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Power draw estimations in experimental tumbling mills using PEPT

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ABSTRACT

Positron Emission Particle Tracking (PEPT) was employed to reconstruct the motion of mono-sized glass beads in an experimental tumbling mill run in batch mode. In each case, the derived trajectory field of a representative tracer particle was used to determine the charge power draw at steady state operation. Two approaches for calculating power draw were considered: the torque of the centre of mass about the mill centre, and the time averaged torque contribution per discrete grid cell summed over the volume of the mill. Results were compared across different operating conditions and particle sizes to measured power.

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1. Introduction

The power draw of a tumbling mill is known to be an important measure in determining its efficiency. Many models have been derived to predict the power draw as a function of characteristics related to charge motion (Harris and Schnock, 1985; Morell, 1992). While these models have been shown to calculate good approximations of mill power, they have been observed to be limited to the scope under which they were defined (Govender et al., 2001a).

As in situ characterisation of charge motion has proved difficult due to the aggressive internal environment of tumbling mills, many models have focused on using empirical relationships to describe the distribution of power draw into the charge. Thus, the charge has often been simplified to a single bulk body over a defined region of the mill. It has been noted that in order to introduce more informative power draw functions, greater understanding of the fundamental mechanisms associated with charge motion is necessary (Govender et al., 2001b).

Positron Emission Particle Tracking (PEPT) offers a way of studying the internal environment of tumbling mills. PEPT is a technique by which trajectory information of single particles in tumbling mills can be obtained (Parker et al., 1997). With this method it has been shown that the bulk properties of a particular size class can be ascertained from tracking the motion of single particles within that size class at steady state (Conway-Baker et al., 2002). The unique value of this aspect is that data from PEPT can be used to calculate charge properties for every size within a given distribution including power draw.

2. Positron Emission Particle Tracking (PEPT)

Positron Emission Particle Tracking (PEPT) is a technique for measuring the flow trajectory of a radioactive particle in a granular or fluid system such as a tumbling mill. This technique was originally introduced in the medical field as positron emission tomography (PET), and has been modified to suit engineering applications (Barley et al., 2004). The premise of the method is the positron annihilation of a "tracer", a particle tagged with a radionuclide. Positron-emitting tracers are normally labelled using radionuclides such as ^{18}F, ^{64}Cu and ^{68}Ga. These radionuclides decay by emission of back to back gamma rays of 511 keV. Simultaneous detection of the two gamma rays in an array of detectors (a PET "camera") defines a straight line along which the particle position lies. At a frequency of up to 250 Hz, the position of the particle can be triangulated in three dimensions.

The accuracy of the method depends on factors such as the speed and activity of the particle, as well as the attenuation of the medium in which it travels. Fig. 1 shows a picture of an experimental mill in a parallel plate PEPT camera system (Positron Imaging Centre, University of Birmingham), along with a schematic describing the method used to detect and triangulate particle positions.

3. Experimental methodology

Single particle tracking experiments using PEPT were conducted for this study at the Positron Imaging Centre, University of

