Improving Biomass Comminution Performance by Optimizing Tool Design and Using Advanced Tool Materials

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This study intends to address the tool wear issue for the Crumbler® rotary shear biomass comminution system by optimizing the tool design and using advanced tool materials. The tool wear mechanism was first investigated based on tribo-system analysis and worn component characterization. Finite element analysis was used to guide the tool geometry optimization. Candidate tool alloys, coatings, and surface treatments were selected and screened by 2-body abrasion tests. Prototype tools are in process to be produced and the comminution performance and tool life will be tested in an actual rotary shear system.

Keywords: biomass comminution, tool wear, finite element analysis, coating

1. Introduction

A new biomass comminution system, Crumbler® rotary shear (see Fig. 1), had been developed to process fuel grade wood chips. The rotary shear is more efficient than the traditional hammer mill in comminuting high moisture biomass and producing narrow particle thickness distributions, low aspect ratios, and minimal fines. [1] However, the milling unit experiences significant abrasive wear in processing hard and dirty biomass. Figure 1 shows example worn components.

This study investigated the tool wear mechanisms and addressed the wear issues by using improved tool design and wear-resistant tool materials.

Figure 1: Crumbler® rotary shear biomass comminution system and its worn components.

2. Methods

Finite element analysis (FEA) was used to determine the range of contact pressure at the tool-biomass interface to guidance the design improvement. Selected worn components were characterized using optical and electron microscopic imaging, EDS elemental mapping, and microindentation. Two-body abrasion tests (ASTM G174-03) were conducted on baseline and candidate tool materials using a 30 µm-girt Al_2O_3 tape.

3. Results and Discussion

The dominant wear mechanisms have been determined to be 2-body/3-body abrasive wear plus adhesive wear for the soft copper alloy clearing plate and chipping for the cutting edge of the hard tool steel cutters. Based on FEA, processing hardwood chips likely results in a high contact pressure, e.g., up to 724 MPa for 12% moisture yellow Birch. The 2-body abrasion test results showed more than 2 and 4 times better wear resistance by using the D2 and M2 tool steel, respectively, to replace the current A2 tool steel (see Fig. 2). A diamond like carbon (DLC) coating has shown a potential to improve the wear resistance by three orders of magnitude.

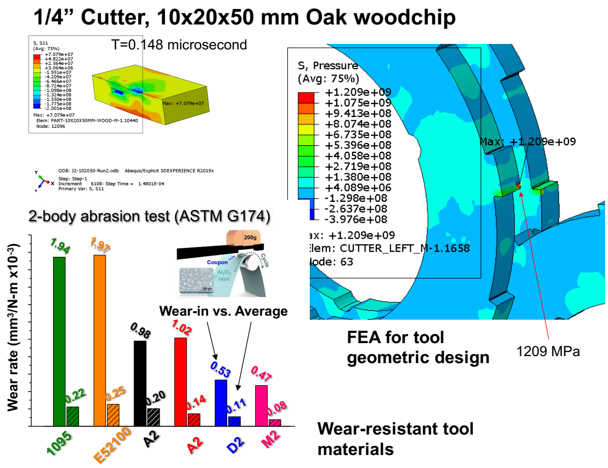

Figure 2: FEA dynamic simulation of the cutter-biomass interface and comparison of wear results of the baseline and candidate tool materials in a 2-body abrasion test.

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4. References

[1] Oyedeji, O., et al., "Understanding the impact of lignocellulosic biomass variability on size reduction process: a review," *ACS Sustainable Chemistry & Engineering*, 8, 2020, 2327-2343.