IECME 2025 Conference

The 2nd International Electronic Conference on Metals

5 - 7 May

Politecnico di Torino

IAM Integrated Additive Manufacturing @PoliTo

Machine learning assisted material development via Laser powder bed fusion process

Alireza Moradi[1], Sanae Tajalli Nobari[2], Amir Behjat[3], Mohammad Taghian[3], Luca Iuliano[3,4], Abdollah Saboori[3,4]

[1] Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129 Torino, Italy

[2] Department of Applied Science and Technology, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129 Torino, Italy

[3] Department of Management and Production Engineering, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

[4] Integrated Additive Manufacturing Center (IAM@PoliTo), Politecnico di Torino, Corso Castelfidardo 51, 10129 Torino, Italy

Outline

Politecnico di Torino

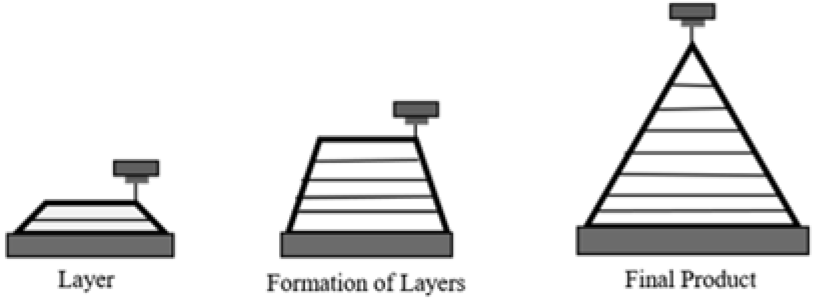
IAM Integrated Additive Manufacturing@PoliTo

IECME 2025 Conference

Introduction

Additive Manufacturing:

- ➢ Producing components from a digital CAD model
- ➢ Adding material layer by layer



Key benefits:

- ✓ Design freedom
- ✓ Material efficiency
- ✓ Customization

Open challenges:

- Poor surface quality
- Limited available materials
- Low production rate

How can we turn these challenges into future strengths?

Introduction

Challenges and solutions

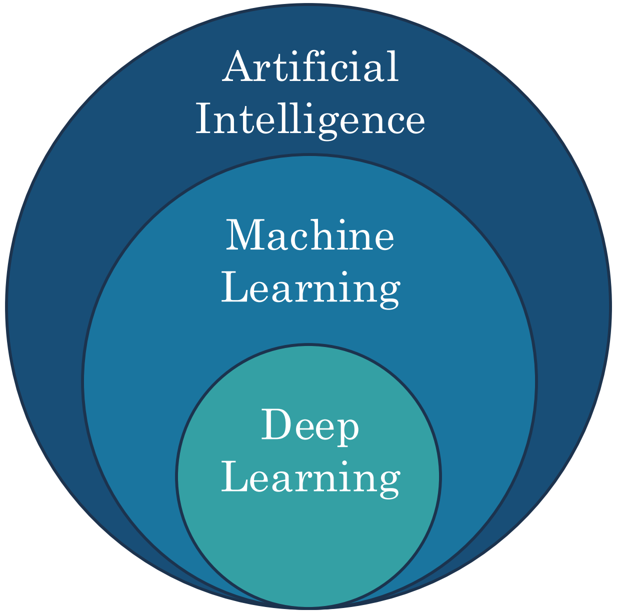
Material development

Process Parameter Optimization

SOLUTIONS

Machine Learning

- ➢ Process parameter optimization
- ➢ In-situ monitoring
- ➢ Post process characterization



