Chaotic Behavior of Gas Solid Suspension by applying Electric Field using Pressure Fluctuations

Avantika Sonalikar
Department of Electrical Engineering
Priyadarshini College of Engineering, Nagpur, Maharashtra

Dr. K.B.Porate
Department of Electrical Engineering
Priyadarshini College of Engineering, Nagpur, Maharashtra

Rupali Sonolikar
Department of Chemical Engineering
National Environmental Engineering Research Institute, Nagpur Maharashtra

Abstract-The investigations were carried out in 2D fluidized bed to study chaos under the influence of electric field for the two modes of operation 1)field first and fluidization last and 2) fluidization first and field last. The chaotic parameters Mutual Information Function and Coorelation Dimension were studied . In Mutual Information Function at low gas velocity of 10 cm/s the time delay initially decreases with voltage for the field first and field last mode At a gas velocity of 14 cm/s, which is higher than velocity of 10 cm/s the time delay for field first mode almost remain constant but does not show the regular behavior.There is no regular behaviour of correlation dimension with field as well as the gas velocity.

Keywords-Chaotic Behavior of particles in the influence of Electric Field.

I.INTRODUCTION

The present investigation has been aimed in applying an axial high voltage DC electric field in a two dimensional Fluidized bed of semi-insulating glass particles to study the chaos parameters Mutual Information Function and Correlation dimension.

II.PROPOSED ALGORITHM

The concept of entropy is the central point of mutual information theory. This concept was developed by Shanon and Wear which states that mutual information function is based on the application of the concept of uncertainty. Accordingly to this concept the uncertainty associated with any measurement depends on the probabilities of various outcomes. Mutual information measures the amount of predictability of a test signal as function of time based on a reference signal.

Fraser and Swinney have shown that time delays, derived from mutual information are more appropriate for nonlinear systems than the first minimum of the auto correlation. They recommend using the time that corresponds to the first minimum of the mutual information function allows for the details of the stretching and folding of the attractor to be observed visually in the phase space. Karamavrue et al. utilized the mutual information theory to identify the periodicity and the predictability of the local instant differential and temperature signals. It was also used to interpret the bubble particle pocket dynamics around the heat transfer tube. In their latter work Karamavaruke et al. have measured the local instantaneous pressure signals in slugging fluidized bed using the dual static pressure probes and differential pressure transducers. For the two air flow rates 1.1 and 1.5 m^3/min the authors noticed that, low flow rates exhibits a high level of mutual information. The breaks in the mutual information are the representative of strong periodic motion. The levels of all mutual information function decreases with the increase in gas velocity and this indicates a rapid loss of information as the time progresses.

The starting point for deterministic chaos analysis is the reconstruction of the attractor of the system in its embedding phase space from a measured time series using e.g. time delay coordinates as based on Takens theorem The reconstructed attractor is a correct representation of the dynamical behaviour of the system and can be characterized by its invariant, dimension.

The correlation dimension expresses the special complexity of the attractor in state space. Strange attractors of chaotic systems are objects with complex geometrical structure which are self-similar at various resolutions. Self-similarity in a geometrical structure of a system is a strong signature of the chaotic behaviour of underlying system. There are several methods to qualify the self-similarity of a geometrical object by its dimension. Grassberger and Procaccia introduced the correlation dimension, D, for practical applications where the geometrical object has to be reconstructed from a finite sample of data points. Non integer value of the correlation dimension shows-self similarity in geometrical structure of a state space attractor. In fact, when the correlation dimension is non integer, the corresponding system has chaotic (nonlinear behaviour). The correlation dimension for simple systems (linear) is an integer.

The power-law relationship correlation integral of a reconstructed attractor and the neighborhood radius, ε, of the assumed hypersphere, C (ε) α ε^P can be used to provide an estimate of the correlation diamensions (Kantz and Skhreiber.

$$q(\varepsilon, m) = \frac{\partial \ln C(\varepsilon, m)}{\partial \ln \in} \tag{6}$$

$$D = \lim_{m\to\infty} \lim_{m\to 0} q(\varepsilon, m) \tag{7}$$

where C (∈) is a correlation integral and is defined as

$$C(\varepsilon) = \frac{2}{M(m-1)} \sum_{i=1}^{M} \sum_{j=j+1}^{M} \theta\, (\in - \| S(i) - s(j) \|) \tag{8}$$

in which s it's a point of the attractor which has M such points; M=N-(d-i)τ, θ is the Heavy side function which is equal to maity / zero = if the value inside the paranthesis is positive / negative. S(i) are the points of the reference trajectory, and S(j) are other points of the attractor in the vicinity of S(i).