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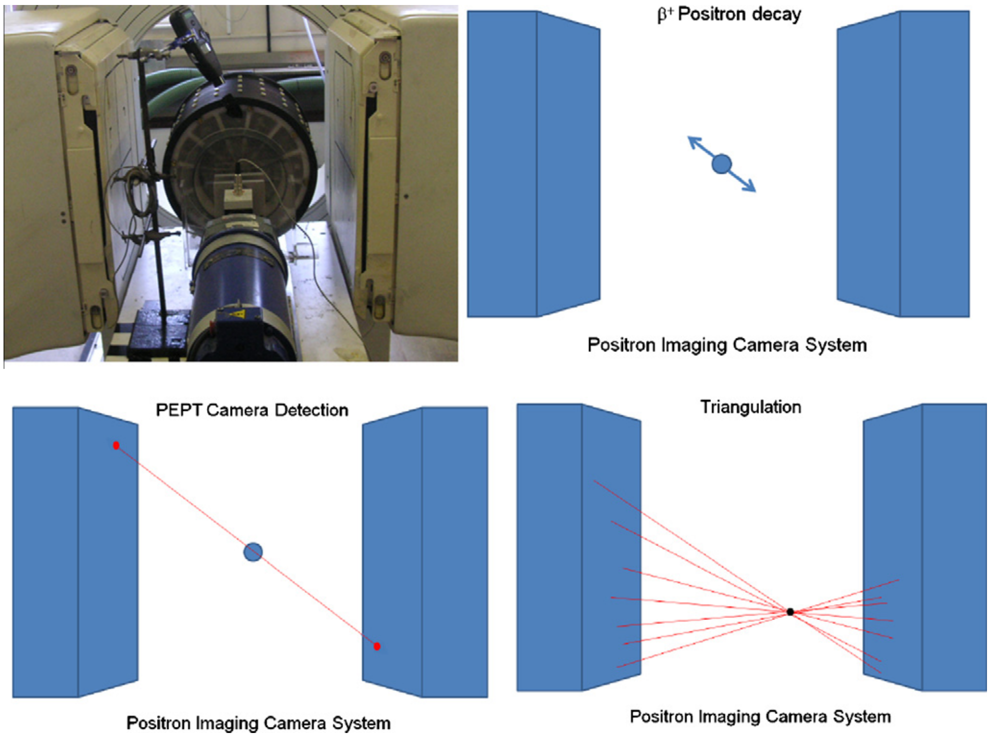

Fig. 1. PEPT camera in parallel plate configuration and schematic of its operation.

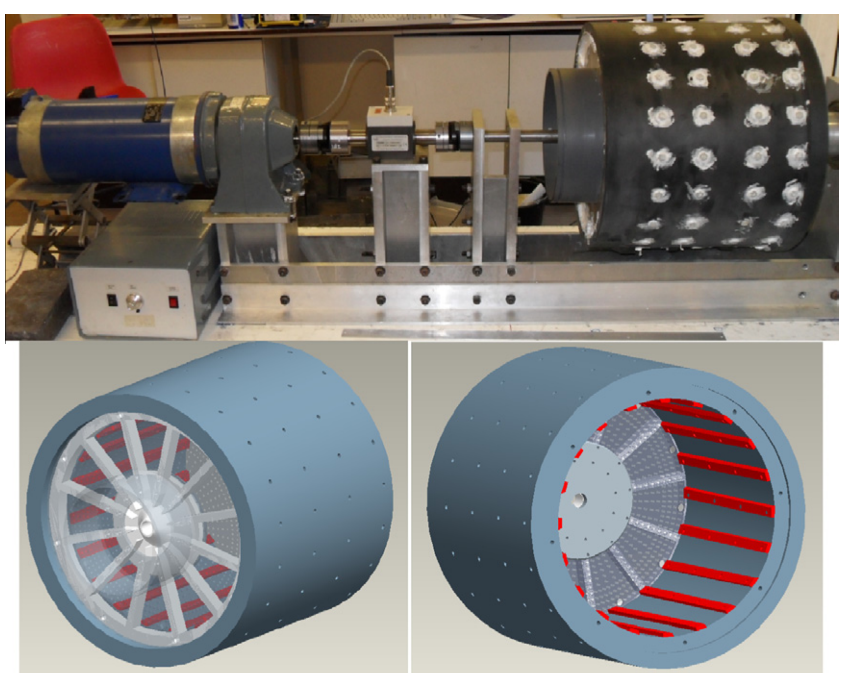

Fig. 2. Picture and schematic of 300 mm tumbling mill used for PEPT experiments.

Birmingham. A 300 mm diameter mill with a variable speed drive was designed for this purpose, whose picture and schematic is provided in Fig. 2. A torque transducer was coupled to the drive shaft to measure the power draw of the mills. Spherical glass beads were used as the dry charge. Tests were conducted using either 3 mm or 5 mm charge. To determine the mass requirements for 31.25% volumetric filling of the mill, the bulk density of the glass beads was determined by assuming a packing ratio of 0.6.

Glass beads for either size were subjected to direct activation using a 33 MeV ^{3}He beam to produce the radioactive tracer particles. The resulting positron emitter was ^{18}F (which has a half life of 109 min). Experiments with each tracer particle were conducted

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