cbecimat26
26° Congresso Brasileiro de Engenharia e Ciência dos Materiais
22 a 26 de novembro de 2026
Costão do Santinho
Florianópolis-SC

Influence of WEDM parameters on the surface integrity of recycled NdFeB magnets from MagLev systems

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Introduction

The production of neodymium-iron-boron (NdFeB) permanent magnets (PMs), which are used in a wide range of applications, including motors and electronic devices, is primarily concentrated in China, which accounted for 94% of global sintered PM production in 2024 [1]. This technological dependence is a concern for Brazil, given the country's growing demand for PMs [2]. Furthermore, most end-of-life PMs are either disposed of in landfills or incinerated. In this context, PM recycling offers an alternative for reducing industrial dependence and mitigating the environmental impacts associated with rare earth elements (REEs). Additionally, NdFeB magnets are brittle and difficult to machine using conventional methods, making wire electrical discharge machining (WEDM) a promising alternative for processing this material.

Objective

The objective of this study is to evaluate the influence of WEDM cutting parameters on the surface integrity of end-of-life (EoL) NdFeB PMs, focusing on process-induced morphological changes and their implications for future investigations into material recovery and reuse.

Methodology

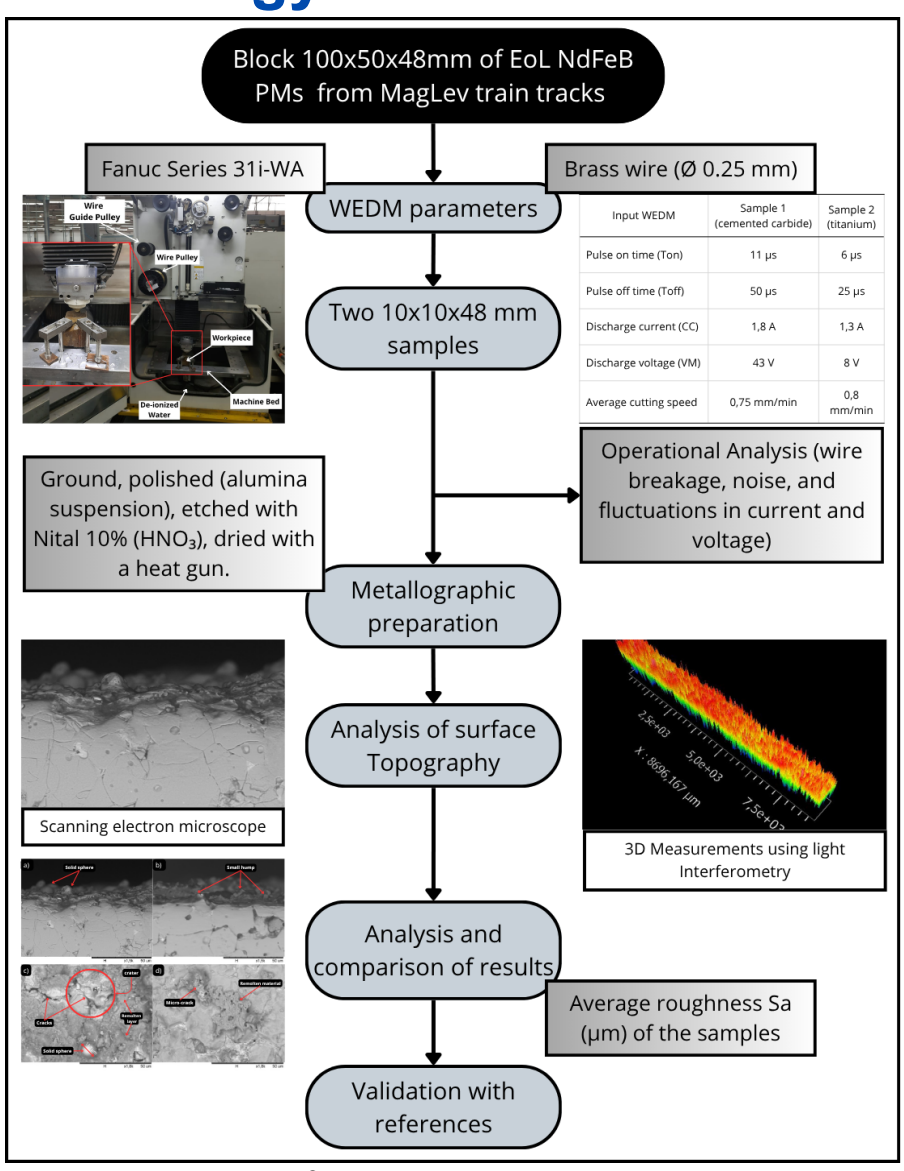


Figure 1. Flowchart of the experimental procedure and characterization steps.

