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Adjustment of a PET Scanner for PEPT

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***Abstract*—**Positron emission particle tracking (PEPT) is a technique in which a single radioactive tracer particle can be accurately tracked as it moves. A limitation of PET is that in order to reconstruct a tomographic image it is necessary to acquire a large volume of data (millions of events), so it is difficult to study rapidly changing systems. By considering this fact, PEPT is a very fast process compared with PET.

In PEPT detecting both photons defines a line and the annihilation is assumed to have occurred somewhere along this line. The location of the tracer can be determined to within a few mm from coincident detection of a small number of pairs of back-to-back gamma rays and using triangulation. This can be achieved many times per second and the track of a moving particle can be reliably followed. This technique was invented at the University of Birmingham [1].

The attempt in PEPT is not to form an image of the tracer particle but simply to determine its location with time. If this tracer is followed for a long enough period within a closed, circulating system it explores all possible types of motion.

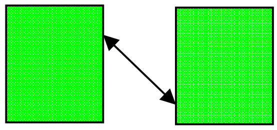
The application of PEPT to industrial process systems carried out at the University of Birmingham is categorized in two subjects: the behaviour of granular materials and viscous fluids. Granular materials are processed in industry for example in the manufacture of pharmaceuticals, ceramics, food, polymers and PEPT has been used in a number of ways to study the behaviour of these systems [2]. PEPT allows the possibility of tracking a single particle within the bed [3]. Also PEPT has been used for studying systems such as: fluid flow, viscous fluids in mixers [4], using a neutrally-buoyant tracer particle [5].

***Keywords*—**PET, BGO, Particle Tracking, ECAT 931, List mode, PEPT.

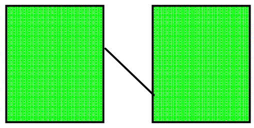
I. Introduction

IN PEPT, a single tracer particle is introduced into the system and can be tracked as it moves [1]. When two gamma rays are detected at particular point in space may be positron annihilation occurred somewhere along the line joining these points which is called "trajectory " (See Fig. 1).

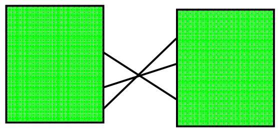
In emission detection all events (coincidence, scatter and random) can be detected. If there are only two coincidence events, with using triangulation the location of the single positron emitter can be localized. In other words, in the absence of scatter and random events all paths for reconstruction will be passed close to a single positron emitter. But in the case of presence of random and scatter events a signification fraction of the reconstructed gamma ray paths will not pass close to the tracer position. So corrupt events (random and scatter) have to discarded to get an accurate location of the tracer in PEPT. A particular tracking algorithm has been developed in Birmingham University [6].



(a) Coincident detection



(b) Reconstruction of Trajectory



(c) Location of source

Fig. 1 Principle of tracer particle

II. PEPT Algorithm

The process of the PEPT algorithm will be described as follows:

Suppose that (x, y, z) are the coordinates of the point which is closest to all of the reconstruction paths (their gamma rays path).With using an analytical process those paths which are furthest from closest point will be discarded as corrupt. This process will be repeated for the remaining paths. The algorithm will be iterated until a fraction f of the original events remain. The fraction f depend on some factors such as [7]-[10]:

1-Positron range, which is defined as the distance that the positron travels before it annihilates.

2-The effect of the slight accolinearity of the two photons.

3-Spatial resolution of the scanner: Spatial resolution is a measure of the ability of the detection system to separate the positions of two adjacent sources and is related to the geometry of the scanner and the detection process [1].

The amount of scattering material present in the system determines the fraction of scattered events. In practice, for many measurements the tracer is surrounded by a considerable amount of material, which scatters the emerging photons. One investigation shows that for a point source sandwiched between two 15mm thick steel plates over 70% of the emitted photons are lost in scatter events and the total detected coincidence rate drops to around 30% of the original rate. For these detected events, optimum PEPT location is obtained

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with *f*=0.2, corresponding to discarding 80% of the detected events. [7]-[8].