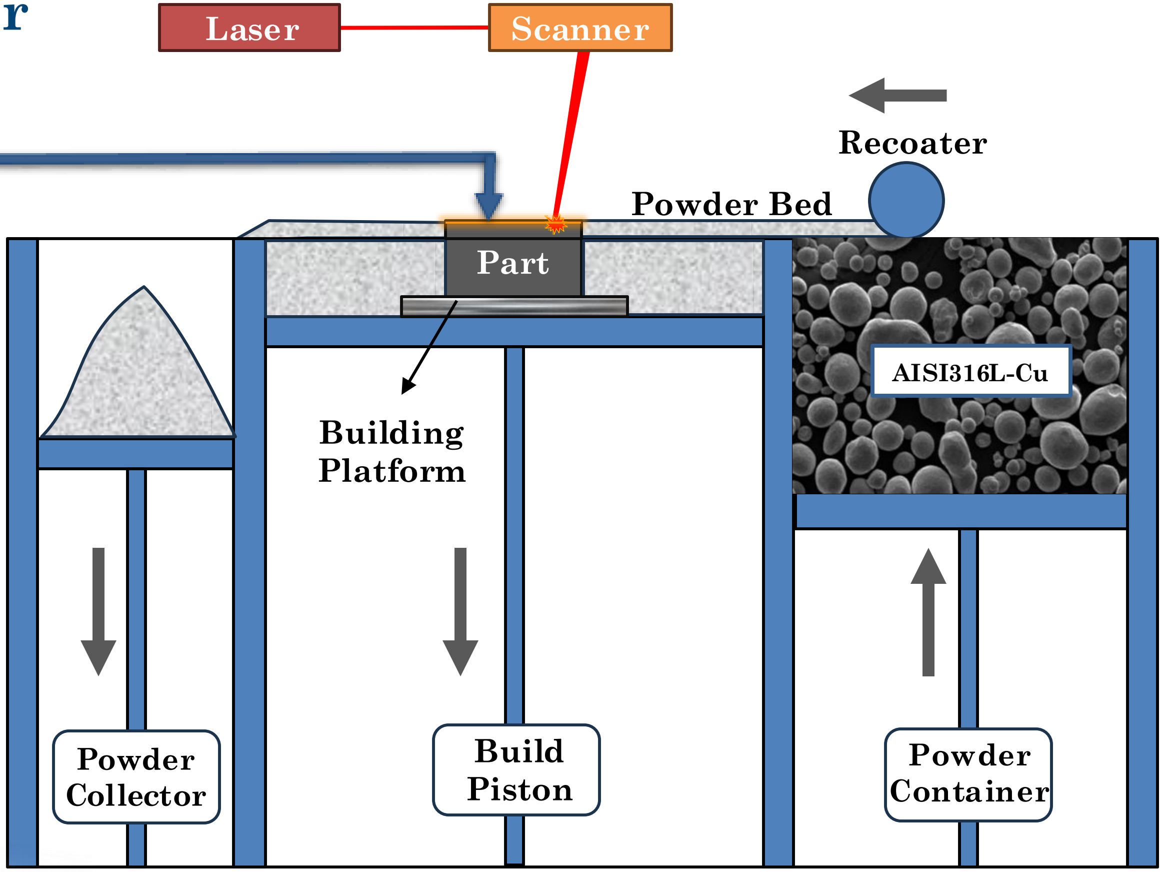
Materials and Methods

Powder Preparation

Jar milling (97.5%AISI316L+2.5%Cu)

Laser Powder Bed fusion

Mechanism explanation: A laser beam is used to **selectively melt** fine metal **powder** and build up fully-dense parts **layer-by-layer**

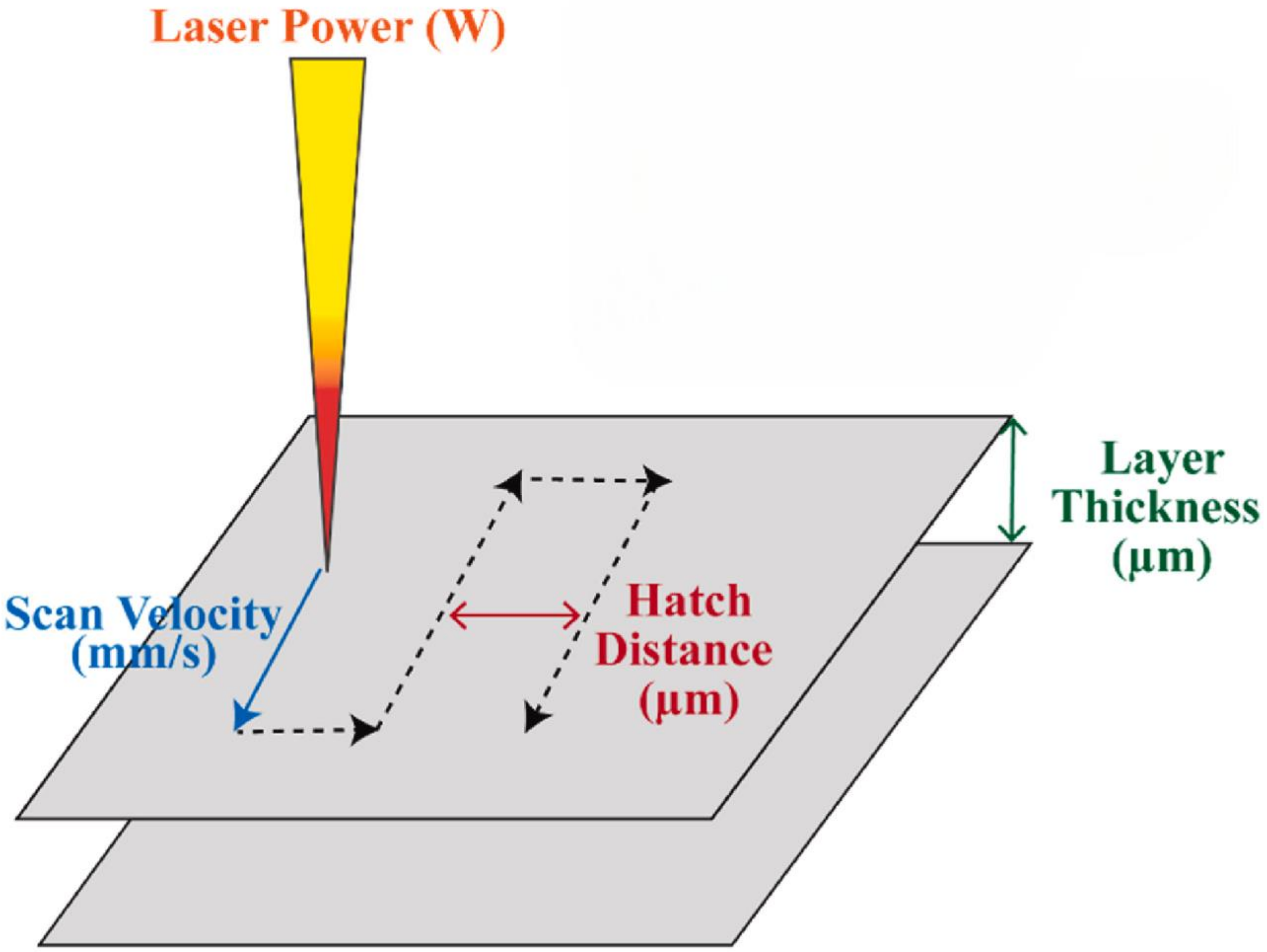


Materials and Methods

Design Of Experiment:

