Supplementary Information

Tribological study of Fe-Cr alloys for mechanical refinement in a corn stover biomass environment

Nicholas Brooks[1], Luke Brewer[2], Ali Beheshti[3*], Keivan Davami[1*]

[1] Department of Mechanical Engineering, University of Alabama, Tuscaloosa, AL, 35487, USA
[2] Department of Metallurgical Engineering, University of Alabama, Tuscaloosa, AL, 35487, USA
[3] Department of Mechanical Engineering, George Mason University, Fairfax, VA, 22030, USA

[*]Corresponding Authors: Ali Beheshti (abehesh@gmu.edu); Keivan Davami (kdavami@eng.ua.edu)

S1. Energy Dispersive Spectroscopy Analysis

Additional analysis of the wear tracks following wet and dry pin-on-disk wear tests of one of the Fe-Cr alloys (420 stainless steel) was performed using energy dispersive spectroscopy (EDS) to identify the distribution of alloying elements and to confirm the existence of carbides within the wear tracks. Prior to EDS analysis, electric discharge machining (EDM) was used to cross-section the wear test specimens. The cross-sectioned specimens were then mounted in a conductive resin and ground and polished using the same metallographic procedures indicated in Section 2.1 of the manuscript. Additionally, to ensure removal of the passive film prior to EDS analysis, specimens were polished with 1 µm diamond suspension just before they were put into the SEM vacuum chamber.

EDS analysis was performed at a beam voltage of 20 keV and a beam current of 3.2 nA with the specimen located at a working distance of 11 mm from the pole piece. EDS elemental maps included in **Figs. S1(a-b)** were obtained using a dwell time of 75 µs for a total of 12 frames at a magnification of 8000X. EDS spot scans shown in **Figs. S2** and **S3** were obtained using the same beam conditions and working distance at a magnification of 6500X. A total of 8 scans were performed at different locations on each specimen, with 5 scans shown for each specimen in **Figs. S2** and **S3**.

