Effect of different tiles on particle coverage in wind tunnel

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Introduction

Wind tunnels have been used for decades to test objects and material behavior in certain windy conditions. Some of the common objects and materials that have been tested in wind tunnels include various plastics, and military equipment such as Humvees, helicopter parts, and fighter jet parts. For example, the Wright brothers used a wind tunnel to help design the first modern plane (Smithsonian Air and Space Institute, 2015). Wind tunnels have also been used to study the behavior of particles on different surfaces. These experiments investigate how environmental variables such as temperature and wind velocity influence particle deposition and resuspension (Fei et al., 2019). Wind tunnels are also used in studies to test the air quality inside a building. By mirroring relevant conditions such as high temperatures, wind tunnels can help scientists predict particle deposition behavior in building air ducts (Sippola & Nazaroff, 2004). The purpose of this project was to study the resuspension behavior of micronized acetaminophen particles on different surfaces inside a wind tunnel.

Materials and Methods

Initial experiments were conducted in a small-scale environmental test chamber (ETC) to compare the particle coverage on the surface of three different materials: Navy chemical agent resistant coating (CARC), Formica, and rusted steel. A total of 3 trials were run (one for each material). Before each trial, a Keyence microscope was used to image the coupons at 20×, 100×, and 500× magnification. In each trial, three coupons of each material type were placed into the ETC, in a leftward position, middle position, and rightward position. A total of 50 mg acetaminophen was then dispersed in the ETC with a Venturi nozzle aerosolizer to coat the coupons. Once the particles had settled, the Keyence microscope was then used to image the powder coverage of each coupon at 20×, 100×, and 500× magnification. Next, ImageJ was used to calculate the percent particle coverage for each coupon by calculating white and black pixels of the image.

Once the experiments in the environmental test chamber (ETC) were completed, a closed-circuit wind tunnel was then utilized (Figure 1). A total of 9 trials were completed, three for each of the materials. In each trial, four coupons of each material were imaged and then placed in the ETC. Fifty milligrams of acetaminophen was dispersed in the ETC using a Venturi nozzle aerosolizer. After dispersion inside the ETC, two of the four tiles were moved into the wind tunnel and subjected to a wind velocity of 10 mph for 10 minutes. The other two tiles remained in the ETC. After 10 minutes, the two tiles were removed from the wind tunnel and the tunnel was activated to clear out remaining particles.

Materials and Methods (cont.)

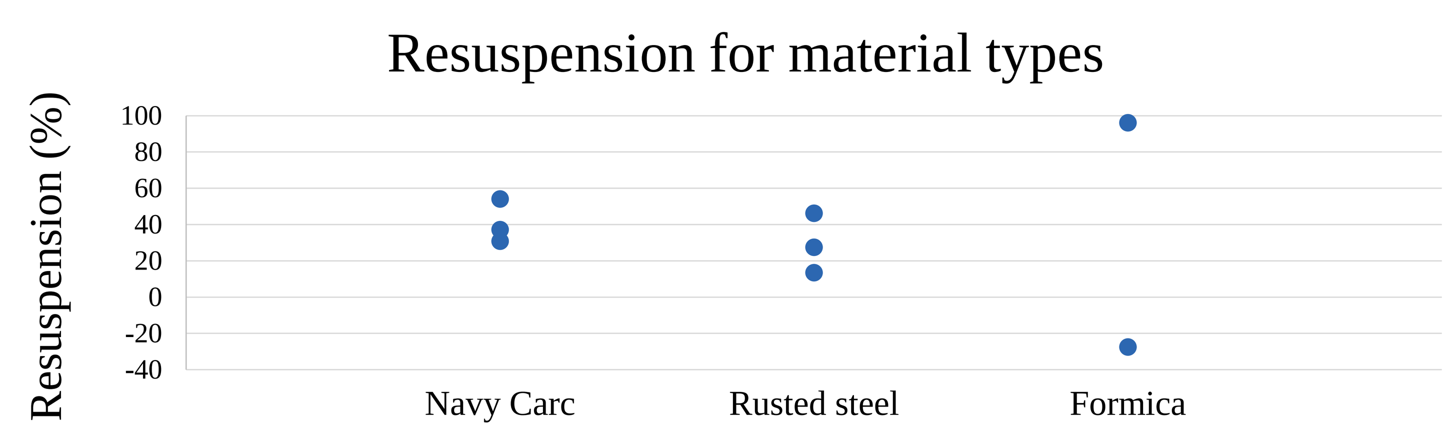
All four coupons were then imaged again with the microscope. The images collected before and after acetaminophen dispersion were then used in ImageJ to compare and analyze particle coverage of the tiles placed inside the wind tunnel after ETC dispersion to the tiles which remained in the ETC.

Results

The initial results determined that the higher magnification images were outside of the testing window for ImageJ, meaning that data collected at 20× was the most useful. Figure 1 and 2 show images that ImageJ analyzed to calculate percent coverage in ETC. They also determined that data collected for Formica was insignificant since resuspension (percent coverage in ETC minus percent coverage in wind tunnel divided by percent coverage in ETC) values were found to be negative, meaning percent coverage increased in the wind tunnel. All resuspension values are shown in Graph 1. Three one-sample *t*-tests were used to determine if resuspension occurred significantly for each material. The results of the tests are shown in Table 1. An ANOVA test to compare the resuspension of different material types was not run, since resuspension did not occur significantly for two of the three materials: rusted steel and Formica.

Figure 1 (above): Particles on a Navy CARC coupon at 20× before the wind tunnel.

Figure 2 (above): Particles on a Navy CARC coupon at 20× after the wind tunnel.



Graph 1 (above): Plotted resuspension values. Resuspension is positive for both Navy CARC and rusted steel, but negative for Formica. One of the Formica trials resulted in a −160% resuspension and is not displayed.

Results (cont.)

Table 1 (below): The results of the three one-sample *t*-tests comparing resuspension for each material to 0 at 20× to determine if resuspension occurred significantly. Found that resuspension occurred significantly for Navy CARC, partially for rusted steel, and the results for Formica were insignificant since imaging was inaccurate.

Navy CARC results	$M = 40.73$	$SD = 12.03$	$t(2) = 5.87$	$p = .028$, rejected null	Significant difference in mean and 0
Rusted steel results	$M = 29.10$	$SD = 16.39$	$t(2) = 3.07$	$p = .091$, accepted null	No significant difference in mean and 0
Formica results	$M = -30.20$	$SD = 127.7$	$t(2) = -0.41$	$p = .722$, accepted null	No significant difference in mean and 0

Conclusions

The three one-sample *t*-tests determined that resuspension occurred in the wind tunnel for Navy CARC, minimally/insignificantly for rusted steel, and did not occur for Formica. These results may be due to Navy CARC and rusted steel having smoother surfaces compared to Formica. Formica was not able to show resuspension because the image settings used were not ideal for its rough surface. Since resuspension did not occur significantly for rusted steel and Formica, comparing resuspension difference between materials was unnecessary. Data could have been affected by factors such as replacing carbon dioxide with nitrogen for the Venturi nozzle aerosolizer, as well as the location the tiles were placed in the ETC and wind tunnel. Future studies can be conducted testing different material types, such as plastic, concrete, and glass. Those results, combined with data from this experiment, can be used to further investigate the effects that different materials have on particle deposition and resuspension.

References

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