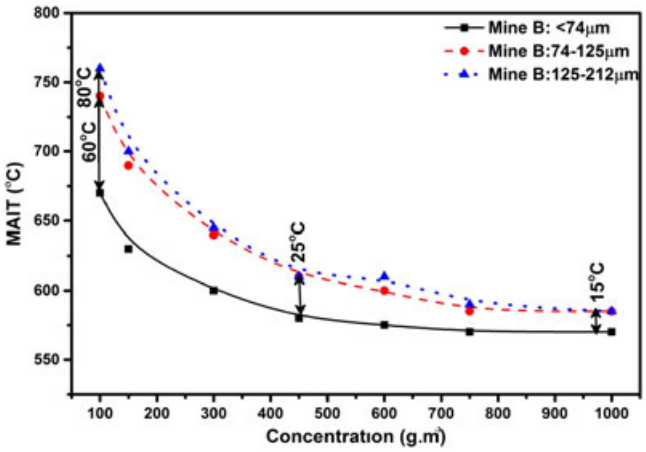


FIGURE 5 Comparison of the minimum auto-ignition temperatures (MAITs) of dust clouds for 3 particle sizes at medium concentrations [Colour figure can be viewed at wileyonlinelibrary.com]

particles size range 125 to 212 μm and 60°C for particles size range 74 to 125 μm. The results obtained for the MAITs at the optimum concentrations for different particle sizes agrees well with the results reported by Nagy.[27,30-33] In addition, it is observed that, for coarser particles, the reaction type is dependent on the ignition of the active sites on the surface of the coal particles, which explains the gap in the MAIT trends. The lower MAIT (at a 740 g.m^{-3} coal dust concentration) of mine B is in good agreement with the data tableted by Cao,[42] shown in Table 3.

TABLE 3 The minimum auto-ignition temperatures (MAITs) of coal dust clouds as tableted by Cao[42] for 3 ranges of particles sized at 740 g.m^{-3}

Particles Size (μm)	Volatile Matter	MAIT(°C)
150-250	35	619
75-125	35	609
Below 74	35	589

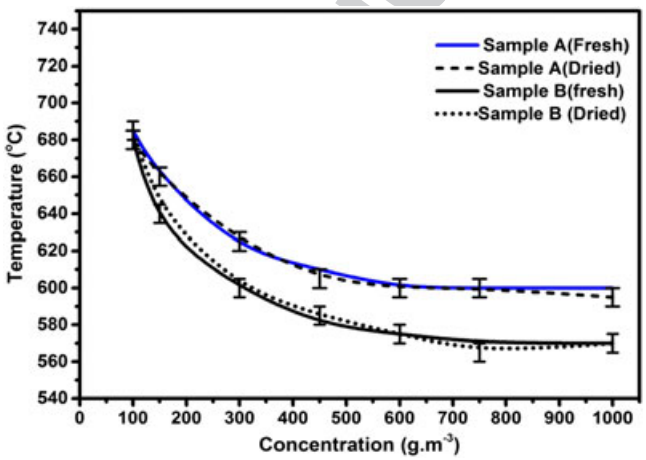


FIGURE 6 Comparison of the minimum auto-ignition temperatures of dust clouds for fresh and dried samples [Colour figure can be viewed at wileyonlinelibrary.com]

3.3 | Moisture effects

The effect of moisture on the MAIT of coal dust clouds has been investigated for the both mine samples (A and B). Each sample was dried at 50°C according to the drying method described by Cao.[42] Figure 6 shows the MAITs of samples A and B for both fresh and dried conditions.

Each sample has been dried by exposing the sample to 50°C for 2 hours. Figure 6 shows the MAITs of samples A and B for both the fresh and dried conditions. The results show that the MAIT of the dried sample was not affected by the sample moisture content, and the maximum found for the error bar is approximately ±5°C.

