Forging Industry

Technology Plan

CY2008-2009

Updated August 12, 2008

Executive Summary

The Forging Industry Association and the Forging Industry Educational and Research Foundation have implemented a strategy of technology development and deployment to improve the competitiveness of the forging industry. The foundation of this strategy is the "Forging Industry Technology Roadmap" and the "Forging Industry Technology Plan". The "Technology Plan" provides detail information on the implementation process, including:

1. New Project/Programs Starts for a FY 2008 – 2009
2. Active projects that have been funded
3. Programs to quantify the technical advantages of the forging process when compared to competing technologies
4. Process Heating/Energy Reduction Programs
5. Cooperation with the Forging Defense Manufacturing Consortium
6. Appendix A - Forging Industry Research & Development from Technology Roadmap 2000- 2007
7. Appendix B – FIERF Fellowships

New Project/Programs Starts for a FY 2008 – 2009 (Funding has been awarded)

1. Ultra-Fast Boriding for Improved Energy Efficiency and Reduced Emissions in Materials Processing Industries (**Bodycote**); Exhibit 3-2, Surface Hardening Technology
2. Magnetic Field Processing (**Ajax Magnethermics**); Exhibit 6-1, Forging Technology Innovations

Projects that are currently active include:

1. Forging Industry Technology Roadmap Update
2. Phase II - Development of Next Generation Heating System for Scale Free Steel Reheating. Project now taking on forging focus.
3. S-P^3 System: Sensor-based Prognostics and Predictive Control for Hot Deformation Processes
4. Surface Quality Assured Steel Bar Program
5. Collaborative Die Wear Research Program at The Ohio State University (FIERF and member companies)
6. Forged Surface Fatigue Studies at University of Toledo (FIERF)
7. Tempering Behavior of Hot Forging Die Steels, Colorado School of Mines, Finkl Challenge Grant
8. STEP Applications Protocol for Forging, ISO 10303, AP 229 and facilitate implementation of the protocol throughout the forging industry.

I.) **Introduction**: The Forging Industry Technology Plan incorporates a review of active projects that have been funded, projects being developed for a FY 2008 - 2009 start, programs to quantify the technical advantages of the forging process when compared to competing technologies, program funding activities at the federal and state levels and cooperation with the Forging Defense Manufacturing Consortium. FIA and FIERF will provide updates as often as it is warranted on their web sites.

(II.) **New Project/Program Starts FY 2008-2009**:

- Two new projects that will affect the forging industry have just been funded by the Department of Energy, Office of Energy Efficiency and Renewable Energy, under Program Announcement No. DE-PS36-08GO98014, ***Energy Intensive Processes 2008 Lab Call (More information on the programs will be released within the next two months).***
    1. Ultra-Fast Boriding for Improved Energy Efficiency and Reduced Emissions in Materials Processing Industries (**Bodycote**); Exhibit 3-2, Surface Hardening Technology
    2. Magnetic Field Processing (**Ajax Magnethermics**); Exhibit 6-1, Forging Technology Innovations
- Preliminary indications are that a separate proposal from Eaton South Bend for Magnetic Field processing will be funded.

(III.) **Active Projects:**

- **Forging Industry Technology Roadmap Update**

  The Forging Industry Technology Plan is a continuing effort that includes a balance of ongoing programs & planned new programs starts. Our overall technology guide is the Technology Roadmap. The Forging Industry Technology Roadmap has been updated using Energetics as a facilitator. Publishing of the Technology Roadmap Update will be completed in the near future.

- **Phase II - Development of Next Generation Heating System for Scale Free Steel Reheating**

  Objective: To develop and test a scale free heating system that reduces scale formation in steel reheating process resulting in substantial reduction in energy use, improvement in steel quality and significant cost advantages for the U.S. steel production and forging industries.

  Benefits: Substantial reduction in energy use, improvement in steel quality and significant cost advantages for the U.S. steel production and forging industries.

