High-Silicon Steel Sheet by Single Stage Shear-Based Processing

DE-EE0007868

Purdue University/M4 Sciences/PNNL

06/15/17 - 06/14/20

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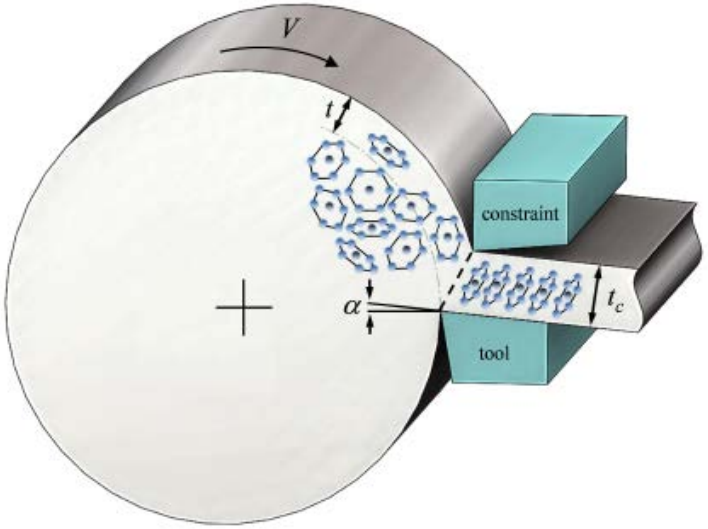
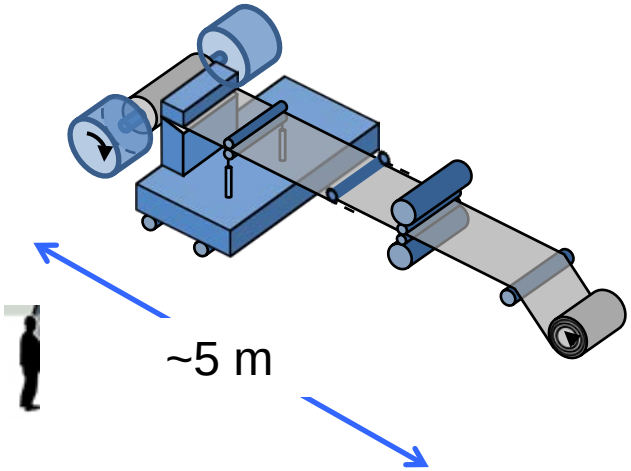
U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
June 13-14, 2017

Project Objective

- Scale up a hybrid cutting-extrusion based process; enables single-step thin sheet production from alloys of low workability.
- Apply the new process to high-Si, low-loss electrical steels;
- Enable high-Si electrical steel sheet production for increased-efficiency electric motors.

