Journal of Cleaner Production 54 (2013) 344–352

Contents lists available at SciVerse ScienceDirect

Journal of Cleaner Production

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

Development of a compact excavator mounted dust suppression system

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ARTICLE INFO

Article history:
Received 22 October 2012
Received in revised form
29 April 2013
Accepted 30 April 2013
Available online 22 May 2013

Keywords:
Dust
Construction demolition process
Dust suppression
Environmental benefits
Cost benefits

ABSTRACT

This paper reports on the investigation of an excavator mounted dust suppression system for demolition and construction activities. Ever increasing pressure is placed on contractors to improve their environmental performance, especially dust emissions. Current methods of dust suppression have been investigated and each of the methods has also been critically analysed to determine their advantages and disadvantages. The investigation also examined the requirements of such a system and a concept system proposal was produced. A working prototype has been constructed for a mini excavator complete with a hydraulic breaker. The proposed system was rigorously tested in various configurations to determine its efficiency and effectiveness in comparison with current suppression techniques. The resulting benefits such as the reduction of water usage and cost are highlighted.

1. Introduction

Dust on construction and demolition sites has always been an issue, particularly regarding the health hazards of inhaling dust and the visibility issues associated with airborne dust particles (Zhao et al., 2012). As health, safety and environmental regulations are increasingly tightened, contractors and clients are forced to explore new ways of controlling dust. Dust is particle matter consisting of very small particles with a diameter ranging from 2.5 to 10 μm. Fugitive dust is one type of these small particles that are most hazardous to human health (Wu and Chen, 2011; Dimari et al., 2008; Driussi and Jansz, 2006).

Ever increasing regulations on environmental responsibility for contractors means that construction and demolition sites no longer have the option to recycle, especially on demolition sites that recycle concrete and stone products which produce fugitive silica dust (Dimari et al., 2008). Recent Health and Safety Executive (HSE) funded research suggested that over 650 construction deaths from silica-related lung cancer occurred in the UK in 2004. This equals 12 construction workers a week and suggests that silica inhalation is currently the second most important cause of occupational lung cancer after asbestos (HSE, 2004). Lung cancer is not the only effect of silica inhalation, which is the inhalation of small dust particles that causes scarring of the lungs known as silicosis. This condition can make the affected person breathless and disabled. Silicosis also increases the risk of serious infections such as tuberculosis (Petavratzi et al., 2005). Dust may not seem very dangerous but, with findings like these, it is imperative that something is done to reduce exposure throughout the construction industry.

Demolition activities involving excavators and hydraulic breakers often involve dust, whether the dust is built up over time in buildings being demolished or produced in the breaking or cutting of dry material such as concrete. With ever tightening health, safety and environmental legislation surrounding airborne dust on construction and demolition sites, contractors and clients are always searching for new initiatives and technology to combat airborne particulate matter. An excavator mounted dust suppression unit could reduce the requirement for excessive amounts of water to be used; due to this reduction in water usage, the amount of slurry produced causing slip hazards and other environmental issues could also be reduced. Internal demolition using mini excavators produces dust in a confined space and large air movers are usually used to extract the dust. However, in buildings with poor ventilation and confined space, it is not always possible to implement such

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http://dx.doi.org/10.1016/j.jclepro.2013.04.048

equipment. This would be the perfect situation to implement a compact excavator mounted dust suppression system as proposed in this research. For this reason, a mini excavator has been used in this investigation to determine the effect of the proposed prototype system.

Conventional methods of dust suppression extract the air and particles, pass the mixture through filters to remove the particles and then recycle the air using wet suppressants to prohibit the dust particles from becoming airborne. However, using extraction equipment is not always practically possible to implement and can also be very expensive to operate, including, for example, regular maintenance and the requirement of large amounts of electricity to power the system. In addition, extraction units are not very effective in ambient environments such as outdoors. This is due to the dispersion of dust particles in the infinite volume of air upon release. Conventional wet methods of dust suppression are generally the most common technique being utilised across the world, mainly due to the feasibility of the system and the simplicity of implementation. Typically, large amounts of water are used to wet material as it is broken out to prohibit the release of dust particles. This type of system is not very effective for large-scale demolition as the working area must be constantly supplied with water, often proving very expensive. Wet dust suppression also creates environmental issues due to the slurry produced between the dust and water which can block drains and cause slip hazards.