3.4 | Diluted coal dust concentrations (below 100 g.m^{-3})

The MAIT for coal dust cloud was examined for low concentrations subjected to the coal concentrations in the VAM stream. A diluted concentration coal dust cloud in this study refers to concentrations below

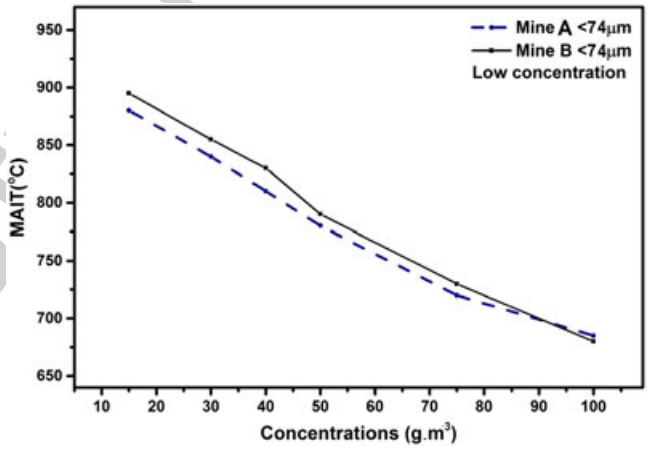


FIGURE 7 Minimum auto-ignition temperature comparison for the 2 different mines' particles below 74 μm [Colour figure can be viewed at wileyonlinelibrary.com]

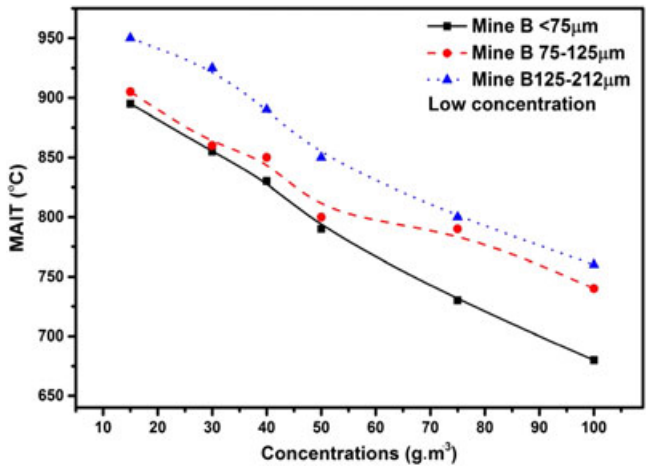


FIGURE 8 Minimum auto-ignition temperature (MAIT) comparison for 3 different particle size ranges, below 74 μm, 74 to 125 μm, and 125 to 212 μm [Colour figure can be viewed at wileyonlinelibrary.com]

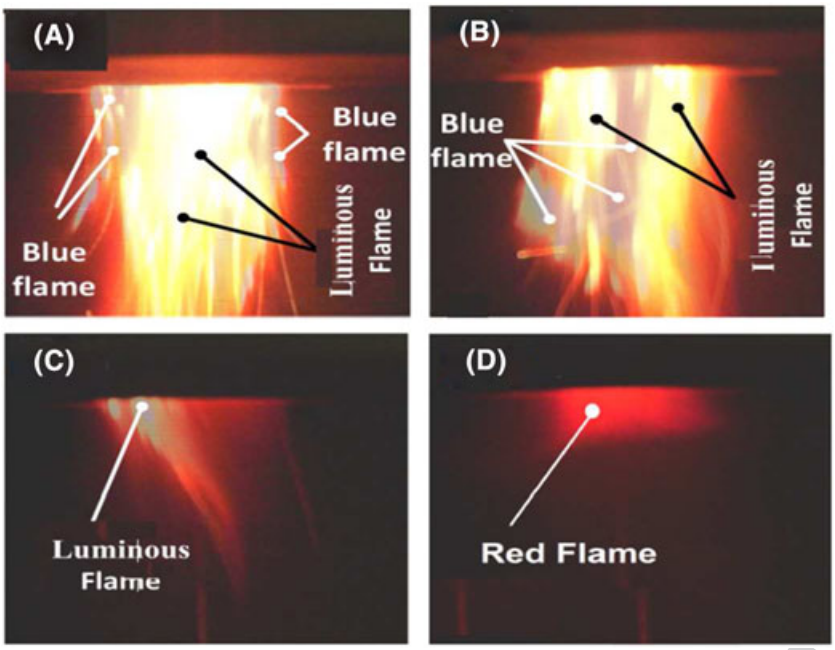


FIGURE 9 A, Auto-ignition for 75 g.m^{-3}; B, auto-ignition for 50 g.m^{-3}; C, auto-ignition for 30 g.m^{-3}; and D, auto-ignition for 15 g.m^{-3} [Colour figure can be viewed at wileyonlinelibrary.com]

100 g.m^{-3}. Figure 7 presents the MAITs for coal dust samples from mines A and B for dilute concentrations.

