Cross Recurrence Quantification Analysis of Gas-solid Flow in Pneumatic Conveying of Plastic Pellets using Electrostatic Sensors

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Abstract

Gas-solid flow synchronisation behaviour of plastic pellets were characterised, and particle velocities were processed using cross-recurrence quantification analysis (CRQA) of electrostatic sensors at different pneumatic conveying operating conditions, including air velocity and solids mass flow rates. Time-series data were collected from arc-shaped electrostatic sensors to reconstruct phase spaces (attractors) using the time delay coordinate embedding method. Cross-recurrence plots were developed from the reconstructed phase spaces to visualise the shared topology in two arc-shaped electrostatic sensors at two locations in a horizontal pipeline. CRQA measures, such as recurrence rate and determinism, were applied to the cross-recurrence plots to quantify the synchronisation between the two sensors for different gas-solid flow patterns: stratified flow, pulsating flow, moving dunes and blowing dunes. The flow patterns were identified using high-speed video imaging sight section of a pipeline and classified at several operating conditions in a flow pattern map and state diagram. The optimal operating conditions at the minimum conveying air velocity in the state diagram are between moving and blowing dunes. The CRQA measures and particle velocity were correlated with the state diagram to understand their relationship at optimal conditions. It was found that the CRQA measures can be used to detect changes in solids mass flow rate and air velocity.

Keywords: Gas-solid flow; Pneumatic conveying; Cross recurrence plot; Cross recurrence quantification analysis

Graphical abstract

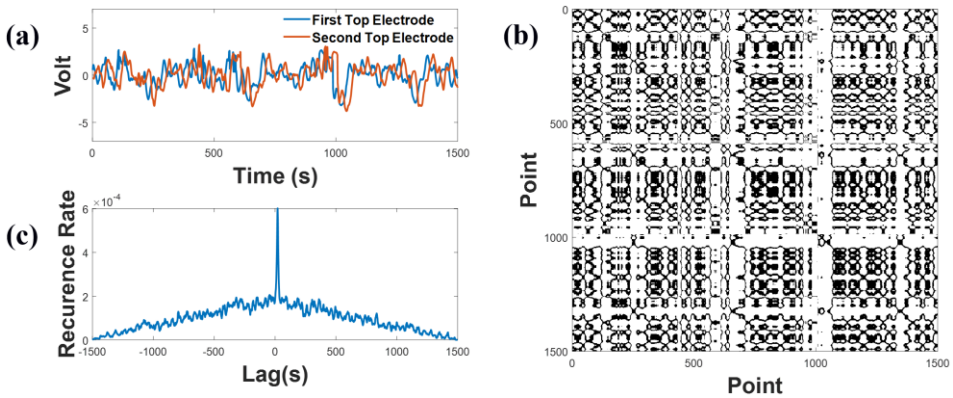

Figure 1: (a) Two top arc-shaped electrostatic sensor signals sampled at 5000 Hz and (b) their cross-recurrence plot and (c) recurrence rate profile at different time lag.

References

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