Results and Discussion

- Sample 1 exhibited a thicker recast material on the surface than sample 2, which was machined using a lower Ton value (11 and 6 µs, respectively) (Fig. 2c-d). This difference may be attributed to the higher thermal energy associated with the longer pulse duration. This observation is consistent with Miller [3], who reported that higher Ton values result in a greater amount of remelted material;

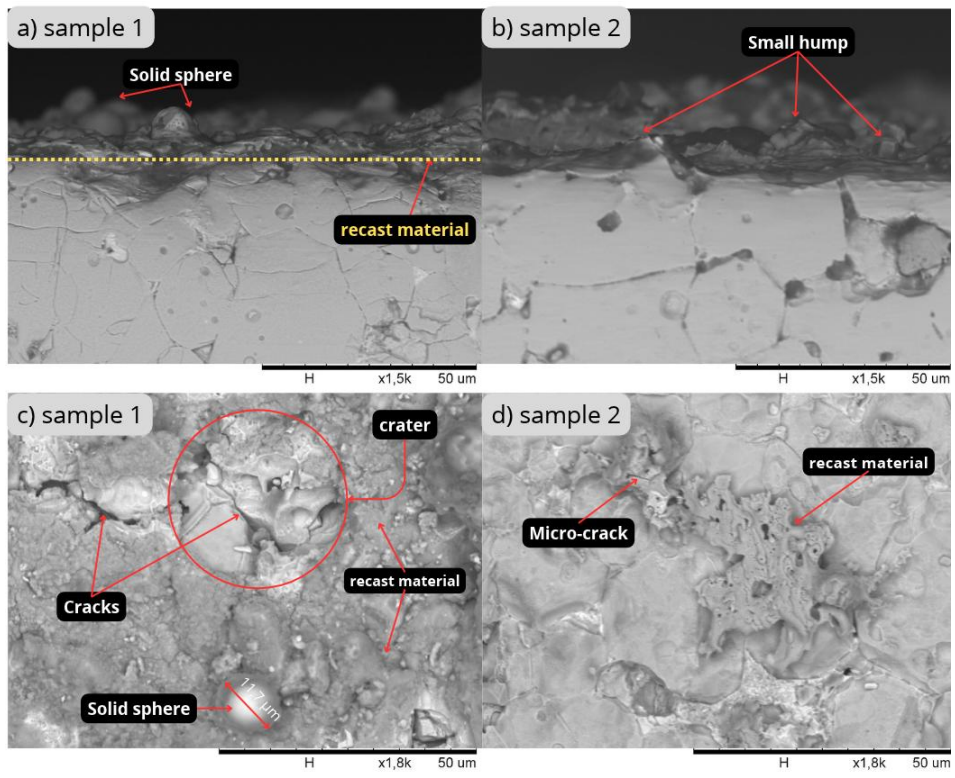


Figure 2. WEDM machined surface: a) cross-section - cemented carbide, vm = 0.75 mm/min; b) cross-section - titanium, vm = 0.8 mm/min; c) top view - cemented carbide; d) top view - titanium.

- The solidified spherical particles and small humps observed in the cross-sections of samples 1 and 2 (Fig. 2a-b) are associated with spark erosion and material redeposition, respectively, in agreement with previous findings [3];
- The surface images (Fig. 2c-d) also revealed a higher occurrence of microcracks in sample 1, which may be associated with increased thermal stresses resulting from its higher voltage and discharge current (43 V and 1.8 A, respectively), compared with sample 2 (8 V and 1.3 A, respectively).

Table 1. Measurement of the areal surface roughness (Sa) of the magnets before and after machining.

Conditions	Sa (µm)					µs	
	meas.1	meas. 2	meas.3	Avg.	SD	T_{on}	T_{off}
Unmachined Surface	12,81	17,23	12,09	14,04	2,78	-	-
Sample 1 - carbide	0,89	0,84	1,36	1,03	0,28	11	50
Sample 2 - titanium	3,87	3,64	3,65	3,72	0,13	6	25

Regarding surface roughness, sample 1 exhibited an average value of 1.03 µm, approximately 72% lower than that of sample 2 (3.72 µm), indicating a better surface finish [3, 4] (Table 1). This finding differs from the trend reported by Miller et al. [3], who observed that lower Ton values favor roughness reduction. In the present study, although sample 1 was machined using a higher Ton value (11 µs), it also had a higher Toff value (50 µs). This suggests that surface roughness may be influenced by the combined effects of these parameters rather than by Ton alone (Table 1).

Conclusions

The results demonstrate the potential of WEDM as a conditioning step for end-of-life permanent magnets in direct recycling processes. The removal of recast material through grinding appears to be a promising approach to improving surface quality. However, further investigations are required to assess the effectiveness of this approach in preserving surface integrity and the magnetic properties of the material.

References and Acknowledgments

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