Data-driven Dimensional Analysis for Electrospinning to Discover Dimensionless Numbers and Scaling Laws

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RESEARCH OBJECTIVE

We present a novel method to discover the controlling dimensionless numbers and the scaling laws between the input and output of the electrospinning process based on a data-driven dimensional analysis approach.

METHODS

Experimental data
Temporary scaling law groups
Sensitivity analysis

Guide the next step parameter design

RESULTS: Dimensionless numbers & scaling laws

Parametric space to be explored:
\[ f(\rho, K, \gamma, \mu, T, U, D, Q, V, T, H, \varepsilon) = \Pi_{out}(d) \quad \Rightarrow f(\Pi_{in}) = \Pi_{out}(d) \]

\[ \Pi_2 = f(\Pi_1) \]
where \( \Pi_1 = \frac{U^2 \sqrt{a}}{K Y S D Q V} \), \( \Pi_2 = \frac{d}{a} \)

\[ \Pi'_2 = f(\lg(\Pi'_1)) \]
where \( \Pi'_1 = \frac{U^3 \sqrt{\rho H}}{a y_5^2 \sqrt{V K} \gamma} \), \( \Pi'_2 = \frac{d}{a} \)

RESULTS: Physical interpretation

\[ \Pi_1 = \frac{U^2 \sqrt{a}}{K Y S D Q V} = \frac{U^2}{K D} \left( \sqrt{a} \frac{1}{\sqrt{V/D}} \frac{1}{\sqrt{Y S}} \right) = \beta \frac{1}{\sigma_0 \sqrt{\gamma Y S Q}} \]

Electrical power: \( P = \frac{U^2}{K} \)  
Surface charge density: \( \sigma_0 = \sqrt{\gamma S / a} \)

Electrical power per unit length: \( \beta = \frac{U^2}{K D} \)  
Shear rate: \( \dot{\gamma} = \frac{V}{D} \)

RESULTS: Sensitivity analysis

Convergence of Monte-Carlo solution

Determine the order of voltage \( U \)
\[ R^2 (d \propto U) = 0.53 \]
\[ R^2 (d \propto U^2) = 0.59 \]
\[ R^2 (d \propto U^3) = 0.17 \]

Especially, the obtained dimensionless number provides \( R^2 = 0.88 \) for 1% PET condition