CONTROLLING MAGNESIUM FIRES BY CELLULOSE FLAKE BLANKETING AND SUBSEQUENT WATER MIST COOLING

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Abstract

A novel technique was developed to fight magnesium fires of different sizes and vigour. In essence, cellulose flakes, as they are used as blow-in insulation material, are modified with inorganic salts. The salts constitute 30 wt% of the mix and are intimately mixed into the flakes. Sodium borate and magnesium sulfate were found to be particularly effective. These salt-laden flakes are transported to a burning magnesium spot by an optimized blow-in machine (dilute phase conveying). From a distance of between 3 and 10m, the flakes are directed at the magnesium fire. What seems to be counterintuitive works effectively and efficiently: The flakes take a few seconds to completely cover the entire metal fire. Then, the fire ceases for a short period of time, due to oxygen deficiency under the "blanket". It is at that point in time that a water mist can be directed at the covered, burning metal heap. The water will soak the upper flakes and then, heated by the lower-lying metal, start evaporating, while the fire is deprived of oxygen and is made to cool down. The water mist attack can be carried out for an extended period of time. The mixture with 15% of sodium borate was found to work best, by yielding the most stable crust. The novel process allows to control a medium to large-scale magnesium fire within less than one minute, with substantially lower danger potential for fire fighters than in current practice.

Keywords: Metal fires, oxyhydrogen explosion, safety, die casting

1. INTRODUCTION

Magnesium allows more lightweight and thinner parts than aluminum and can be the material-of-choice for several specialty and high-volume applications[1]. One of the drawbacks of magnesium is its autoignition behavior of the melt, which needs to be controlled with complex measures. For instance, in Mg die casting processing, the melt is blanketed with heavy gasses such as SF_6 or SO_2. Also, magnesium chips bear a fire risk. When a magnesium fire does occur, be it at a die casting factory, at a scrap yard, or worse, during transportation, it is difficult to extinguish, because of the high flame temperatures. The traditional approach to attack a magnesium fire is to shovel sand onto the burning metal, in order to shield it from atmospheric oxygen. This technique has 2 disadvantages: 1) fire fighters need to approach the fire closely; 2) when the sand is tossed onto the metal fire, its high density will cause splashes, which might cause a spread of the fire, and perils for the first line attackers, from oxyhydrogen explosions resulting from moist sand to molten metal drops damaging the protective equipment and endangering the fire fighter.

Despite the known precautions, magnesium fires still occur, with great damage potential [2].

The aim of this work was to develop an alternative approach to extinguishing magnesium fires. There is also a fire risk from other metals, e.g. lithium in lithium ion batteries, so the topic is a very current one. When embarking on the project, the authors were determined to develop a solution which does not rely on halogenated compounds. The work started with a thorough literature research on magnesium fire fighting [3]. Fine magnesium powder is also dust-explosive [4, 5].

Magnesium ignition and flammability depend on the chosen alloy [6].

In [7], pneumatic conveying was used to transport cement powder to a magnesium fire. The fire suppression tests in [7] *"demonstrated that pneumatic conveying could effectively transport cement powder to the combustion area for suppressing metal magnesium fire. The fire suppression effect of cement powder in metal magnesium fire is ascribed to the formation of a thermally insulation layer as physical barrier".*

Therefore, the purpose of this work was to find a new approach to make fighting a magnesium fire safer.

2. EXPERIMENTAL

It was decided to carry out field tests with larger quantities of magnesium flakes, to obtain results with high relevance for practitioners (fire fighters). Hence, the focus of this work was not on a detailed description of the combustion process in a controlled lab environment, but rather on whether the process works under real-world conditions with e.g. influences by the weather. A quarry in St. Gallen/Austria was chosen for the experiments.

Flakes of magnesium were piled up on dry sand with quantities between 2 kg and 75 kg and ignited with a torch. After full development of the metal fire, cellulose flakes containing 30 wt% of inorganic salts (sodium borate, sodium chloride, magnesium sulfate, potassium chloride and boric acid) were applied by pneumatic conveying. The delivery rate was 20-60 kg/min. Depending on the size of the fire, the time to completely cover the flames was between 10s and 90s. Interestingly, the flakes caused the flames to disappear, from the effect of shielding the unburnt metal from fresh air/oxygen. Before the flames could reemerge (which would happen after 20 to approx. 100 seconds, depending on the thickness of the applied flakes and the amount of burning metal, a water mist was applied to the pile of flakes. Thereby, the fire could be controlled effectively. The water partly soaked the unburnt, upper part of the cellulose cover, and was evaporated from the underlying heat. The charred bottom part of the cellulose flakes were found to provide a sufficiently stable crust for the water mist. A water jet would have "blown off" the charred cellulose cover and immediately have led to a spread of the molten metal and its reignition, with oxyhydrogen explosion. The mixture of the salts in the cellulose flakes had been optimized in lab trials [8], and was confirmed in a field trial with up to 75 kg of burning magnesium. The amount of flakes there was needed to control magnesium fires of different sizes – see **Figure 1** below.