Investigations of the authors studying the correlation dimension in fluidized bed are discussed below. Scouten and Van den Bleek developed a non-steady state model of the hydrodynamics of fluidization using deterministic chaos theory. The model describes the axial motion of particles in a one-dimensional array in a (Shallow) fluidized bed. The particle array model is based on force balances over each particle including drag force, net particle weight and particle collisions. The dependence is determined of the correlation dimension on Reynolds number and the coefficient of restitution (which is measure for the elasticity of particle collisions). It is found that the variation of correlation dimension with the helps in detecting the fluidization transitions due to sharp.

Michel et al. have studied the correlation dimension through pressure fluctuation measurements in a circulating fluidized bed. It is found that correlation dimension (CD) increase in the bottom part of the riser, remains almost for height above 1.5 m and slightly increases in the upper most zone. Hay et al. [20] reported that the regime of gas-solid fluidized bed can be characterized by the correlation dimension. For a gas velocity range up to 0.3 cm/s the CD has shown a constant value of 4.2 and has also been found to be independent of bed height to diameter ratio (a constant value of 4.25).

Ding and Tom compared the results obtained by Daw and Halow [18] and Scouten and Bleek [41] for correlation dimension. The basis of the comparison of these authors is U/U_{mf} ratio and the magnitude of correlation dimension (D). For U/U_{mf} between 1.04 and 2.93 the Dx loes between 2 and 3 (Ding and Tom [43]. Whereas for U/U_{mf} = 1.07 obtained at value of D less than 2 (Scoutan and Bleek [41]). These values do not, match with the results of Ding and Tom [43] as they found D upto 6. Huilin et al. circulating fluidized bed values on D between 1.5 to 1.9 for Ug = 2.9 m/s and solid flux of 20 Kg/m^2 S.

A new parameter electric field intensity has been added to a fluidized bed to notice its effect on correlation dimension for field first and field last mode of operation at a gas velocity.

III.EXPERIMENT AND RESULT

The experimental studies were carried out in a two dimensional unit (Fig. 1) with a width of 20 cm, depth of 1.5 cm and height of 60 cm. Experiments were carried out in presence and absence of electric field for a bed height of 22cm of settled bed. The fluidizing particles of 275 micron glass beads were used and the fluidizing gas was air. The electric field intensity of 20kv, 40kv, 55kv and 70kv were used in the present studies. The pressure fluctuations at 3cm and 22 cm were measured by absolute pressure transducer. A fine mesh screen (10 micron) was attached to one end of the tube placed at the sampling point to avoid the solids penetration in the transducers thereby avoiding their obstructions. The magnitude of pressure fluctuations from the transducers were observed in a data acquisition system and finally stored in a storage oscilloscope. The numbers of points in one slot were 2500 and such 12500 points were taken for one time series analysis. For statistical and spectral analysis the packages used are MATLAB AND TISEAN and for the chaos analysis the package used is RRCHAOS.

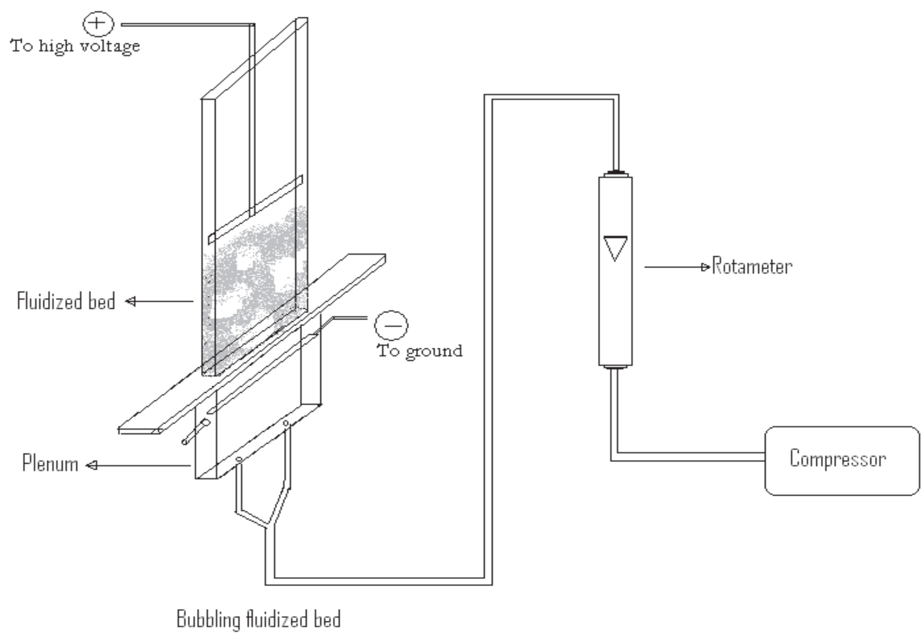
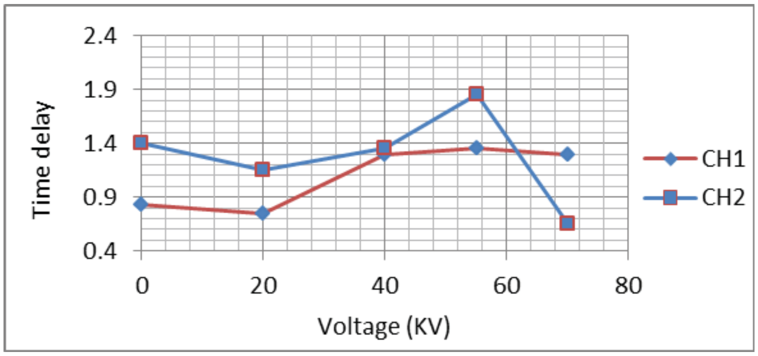