64 different process parameters

- Power
  100, 190, 200, 270, 340 W
- Scan Speed
  400, 600, 800, 1000 mm/s
- Hatch Distance
  0.1, 0.11, 0.12, 0.13, 0.2 mm
- Layer Thickness
  0.03 mm



Politecnico di Torino

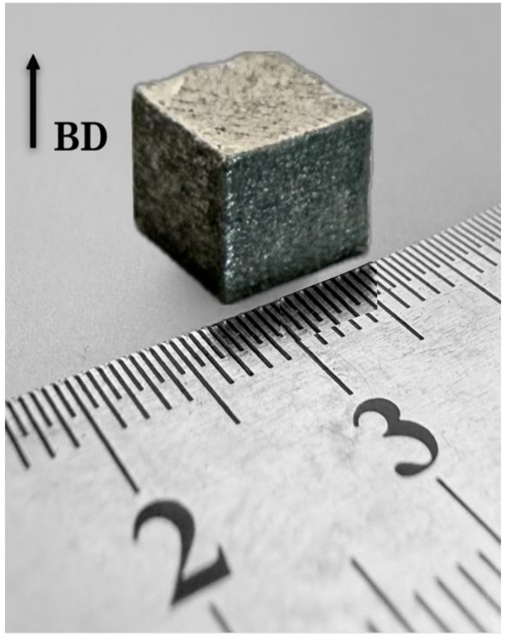
IAM Integrated Additive Manufacturing@PoliTo

IECME 2025 Conference

Materials and Methods

DESIGN OF EXPERIMENTS: 64 Cubic Specimens

- Powder Feedstock: AISI316L-2.5%Cu
- Metal AM Technology: L-PBF
- Analyzed conditions: As-Built
- Characterizations: Powder, Density
  Process Parameter Optimization,



Result and Discussion

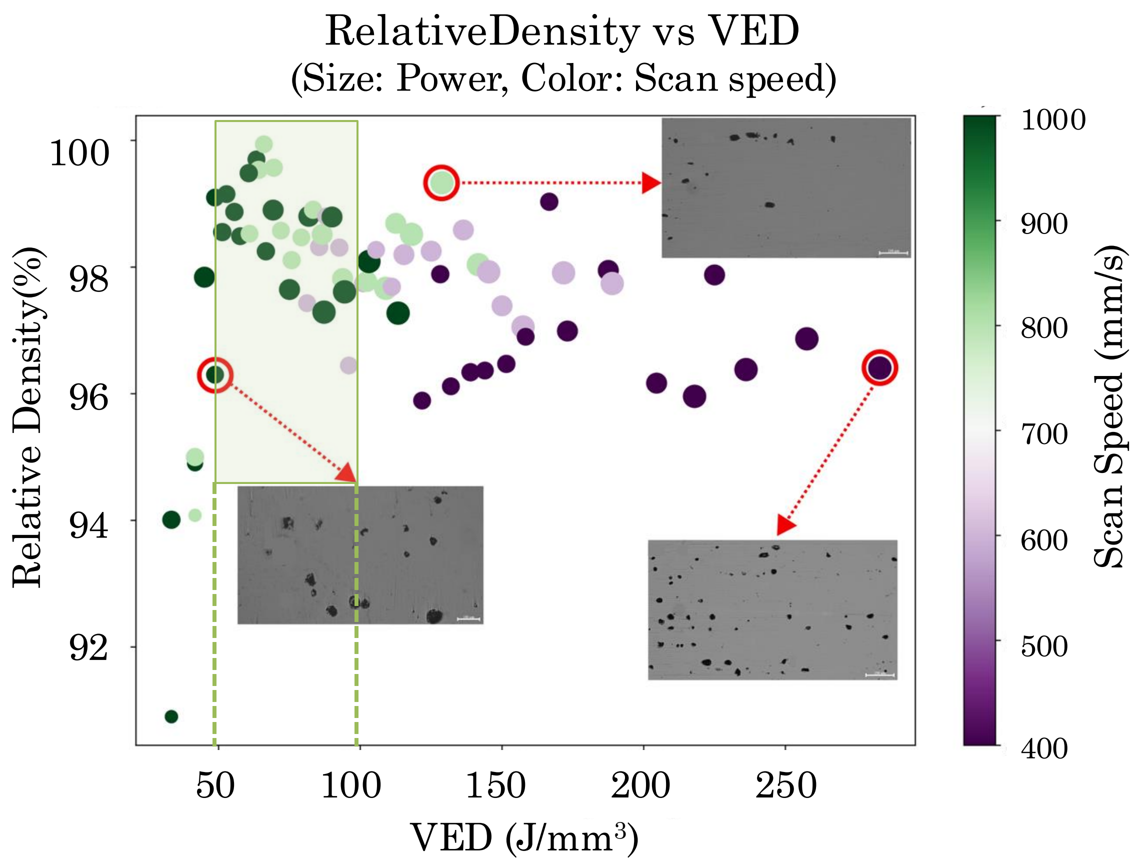
Volumetric **E**nergy **D**ensity (VED): 33 ~ 283 J/mm^3

$$VED = \frac{P}{v.h.t}$$

- Power
- Layer Thickness
- Hatch Distance
- Scan Speed

Max. Relative Density: 99.9
P: 190 (W), v: 800 (mm/s), h: 0.12 (mm)

Min. Relative Density: 90.9
P: 100 (W), v: 1000 (mm/s), h: 0.1 (mm)



Applying **Machine Learning** models

Splitting the data into **training** and **testing** → Analysing the **three most effective** hyperparameters → Choosing the **best algorithm** → **Prediction**

Result and Discussion

Mean Absolute Error

- Average absolute deviation for each statistic
- The same unit as the target variable
- The lower, the better!