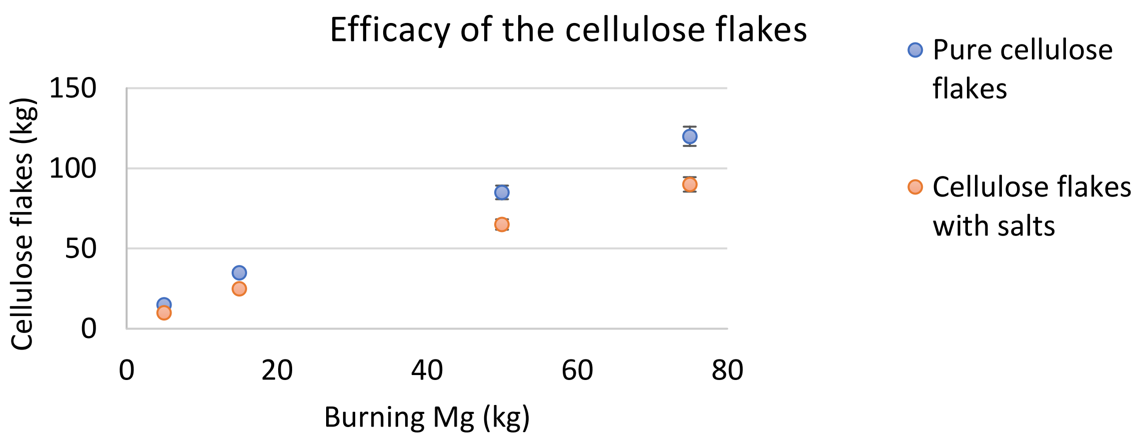

Figure 1 Control of magnesium fires with cellulose flakes

As it can be seen, 90 kg of flakes were needed to control 75 kg of burning magnesium. With uncoated, pure cellulose flakes, also a remarkable result could be achieved, with 120 kg of required material.

For the application of the flakes, a special container was developed, with blow-in machine, diesel-based power generator, control system and storage room for the flakes, see **Figure 2** below.

Figure 2 The container for fighting magnesium fires, prototype (2022)

The fire fighting approach presented in this work seems counterintuitive, because water is used to extinguish burning metal. This is rendered possibly for firstly applying a cover of cellulose flakes, which becomes solid due to charring and the contained mineral salts. The critical success factor of the cellulose flakes is their low bulk density, which avoids splashes of molten metal, in contrast to heavier agents such as sand or pure salts. The novel technique can increase the safety of fire fighters in the magnesium processing industry, such as in die casting operations, or also where magnesium flakes are processed, e.g. in the recycling industry.

3. DISCUSSION

In this work, the authors could demonstrate that magnesium fired with up to 75 kg of burning metal can be controlled by covering them in a blanket of cellulose flakes, which contain metal salts. The subsequent water mist cooling was found not to provoke any oxyhydrogen explosion, but rather to withdraw heat. Thereby, the fire can be controlled effectively and efficiently. Splashes of molten metal are avoided, and the heat can be extracted. A major added value of the new process is increased safety for the fire fighters, since traditionally, they had to approach the metal fire really closely in order to control the flames fast. That safety-related problem could be eliminated, because the cellulose flakes can be applied to the fire from a greater distance than e.g. sand or cement particles.

Trials were made with up to 75 kg. It is expected that magnesium fires in die casting factories will involve lower quantities of metal. Larger quantities can be encountered in scrap containers. Also for such fires, the approach of using cellulose flakes is recommended as first line of attack. Also, it is suggested that fire fighters that could be sent to magnesium fires get a training in the novel process.

The flakes should be kept in sealed bags to avoid that they absorb moisture. Like this, they can be stored over extended periods of time. The functioning of the mobile power generator should be checked regularly to ensure its operability when needed.

4. CONCLUSION

The traditional methods of fighting metal fires are not always safe for fire fighters. Coated cellulose flakes, which contain approx. 30 wt% of inorganic salts, are blown onto the fire from a distance of several meters. Due to the low bulk density, the material settles smoothly on the fire and immediately covers the flames for several seconds. Before the hot, covered metal can break through the cover, in a second step a fine water mist is applied to the now-covered fire. It was observed that no hydrogen is formed and that the fire can be controlled in this way. 90 kg of flakes could safely bring a pile of 75 kg of burning Mg flakes under control. By using a pneumatic conveying unit for the flakes, fire fighters can effectively and efficiently cover the flames from a safe distance. The novel method can be recommended to fire fighters in industrial magnesium processing plants, and to local fire fighters in the vicinity of such plants.

The presented approach to attack magnesium fires is definitely not a "classic, textbook-style" magnesium-fire remedy, but definitely an attractive one from the angle of safety, costs and environmental performance. Right application requires some on-the-job training, which can be administered at short notice.

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