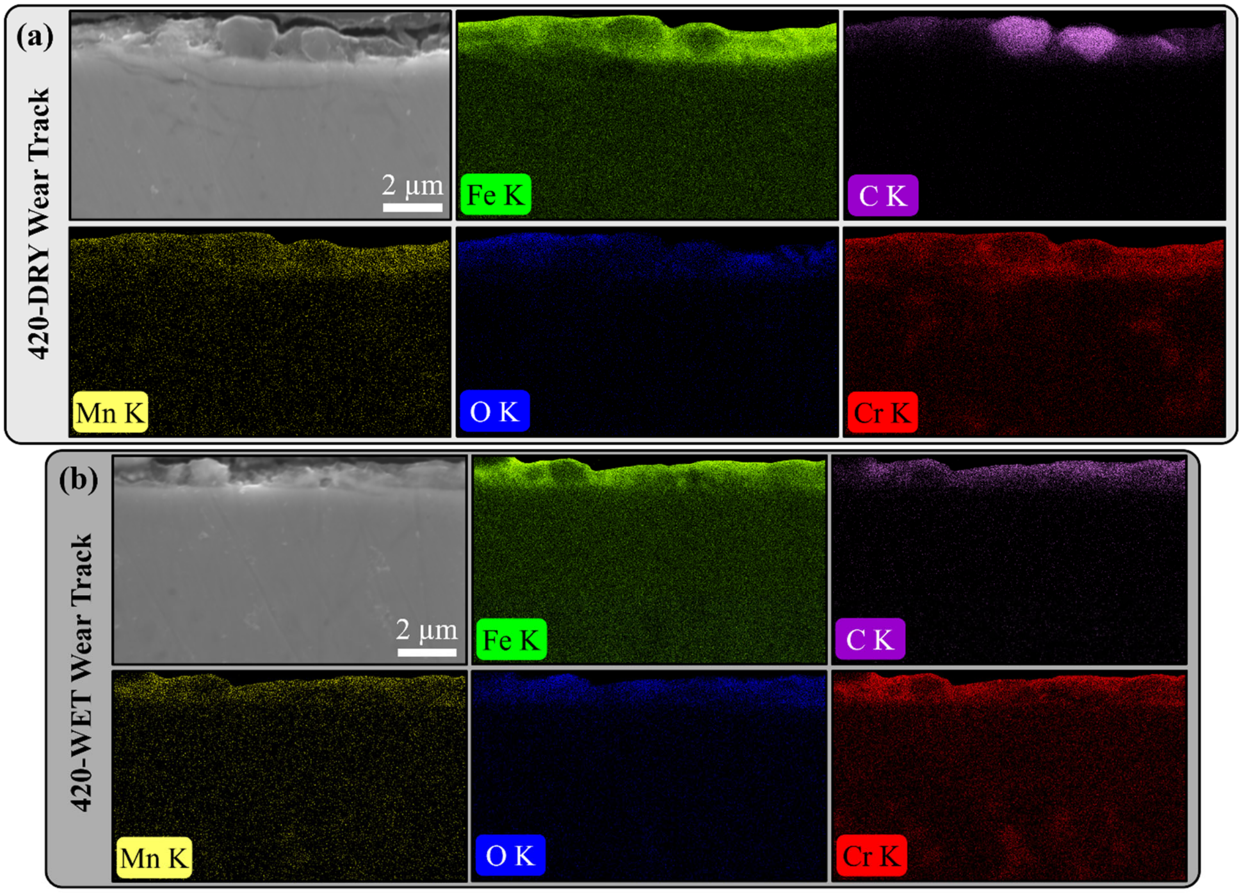

Fig. S1. *EDS maps obtained from the cross-sectioned wear tracks of the 420 stainless steel specimens following (a) dry and (b) wet pin-on-disk wear tests. Mounting material on top of maps was blacked out in EDS maps to prevent confusion.*

Elemental maps shown in **Figs. S1(a)** and **S1(b)** include the primary alloying elements in the 420 stainless steel (Fe, Cr, C, and Mn), and O to identify the Cr-rich passive oxide film. This specimen was chosen for the analysis since it has a Cr content in-between those of the 410 and 440C stainless steels to be representative of all three Fe-Cr alloys investigated in this study. Observing the EDS maps in **Figs. S1(a)** and **S1(b)** for the 420 stainless steel specimens tested in both wet and dry conditions, it can be seen that C is present within the wear tracks. An especially localized high concentration of C can be observed on the wear track in **Fig. S1(a)** suggesting the presence of carbides. In addition, carbide forming elements (Fe, Cr, and Mn which form M_7C_3 and $M_{23}C_6$ carbides in Fe-Cr alloys [48, 49]) are also present. The high amounts of Cr and O within the wear tracks, near the exposed surface of the specimens, also show the existence of the Cr-rich passive oxide film which often forms on Fe-Cr alloys when exposed to an oxidizing environment [22, 23, 24].

Additional EDS spot scans were performed within this region of the wear tracks of the 420 stainless steel specimens tested in wet and dry conditions. The results from these spot scans corroborate the data shown in the EDS maps.