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$$

Coefficient of Determination

$$-\infty < R^2 < +1$$

- Level of variation in the target variable by changes in the input variables

$$\text{R}^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Politecnico di Torino

IAM Integrated Additive Manufacturing@PoliTo

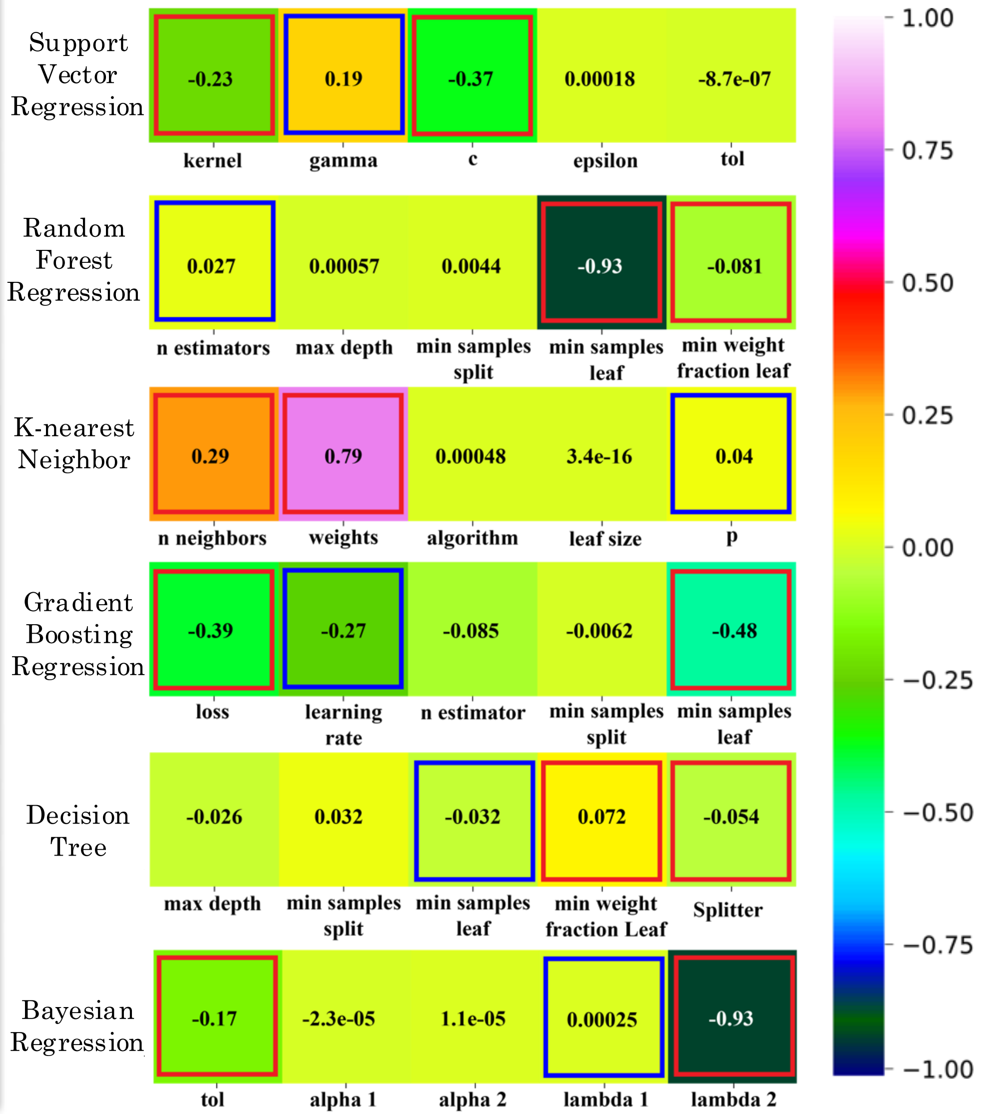
IECME 2025 Conference

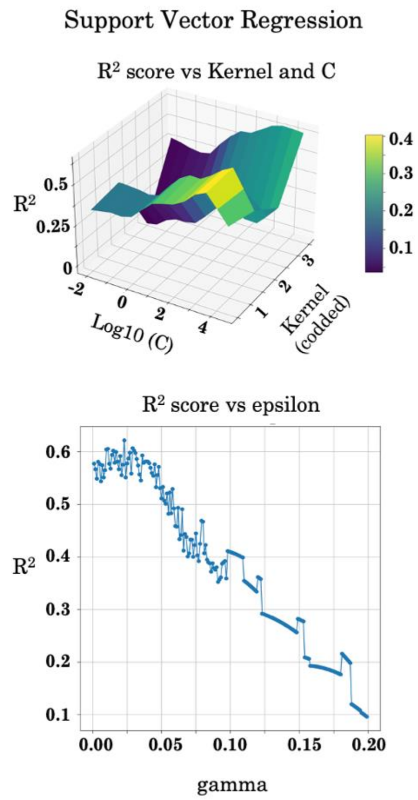
Result and Discussion

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$$

$$\mathrm{R}^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Effect of hyperparameters on prediction accuracy