Fig 1:Experimental Set up(2D)

The Mutual Information Function is based on the application of the concept of uncertainty. The MIF measures the amount of predictability of a test signal as a function of time based on the first minimum from the variation of MIF with time lag. Apart from the parameters, the effect of gas velocity it is measured with the new parameters viz. voltage, tap position and mode of applied voltage.

Fig..1 to fig. 4 shows the variation of time delay (obtained from the mutual information function) with the voltage at the tap position of 3cm (CH1) and tap position of 24 cm (CH2). The variation is neither regular nor it shows the systematic behaviour. Fig. .3 shows the time delay of 0.56 a constant value for a variation of voltage.

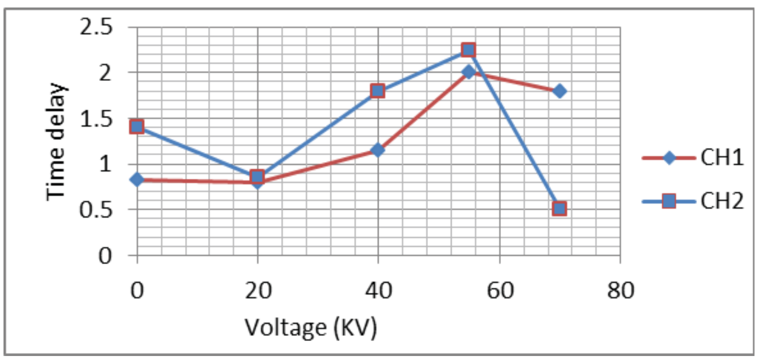
Variation of Mutual Information function with time lag in presence and absence of electric field. d_p = 275 µm, CH1- Tap position=3 cm, CH2- Tap position = 24cm, FF-Field first and fluidization last, FL- Fluidization last and field first