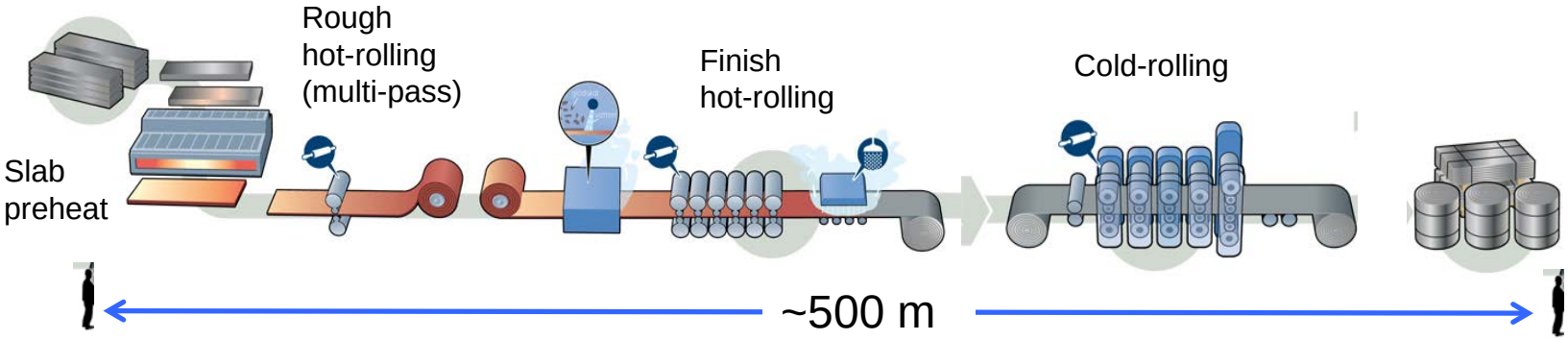


Hybrid cutting-extrusion
proposed process



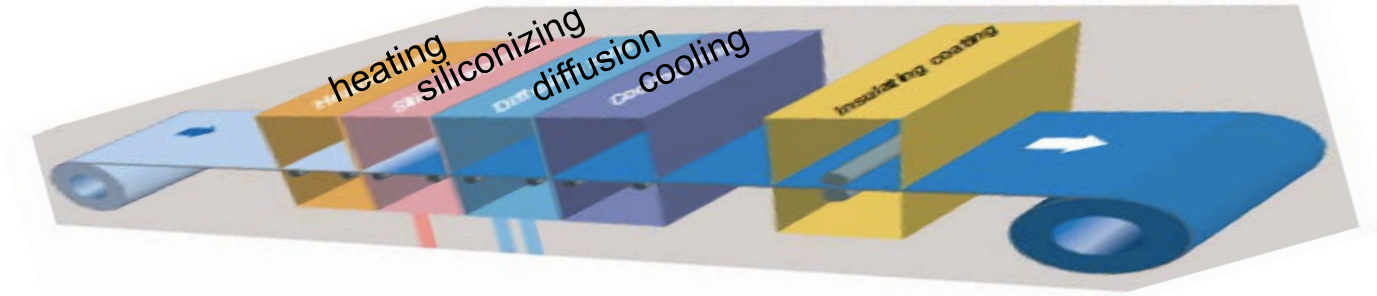
Technical Innovation

- Virtually all metal alloy sheet is produced by rolling processes.



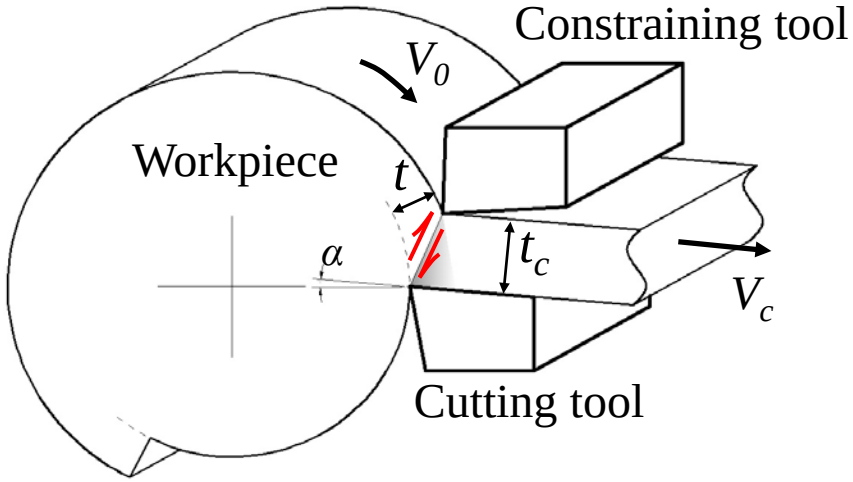
Multi-step (incremental) reduction, energy intensive,
large infrastructure, limitations for low-workability alloys

- High-Si steels: Not cold-rollable above ~3.5% Si; need ~6% Si to reach resistivity target of >80 μΩ-cm; JFE (Japan) CVD siliconization process, $$$.