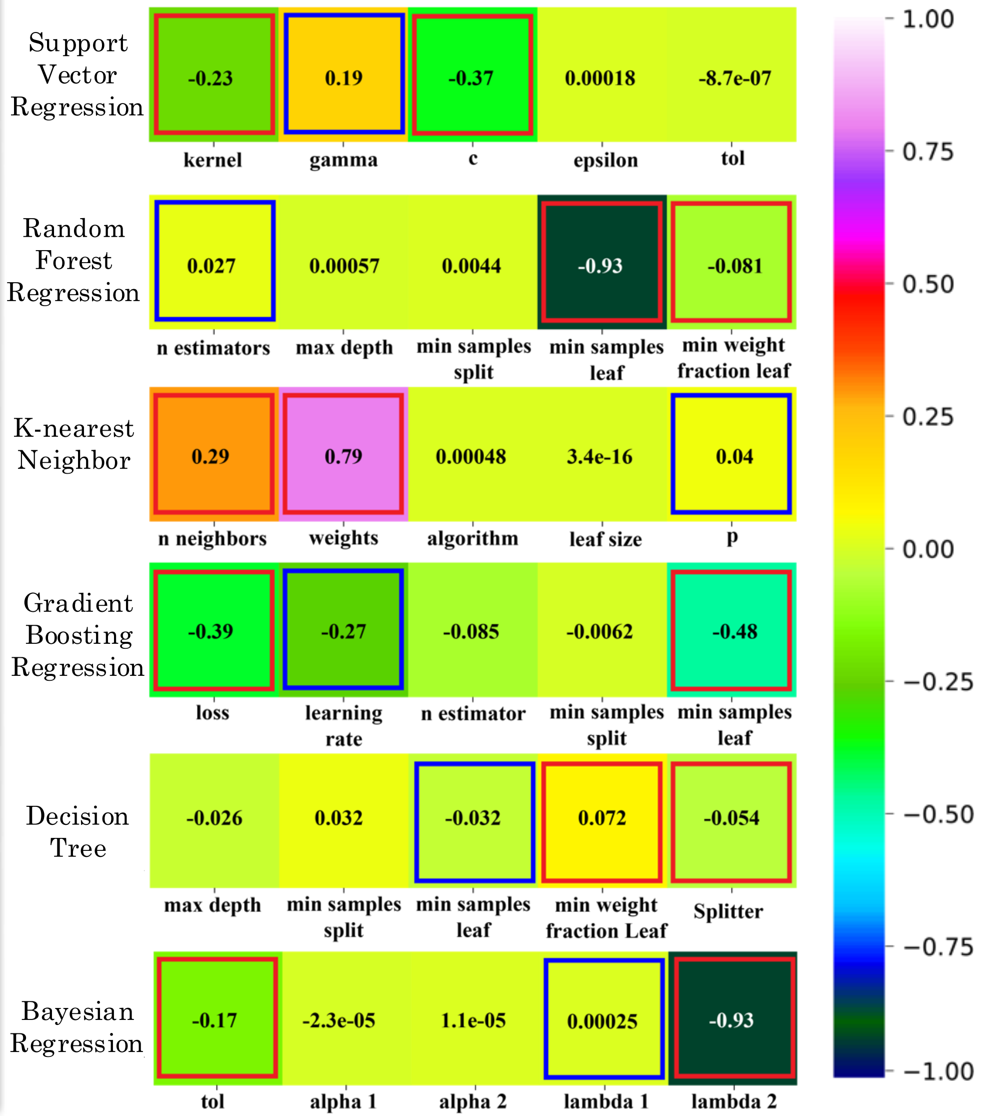
Politecnico di Torino

IAM Integrated Additive Manufacturing@PoliTo

IECME 2025 Conference

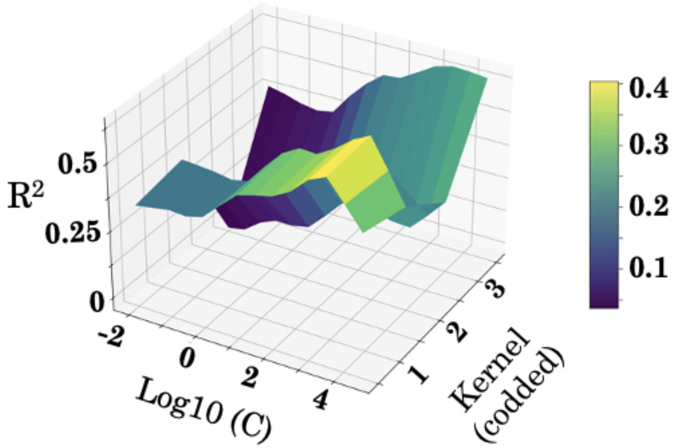
Result and Discussion

Effect of hyperparameters on prediction accuracy

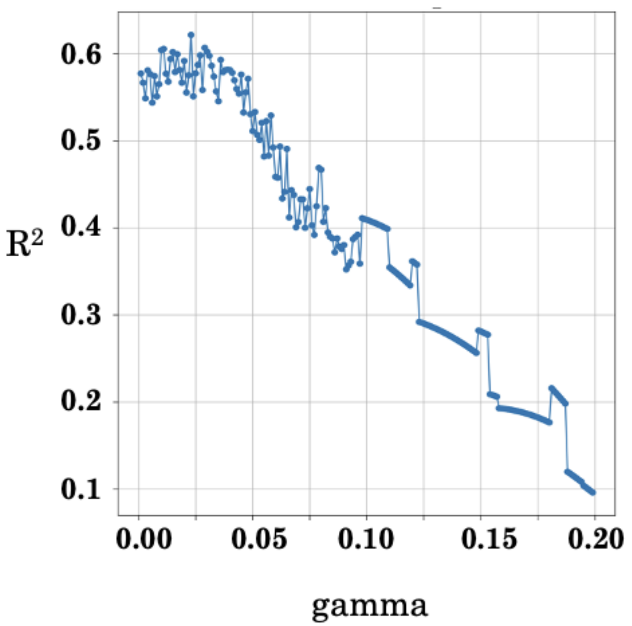


