I/UCRC Executive Summary - Project Synopsis	**Date**: April 2022
Center/Site: CANFSA/Colorado School of Mines	
Tracking No.:62B: Maximizing Scrap Recycling by Designing Cu Tolerant Steel Compositions	**E-mail :** hgeerlings@mines.edu **Phone :** (805) 754–6622
Center/Site Director: CANFSA/M. Kaufman/P. Collins/A. Clarke	**Type: (Continuing)**
Project Leader: Henry Geerlings, Lionel Promel	**Proposed Budget**: CANFSA

Project Description: This project aims to increase the amount of recycled scrap steel allowed in several electric arc furnace (EAF) steel products by expanding the tolerance of hard to remove residual elements such as copper and tin. At high enough concentrations, residuals can cause enrichment of copper-rich liquid at the steel-scale interface due to rejection from the oxide layer, causing grain boundary penetration and subsequent cracking within the austenite during hot working, i.e. "hot shortness". By modeling thermomechanical processing (TMP) routes and corresponding damage, this work intends to broaden the amount of residual copper within EAF steels while mitigating hot shortness, leading to increased savings and decreased energy consumption for steel suppliers and producers.

Experimental plan: Material for the four EAF steel products (low carbon sheet, low carbon plate, medium carbon bar, and high carbon wire) is being procured from industry partners. Hot shortness damage is to be assessed as a function of residual element composition for several relevant processing routes, including Gleeble thermomechanical simulations, dilatometry, and hot rolling. This process has begun for existing medium carbon bar material with copper concentration ranging from 0.21 – 0.38 wt.%. Gleeble samples have been machined and dilatometry samples are currently being prepared. Compositional makeup, processing parameters, and hot shortness assessments will be used to populate a database that can then be used to establish correlative relationships and predictive models of hot shortness susceptibility.

Related work elsewhere: Environmental and techno-economic assessments of the steel scrap cycle have been published out of University of Cambridge. The effects of alloying additions such as nickel, tin, and silicon, have been studied and published from Carnegie Melon University. Previous work here at Colorado School of Mines quantified the relationship between oxidation time/temperature on hot shortness in the Gleeble. This last study is in fact where the medium carbon barstock has been procured from.

How this project is different: While many studies have focused on the effects of specific alloy additions or oxidation studies within a specific steel alloy, this project is more holistic in approach, with a scope ranging from scrap supply chain analysis and casting, all the way to subsequent processing (e.g. weldability, hardening, annealing behavior) and predictive modeling. This study also targets a wide range of carbon compositions and product forms.

Milestones for the current proposed year: Draft review paper on hot shortness during TMP. Complete design of experiments for steel products. Verify experimental results with ThermoCalc simulations.

Deliverables for the current proposed year: Procure remaining steel products from industry partners. Gather dilatometry and Gleeble results from medium carbon bar product. Help establish damage metric and process featurization for modeling efforts.

How the project may be transformative and/or benefit society: Increasing the amount of residual copper permissible in EAF recycled steels will drastically lower both cost and carbon footprint of steel manufacturing by avoiding existing energy-intensive methods, including pig iron dilution.

Research areas of expertise needed for project success: Representative TMP conditions seen in industry that can be emulated on Gleeble. ThermoCalc and liquid phase modeling; data analytics.

Potential Member Company Benefits: Hot shortness is not necessarily specific to steels. While granting reduced cost and pollution for steel producers, this work may speak to liquid metal embrittlement more generally while establishing data best practices for similar studies.

Progress to Date: Medium carbon barstock obtained, chemically analyzed, and machined for dilatometry and Gleeble TMP simulations. Gleeble experimental setup in the works. Medium carbon plate obtained by Vallourec, chemical analysis under way. Literature review ongoing, with review paper scaffolded.

Estimated Start Date: Fall 2021	**Estimated Knowledge Transfer Date**: Fall 2024