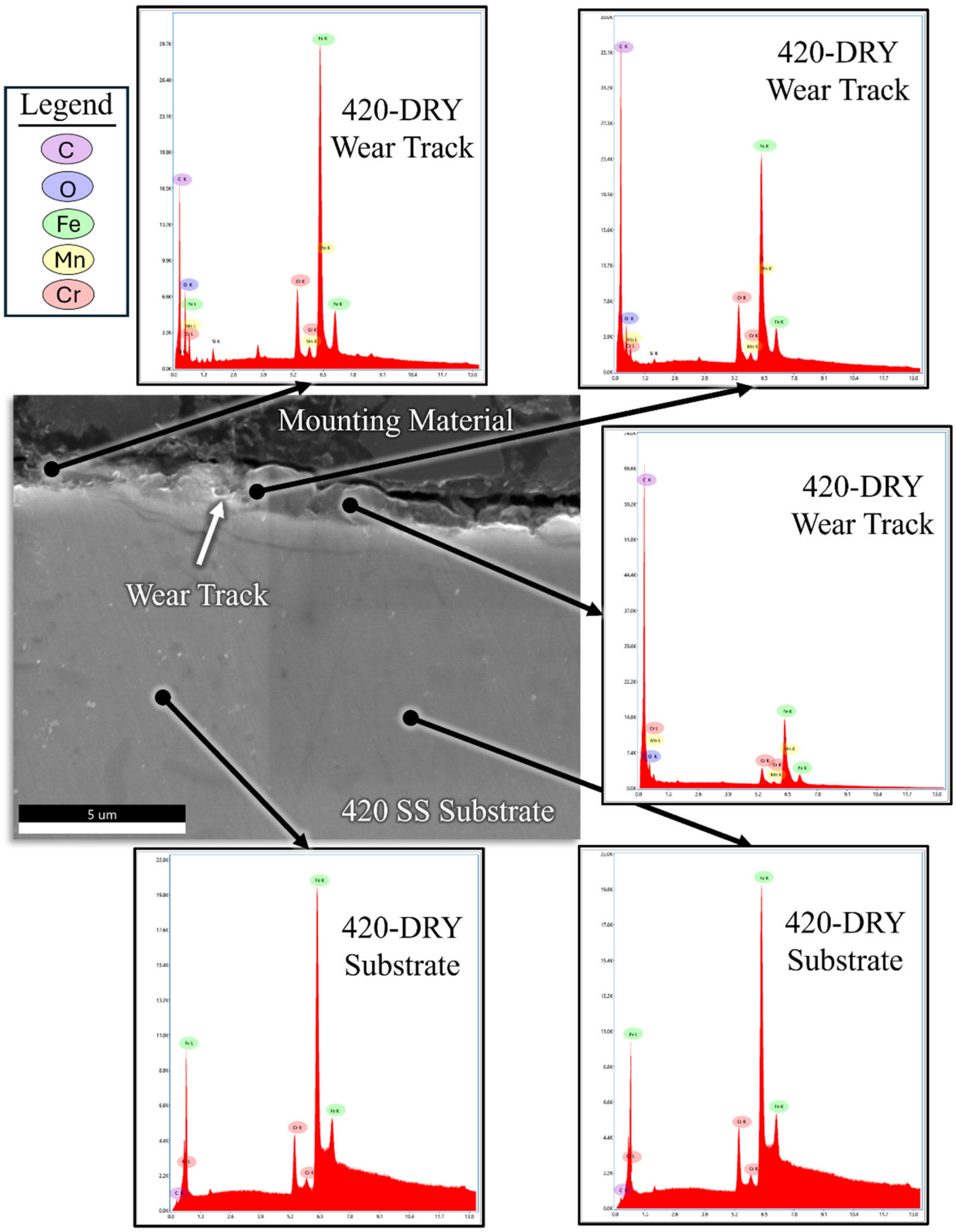

Fig. S2. *EDS spot scans obtained from the cross-sectioned wear tracks of the 420 stainless steel specimens following dry testing. Colored bubbles indicate elements which were included in EDS map scans.*

X-ray emission lines corresponding to the elements shown in the EDS maps in **Fig. S1** are highlighted in their respective colors in **Figs. S2** and **S3**. Spot scans included in **Fig. S2** which were performed within the cross-sectioned wear track show the existence of C in addition to carbide forming elements like Fe, Cr, and Mn. Comparing the spectrum obtained from locations within the wear track to those obtained from the substrate of the 420 stainless steel, it can be seen that the C peaks are much less pronounced in the substrate with only primary alloying elements like Fe, Cr, and Mn being clearly observed from the spectrum. This again signifies the existence of carbides on the wear track. Similarly, the same conclusion can be drawn for the scans included in **Fig. S3** which were obtained from the wear track 420 stainless steel specimen tested in the wet condition. The high concentration of C on the wear track and relatively lower concentration of C in the substrate can be observed.