Support Vector Regression

R^2 score vs Kernel and C



R^2 score vs epsilon



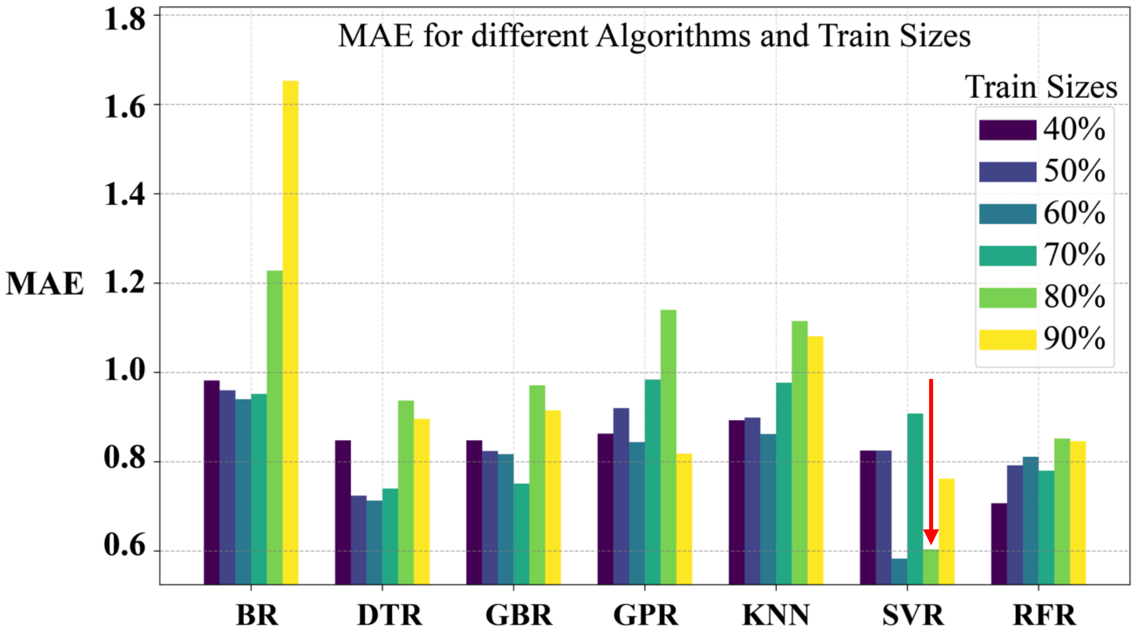
Politecnico di Torino

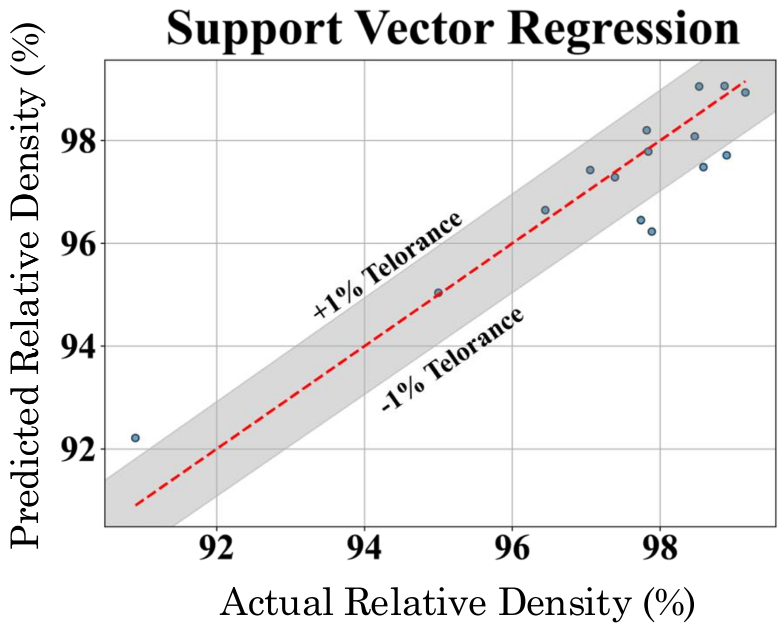
1859

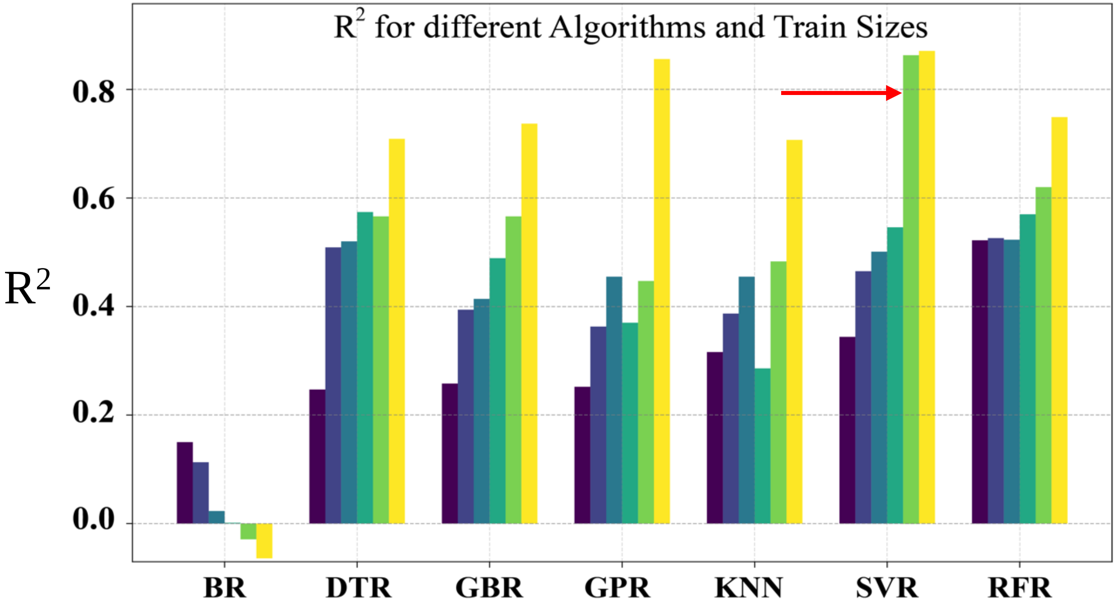
IAM Integrated Additive Manufacturing@PoliTo

