VII. Improving the Binder Jetting Gear Performance Through Shot Peening –

Matheus Rubik, M.Sc. (ITA)

Additive manufacturing through Binder Jetting (BJT) has emerged as a promising technique for the production of complex metallic components, including gears. However, its inherent porosity and heterogeneous densification pose significant challenges for surface integrity and contact strength. This work investigates the use of post-processing strategies to improve the load-carrying capacity of BJT parts, focusing on the application of shot peening as a dual action technique: increasing surface densification and inducing compressive residual stresses. An experimental campaign was conducted, covering the manufacture, post-processing and mechanical testing of specimens subjected to different process chains. Surface and subsurface characterizations, including porosity and residual stress profiles, were carried out to evaluate the effects of post-processing. The mechanical response was assessed using rolling contact fatigue tests . Weibull statistical analysis was used to compare the contact strength between the routes. The results show that shot peening significantly improves fatigue life by closing surface pores and introducing beneficial residual stress states, even in samples with relatively low initial density. This study contributes to a better understanding of the failure mechanisms associated with BJT and proposes a replicable post-processing strategy aimed at extending the service life of functional components manufactured in sub-optimal density conditions.

Improving the Binder Jetting Gear Performance Through Shot Peening

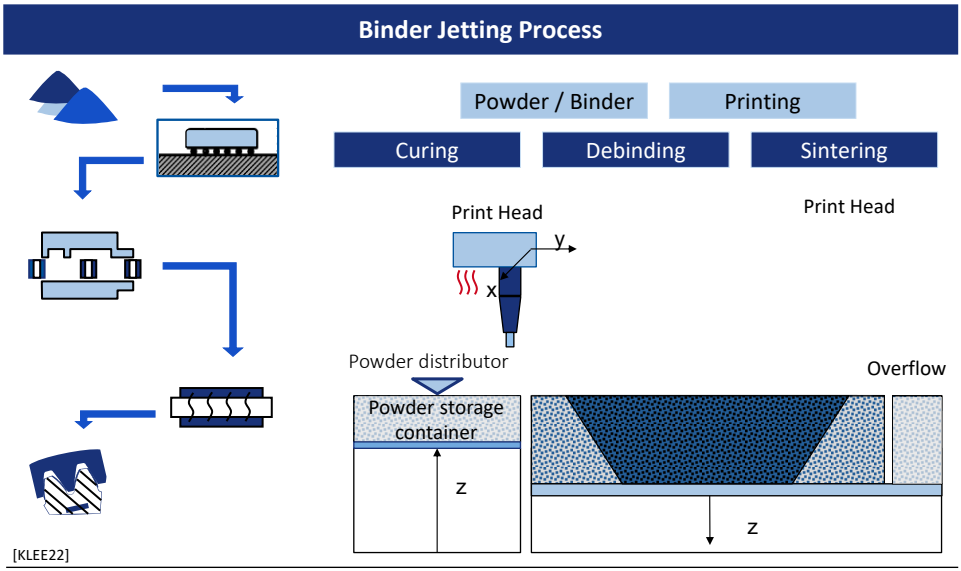
Matheus Rubik M.Sc. *(ITA)*

São José dos Campos, August 13th & 14th, 2025

Agenda

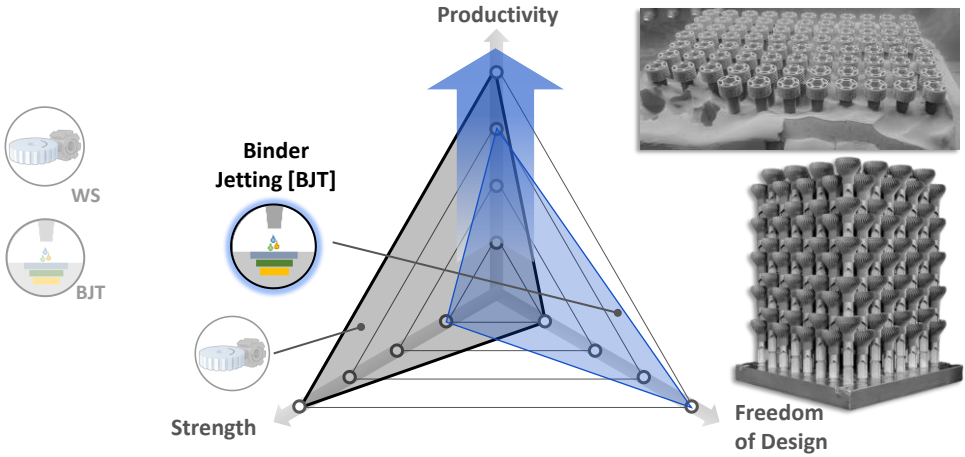
1. Introduction & Approach
2. Surface Properties Evaluation
3. Load Capacity Evaluation
4. Outlooks

