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

Tribological improvements from friction stir processing in cast and thixoformed aluminum–niobium carbide composites

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Introduction

A380 is one of the most used high-pressure die-casting alloys, but coarse α-Al dendrites, porosity and acicular β-Al_5FeSi limit its sliding wear resistance. **NbC** particles add hardness without forming Al_4C_3, **thixoforming** produces a globular, less porous matrix, and **friction stir processing (FSP)** refines the surface by severe plastic deformation. FSP studies usually start from dendritic cast structures; how a globular starting matrix changes the FSP response of A380/NbC is still unknown.

Objectives

- Assess how the initial route (as-cast or thixoformed) conditions the response of A380/NbC to FSP
- Quantify the effect of NbC content (0, 5 and 15 wt.%) on stir-zone (SZ) structure and hardness
- Relate hardness, friction and wear volume to the wear mechanisms

Methodology

- **Composites:** stir casting at 750 °C, 400 rpm for 5 min, with 0, 5 and 15 wt.% NbC
- **Thixoforming:** 562 °C (~60% solid), 90 s hold, 90 MPa
- **FSP:** H13 tool (Ø12 mm shoulder, Ø3 × 4 mm pin), 1176 rpm, 42 mm/min, 2° tilt, single pass
- **Characterization:** OM, SEM-EDS and transverse HV0.05 profiles (ASTM E384)
- **Wear:** ball-on-flat reciprocating test (ASTM G133, modified), AISI 52100 ball, 5 N, 5 Hz, 120 m, dry
- **Design:** 2 routes × 3 NbC contents × 2 FSP states, n = 3, factorial ANOVA

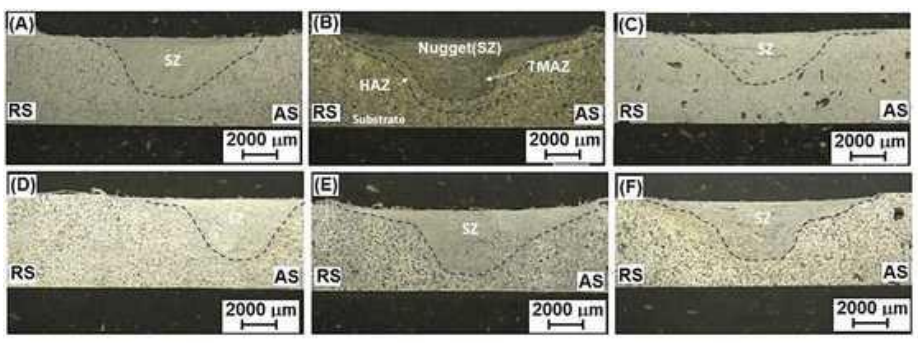

Figure 1. Transverse sections after FSP: (A) C0, (B) C5, (C) C15, (D) T0, (E) T5, (F) T15 (C = as-cast, T = thixoformed).

