Residence Time Distribution of Stirred Media Mills

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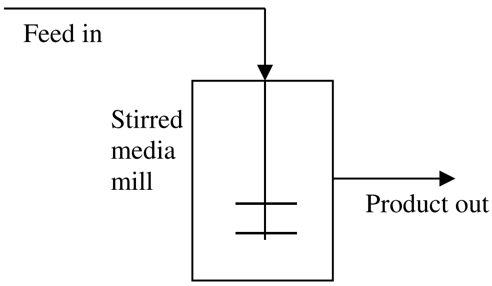
Stirred media mills are used for particle size reduction of calcite (calcium carbonate); they consist of a grinding chamber, ceramic beads (media), and impellers. The specific energy input during the milling process is proportional to the reduction in size of the particles [1]. Milling is a high energy process but product quality and energy requirements can be improved through process optimisation, of which residence time distributions are a part.

Residence time is a measure of the time a particle spends within the boundaries of a process. The residence time distribution (RTD) is used to examine the extent of macromixing inside a system in which the bounds are complete segregation and maximum mixedness. There are several experimental techniques available to calculate the residence time distribution: negative step change (washout), positive step change, impulse, and convolution integral for other time-varying tracer concentrations. Washout experiments are preferred as the concentration of the tracer at both $t = 0$ and $t = \infty$ are known. However, a larger amount of tracer is needed than for either impulse or positive step change experiments. [2]

In order to obtain a consistent product the residence time for all the particles must be as near to the optimum value as possible. Significant deviation from the optimum value will result in a decrease in product quality. By-passing (also short-circuiting) and hold-up due to stagnant regions (or the system being too well-mixed) will contribute to this. However, the RTD can help significantly in identifying these issues.

Figure 1: Diagram of continuous stirred media mill used to calculate RTD (not to scale)



In this study the RTD for a single pass continuous stirred media mill, shown in Figure 1, is calculated using tracers. A washout experimental technique is utilised where the tracer concentration into the system at $t \leq 0$ is at a maximum. At $t = 0$ the concentration of tracer in the feed is reduced to 0 and samples are taken to assess the tracer concentration exiting the system. The resulting distribution is referred to as $W(t)$, defined in Equation 1 where C is the concentration of the tracer at time t and C_0 is the concentration of the tracer at $t = 0$. [2]

$$W(t) = \frac{C}{C_0} \tag{1}$$

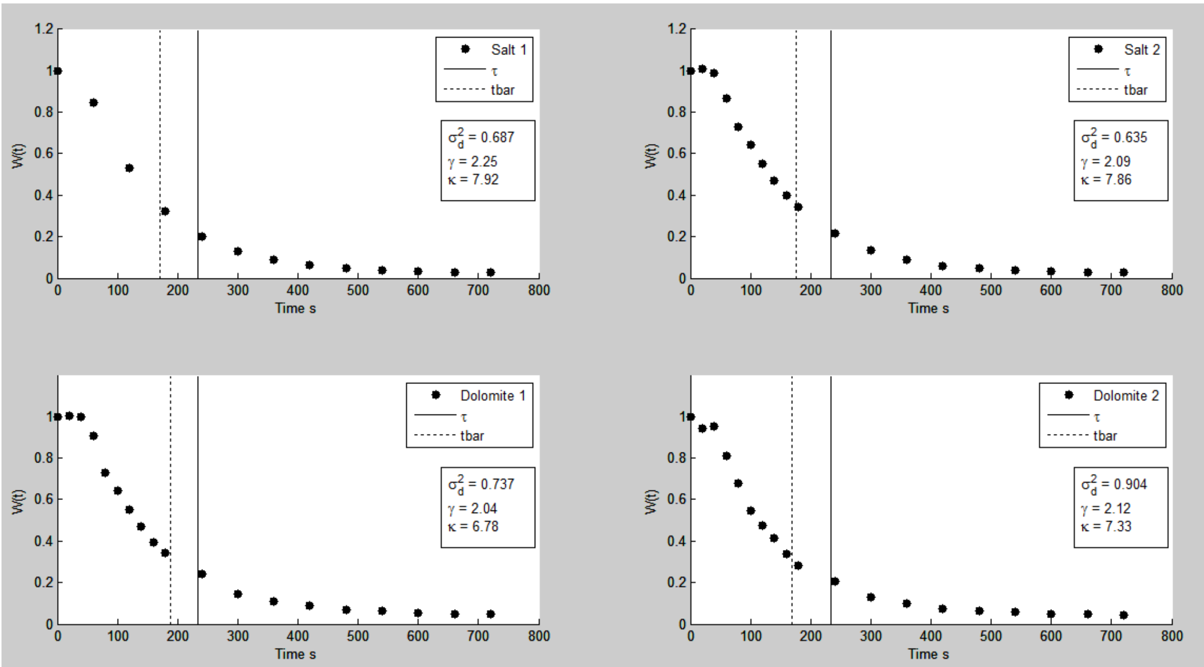
Sodium chloride is used to mark the liquid component, with dolomite (calcium magnesium carbonate) used to trace the calcite component of the slurry. The conductivity and magnesium content of the solid fraction by X-ray fluorescence denote the concentrations of salt and dolomite respectively.

Theoretical residence time τ is found by dividing the volume of the vessel by the volumetric flowrate in. The mean residence time $\bar{t}$ is found by calculating the first moment of the RTD, shown in Equation 2 [2]. However, due to the high complexity of fitting curves to distributions, numerical integration is generally used. (2)

Figure 2 shows two RTDs using salt tracer and two RTDs using dolomite tracer in a 9.37×10^{-3} m^3 stirred media mill.

$$\bar{t} = \int_0^\infty W(t)\,dt \qquad (2)$$

Figure 2: RTDs for single pass continuous laboratory scale vertical stirred media mill, σ_d^2, γ, and κ denote dimensionless variance, skewness and kurtosis respectively



In conclusion, the graphs in Figure 2 show that the mean residence time and RTDs for the solid and liquid fractions of the product are very similar, indicating the two phases do not separate during processing. This study shows that sodium chloride and dolomite work in principal to examine the RTD in the particle size reduction of calcite. Future work will involve using these tracers at a pilot-scale plant with the view to using this technique to identify and solve issues at full-scale industrial plants.

1. Lowrison, G.C., *Crushing and Grinding*. 1974: Butterworth & Co.
2. Nauman, E.B., *Residence Time Distributions*, in *Handbook of Industrial Mixing: Science and Practice*, Paul, E.L., Atiemo-Obeng, V.A., and Kresta, S.M., Editors. 2004, John Wiley & Sons, Inc.: New Jersey.