Generally, the MAIT decreases significantly with increasing coal dust concentrations. As shown, the MAIT decreases from approximately 900°C to below 700°C for samples B and A. The comparison between the MAIT trends in Figure 7 reveals that the MAIT curve for mine B overlaps the curve for mine A. It is believed that at a certain temperature and specific concentration, the ignition of the dust cloud is controlled by a single driving reaction (the heterogeneous reaction) only. In addition, it can be presumed that the particle size has more impact on ignition than the volatile matter, as the D_{50} for mine B is relatively higher than for mine A. These results show that the MAIT for diluted concentrations are affected more by particle size (D_{50}) than by volatiles and fixed carbon.

Figure 8 indicates the impact of coal-dust particle size effects on MAIT for lower coal dust concentrations. Three ranges of particle sizes, 74 μm, 74 to 125 μm, and 125 to 212 μm, from mine B were selected for this purpose. The results for these experiments showed that the MAITs significantly decreased with increasing coal dust concentrations. The MAITs almost follows a linear trend for all 3 particle size ranges. The MAITs for larger particles (ie, 125-212 μm) were observed to be relatively higher in comparison with the smaller size particles (ie, 74 μm). For example, at a concentration of 30 g.m^{-3}, the MAIT decreased from approximately 930°C to 860°C for the finest (<74 μm) and the coarsest (74-125 μm and 125-212 μm) particle sizes.

Similar to the optimum concentration area shown in Figure 4, the gap between the MAITs for the fine and coarse particles from the mine B samples was approximately constant. This can be attributed to the domination of the heterogeneous reaction, thus limiting the MAIT of the dust cloud. This phenomenon can be partly explained by aspects of the flame captured during the experiments. Experimental observations showed that under constant conditions, the shape and the illumination of the flame changes with the coal dust concentration. The size and colour of the flame is relatively larger and brighter for higher coal dust concentrations in comparison with lower concentrations. For example, in the case of 75 g.m^{-3}, the flame propagates out from the bottom of the furnace by several centimetres; whereas for the lower concentrations (such as 15 g.m^{-3}), the flame appears at the neck of the furnace only. The luminous area was produced from the ignition of the coal dust clouds, while the blue area is produced by the ignition of the ignitable volatile gases.[53]

Figure 9A-D illustrate the flash flame propagations for different coal dust concentrations. Image 9A exhibits a blue flame, accompanied by luminous light at 75 and 50 g.m^{-3}. However, for concentrations below 50 g.m^{-3} (image 9B), only the luminous flame appeared. For very low concentrations, such as 30 and 15 g.m^{-3} (images 9C,D), a dark red glowing light appeared that is related to the combustion of coal particles inside the furnace only.

4 | CONCLUDING REMARKS

In this experimental work, the measurements of coal-dust cloud ignition were performed using a GG furnace. From the analysis of the present results, the following findings were made:

- The presence of a diluted amount of a coal dust concentration (ie, 15 g.m^{-3}) in the processing industry and/or a hot environment is a potential hazard as a source of ignition. Below a 15 g.m^{-3} coal dust concentration, auto-ignition was not possible, even when applying higher temperatures.
- The results obtained from this study indicate the existence of 2 controlling mechanisms for coal dust cloud combustion, namely, the volatile matter and the particle size. However, it has been found that there is no significant effect of moisture (0%-4.1%) on the MAIT of the dust cloud. It was revealed that, for coal dust concentrations above 300 g.m^{-3}, the volatile matter has a profound impact by reducing the MAIT. The effect becomes more pronounced when the volatile matter is presented and ignited in homogeneous form.