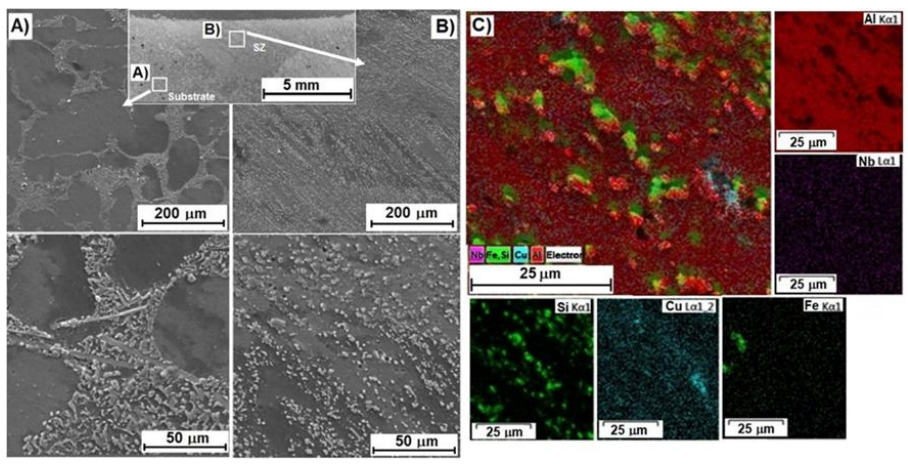

Figure 2. SEM micrographs and EDS maps of T5-FSP

Results and Discussion

- FSP refined the SZ in both routes; Nb was redistributed more uniformly in thixoformed samples (Fig. 2)
- T15-FSP reached **207 HV0.05** in the SZ, about twice the surrounding material; C15-FSP showed no consistent hardening (Fig. 3)
- Mean COF stayed between 0.54 and 0.67 and did not correlate with wear volume (r = 0.09)
- Wear depended on route × NbC × FSP (p = 0.019): at 15 wt.% NbC, FSP **cut wear 27%** after thixoforming but raised it 39% as-cast (Fig. 4)

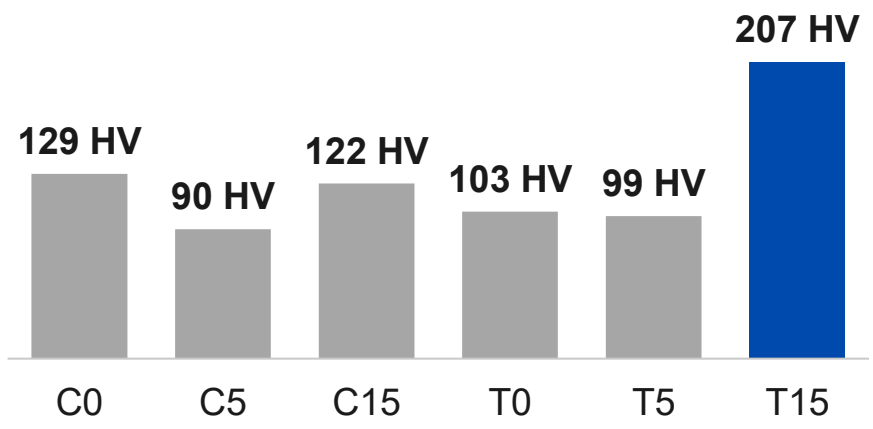

Figure 3. Stir-zone microhardness after FSP, HV0.05 (mean of 3 profiles)

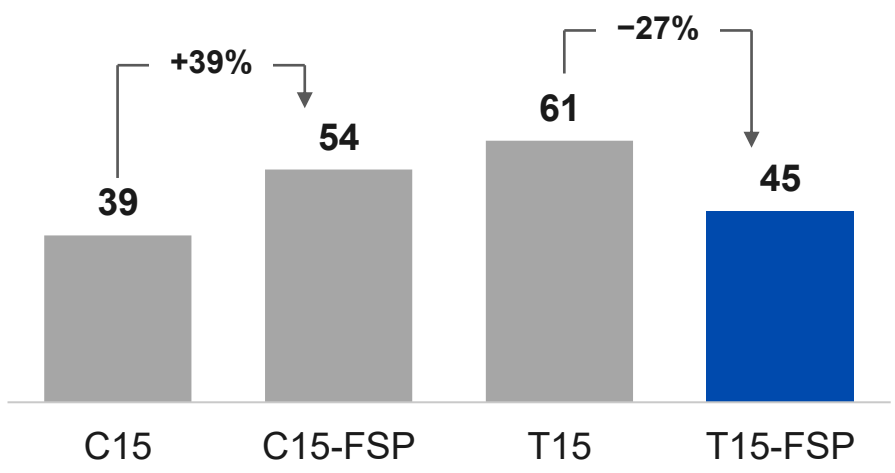

Figure 4. Wear volume at 15 wt.% NbC without and with FSP, 10^{-3} mm³

Conclusions

- The FSP response of A380/NbC depends on the substrate microstructure, not on NbC content alone
- **Thixoforming + 15 wt.% NbC + FSP** gave the highest SZ hardness and the lowest wear volume among processed conditions (0.0446 mm³).
- Mean COF does not predict material loss: wear gains come from hardness and load support, not lower friction
- Worn surfaces move from deep abrasive-adhesive grooves (C0-, C15-FSP) to shallow grooves and a compacted tribolayer (T15-FSP)

References and Acknowledgments

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Acknowledgments: C²MMa Multi-user Laboratory (UTFPR, Ponta Grossa) and CAPES, Finance Code 001.