  Funding: DOE Funding with in-kind: $1.5 million. DRE funding: $20,000

  Timeline: **Contract completion date is October 2008. A six month extension is expected.**

  Status: **The project is 60% complete**. New burner technology and substoichiometric combustion of natural gas to produce a non- oxidizing furnace atmosphere is being installed at Steel Dynamics. This technology is being successfully used in production at Chamberlain Engineering for forging shell casings.

- **S-P3 System: Sensor-based Prognostics and Predictive Process Control for Hot Deformation Processes**

  Objective: A method to accommodate the hot, rough finished workpiece for feature detection with a mathematical approach to handle the uncertainties from HotEye and other sensing data

  Benefits: Real-time control of the forging process with predictive capabilities.

  Funding: Funding is **$1.395 million** from National Science Foundation and Michigan's 21st Century Job Fund). Team members include OG Technologies, University of Michigan, American Axle and Manufacturing, FormTech, Bharat Forge America, Inc., FIA and MACSTEEL.

  Timeline: Three year program to be completed by October 2009. The program is 60% complete and on target for successful completion by the program end date

  Status: The University of Michigan has still not completed its work (Reference Board Meeting at University of Michigan). Tonnage Signal testing is underway and data is being collected. Bharat Forge America has expressed interest in monitoring roll forming.

- **Surface Quality Assured Steel Bar Program**
  - Objective: Eliminate or identify all steel bar surface quality related rejects before the material is forged
  - Benefits: Higher productivity and lower energy consumption in the forging industry, the main customer for SBQ steel. The project group includes OG Technologies, Inland Steel, FormTech Industries and two universities.
  - Funding: **$2.5 million;** DOE-OIT ***Controls and Automation Crosscutting Technologies*** Program
  - Timeline: **Project Completion expected October 2008.**
  - Status: **Unit has been successfully commercialized with the final phase of the project being used to fine tune the device.**

- **Collaborative Die Wear Research Project at The Ohio State University**
  - Objective: Predict and reduce die wear
  - Benefits: Higher productivity, less down time and decreased dimensional spread between parts
  - Funding: FIERF funded grant with in-kind from industry participants ($55,000)
  - Timeline: Continuing program
  - Status: Major work now being done at Hirschvogel on automated press with data download.

- **Forged Surface Fatigue Studies at University of Toledo**
  - Objective: Refute inaccurate data in Mechanical Engineering Handbooks that lowers the fatigue strength of parts with as forged surfaces by 75%.
  - Benefits: Design engineers can select forgings for a wider range of applications
  - Funding: FIERF funded program with AISI input and steel provided by MACSTEEL
  - Timeline: October 2009
  - Status: Dies have been sunk and steel has been shipped. Samples will be forged at Green Bay Drop Forge. Once sample have been manufactured, testing will start at University of Toledo.

- **Forging Defense Manufacturing Consortium (FDMC)**
  - Objective: Support the warfighter by enabling the Defense Logistics Agency to procure legacy systems forgings more easily.
  - Benefits: New technologies and tools are being developed for defense related applications that are useful in producing commercial parts.
  - Funding: **A new $15 million contract** has been awarded from DOD. All DRE expenses as a member of the Technical Advisory committee are now covered by contract.
  - Timeline: Project is expected to last 5 years.
  - Status: The program is managed by Advanced Technology Institute under the direction of the FDMC Board (FIA company members). Projects are available for review on the FDMC web site

Process Heating / Energy Reduction Programs: Energy costs are major forging process cost component and are very susceptible to near term increases. Collaboration with the Department of Energy has been very successful and resulted in substantial funding of programs. This effort will continue to be a FIERF priority:

1. **Industrial Assessment Centers** (IACs), sponsored by DOE's Industrial Technologies Program, provide eligible small- and medium-sized manufacturers with no-cost energy assessments through a local university system. Additionally, the IACs serve as a training ground for the next-generation of energy savvy engineers. Teams are composed mainly of engineering faculty and students from the centers. New IAC Schools will be developed and the solicitation will be sent to all magnet schools.
2. **Infrared Heating Technology:** Applications has been extended from heating dies to heating billets and heat treating. While this technology is being used to produce production aluminum forgings, more work is required for it to realize its full potential. Queen City Forge and Oak Ridge National Laboratory, with DRE input, are still working on potential applications for this heating method.