- Unlike with higher concentrations, the volatile matter has less impact on the MAIT in low coal dust concentrations. For low concentration (ie, below 100 $g.m^{-3}$) the reactions on the surface drive the ignition process and define the MAIT (D_{50}).
- Unlike with higher concentration, for low concentration (ie, below 100 $g.m^{-3}$), the volatile matter has less impact on the MAIT. But for concentrations lower than 100 $g.m^{-3}$, the reactions on the surface drive the ignition process and define the MAIT (D_{50}).

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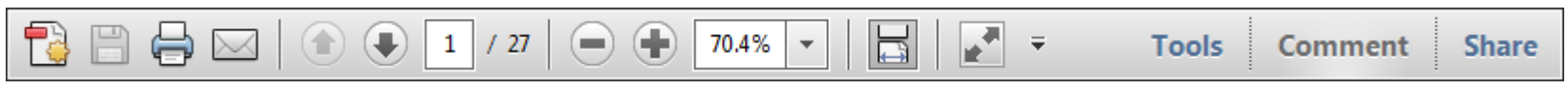
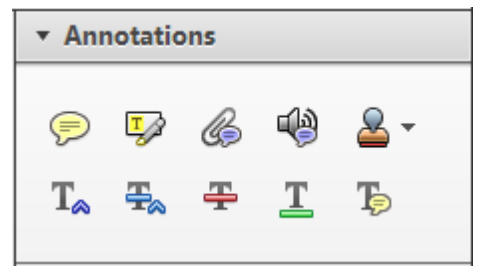
USING e-ANNOTATION TOOLS FOR ELECTRONIC PROOF CORRECTION

Required software to e-Annotate PDFs: Adobe Acrobat Professional or Adobe Reader (version 7.0 or above). (Note that this document uses screenshots from Adobe Reader X)
The latest version of Acrobat Reader can be downloaded for free at: http://get.adobe.com/uk/reader/

Once you have Acrobat Reader open on your computer, click on the Comment tab at the right of the toolbar:



This will open up a panel down the right side of the document. The majority of tools you will use for annotating your proof will be in the Annotations section, pictured opposite. We've picked out some of these tools below:

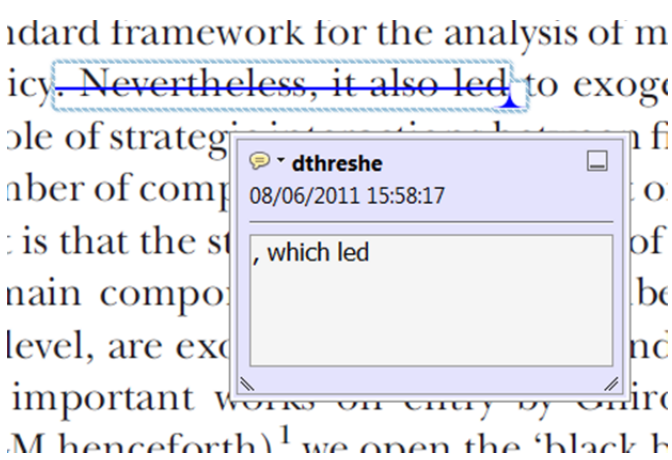


1. Replace (Ins) Tool – for replacing text.

Strikes a line through text and opens up a text box where replacement text can be entered.

How to use it

- Highlight a word or sentence.
- Click on the Replace (Ins) icon in the Annotations section.
- Type the replacement text into the blue box that appears.

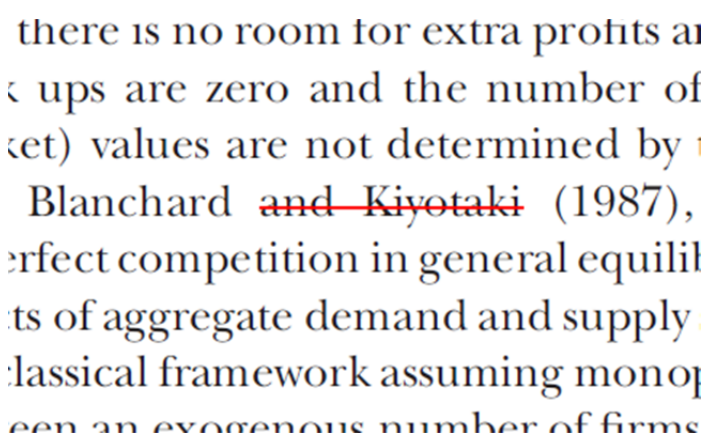


2. Strikethrough (Del) Tool – for deleting text.

Strikes a red line through text that is to be deleted.