Introduction: *Process Chain Binder Jetting*

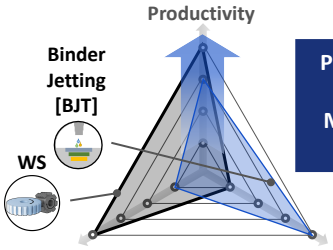


Binder Jetting: *Productive Efficiency*

- Demands of improvement in **design**, **strength** and **productiveness**.



Binder Jetting: *Technical Challenges*



Productivity Vs. **Mechanical behavior**

AM Process	Build Speed [cm³/h]	Build Density	Surface Finish
L-PBF (Direct)	**40**	99%	Good
BJT (Indirect)	2400	**60% to 99%**	**Avg.**

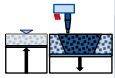
How to Improve Density?

Hot Isostatic Pressing | Shot Peening

	HIP	SP
Surface Density	~100%	>99%
Surface Pores	Unable	Suitable
Cost	High	Low to moderate
Application	High-value components	Scalability

Binder Jetting: *Testing Challenges*

Fatigue

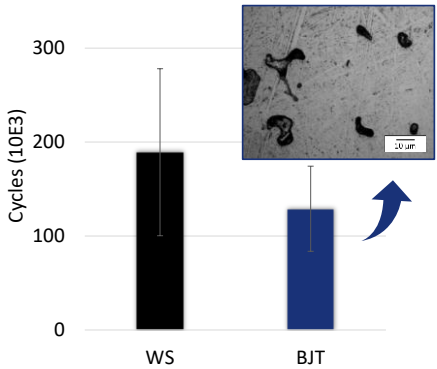


BJT Characteristic life [η] = **1.4E05**; Failure distribution [β] = **3.16**

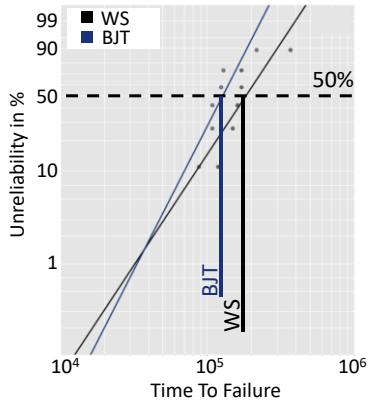
