Towards the Development of Mathematical Model for Predicting Cold Spray Process Outputs For Polymeric Materials Using Regression Analysis

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Research Overview

Cold spray can deposit various materials onto different surfaces at low temperatures, making it ideal for polymeric materials. However, the literature lacks coherent view on the best process parameters for effective cold spray deposition for polymers [1]. In this work, we showed that, by optimizing specific cold spray parameters, we could achieve a higher deposition efficiency (66%) by depositing nylon 6 onto a polystyrene substrate. Hence, more research is needed to uncover how the relationship between these parameters governs the deposition of polymer particles onto polymer substrates, by developing a mathematical model to optimize the process.

Motivation

The motivation for this work is to improve the understanding of how cold spray parameters affect the deposition efficiency of polymers. By identifying the factors that have the most significant impact on the process, researchers can optimize the cold spray process to achieve better performance and reduce costs.

Experimental Section

- Nylon 6 powder (65-75 µm, BASF, Germany) and polystyrene (PS) substrate (3 x 3 x 0.25-inch, GRAINGER, USA).
- A CSM 108 cold spray facility (BaltiCold Spray LTD, Estonia) was used to spray nylon 6 powder on a PS substrate using compressed air as a carrier gas [2].
- The cold spray parameters considered in this work are shown in Table 1.
- To determine which of the parameters with the greatest impact on deposition efficiency, we used a one-factor-at-a-time (OFAT) approach.

Approach

- In this approach, one process parameter was varied at a time while keeping the other parameters constant.
- It was ensured that the selected parameters were varied within the range that complies with the materials and cold spray system requirements.
- Finally, the deposition efficiency (DE) was recorded for each experiment as shown in Figure 1, following equation 1.

Table 1. Parameters considered in this work.

Parameters	Range
Syst. temperature (°C)	30 - 185
Syst. pressure (bar)	4.6 - 7
Standoff distance (mm)	5 - 30
Feed rate (rev/min)	5 - 21
Raster speed (mm/min)	500 - 5000

$$DE = \frac{\text{Mass of Nylon 6 deposited}}{\text{Total mass of Nylon 6 sprayed}} \times 100 \quad (1)$$

Composite Experimental Design

- Five coded levels were used to represent the coordinates of the location points where possible values of process parameters could be found.
- Coded levels were set at values of -1.682, -1, 0, +1, and +1.682.
- The parameters of the process were calculated using equation 2, which relates the given coded level (Xi) with the respective process parameters X.
- X_{max} and X_{min} represent the upper and lower limits of the process parameters.
- The results of these calculations are presented in Table 2.