Mutual Information Function

Ug=10 cm/s, FF

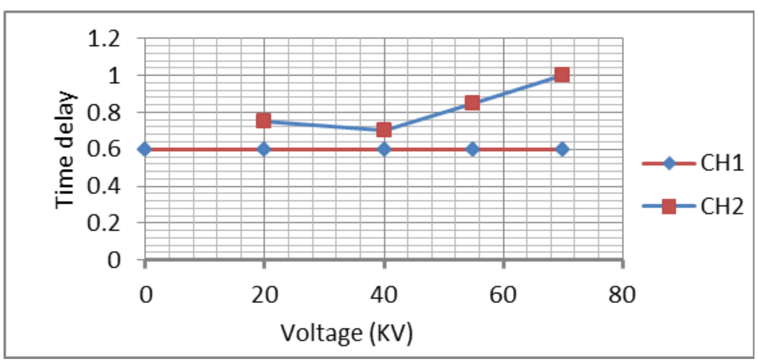
Fig.1



Mutual Information Function

Ug=10 cm/s, FL

Fig.2



Mutual Information Function

Ug=14 cm/s, FF

Fig..3

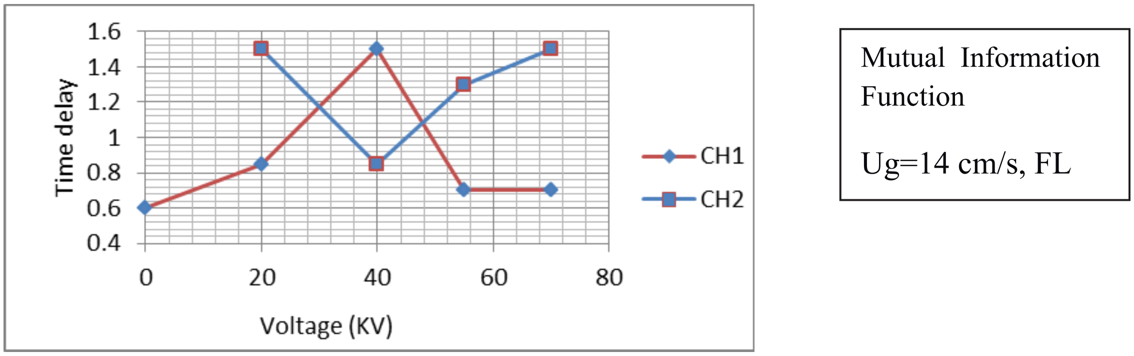


Fig.4 Variation of time delay with applied field

Correlation dimension expresses the degrees of freedom of a dynamic system. The effect of the parameters: gas velocity, sampling position is reported in absence of field. The additional parameters effect of electric field and mode of operation is discussed.

Effect of voltage (V) on correlation dimension (D_{ML}) at 3cm and 24 cm of tapping position for the field first and field last mode are shown in Fig. 5 and Fig. .6 The method adopted for evaluation of D_{ML} is the maximum likelihood estimates.

The range of D_{ML} = 5.125 (V=0) to D_{ML} = 2.948 (V = 70 kv) at 3 cm position is obtained for field first mode.

The non integer values of D_{ML} shows a chaotic behaviour. The lowering of D_{ML} at V = 70 kv might be the cause of formation of vertical chains and restricted movement of fluidization particles due to interparticle attraction. The DML = 5.125 in absence of the field is in the range reported in the literature DML = 7.1 by Zargharm et al . At the tapping position of 24 cm the particles has free board region and DML oscillates between 9.81 (V= 0) to 13.1 (V = 40 kv).

Field last mode, at 3cm and 24 cm for the variation of D_{ML} with voltage is depicted in Fig. 6 For 3cm tap point the D_{ML} increases from 5.2 to 42 when V changes from V = 0 to V = 55 kv. A decrease is noticed at 24 cm for V = 0 (D_{ML} = 9.81) to V = 40 kv (D_{ML} = 3.29) but this value suddenly increases to D_{ML} = 41.18 for E = 55 kv, because it meets to free board region.

Another gas velocity at which the effect of electric field is studied, Ug = 14 cm/s has the identical condition as recorded at Ug = 10 cm/s. for the field first mode and is shown in Fig. 7

At 3 cm a bottom tap point, D_{ML} shows very small variation, 4.7 to 4.9 when electric field varies changes from V = 0 to 40 KV and attains a maximum D_{ML} = 6.752 at V= 55 KV. At 24 cm, D_{ML} has almost constant value, 4.5 but in the range of V = 0 to 40 KV but increases to 6.357 at 55 KV. Fig. 8 shows the variation of correlation dimension with voltage at 3 cm and 24 cm for the field last mode. The D_{ML} initially increases from 4.668 (V = 0) to 7.1 (V = 70 kv). D_{ML} = 7.1 is maximum value but decreases to 7 at V=55 .

Correlation dimension, DML (obtained by maximum likelihood method) of absolute pressure fluctuations is a function of voltage for field first and field last mode.