Therefore, a new system is required to overcome these shortcomings. As such, a prototype concept was proposed and analysed, initially using Computer-Aided Engineering (CAE) simulation. The prototype was then manufactured and tested with Tyne Tees Demolition Ltd (now PTS Demolition and Dismantling Ltd) in County Durham, UK. The layout of this paper is as follows: Section 2 describes the relevant literature. Section 3 discusses the proposed solutions. Section 4 discusses the methodology and implementation issues. Section 5 describes a case study and data analysis and, finally, the conclusion and future work is presented.

2. Literature review on conventional dust control

As more and more clients and contractors introduce no dust policies, dust suppression and environmental impact become very strong arguments during meetings of the National Federation of Demolition Contractors. Under Part 5 of the Environmental Act 1995 and the UK Air Quality Strategy, construction site operators need to demonstrate that both nuisance dust and fine particle emissions from their sites are adequately controlled and are within acceptable limits (Makuch and Karyampa, 2012). These limits vary between local authorities, depending on their environmental targets.

Almost all processes that create dust on construction and demolition sites are undertaken by the HSE using wet methods and local exhaust ventilation (HSE, 2010). The wet method suppresses dust but creates slurry making the working area slippery and potentially hazardous. The local exhaust ventilation system does not produce wet slurry; however, using an industrial wet and dry vacuum cleaner on-site creates noise issues and also trip hazards because of the cables used to power the equipment.

Dust collection is often a process used in the manufacturing of aggregate products such as cement. This is often more expensive to implement and maintain but when wet systems cannot be used due to chemical reactions or environmental issues, the process is often the best solution. Chemco manufacturing (Schweizer and Motter, 2001) has a filter cartridge to collect dust and powders as small as 0.3 μm. The cartridge is very large and the efficiency is only really increased by agitating the filter to ensure maximum surface area is contacted by the particles. Cyclone technology (Ahn et al., 2006) is also utilised to scrub off coarse particles (>2 μm). These systems are often used together to increase efficiency. These processes require large equipment and lots of power that is not suitable for portable sites.

Wet dust suppression is the simplest way of suppressing dust, especially that caused on-site. Conventional methods use large quantities of water and fire hoses to douse the working material to prohibit dust generation. This again causes slurry that is hard to dispose of and often causes hazards. The requirements for large quantities of water on-site and the time required for refilling obviously have a negative effect on project profitability (Gambatese and James, 2001).

Recent developments have introduced machines into the industry to combat the problems of water usage and water distribution. A system that has taken off globally is the “Dust Boss System” (DBS) (Holman, 2012). However, no two demolition projects are the same so the versatility of the DBS is paramount. The DBS operates using a ring of atomising nozzles emitting high pressure water to create a fine spray and, with an inbuilt fan, projects the mist to create a blanket of mist to suppress dust particles.

In accordance with Peterson (2011), the most effective atomised spray control system is the one that produces droplets approximately the same size as the airborne particles, meaning there should be a greater chance of collision between droplets and the dust particles. Gambatese and James (2001) proved that changes in water flow pressure of an atomised spray control system would affect the efficiency of the suppression system. Their testing also showed that with a low pressure and low flow system to produce larger droplets, the effectiveness of changing the flow between medium and low systems has little effect. This provides some interesting information in the fact that a reduction in flow is not always detrimental to the efficiency of the suppressant system. This would be useful for the development of the compact excavator mounted dust suppression system. Although this new dust suppression technology is proving its worth within the demolition industry, according to researchers at Utrecht University (Nij et al., 2003), “Wet dust suppression and use of ventilation systems in tunnels were not strongly associated with lower levels of exposure. When the material worked on was only moist instead of wet, exposure levels were even elevated relative to working on dry material”. Further evidence by researchers at Utrecht University (Nij et al., 2003) states: “It could be that when the material is moist, working on it might seem less hazardous and as a result enhance the workers’ exposure”. This shows that the investigation should perhaps consider the effectiveness of the system against two baselines:

1) suppression and;
2) full dust suppression (large quantities of water).

A Caterpillar excavator mounted dust suppression system was investigated by Innovative Technology (1998) and the system is still operational after more than a decade (Ahn et al., 2009; Edwards et al., 2002). The system consists of a 2000 L water tank and a high pressure pump connected with a high pressure nozzle. The system provides an 18% reduction in labour cost and a 90% reduction in water usage. The system massively reduces the risk of contamination through waste water and drastically reduces the costs of labour and water. The main disadvantage of the system is that the sheer volume of water required is not feasible for smaller demolition equipment. The usage of water is approximately 57.5 L/min; thus, this requires the 2000 L tank to be filled every 35 min during operation (Innovative Technology, 1998). Therefore, part of the aim in this investigation is to reduce the water