$$Xi = 1.682[2X - (X_{max} + X_{min})]/[X_{max} - X_{min}] \quad (2)$$

Preliminary Results

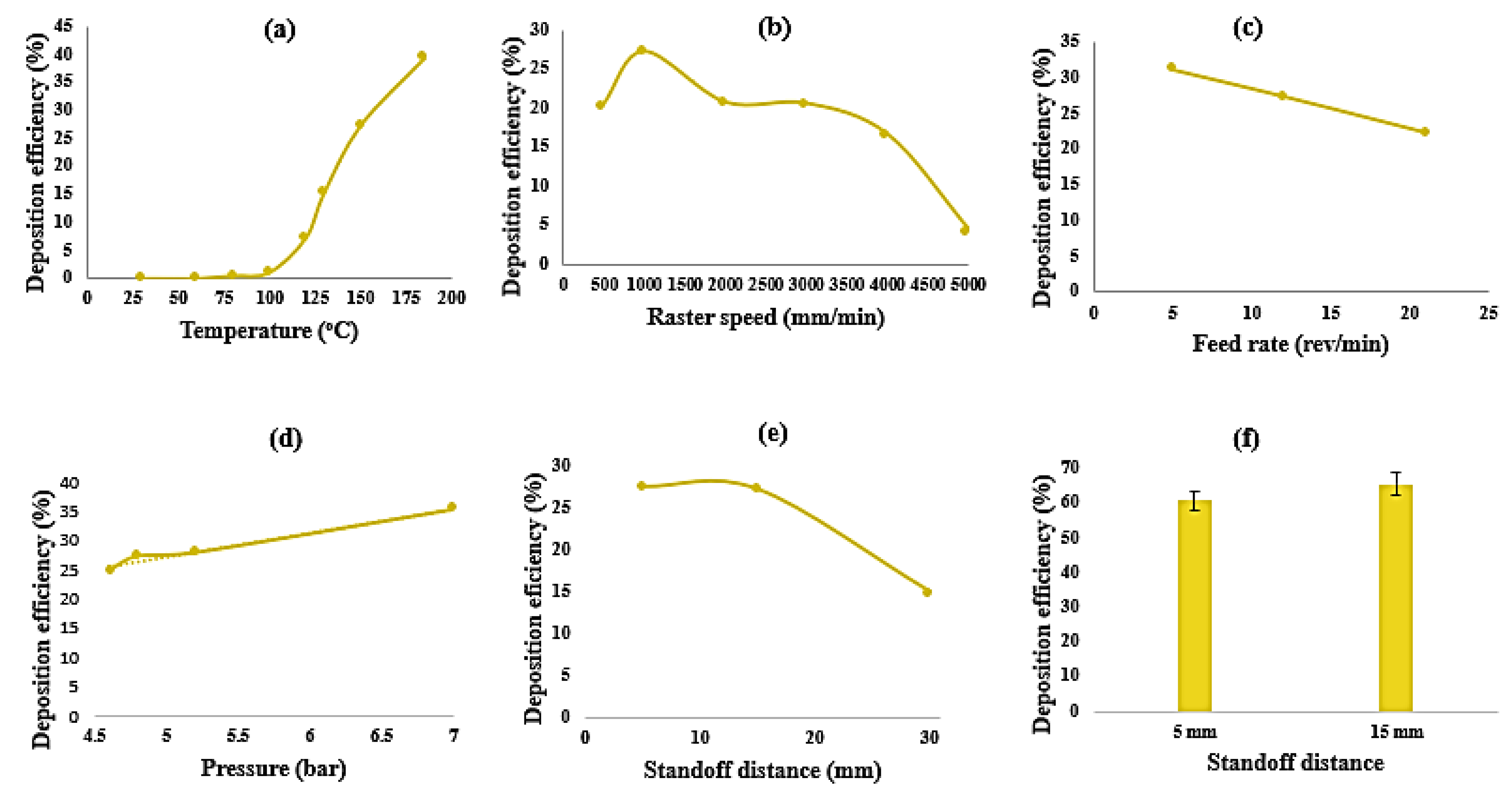

Figure 1. The graph of deposition efficiency versus (a) temperature (b) raster speed (c) feed rate (d) pressure (e-f) standoff distance.

Table 2. Selected Cold spray Parameters and their levels for composite experimental design

Parameters	Notation	units	Level (Xi)				
			-1.682	-1	0	+1	+ 1.682
Temperature	T	°C	115	129	150	171	185
Standoff distance	Sd	mm	5	10	18	25	30
Feed rate	Fr	rev/min	5	8	13	18	21

Raster speed (1000 mm/s), Pressure (7 bar), number of passes (10) and layer (1).

Conclusions and Future Work

Higher temperature, lower standoff distances, and lower feed rates result in higher deposition efficiency. Optimal deposition efficiency was achieved at a threshold raster speed of 1000 mm/min. Future work will involve developing a mathematical model to optimize deposition efficiency while keeping raster speed and pressure constant at a value that yields optimum deposition.

References

1. Khalkhali, Zahra, et al. "Surface and Coatings Technology 383 (2020): 125251.
2. Bacha, Tristan, et al. "Journal of Thermal Spray Technology 32.2-3 (2023): 488-501.

Acknowledgements

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