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

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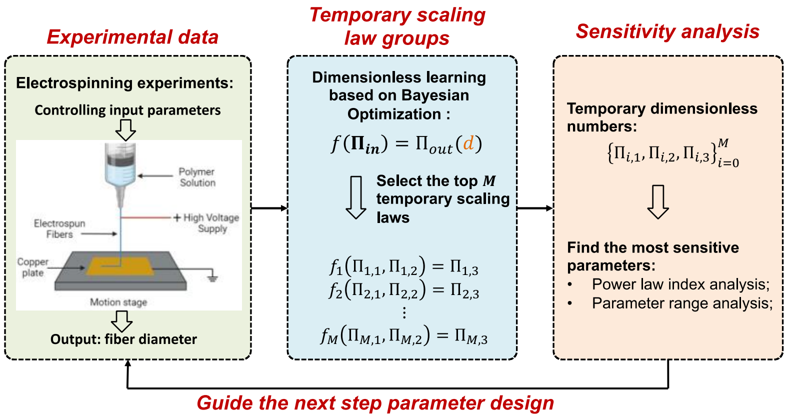
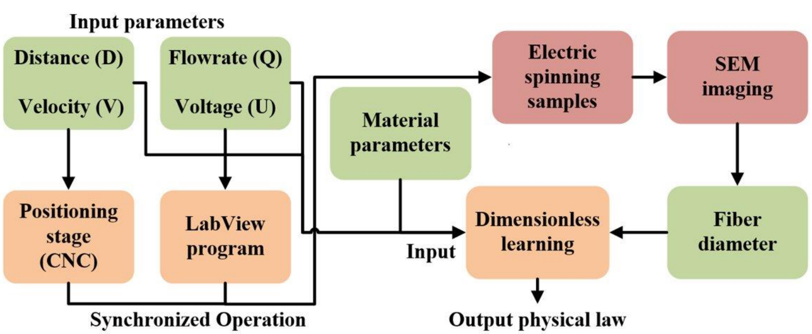
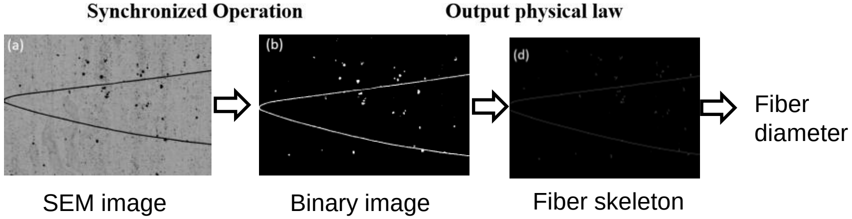
RESEARCH OBJECTIVE

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

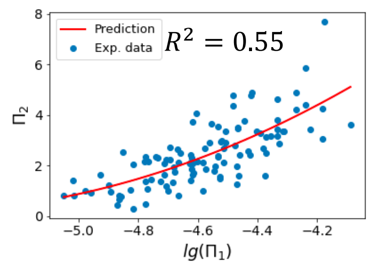


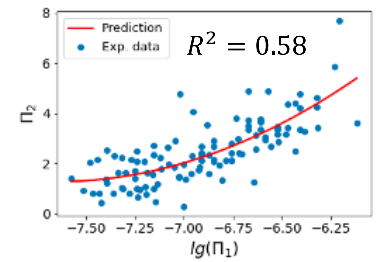


RESULTS: Dimensionless numbers & scaling laws

Parametric space to be explored:

$$f(\rho, K, \gamma_s, \mu, T_b, U, D, Q, V, T, H, \varepsilon) = \Pi_{out}(d) \quad \Rightarrow f(\boldsymbol{\Pi}_{\mathbf{in}}) = \Pi_{out}(d)$$





$$\Pi_2 = f(\Pi_1), \text{ where } \Pi_1 = \frac{U^2\sqrt{a}}{K\gamma_s\sqrt{DQV\varepsilon^3}}, \Pi_2 = \frac{d}{a}$$

$$\Pi_2' = f(\lg(\Pi_1')), \text{ where } \Pi_1' = \frac{U^3\sqrt{\rho H}}{a\gamma_s^2\sqrt{VK^3\varepsilon^5}}, \Pi_2' = \frac{d}{a}$$

RESULTS: Physical interpretation

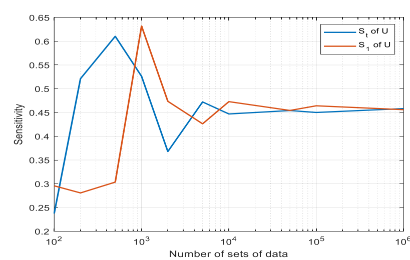
$$\Pi_1 = \frac{U^2\sqrt{a}}{K\gamma_s\sqrt{DQV\varepsilon^3}} = \frac{U^2}{KD}\sqrt{\frac{a}{\gamma_s\varepsilon}}\frac{1}{\sqrt{V/D}}\frac{1}{\varepsilon\sqrt{\gamma_s Q}} = \frac{\beta}{\sigma_0\dot{\gamma}\varepsilon}\frac{1}{\sqrt{\gamma_s Q}}$$

Electrical power: $P = U^2/K$ Surface charge density: $\sigma_0 = \sqrt{\gamma_s\varepsilon/a}$

Electrical power per unit length: $\beta = U^2/KD$ Shear rate: $\dot{\gamma} = V/D$

RESULTS: Sensitivity analysis

Convergence of Monte-Carlo solution



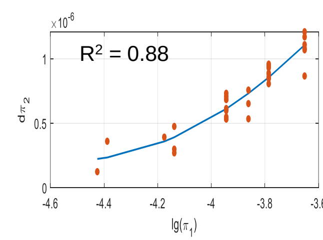
Determine the order of voltage U

R^2 ($d \propto U$) = 0.53

R^2 ($d \propto U^2$) = 0.59

R^2 ($d \propto U^3$) = 0.17

The order of U is determined to be 2.



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

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