VS

WS Characteristic life [η] = **2.1E05**; Failure distribution [β] = **2.44**

Fatigue Life



Weibull Probability



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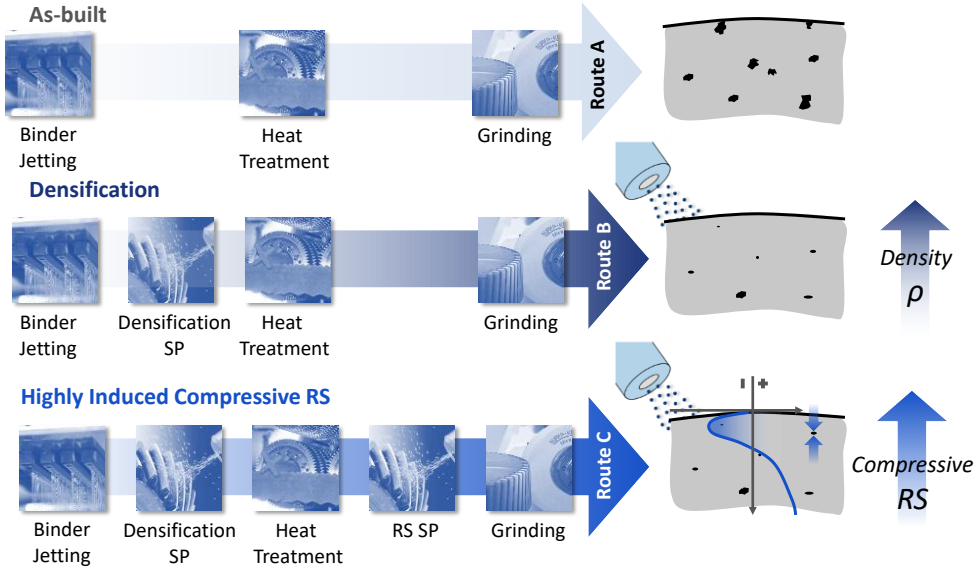
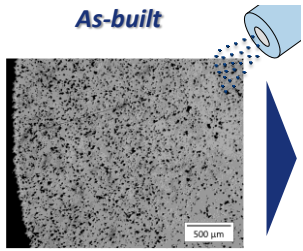
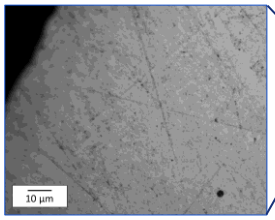
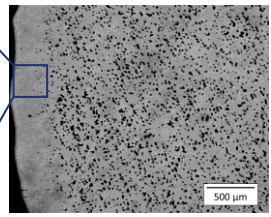
Failure Mechanism and Value-added Production Chain



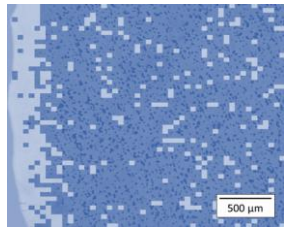
Shot Peening: *Densification*

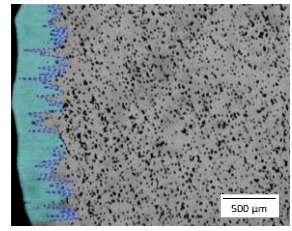






Density Analysis





MATLAB

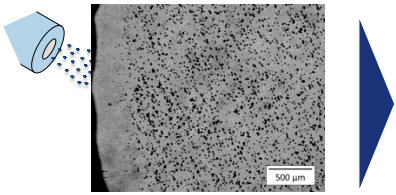
Density ≥ 99%
Density < 99%

Densification Depth - 348 µm

Morphology of the remaining pores

- **Small** and **isolated** pores.
- Improvement **aspect ratio** and reduction **equivalent diameter**.

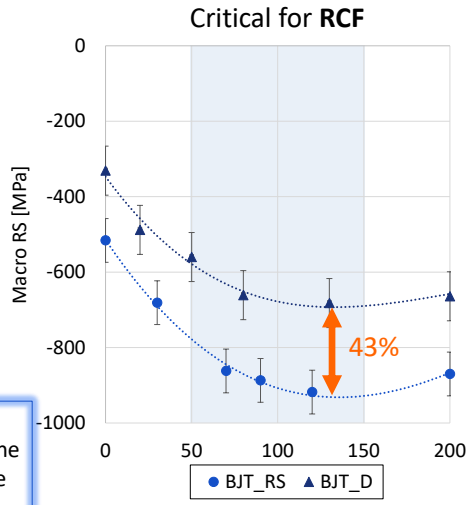
Shot Peening: *Residual Stress Induction*



