Dynamic analysis of flooding phenomena in structured packed columns using advanced signal processing techniques

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Gas-liquid contactors are essential components in chemical and biochemical processes, enabling efficient mass and heat transfer between phases. Among these, structured packed columns are particularly advantageous, offering enhanced interfacial area and mass transfer rates while minimizing energy consumption. Optimal operation of such columns is achieved between the loading and flooding regimes. Flooding, characterized by large pressure drop instabilities driven by excessive liquid holdup within the packing, imposes operational constraints. To maintain stability, columns are typically operated at 70 - 90% of the flooding capacity; however, under these conditions, even minor fluctuations in gas or liquid flow rates can trigger transitions to incipient or fully developed flooding. A deeper understanding of the dynamic behavior of structured packed beds near flooding is therefore essential for performance optimization and advanced process control.

This study presents a dynamic analysis of pressure drop signals in structured packed beds under partially and fully flooded conditions. Pressure measurements were systematically collected across a range of liquid loads and gas superficial velocities to investigate hydrodynamic behavior during the onset of flooding. Two complementary signal processing techniques were employed: Fast Fourier Transform (FFT) analysis to extract dominant frequency components associated with flooding, and Wavelet Transform analysis to perform time-frequency decomposition, revealing both the spectral content and its temporal evolution. The integration of these methods enabled a detailed characterization of the transition from loading to flooding, offering both global and localized insights into system dynamics.

Future work will expand the experimental dataset and validate the analytical approaches under diverse operating conditions. Furthermore, these methodologies hold significant promise for exploring the dynamic behavior of sandwich packings, composite structures composed of alternating layers of structured packings with different specific surface areas. Although sandwich packings offer potential advantages in contact efficiency and flow distribution, their hydrodynamics are not yet fully understood, and limited mass transfer data are available. Addressing these gaps is crucial for advancing their industrial adoption.

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