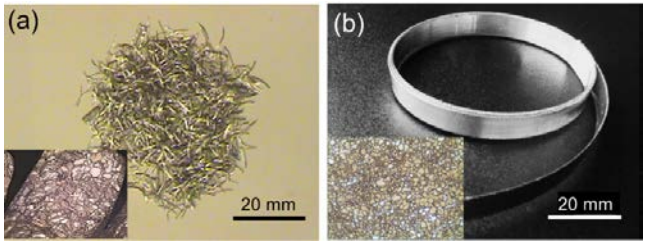
Technical Innovation

- Hybrid cutting-extrusion produces sheet and foil in a single stage of deformation, even from low-workability alloys, e.g., Mg, Ti, Fe-Si.
  - Unique deformation geometry: highly confined shear, temperature and hydrostatic pressure enhances workability
  - Single-step production of sheet with compact infrastructure



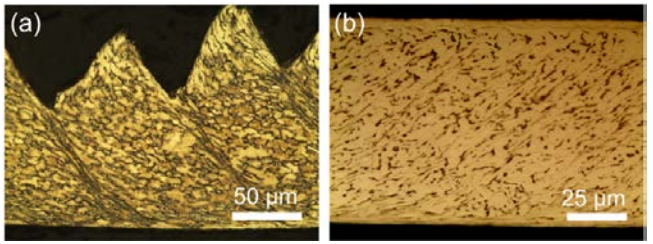
no constraint **constraint**

Mg-3Al-1Zn



- Prior Freedom Car Program (w/PNNL) demonstrated continuous Mg sheet and foil.

Ti-6Al-4V



Technical Approach

- Tailor high-resistivity electrical steel for hybrid cutting-extrusion process in two phases:

  Phase I: Rotary process configuration, up to 50 mm x 0.3 mm

  Process and sheet characterization

  Phase II: Based on results of Phase-I scaling (rotary or linear)

  Scale-up to 150 mm wide x 0.5 mm thick

- Multi-disciplinary team combining process and equipment design (Purdue and M4 Sciences) and materials characterization (Purdue and PNNL)
  - Complementary interaction with AK Steel and tool/die mfrs.

Technical Approach

Risks and unknowns:

- Machine power constraints
- Workability limits for the high-resistivity alloys
  - Process limitation in shear banding/cracking at larger sheet cross-sections
  - Sheet quality attributes and stampability
  - Possible new (and controllable) shear textures

Unique Execution Attributes:

- Prior success in commercializing modulation-assisted drilling processes and process for metal fiber manufacture (from research to product prototyping and commercial sales) M4 Sciences LLC and Purdue.

Transition (beyond DOE assistance)

- Stake holders: Next-generation electric motor manufacturers, motor user industries, public.
- Directly implementable by motor designers and manufacturers using current manufacturing methods.
- Partnership between university, small advanced manufacturing company and electrical steel/motor producers.
- Strong IP model (patents and trade secrets) and freedom to operate.

Measure of Success

- New *enabling* method for production of high-Si electrical steels.
- Projected savings in energy costs, impacting large volume electric motor market (>10,000 GW-h/y).
- Success determined by scaled up process and commercial adoption of the new steel sheet.
- Process beneficial for manufacturing variety of other sheet metals, especially lightweight Mg, Al, Ti alloys.

Project Management & Budget

- Three-year project (06/15/17 – 06/14/20)
- Tasks and key milestones

1. Alloy-Process Development (Q1-Q5)

   > *SMART1: Selection of alloy for scale-up processing*

2. Process Scaling – Phase I (Q4-Q6)

   > *SMART2(Go/No-Go): 50-mm wide sheet*

3. Process Scaling – Phase II (Q7-Q12)

   > *Go/No-Go: process for 150-mm wide sheet*

4. Steel Properties/Attributes (Q12)

   > *SMART3: a) 150-mm sheet having core loss <50% of Fe-3.2Si (M19), target stacking factor >0.9 (ASTM A719); b) assess conversion to discs (50 mm min. size) compared to M19.*

Total Project Budget	
DOE Investment	1,500,000
Cost Share	179,147
Project Total	1,679,147

Results and Accomplishments

- New project just beginning.
- Work to be completed: Tailor low-loss Fe-Si based alloy to new hybrid cutting-extrusion process; Scale up sheet production in two phases (50 mm and 150 mm widths), establishing necessary machine technology and process attributes.