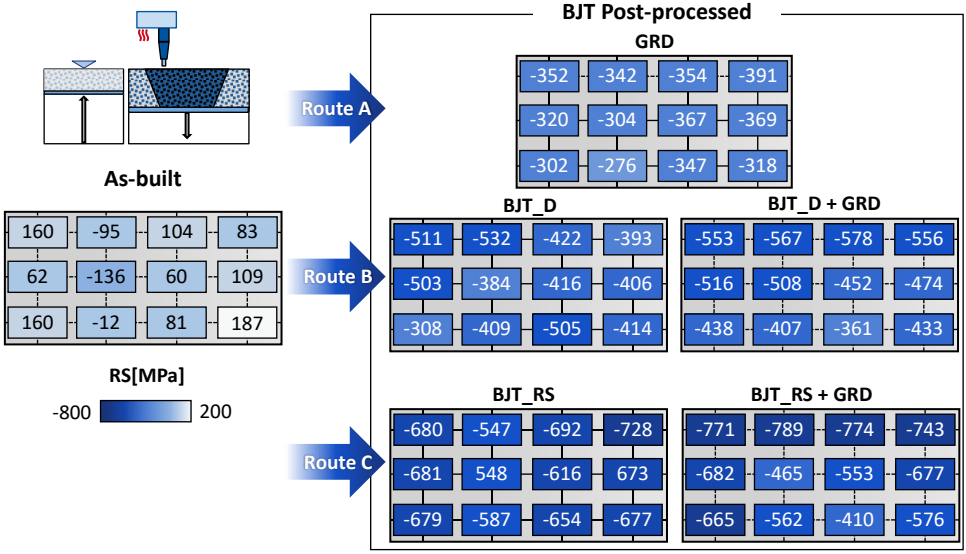
BJT_D	
Surface RS	-331 MPa
Maximum absolute RS	-682 MPa
Peak depth	130 µm

BJT_RS	
Surface RS	-516 MPa
Maximum absolute RS	-918 MPa
Peak depth	120 µm

Up to **43% compressive RS increase** in the critical region for rolling contact fatigue



Shot Peening: *Surface Residual Stress*



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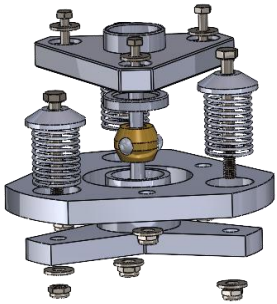
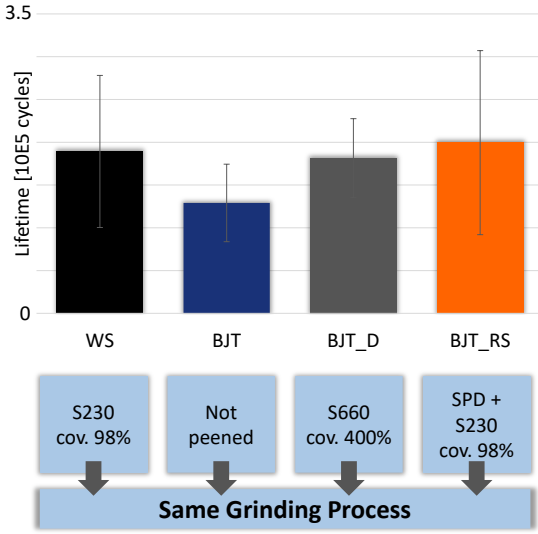
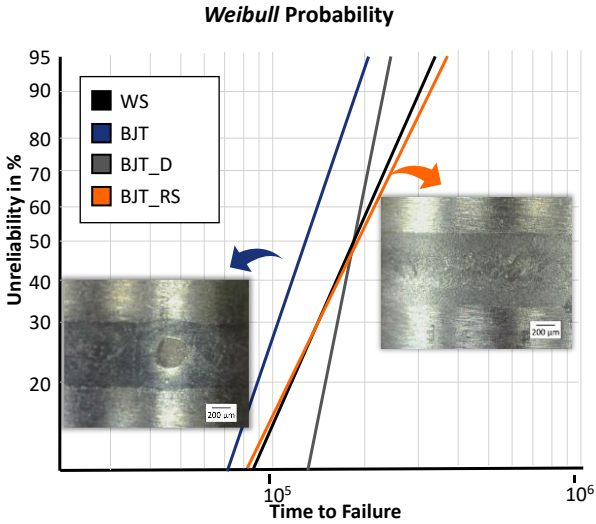
Dynamic Behavior Evaluation