IECME 2025 Conference

Result and Discussion



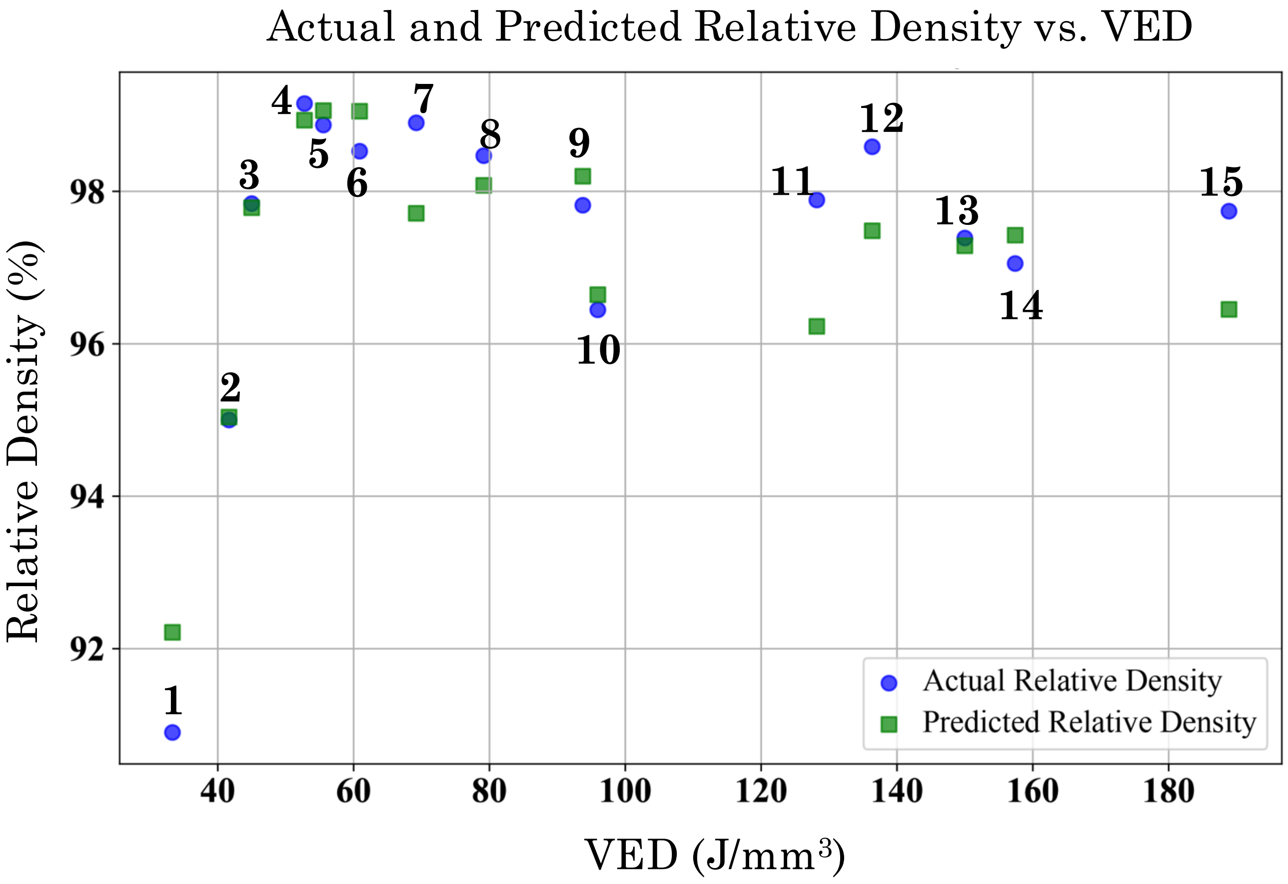




- R^2 or MAE **alone can not be considered** for comparison of prediction accuracy.
- Although the training size of 90% has the highest R^2, its MAE value is high.
- The **best algorithm** was **SVR**, with a training size of 80%.