The accuracy of location in PEPT is described below (ref 2). Suppose there is a slow moving tracer (or stationary tracer) and its location can consider within the value Δ.If N be the number of coincident events then standard deviation of N measurement is σ .Since there are corrupt events(random and scattered) so the precision of location of tracer in N measurement is given approximately by:

$$\Delta \approx \frac{\sigma}{\sqrt{N`}} \quad (1)$$

Where N`= *f* N is the number of gamma ray paths used in the final calculation after corrupt events have been discarded. An example of a PEPT data file which has been taken from the ADAC scanner and processed by the PEPT algorithm is shown in Table I [1]-[9].

Fig. 2 shows the results obtained with the ECAT scanner for a tracer particle (a point source ^{18}F) with activity of 37MBq was mounted on a rotating turntable which has a radius of 90mm and was placed in the xy plane [4]. Data were measured when the turntable was rotating at 3.4rev/s (particle speed 2m/s). The coincidence data for this rotating point source was recorded in list mode into 5 buffers. The average count rate was approximately 70k events/s. Consequently the locations were derived with N=250 events and different fractions of trajectories (*f*). For each calculation the uncertainty in location (Δ) was given by the root –mean square (r.m.s) deviation of the locations from the fitted sinusoidal curves and the best result was obtained when *f* was equal to 70%. For each location the coordinates (x, y, z) are plotted, and also the estimates of the velocity components (v_x, v_y, v_z) and the overall speed. A little variation in the "z" direction is seen in Figs. 6-10. This is due to the tilt of turntable in the "z" direction. For this point source which was giving 70 kevents/s at a speed of about 2m/s approximately 270 PEPT locations were obtained per second with Δ=1.3 mm in 1D, 1.9mm in 2D (xy plane) and 2.0 mm in 3D.

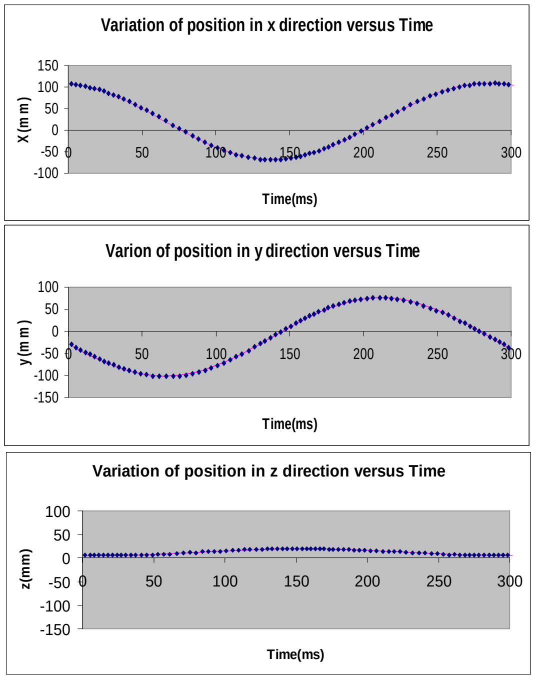

Fig. 1 PEPT data for a tracer on a turntable rotating in the xy plane at 2m/s [11]

As the tracer particle is directly tracked in PEPT, so four principal types of information can be extracted over a period during which it circulates throughout the mixing container: First is a trajectory plot movement of the tracer particle from location to location at actual speed.

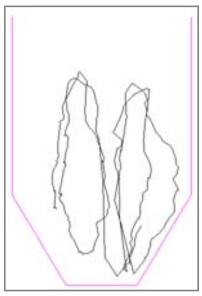

Fig. 2 Trajectory Plot movement of the tracer

Secondly, the fraction of time spent by the tracer particle at each point in the bed can be plotted. Over the experimental timescale this plot represents the density of particles at each point in the bed. Separation effects can be investigated by using different sizes or densities of tracer particle.

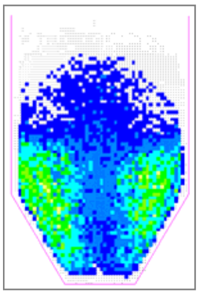

Fig. 3 Occupancy Plot: indicates the proportion of the total run time spent in each volume element

Thirdly, the time averaged velocity at each point in the bed can be calculated, and the velocity field can be compared to models.

