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# Rheology of cohesive powders in a pilot scale planetary blender

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## Abstract

Powder agitation experiments in a bladed planetary mixer have been performed with the objective of establishing correlations based on dimensionless numbers. Powders of different kind have been studied: free flowing (semolina) and cohesive (lactose, talc and milled sand). Mixtures of free flowing and cohesive powders have also been studied to get a more complete range of powders of different properties. It has been observed that the gyration motion plays an important role in the power consumption of cohesive powders. The relation between a modified power number ($N_{pM}$ $=P/\rho_b u_{ch}^3 d_s^2$) and a modified Froude number ($Fr_m = u_{ch}^2/gd_s$) used in several previous publications is adapted and shown to depend on powder cohesion. These dimensionless numbers are built on the basis of a characteristic speed $u_{ch}$, a characteristic length $d_s$, the bulk density $\rho_b$ and the power consumption P. The filling ratio $f$ is also taken in account. For a free flowing powder, of cohesion smaller than 0.3 kPa, $N_{pM} = a(f).F_{rM}^{-1}$ while for a more cohesive powder, of cohesion higher than 0.6 kPa the correlation $N_{pM} = 6.F_{rM}^{b(f)}$ is more appropriate. For both equations, a and b are powder-dependent parameters. Their linear dependency on the filling ratio of the blender has been established.

## Introduction

Powder mixing is an important unit operation for the manufacture of several products in many industries, like tablets in the pharmaceutical industry or fuel pellets in the nuclear industry. The goal is to blend different powders having intrinsic properties that may not work together. In the pharmaceutical industry for example, an active pharmaceutical ingredient (API) is mixed with excipients to enable the drug to be manufactured properly and be handled by patients. The challenge in powder mixing is to provide homogeneous mixtures at the wanted scale, knowing that powders can segregate during and after the operation.

Powders can be divided into two groups, according to their flow behavior: free flowing or cohesive. The first group represents powders that can flow easily under gravity, the grains being able to move almost individually. At the opposite, cohesive powders can be defined as particulate systems for which attraction forces are stronger than gravity. These forces can be surface tension of a free interstitial liquid, electrical double layers, Van Der Waals forces and local joining of particles due to compaction. Concerning dry powders, Van Der Waals forces are the most important cause of cohesion, typically when the particle size is smaller than 100 µm [1]. There is an increasing interest in manufacturing fine powders. In particular, size reduction is known to enhance some properties like bioavailability for APIs, since poorly aqueous soluble drugs are more readily bioavailable when administrated in a form of larger surface area [2]. However fine powders are also known for their reduced flowability which is the source of many issues in industries like waste and maintenance problems [3], or increased risks of dust explosions [4]. If cohesive powders are not subjected to problems of demixing by segregation like free flowing powders, understanding and modeling their