How to use it

- Highlight a word or sentence.
- Click on the Strikethrough (Del) icon in the Annotations section.



3. Add note to text Tool – for highlighting a section to be changed to bold or italic.

Highlights text in yellow and opens up a text box where comments can be entered.

How to use it

- Highlight the relevant section of text.
- Click on the Add note to text icon in the Annotations section.
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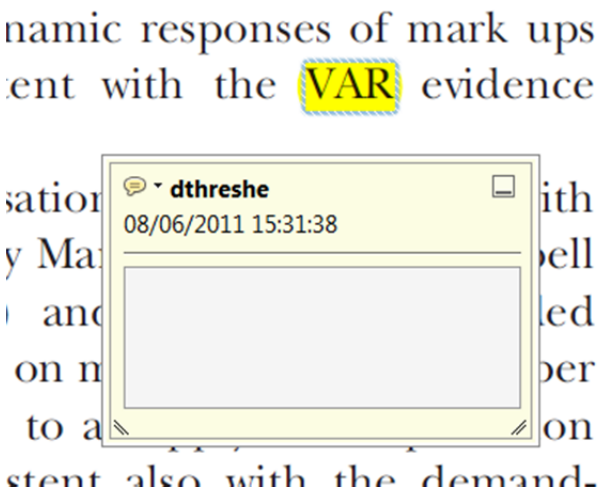
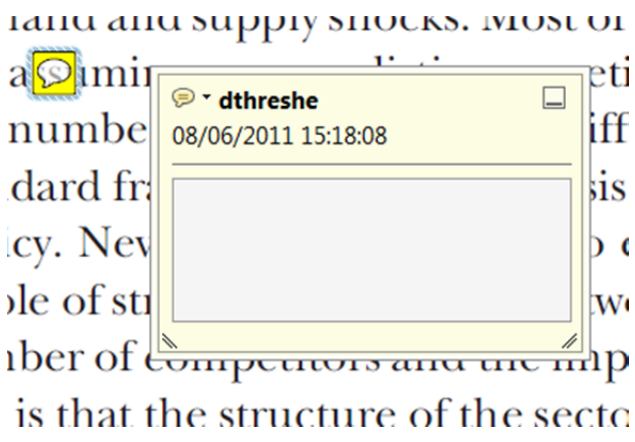


4. Add sticky note Tool – for making notes at specific points in the text.

Marks a point in the proof where a comment needs to be highlighted.

How to use it

- Click on the Add sticky note icon in the Annotations section.
- Click at the point in the proof where the comment should be inserted.
- Type the comment into the yellow box that appears.

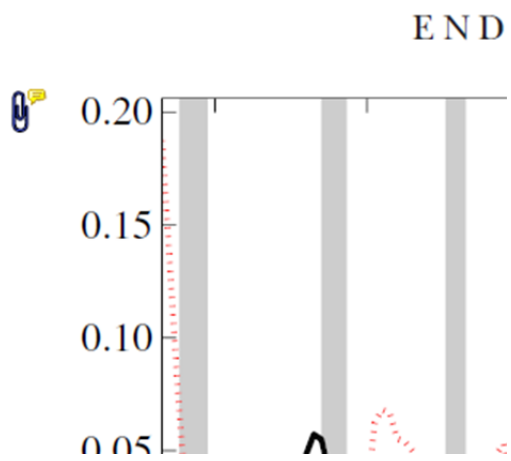


5. Attach File Tool – for inserting large amounts of text or replacement figures.

Inserts an icon linking to the attached file in the appropriate pace in the text.