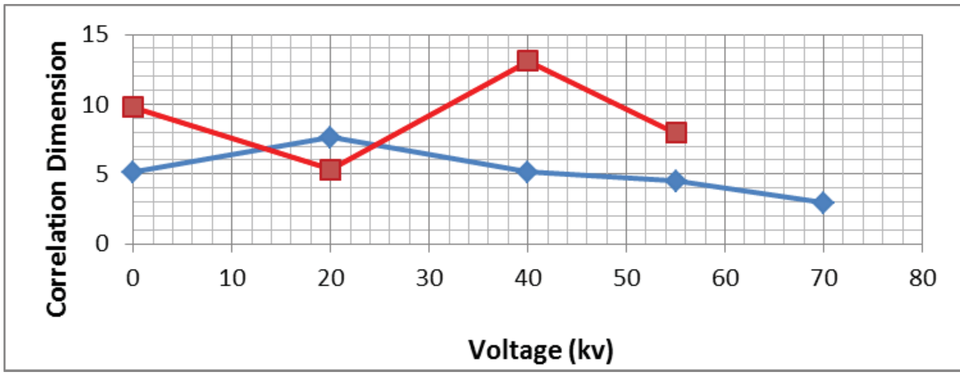


Fig.5

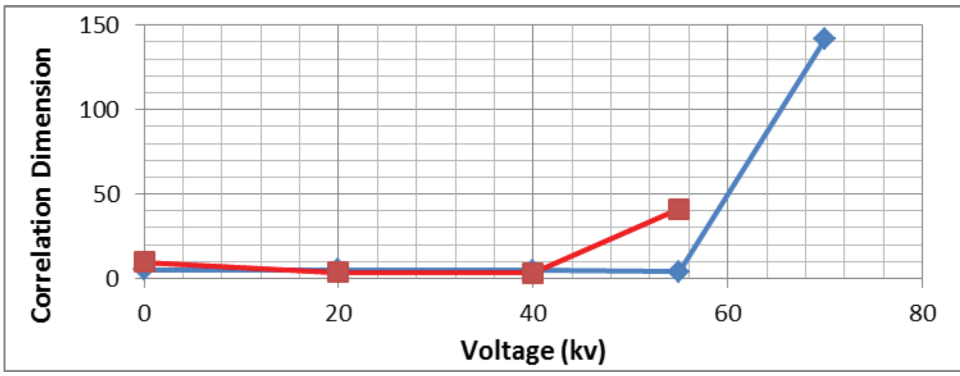


Fig.6

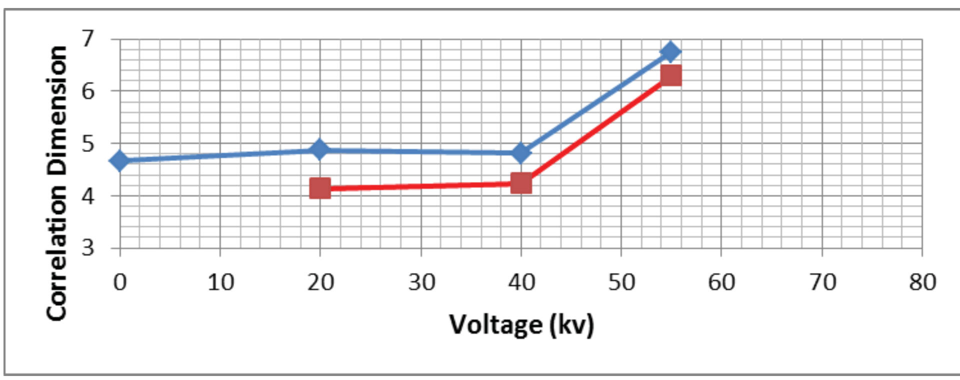


Fig.7

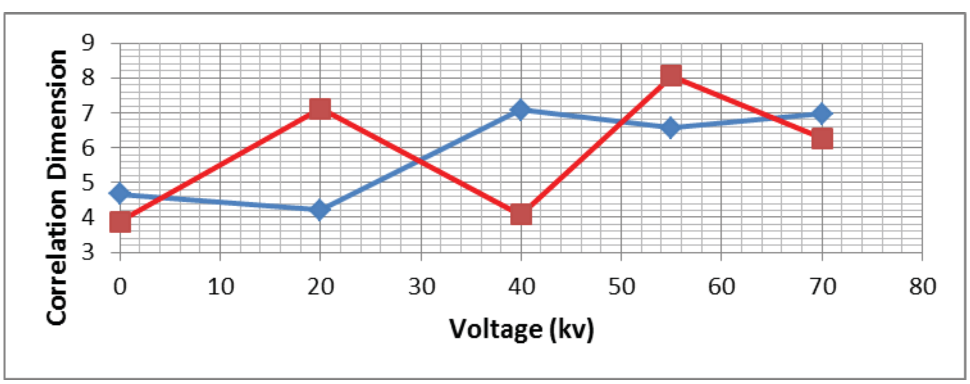


Fig.8. Variation of correlation dimension with voltage

IV.CONCLUSION

1) In Mutual Information Function at low gas velocity of 10 cm/s the time delay initially decreases with voltage for the field first and field last mode.At a gas velocity of 14 cm/s, which is higher than velocity of 10 cm/s the time delay for field first mode almost remain constant but does not show the regular behaviour.

2)There is no regular behaviour of correlation dimension with field as well as the gas velocity.

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