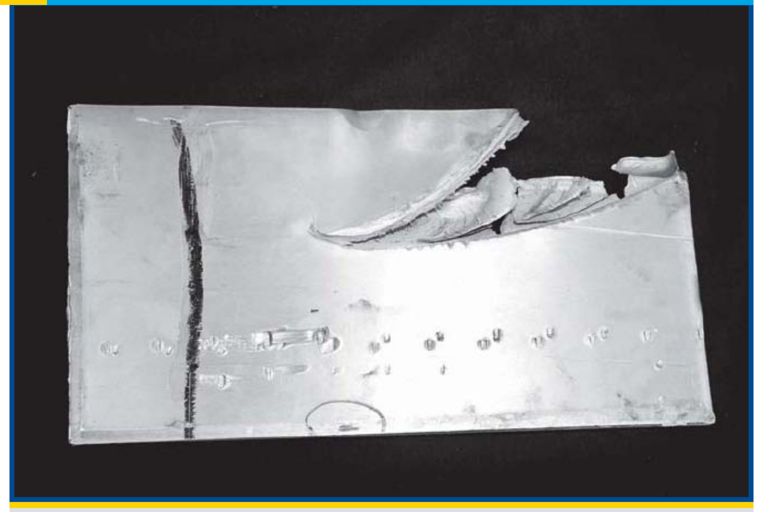
Hot Rolling Scrap Reduction through Edge Cracking and Surface Defects Control

Improving Energy Efficiency in Hot Rolling by Increasing Recovery Rates

Hot rolling of large ingots is the predominant process for producing plate, sheet, and foil aluminum products. Hot rolling has typical recovery rates of 82%, because 18% of the original material is lost as planned end cuts and scalping, or as incidental (unplanned) scrap. Hot rolled scrap is then typically re-melted to either form fresh ingot material or used to form secondary metal. If the amount of scrap could be reduced, significant energy could be saved by reducing the amount of remelt energy and energy to process recycled material.

Edge cracking of hard alloys and surface defects of soft alloys are some of the main reasons for scrap generation. In processing aluminum-magnesium alloys, hot rolling edge cracking tends to dramatically increase with higher magnesium concentrations, commonly resulting in scrap rates as high as 40%. In hot rolling soft alloys, surface defects occur because rolling plants only scalp the top and bottom ingot surfaces before rolling, not the sides of the ingot. The un-scalped ingot sides roll over to the top and bottom product surfaces, causing surface defects in the final product. In this process, slivers are routinely generated due to the un-scalped "rough" surface interacting with the roll table, and are then carried through the subsequent rolling passes and even to the cold rolling process. These slivers damage the surface of soft alloys in an unpredictable manner, causing large recovery losses.

The fundamental inability to reduce or eliminate these recovery losses is due to a lack of integrated models that relate structural properties to manufacturing processes and the materials employed. The development of such integrated models is a top priority for the aluminum industry. In today's operations, processing parameters are largely based on trial and error and experience, making it difficult to optimize the process even on a macro scale, and almost impossible at a microstructure level. Significant improvements in energy efficiency could be realized if the slab material response to the hot rolling process were sufficiently understood, such that processing parameters could be chosen to minimize product losses. This project will develop integrated computer models and process optimization tools to reduce scrap and improve energy efficiency in hot rolling.



Hot Rolling Edge Cracking.

Image courtesy of the University of Illinois at Urbana-Champaign.

Benefits for Our Industry and Our Nation

The models developed in this project will serve as efficient process design tools to reduce scrap generation from edge cracking and rolling surface defects by up to 50 percent. The technology will provide significant energy and cost savings while reducing sulfur oxide (SO_x), nitrogen oxide (NO_x), carbon dioxide (CO_2), particulate, and volatile organic compound (VOC) emissions.

Applications in Our Nation's Industry

The models will significantly improve the energy and environmental footprint of the domestic aluminum industry. The results of this project also have the potential to evolve into a successful example of integrated models for other manufacturing processes.

Project Description

The goal of the project is to develop integrated models for scrap reduction in hot rolling operations. The project approach will integrate microstructure characterization, computational modeling of microstructures and fracture nucleation, 3D rolling modeling and process optimization approaches.

Barriers

The following are technical hurdles this project faces:

- Characterization of the microstructure of the alloy's initial material, and its evolution in hot rolling to a level of detail that allows conversion into numerical model for simulations
- Development of computational models that incorporate the details of the alloy microstructures
- Establishment of a fracture and failure criterion that accounts for the details of microstructure and damage evolution
- Construction of 3D model of the roll/slab interaction of sufficient fidelity to capture the features necessary for accurate numerical simulation of hot rolling

Pathways

- Develop integrated models to link microstructures to macroscopic properties of aluminum and rolling process parameters
- Demonstrate the predictive ability of the integrated model as a process optimization tool for hot rolling
- Use the integrated models/tools to reduce both planned and incidental scrap in hot rolling

Milestones

- Development of mesoscale model for damage evolution in hot working (Completed)
- 3-D Finite Element Simulation of hot rolling process (Completed)
- System Integration
  - Constitutive model for 3-D code
  - Integrated simulation of 3-D hot rolling
  - Lab scale hot rolling experiments
  - Full production scale validation
- Commercialization
  - Implement in one Alcoa plant for hot rolling edge cracking control
  - Implement in one Alcoa plant for sliver and rollover reduction

Commercialization

The result of this project will be a very complex, 3D, multi-physics simulation program that has not previously been accomplished in the studies of hot rolling, which could be commercialized immediately upon completion. It is worth noting that this process optimization technology must be specifically tuned to each hot rolling plant, by defining variables such as pass schedule, lay-on temperature, heat or re-heat condition, friction condition, roll geometry and rolling speed. These models will be made available to the aluminum industry through journal publications and/or technical presentations.

Project Partners

University of Illinois at Urbana-Champaign
Urbana, IL
Principal Investigator: Armand J. Beaudoin
E-mail: abeaudoi@uiuc.edu

Alcoa, Inc.
Alcoa Center, PA

Lawrence Livermore National Laboratory (LLNL)
Livermore, CA

Ohio State University
Columbus, OH

For additional information, please contact

Glenn Strahs
Technology Manager
U.S. Department of Energy
Industrial Technologies Program
Phone: (202) 586-2305
E-mail: glenn.strahs@hq.doe.gov

DOE/EE-0408 • May 2011
Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.