How to use it

- Click on the Attach File icon in the Annotations section.
- Click on the proof to where you'd like the attached file to be linked.
- Select the file to be attached from your computer or network.
- Select the colour and type of icon that will appear in the proof. Click OK.

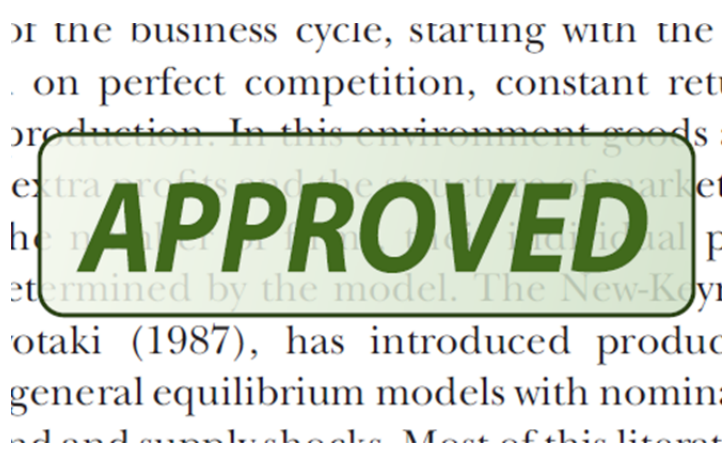


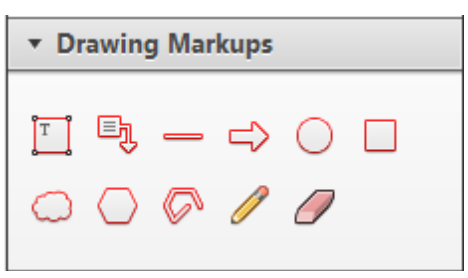
6. Add stamp Tool – for approving a proof if no corrections are required.

Inserts a selected stamp onto an appropriate place in the proof.

How to use it

- Click on the Add stamp icon in the Annotations section.
- Select the stamp you want to use. (The Approved stamp is usually available directly in the menu that appears).
- Click on the proof where you'd like the stamp to appear. (Where a proof is to be approved as it is, this would normally be on the first page).



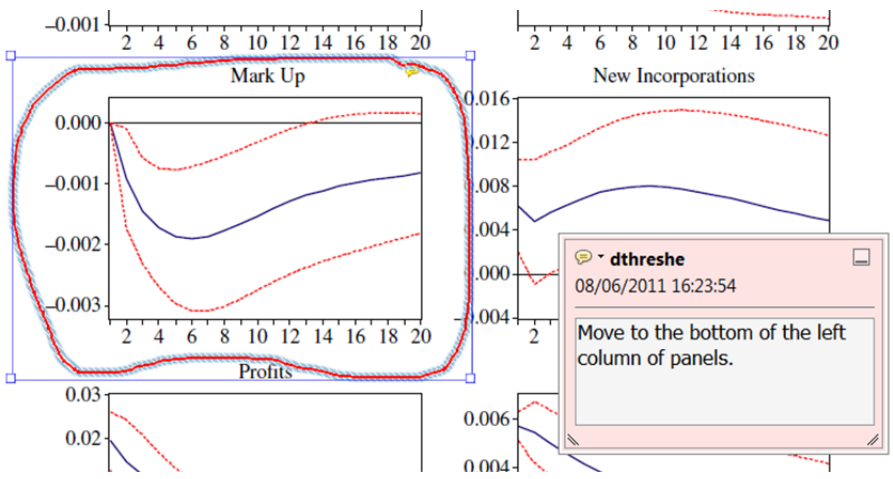


7. Drawing Markups Tools – for drawing shapes, lines and freeform annotations on proofs and commenting on these marks.

Allows shapes, lines and freeform annotations to be drawn on proofs and for comment to be made on these marks..

How to use it

- Click on one of the shapes in the Drawing Markups section.
- Click on the proof at the relevant point and draw the selected shape with the cursor.
- To add a comment to the drawn shape, move the cursor over the shape until an arrowhead appears.
- Double click on the shape and type any text in the red box that appears.



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