Journal of Materials Research and Technology 42 (2026) 12209–12231

Contents lists available at ScienceDirect

Journal of Materials Research and Technology

journal homepage: www.elsevier.com/locate/jmrt

In-situ carboboride-reinforced metal matrix composites via spark plasma sinterning-laser surface melting hybrid processing: Microstructure and wear behavior

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ARTICLE INFO

Keywords:
Spark plasma sintering
Laser surface melting
Heat treatment
Multi-component alloy
Carboboride/martensite composites
Microstructure
Microhardness
Sliding wear

ABSTRACT

This study compares the microstructure, hardness, and dry-sliding wear behavior of a new multicomponent Fe–C–B–W–Mo–V–Cr–Ti carboboride/metal (martensite) matrix composite fabricated via spark plasma sintering (SPS) and laser surface melting (LSM), against its sand-cast reference – multicomponent cast iron (MCCI). The SPS/LSM specimens exhibited a 1 mm thick, porosity-free surface layer with a hierarchical composite microstructure. This layer consists of hard eutectic colonies ("Chinese script" (CS) and ledeburite) and equiaxed (Ti, W)-rich multiphase carboboride/C–O–N inclusions within a martensitic matrix. Internally, the CS colonies consist of interconnected $(W,Mo,Cr,V)_2(B,C)_5$ eutectic plates branching within the local martensitic matrix, whereas the ledeburite colonies consist of a matrix of $(Fe,Cr,W,Mo,V)_2(C,B)$ plates penetrated by fine martensitic rods. Although similar to MCCI in morphology and phase composition, the SPS/LSM structure was notably refined. Heat treatment (HT) of the SPS/LSM specimens (annealing at 1150 °C for 2 h followed by oil quenching) increased matrix carbon, retained austenite volume fraction and dislocation density, and induced alloying element redistribution between microconstituents. The SPS/LSM composite outperformed MCCI in dry-sliding wear resistance (1.7 times as-fabricated, 1.5 times post-heat treated). Laser melting and post-heat treatment increased the wear resistance of the SPS alloy by a factor of 3.2. The SPS/LSM and SPS/LSM/HT composites wore through low-cycle fatigue, with limited microcracking and delamination, abrasion and surface oxidation. In contrast, MCCI exhibited severe surface deterioration characterized by extensive plastic flow and lateral build-up formation, which preceded material removal.

Abbreviations

BCC	Body-Centered Cubic
BSE	Backscattered Electrons
CoF	Coefficient of Friction
CS	Chinese Script
EBSD	Electron Backscatter Diffraction
EDX	Energy-Dispersive X-ray spectroscopy
EPMA	Electron Probe Microanalysis
FCC	Face-Centered Cubic
GND	Geometrically Necessary Dislocations
HAGB	High-Angle Grain Boundary
HEA	high-entropy alloy
HT	Heat Treatment
KAM	Kernel Average Misorientation
LPBF	Laser Powder Bed Fusion
LSM	Laser Surface Melting
MCCI	Multi-Component Cast Iron
MMC	Metal Matrix Composite
SC	Sand-Cast
SE	Secondary Electrons
SEM	Scanning Electron Microscopy
SPS	Spark Plasma Sintering
XRD	X-ray Diffraction

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https://doi.org/10.1016/j.jmrt.2026.06.038
Received 25 March 2026; Received in revised form 23 May 2026; Accepted 3 June 2026
Available online 4 June 2026
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