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Physicochemical characterization of oily particles emitted from different machining processes

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ABSTRACT

Oily particles emitted from different machining processes can get deep into the respiratory system and have adverse effects on human health. But the toxic associated physicochemical characterization of the oily particles is still not fully understood. This study combined with an improved strategy and off-line analysis to obtain the characteristics of the oily particles emitted from different machining processes. A factory was selected for our study where the grinding, wet-lathing, dry-lathing, milling and intercritical hardening processes intensively lay together with operational workers. The results showed that the particle concentration of the various machining processes ranged from 2.1×10^5 to 2.8×10^5 p/cm^3 with a large proportion of fine and ultrafine oily particles. Most of these particles agglomerated into flakes having small spheres attached to them, but a special rod shape particles were observed in the milling processes. The oily particles contained Fe, Si, Na, Mg and Al, and the metallic elements had a comparable mass in both fine and coarse particles. In addition, ultrafine particles had higher oil portion than the larger particles. The results could be employed for exposure assessment and were helpful for industrial hygienists to develop better strategies for the removal of the particles from workplaces.

1. Introduction

Air in machining factories contains a large amount of oily particles including a large amount of fine oily particles (<2500 nm), ultrafine oily particles (<100 nm) and some coarse oily particles (>2500 nm) (NIOSH, 1996). The small particles are likely to be liquid-coated particles formed during the process of the metal working fluid evaporating then condensing onto the surface of the metallic condensation cores, while the large particles could be the oil droplets formed by impaction and centrifugal forces during the machining processes (Thornburg & Leith, 2000). In China, most machining factories are running all day and the machines are usually not equipped with effective exhaust systems, which ends up generating a huge amount of the oily particles into the air (Ma, 2012; Xie et al., 2014). Workers with long-term exposure to these oily particles can develop adverse health outcomes, such as inflammation, disorder or even cancer to the respiratory system, liver and brain (Bukowski, 2003; Kermanizadeh et al., 2015; Zhang & Balasubramanian, 2014).

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The toxicity of the oil mists is mainly associated with its physicochemical characterization (Cassee et al., 2013; Grass et al., 2010; Sgro et al., 2012). The particle concentration and the size distribution influence both the internal dose and the regions where the particles are more likely to cumulate in our body. However, these two parameters are not easy to be identified by the conventional method of taking measurements at a certain distance away from the source (or the process) used in the previous studies (Cheng et al., 2008; Park et al., 2010; Peters et al., 1997), because the layouts in some factories are too narrow to take accurate measurements closed to the target machines. This conventional method might only be useful for the factories, for instance welding or foundry factories, where emission sources are located far apart and workers are close to the sources for most of the working time. For the factories where the machining processes were placed intensively as arrays of assembly lines and the workers walked around several machines to transport the work-pieces, this conventional method will not be sufficient to represent the actual exposure levels of the workers. However, due to the lacking of a better measuring strategy, accurate information on particle concentrations and size distribution of various machining processes (especially for milling, lathing and intercritical hardening processes) has not been reported. In light of that, a good measurement strategy is desired to investigate the particle concentration and the size distribution of the particles emitted from different machining processes.

The morphology of the particles is another important parameter related to the hazard of particles. The morphology containing the form and the total surface area of a particle can be used to determine the ability and probability of this particle interacting with the surrounding cells in our body. Studies (Anna et al., 2007; Katsumiti et al., 2014; Lamberti et al., 2014) have found that small single particles have higher surface energy than the agglomerated ones, and that particles with larger total surface area are more toxic as they are more likely to attach to other cells. The morphologies of the particles from various processes have been studied. Kim et al. (2013) studied the particle characterization of rubber manufacturing process. Miller et al. (2010) measured the morphological changes of emitted particles during silver refinery process. Meanwhile, many other researchers have studied the shape and configuration of various welding processes (Dasch & D'Arcy, 2008; Lehnert et al., 2012; Moroni & Viti, 2009). However, to our knowledge, there are very limited studies describing the particle morphology from grinding process (Iavicoli et al., 2013; Pourghahramani & Forssberg, 2005), and none of current studies has obtained and analyzed the shape, structure and the morphologies of the oily particles with different particle sizes from milling, lathing and intercritical hardening.

Meanwhile, the chemical content of the oily particles is also associated with particles' toxicity (Fernández-Camacho et al., 2012; Hesterberg et al., 2012). Studies have shown that exposing to a certain level of iron in the air could cause chronic bronchitis, pneumoconiosis and other diseases (Guadagnini et al., 2013). Silicon exposure could induce lung lesions (Michel et al., 2012), and trace elements such as manganese and zinc are the precipitating factors of cancer (Richman et al., 2011; Wu et al., 2013). Existing studies mainly focused on the chemical composition of the particles emitted by the welding processes (Oprya et al., 2012), the chemical content information of the particles from other machining processes are still not clear.

The oily particles consist of oil as well as solid components. Studies have shown that particles with different oil/solid ratio in different sizes may have different biological effect (Alföldy et al., 2009; Giechaskiel et al., 2009). However, besides D'Arcy et al. (1996) and Hands et al. (1996) studies focusing on the oil contents for the total particles, no other study is available. More studies are needed to investigate oil/solid ratios in different particle sizes, and such studies will help people in better understanding particle hazardous property to our health.

Therefore, the aim of this study was to investigate the physicochemical characterization of the particles emitted from different machining processes. In our investigation, we selected an automotive part manufacturing factory including five main machining processes of grinding (GR), milling (MM), wet-lathing (LA-W), dry-lathing (LA-D) and intercritical hardening (IH) processes, and evaluated the particle concentration, size distribution, morphology, chemical composition and the ratio of oil to solid component (oil content). Our findings will be useful for industrial hygienists to understand exposures and will be helpful for engineers to design and implement more effective particle control strategies in the field.

Table 1
Description of different machining processes.

Machining process	Description	Metal working fluid (MWF)	Loading time (s)
Grinding (GR)	Polishing the surface of workpiece	Semisynthetic oil (aqueous portion 0–5%, mineral oil ~50%)	25–45
Milling (MM)	Drilling holes	Synthetic oil (aqueous portion 0–10%, mineral oil ~75%)	20–30
Lathing (LA-W)	Cutting grooves	Synthetic oil (aqueous portion 0–10%, mineral oil ~75%)	4–10
Dry-Lathing (LA-D)	Cutting grooves	None	60–70
Intercritical hardening (IH)	Heating the workpiece to make it from pearlite into austenite	Quenching liquid (aqueous portion 0–10%, mineral oil ~70%)	65–80