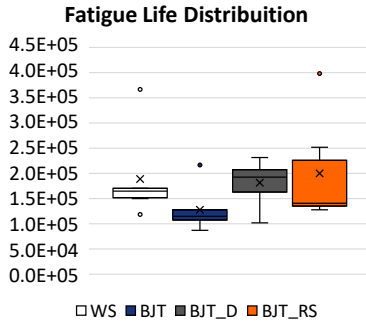
Process Parameters	
Normal load	100 N
Hertzian pressure	2.8 GPa
Rotation	3600 rpm
T_a	21 °C





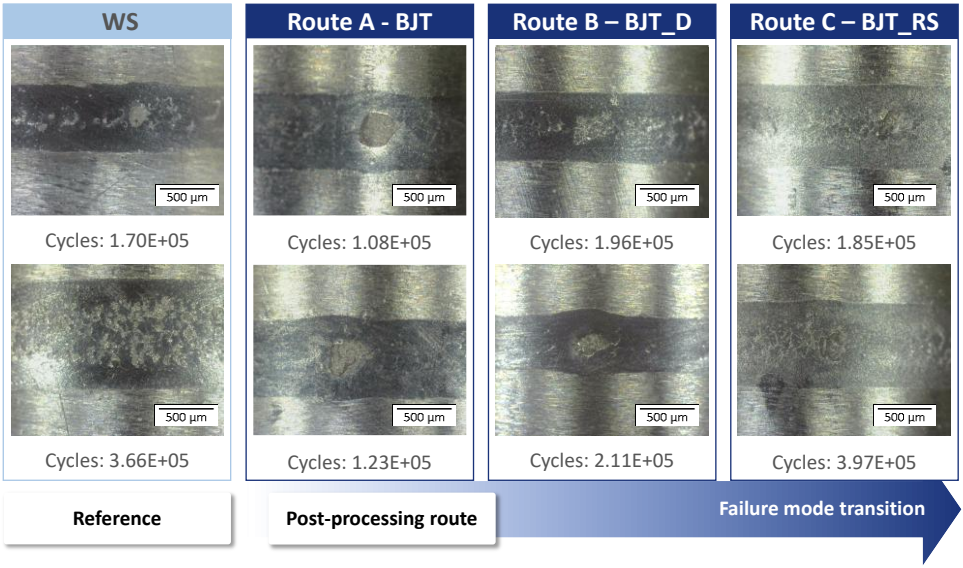
Dynamic Behavior Evaluation





On average, BJT_RS showed **54% higher fatigue life than BJT** and **surpassed WS** condition

Dynamic Behavior Evaluation*: Failure Mode*



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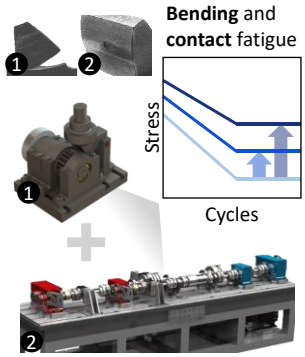
Outlook

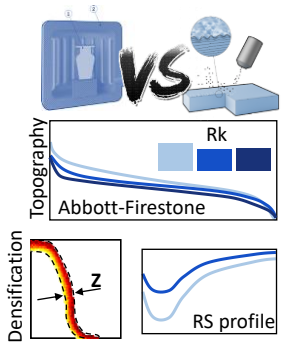
Dynamic Behavior

Explore residual stress compatibility and failure mechanisms in operational conditions



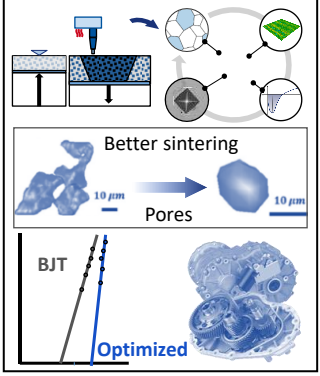
Processes Optimization

Tailoring SP and finishing for improve densification and compressive residual stress



Improved Deposition

Optimizing deposition and sintering to enhance part uniformity and scalability for e-mobility



Outlook