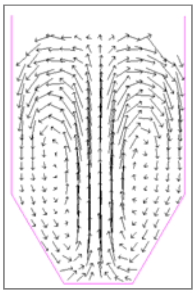

Fig. 4 Time-averaged velocity vectors, indicating direction and speed of tracer

Fourthly, for studying mixing it is useful to select an initial "marked" volume. A picture of how material initially within this volume disperses with time can be build up by following the history of the tracer particle each time it emerges from this volume. In this way the data can be used to determine a mixing index as a function of mixing time.

III. Comparison between PET and PEPT

PET is a radioactive tracer imaging technique. This technique is used to see the distribution of radioactive fluid when it mixes inside a system. PEPT is a technique for studying the motion of a positron emitting labelled particle within a closed, circulating system. When a labelled particle is tracked for a long enough period, then all possible types of motion are explored.

PET is a very slow process as it needs 10^6-10^7 events to produce an image. Unlike PET, PEPT is a fast process and it is not necessarily to detect so many events and it needs about 10^2 events to determine a tracer location.

In the PET technique, random and scatter events distort the image and can only partially be corrected after image reconstruction. The straightforward method for correcting random events is that they can be directly measured by introducing a delay line into the one arm of the coincidence circuit and then random coincidence events can be subtracted from the full data. Two general methods for scatter correction are: first, ignore scatter events which have energy less than 511 keV using energy resolution and second, employing collimating septa which block photons incident at large angles in an attempt to discriminate against scatter events.

Because of the fundamental differences between image reconstruction in PET and PEPT, different approaches are necessary. Principally, as has been described, in PEPT random and scatter events can be discarded by iteration and they do not contribute to tracer location. In this manner PEPT actually offers a more powerful way of observing the bulk distribution in three dimensions than PET, since in PET some events (scatter and random) distort the image in a way which can only partially be corrected after backprojection, whereas in PEPT these events are almost entirely discarded.

References

[1] Parker D. J,Broadent C.J, Fowles P, Hawkesworth M. R & McNeil P .A, Positron emission particle Tracking-a technique for studying flow within engineering equipment, Nuclear Instruments &Methods In Physics Research,A 326(1993)592-607.
[2] Parker D.J, Hawkesworth M.R, Broadbent C.J, Fowles P, Fryer T.D & McNeil P.A Industrial positron-based imaging: principles and applications Nuclear instrument & methods in physics research, A348(1994)583-592.
[3] Stein M, Ding Y.L, Seville J.P.K & Parker D.J, Solids Motion In Bubbling Gas Fluidised Beds, Chemical Engineering Science, 55 (2000) 5291-5300.
[4] Bakalis, S, Fryer, PJ. Parker, DJ. 2004. Measuring velocity distributions of viscous fluids using positron emission particle tracking (pept). AIChE Journal 50(7):1606-13.
[5] Fairhurst PG, Barigou M, Fryer PJ, Pain JP, Parker DJ, Using positron emission particle tracking(PEPT) to study nearly neutrally buoyant particles in high solid fration pipe flow, international journal of multiphase flow, Volume27,Issue 11, novemember2001.pp 1881-1901
[6] Hawkesworth M.R, Odwyer M.A, Walker J, Fowles P, Heritage J, Stewart P.A.E, Witcomb R.C, Bateman J.E, Connolly J.F & Stephenson R,A Positron Camera For Industrial Application, Nuclear Instruments &Methods In Physics Research,A253(1986)145-157.
[7] Parker D.J, Forster R.N, Fowles P and Takhar.P.S. Positron Emission Particle Tracking Using the New Birmingham Positron camera, Nuclear Instruments & methods in physics research A 477(2002)540-545.
[8] Turkington T.G, Introduction to PET Instrumentation, The Journal of Nuclear Medicine Technology,Vo l29, No.1 (2001) 4-11.
[9] Parker D.J,Forster R.N,Fowles.P & Takhar P.S, Positron emission particle tracking using the new Birmingham positron camera,Nuclear Instruments & methods in physics research A 477(2002)540-545.
[10] Forster R.N, Seville J.P.K, Parker D.J & Ding Y, Tracking Single Particles in Process Equipment or Probing Processes Using Positrons, KONA, No18 (2000)139-148
[11] Sadrmomtaz A.R, Parker D.J and Byars L G, 2007, Modification of a Medical PET Scanner for PEPT studies, Nuclear Instruments and Methods in Physics Research A, 573, 91-94.