Result and Discussion

Model Verification(Comparison of actual and predicted density using SVR at 80% training size based on VED)



N. point	Actual Relative Density (%)	Predicted Relative Density (%)	Error (%)
1	90.90	92.21	1.45
2	95.00	95.03	0.04
3	97.84	97.78	0.06
4	99.15	98.93	0.22
5	98.87	99.06	0.19
6	98.52	99.05	0.53
7	98.89	97.71	1.20
8	98.46	98.07	0.40
9	97.81	98.19	0.39
10	96.44	96.64	0.21
11	97.88	96.22	1.69
12	98.58	97.48	1.12
13	97.38	97.28	0.10
14	97.05	97.42	0.38
15	97.74	96.45	1.32

✓ **Average Error: 0.62 %**

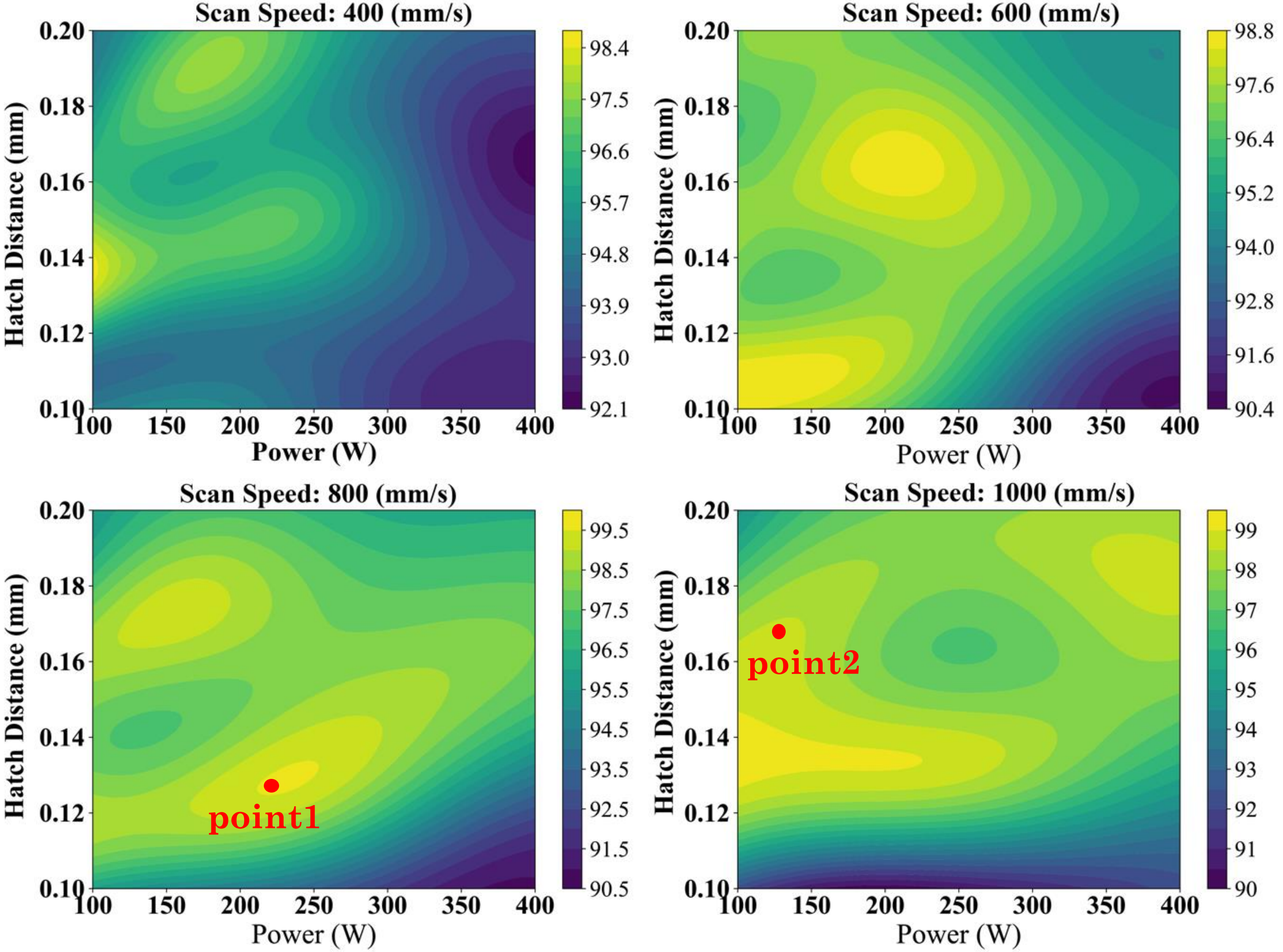
Politecnico di Torino

IAM Integrated Additive Manufacturing@PoliTo

IECME 2025 Conference

Result and Discussion

Process parameters defect content relationship



BR= v. h. t (productivity)

BR is build rate (mm^3/s)
v is speed(mm/s)
h is hatch distance (mm)
t is layer thickness(mm)

- Point 1

Porosity: 0.4%
productivity: 3.04 mm^3/s

- Point 2

porosity: 0.9%
productivity: 5.10 mm^3/s

Conclusions

1. ML techniques accurately predicted the relationship between process parameters and defect content and enhanced the building rate, thus addressing quality and productivity issues in the L-PBF process.

2. The SVR model (training size: 80%) was the best model for predicting the relationship between process parameters and defect content.

3. The SVR model achieved a 0.62% average error, demonstrating its reliability for optimizing process parameters in L-PBF and minimizing material waste.

Any Question!

Machine learning assisted material development via Laser powder bed fusion process

Alireza Moradi[1], Sanae Tajalli Nobari[2], Amir Behjat[3], Mohammad Taghian[3], Luca Iuliano[3,4], Abdollah Saboori[3,4]

[1] Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129 Torino, Italy
[2] Department of Applied Science and Technology, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129 Torino, Italy
[3] Department of Management and Production Engineering, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy
[4] Integrated Additive Manufacturing Center (IAM@PoliTo), Politecnico di Torino, Corso Castelfidardo 51, 10129 Torino, Italy