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Invited original paper

Analysis of enzyme dust formation in detergent manufacturing plants

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Abstract—In the detergent industry, enzymes are used to catalyze the breakdown of tough stains such as oils and fats, which cannot be easily removed with surfactants and bleaches. In the 1960s, a number of plant workers developed respiratory allergies from inhaling enzyme dust over long periods. The response from the enzyme manufacturing companies was to encapsulate the enzymes by granulation, fluid bed coating, extrusion and other techniques. The end users of encapsulated enzymes such as the detergent industry concentrated on the installation of engineering containment and dust extraction systems. These were combined with other safe systems of work, including airborne monitoring and health surveillance. The result was a significant decrease in the concentration of airborne enzyme dust in the working environment and virtually eliminated the incidence of respiratory allergy. However, enzyme dust generation has not been eliminated completely and the integrity of the enzyme encapsulates remains a key control point. In 2000, the Enzyme Dust Consortium was formed with the objective to design a validated test method with a protocol (for granule qualification and quality control) to correlate with dust levels in plant. Current test methods for dust formation do not replicate the mechanical stresses in the detergent plant and limit the enzyme manufacturer's ability to develop better granules. Our efforts are focused on evaluating the prevailing mechanical stresses in detergent manufacturing plants and their effect on enzyme granule attrition. Dust sampling of the factory ventilation ductwork show a large variation in enzyme dust levels. This may be attributed to the presence of some weak granules. Nevertheless, the likely sources and mechanisms of enzyme dust need to be identified. Once a new testing procedure is established, enzyme manufacturers will be able to design and produce improved products that will result in a further reduction of enzyme exposure in detergent manufacturing facilities.

Keywords: Attrition; breakage; compression; dust sampling; enzyme dust; enzyme granules; impact.

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NOMENCLATURE

d	particle size or height (m)
F_{f}	failure force (N)
i	sequential number of data (–)
m	Weibull modulus (–)
M_{f}	mass of feed (kg)
M_{de}	mass of debris (kg)
M_{m}	mass of mother (kg)
n	total number of data (–)
P	probability of failure (–)
R_i^-	incremental lower extent of breakage (%)
R_i^+	incremental upper extent of breakage (%)
R_i^*	incremental extent of breakage based on impact products (%)

Greek

α_{p}	particle deformation after loading (m)
β_{o}	Weibull scale factor (–)
σ	crushing stress (Pa)
σ_{f}	tensile stress (Pa)

1. INTRODUCTION

The use of enzymes in laundry detergents was first investigated by the German chemist Otto Röhm in 1913. Röhm used pancreatic enzymes in a pre-soaking detergent composition and patented his work [1]. Enzymes have been used in detergents, their largest application, since the 1930s based on Röhm's patent. The manufacturing of industrial detergent enzyme granules includes processes such as high shear granulation, fluidized bed coating, prilling (redundant), extrusion or a combination of these methods. The amount of protein present in the granule is typically 0.5–5%, and the remaining ingredients are salts, polymers and binders. The granules are manufactured in a way such that their size range is similar to the size range of a typical detergent formulation in order to avoid segregation.

Enzyme dust is formed as a result of the handling of enzyme granules in processes such as conveying, filling, mixing, discharging or even from impacts inside the dust extraction systems. The type of stressing plays an important role in enzyme dust generation. Typically, in a detergent manufacturing plant impact (drops in chutes and on to conveyors), consolidation (whilst storing) and shear forces (discharging and in feeder valves) are present that can damage weaker granules, releasing smaller particles that contain enzyme. The amount of enzyme dust present in the breathing zone of plant operators and dust extraction systems is typically less than 15 ng/m^3 for the breathing zone and less than 2 mg/m^3 in the extraction system, and cannot be measured by gravimetric means. Methods such as the protein activity assay