**From Electrical Signals to Spray Mode Control:**

**An eXplainable AI Framework for Electrospray Processes**

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Electrospraying, or electrohydrodynamic atomization (EHDA), is a successful process that finds several applications in chemical processes, additive manufacturing and the pharmaceutical industry. The process involves spraying through a nozzle under the influence of an electric field. For a given flow rate, EHDA allows several spray modes, producing drops of varying sizes and numbers depending on the operating flow rate and electric field strength. Usually, the online control of EHDA units is achieved using optical systems to correlate the meniscus/lamina shape and the relative drop size distribution with the operating conditions (i.e. flow rate and applied voltage) and liquid physical-chemical properties (e.g. density, surface tension, viscosity, etc.). However, image analysis is expensive, and there are various applications where optical access to the system is not available. Therefore, several authors have developed EHDA spray modes recognition tools based on the electrical current signals acquired from the system. This work proposes the use of an eXplainable Artificial Intelligence (XAI) framework to classify four of the main EHDA modes, such as dripping, intermittent, cone-jet, and multi-jet. The XAI framework is based on the implementation of a 1-D Convolutional Neural Network (1D-CNN) with a supervised learning approach, which performs the classification by analyzing the Fast Fourier Transforms (FFTs) of the electrical current signals associated with the different EHDA spray functioning modes. The dataset for the training was acquired through dedicated experiments by testing different Ethanol-NaCl mixtures and pure ethylene glycol, so as to investigate the effect of the different physical-chemical properties. Moreover, the AI framework uses XAI post-hoc techniques (i.e. Grad-CAM) to investigate and validate the 1D-CNN decision-making process. The model delivered high classification accuracy and adaptability for the different liquids, and the Grad-CAM methods used for the post-hoc explainability analysis addressed the characteristic frequency distribution of the different EHDA modes along the spectrum used for classification, with values consistent with experimental and theoretical evidence. The online implementation of the proposed XAI framework will enable real-time monitoring and control of EHDA systems, improving the reliability of EHDA units by allowing automatic adjustment of control variables based on an identified spray regime.

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