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Title: Collecting Mine Dust Particles with Liquid-Coated Vibrating Meshes

Organization: Virginia Tech and Michigan Tech

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Topic: Atmospheric Purification Technologies

Concept Summary: Dust is an inherent byproduct of mining activity that raises notable health and safety concerns. In coal mining, concentrated airborne dust can generate explosive mixtures that are easily ignited and self-propagating, and the inhalation of small, respirable dust particles can cause incurable lung diseases, including silicosis and coal worker's pneumoconiosis. Mine operators have typically employed preventative particle-collecting devices in underground mines to suppress airborne dust, and Mine Safety and Health Administration's (MSHA) recent respirable dust rule mandates even further reductions to respirable dust concentrations. The flooded-bed scrubber has been developed and widely used for over 20 years as a preventative dust remover in continuous mining operations and has been recently tested on longwall shearers. Despite the proficiency of the scrubber, there are numerous technical challenges that limit the performance and efficiency of the flooded-bed scrubbers. In particular, the static panel filter, instrumental in most scrubber designs, is fundamentally limited in collection efficiencies, and causes numerous operational challenges. Known technical challenges, noted in the literature, are to reduce filter clogging, to achieve uniformity of wetting, to maintain high air flow rates, and to enhance particle-liquid adhesion.

In this proposed work, the PIs will leverage our resources from an interdisciplinary collaboration including fluid dynamics, dynamical systems, surface chemistry, and minerals engineering expertise to design and develop a prototype of an improved flooded-bed scrubber for coal mine applications through theoretical and experimental studies. The new scrubber is intended to increase the overall dust collection efficiency and include a specific selectivity for silica particles. The scrubber design will also induce a self-cleaning feature that will reduce or eliminate the need for frequent maintenance due to particle clogging. The PIs propose to use liquid-coated vibrating filter meshes rather than stationary ones and anticipate to improve the particle-collecting efficiency with advancements in the four technical challenges mentioned above. The underlying innovation lies in that the induced vibration motions of mesh, when coordinated with the mesh material properties, will reduce the clogging by shedding large particle-drop agglomerates, and simultaneously increase air flow rate with non-clogged open areas in the mesh. In addition, our proposed liquid-interface modification is able to uniformly wet the filter mesh with low contact angles, and increase adhesion between mine dust particles and liquid surfaces.

The proposal will have three tasks led by the PIs collaboratively. First, microscopic particle-liquid forces are characterized and optimized with different fluid conditions. Second, macroscopic particle sliding and capturing motions on a vibrating mesh are investigated both experimentally and computationally. Finally, the PIs will design a proof-of-concept scrubber prototype with multi-layered vibrating wet meshes that will be tested in simulated mine conditions. Through collaboration, the PIs will be able to conduct virtual testing and explore our options without the real-life costs associated with an iterative process in field experiments.

At the end of the project, the PIs will deliver a laboratory-scale prototype with vibrating meshes capable of removing particles in simulated conditions similar to underground mining. In the implementation phase with a prospective supplementary funding, the PIs are able to work on a commercial prototype by optimizing various physical parameters to enhance its efficiency along with industrial partners.