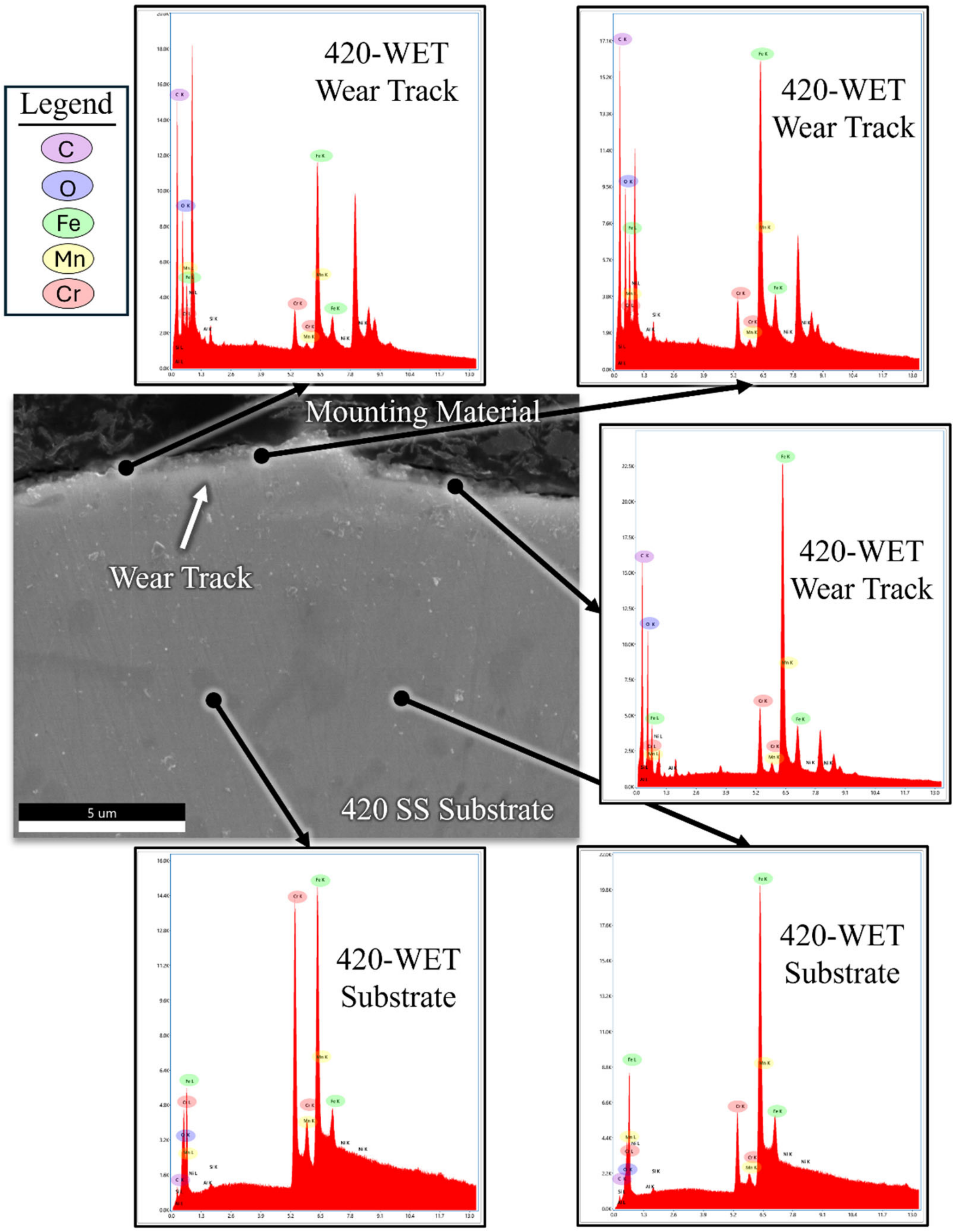

Fig. S3. *EDS spot scans obtained from the cross-sectioned wear tracks of the 420 stainless steel specimens following wet testing. Colored bubbles indicate elements which were included in EDS map scans.*

References for Supplementary Information (Same numbering as manuscript)

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