CLEANING OF SUBMICRON PARTICLES FROM PAPER USING A COMBINATION OF CO_2 BLASTING AND PLASMA

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INTRODUCTION

Dry cleaning

Brushes, erasers, vacuum cleaners, compressed air, or sophisticated machinery

➡ Predominantly remove only coarse particles

Submicron particles

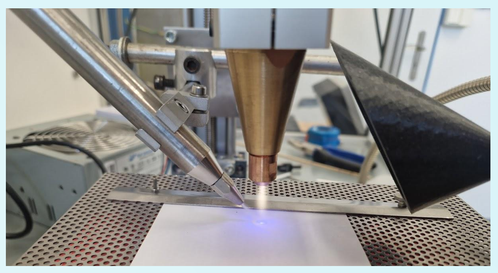
- Adhesive force between the particle and surface: F_{adh}~d
- Aerodynamic drag force of moving gas on a particle: F_d~d^2
- Gas flow alone cannot generate sufficient forces to remove submicron particles
- Organic matter represent more than 50% of indoor PM

Aim

Investigate the application of combination of CO_2 snow blasting and plasma for cleaning of particles from paper

TWO-PHASE SPRAY AND PLASMA

- Two-phase spray (CO_2 snow particles in carrier gas) enriched with reactive plasma particles strike the contaminated surface
- Physical and chemical interactions lead to particulate and organic contamination removal
- Plasma (with carrier gas containing oxygen) contains reactive components that are effective in breaking most organic compounds
- The collision of CO_2 particles transfers momentum from the snow to the surface contaminant and can overcoming the adhesive forces
- Residue-free and non-destructive method

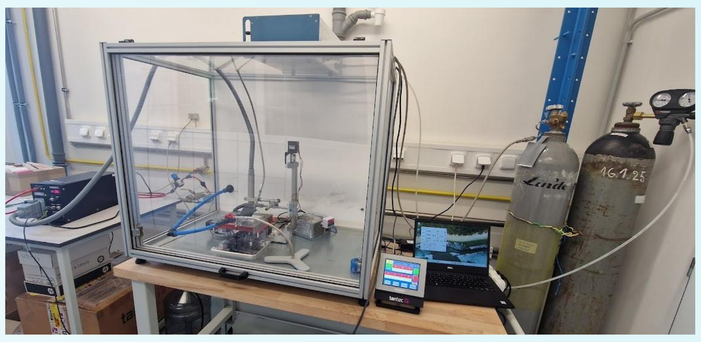


Mixing of plasma stream and two-phase spray

Ref.: Jackson D.J., Endres, J.D., Particle-Plasma Ablation Process. Patent US 9,352,355 B1, (2016).

METHODOLOGY

- Two-phase spray generator: SnoPen 2000 (N_2 carrier gas, Cleanlogix)
- Plasma generator: Plasma TEC-X (CDA carrier gas, Tantec)

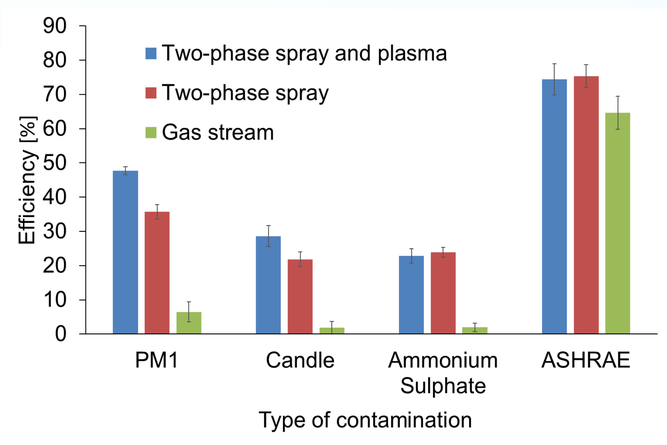


Automatic cleaning station

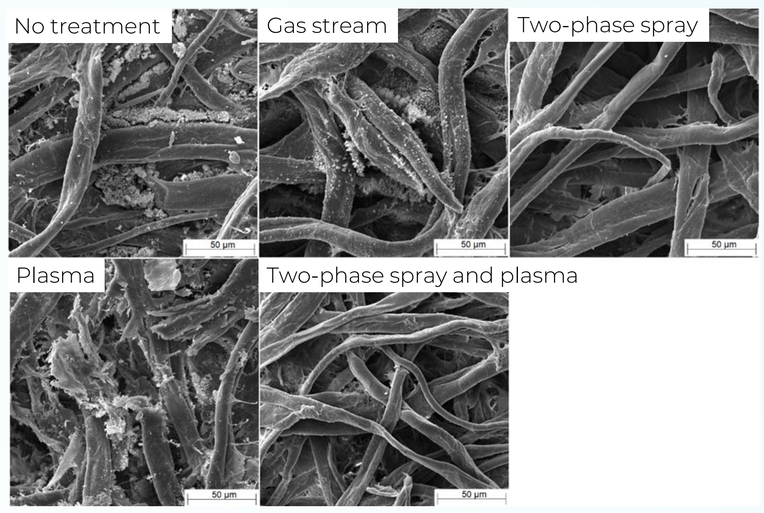
RESULTS

Overview of properties of particles used for paper contamination

Type of contamination	Mode	Chemical composition
PM1	0.3 µm	Organic matter, elemental carbon, ammonium sulphate
Candle	0.1 µm	Elemental carbon, organic and anorganic compounds
Ammoniu Sulphate	0.2 µm	Ammonium Sulphate
ASHRAE No. 1	10 – 100 µm	Crustal matter, elemental carbon, cotton fibres



Removal efficiency of different types of particles using differet cleaning methods



Example of SEM images of paper contaminated using PM1

CONCLUSION

- Coarse particles (ASHRAE) – comparable efficiency for all methods
- Fine particles (PM1, candle, ammonium sulfate) – gas stream ineffective
- Inorganic particles (ammonium sulfate) – comparable efficiency of two-phase spray and two-phase spray with plasma
- Particles with organic matter (PM1, candle) – efficiency of two-phase spray with plasma was higher (¬20–30%) than without plasma – indicates breaking of organic bonds using plasma
- Under selected conditions, cleaning using the two-phase spray and plasma shows good results, especially in removing submicron particles containing organic matter

ACKNOWLEDGEMENTS

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