I/UCRC Executive Summary - Project Synopsis	Date: March 2019

Center/Site: CANFSA/Colorado School of Mines

Tracking No.:31: Accumulative Roll Bonding of Al and Ti Sheets Toward Low Temperature Superplasticity	**Phone:** (503)866–6530	**E-mail:** bmcbride@mines.edu

Center/Site Director: CANFSA/M. Kaufman/P. Collins/A. Clarke	**Type: (Continuing)**
Project Leader: Brady McBride	**Proposed Budget**: $240,000 Leveraged

Project Description: Accumulative roll bonding (ARB) is a severe plastic deformation technique used to produce ultrafine grained materials with a convention rolling mill. This processing technique has shown significant Hall-Petch strengthening behavior and enhanced superplastic formability. Materials subject to ARB exhibit typical superplastic behavior at reduced temperatures and increased strain rates, which has the potential to significantly impact the cost and processing time of superplastic sheet forming. This project investigates the temperature dependence of superplastic forming of materials produced using ARB.

Experimental plan: An ARB process will be developed at the Colorado School of Mines with existing equipment to gain a fundamental understanding of the process using aluminum alloys. Multiple alloys of work-hardenable 5xxx series aluminum will be investigated to see if composition and initial microstructure have an effect on grain refinement in the ARB process. The mechanical properties of ARBed material will be characterized at room and elevated temperatures to explore strengthening and superplastic responses. Microstructural evolution, texture and bonding interface development will be explored as needed to develop a comprehensive understanding of the ARB process. After a reliable process is established, different alloy systems, including titanium alloys, will be explored.

Related work elsewhere: The majority of previous work has been focused on proof-of-concept studies pertaining to ARB. Research has been conducted for the past decade at Osaka University of Japan on the development of the ARB process and processing parameters that effect grain refinement. Similar work has been conducted out of the Isfahan University of Technology in Iran. Los Alamos National Laboratory has been studying the ARB process for producing nano-lamellar metallic composites.

How this project is different: Few studies have examined the superplastic behavior of ultrafine grained materials produced by ARB. Recent developments have proven the enhancement of superplastic behavior in specific alloys, such as Al 5083, but have not comprehensively studied alloy composition or starting microstructure to optimize superplastic response. This project will extensively study the influence of processing parameters on superplastic formability and will fully characterize the observed superplastic behavior in select alloys.

Milestones for the current proposed year: Use ARB to produce and quantify ultrafine grain structures in several aluminum alloys, including 5083, 5182 and 5754. Experiment with starting microstructure to see if the distribution of 2^{nd} phase particles has an effect on grain refinement and superplasticity. Experiment with modifications to the ARB process to see if edge cracking can be avoided by reducing lateral spread. Begin experimenting with commercial pure titanium to produce ultrafine grained structures using methods learned from aluminum.

Deliverables for the current proposed year: Room and elevated temperature tensile data of ARBed aluminum alloys, such as 5083, 5182 and 5754 will be obtained. An investigation of starting microstructure on grain refinement and superplasticity through ARB processing will be performed. An update of preliminary work centered around ARB of titanium alloys will be provided.

How the project may be transformative and/or benefit society: An in-depth understanding of ARB will be developed with respect to multiple aspects (microstructural refinement, texture development, strengthening, superplasticity, strain rate sensitivity) in select alloys. This will act as a detailed case study to showcase the full potential of ARB as a novel processing method and its benefit to industry. The research provided will serve as a baseline for the development of ARB processes in other alloy systems.

Research areas of expertise needed for project success: Access to a high capacity rolling mill (>50 tons) is vital for producing samples that are wide enough to minimize edge cracking. Custom made rolls with specific friction conditions or machined channels may be needed to reduce lateral spreading. Knowledge of submicron microstructural characterization techniques, such as transmission electron microscopy (TEM), electron backscatter diffraction (EBSD) and transmission kikuchi diffraction (TKD) will be developed through the project.	
Potential Member Company Benefits: Enhanced superplasticity by means of reduced temperature or increased strain rate has the potential to increase cycle time of forming operations while reducing costs. Cost reduction can be found in both reduced cycle time and reduced heating requirements. Superplastic forming at lower temperatures has the potential to reduce wear on forming dies.	
Progress to Date: An ARB process was developed using the rolling mill at Colorado School of Mines using Al 1100 as a model material. Changes to this process, including wire binding sheets and preheating before rolling allowed the completion of 5 successful roll bonding cycles of Al 5083. Preliminary grain size analysis through TEM has shown grain sizes on the scale of 200 nm – 500 nm have been obtained.	
Estimated Start Date: Fall 2017	**Estimated Knowledge Transfer Date**: Spring 2021

The Executive Summary is used by corporate stakeholders in evaluating the value of their leveraged investment in the center and its projects. It also enables stakeholders to discuss and decide on the projects that provide value to their respective organizations. **<u>Ideally, the tool is completed and shared in advance of IAB meetings to help enable rational decision making.</u>**