3. **Department of Energy Networking Activities:**
   - **DOE-ITP Allied Partner Program**: FIA continues to be DOE-ITP Allied Partner to gain access to BestPractices information and software tools, including training modules, and ITP assistance in telling the forging industry story. DRE will disseminate DOE-ITP tips, case studies, software tools, and other BestPractices resources that can help cut forging plant energy bill.
   - **Process Heating Steering Committee of DOE**: DRE is a committee member and has been elected chairman of the Process Heating Tools and Protocols Subcommittee. As such, the DRE has been able to access additional DOE resources for specialized energy savings training of member companies.

V.) **Technical Advantages of Forging:** The major objective of this effort is to show quantitative property advantages of the Forging Process compared to competing processes & technologies. Another aspect of this activity is to provide the forging industry with a more accurate assessment of the direction alternate forming technologies is taking and their immediate or future threats to the forging process.

1. **Forged Surface Fatigue Study –** Study at the University of Toledo is being undertaken to refute old design charts that severely degrade component properties with as-forged surfaces. There has been a problem obtaining fatigue test bars with as-forged surfaces that meet the dimensional constraints needed for testing.

VII.) **FIA Technical Committee:** The general technology scope of Technical Committee is metals & the forging process. There can be some technical overlap with Plant Engineering committee in areas like lubrication. The planned CY08/CY09 activities are:

1. **Implementation of the Technology Roadmap and Project Development**:

2. **Forging Industry Technical Conference (September 2009)**: The conference will be chaired by a FIERF Board member and will be planned by the DRE, Technical Committee and Plant Engineering Committees. The focus of the conference will be on alternate energy sources.

3. **Visits to National Laboratories and other Research Facilities**: Purpose is to determine what existing technologies are of immediate benefit to the forging industry and are available for short term Technology Transfer.

VIII.) **Educational Activities Support – Magnet Schools & Industry Programs:** FIERF technical emphasis and continuity is very important aspect of educational programs. The major emphasis is the Magnet School program support. Industry collaboration and funding is very important to Universities. University participation in technology programs is very attractive to government agencies & can assist in obtaining government funding of technology programs. The second aspect of educational support is the forging industry training.

1. **Technical Assessments / Recommendations University Programs**: Methodology was established for assessment & funding university technical projects. The DRE will perform the initial technical evaluation & provide funding recommendations to the FIERF Educational Committee.

2. **Magnet School Selection**: University contacts will be based on a willingness to become involved in projects that further implementation of the Technology Roadmap. These Universities would be preferred choices for incorporation in the Magnet School program. The primary source of new Magnet School recommendations will be the DRE & Technical Committee.

Appendix A

Forging Industry Research & Development from Technology Roadmap 2000- 2007

(See FIA website for reports)

The following programs have been completed since the Forging Industry Technology Roadmap was published:

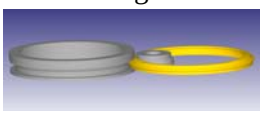
An Investigation of the Proper Hot Forging Temperatures for Various Steel Grades, Colorado School of Mines, Finkl Challenge Grant

Application of Advanced Die Materials and Lubrication Systems for Reduction of Die Wear in Warm and Hot Forging, Collaborative Project headed by Ohio State University

Application of Intelligent Component Evaluation to the Design of RSP Tooling, Cleveland State University, Finkl Challenge Grant

Application of Rapid Infrared Heating for Processing of Aluminum Forgings, Oak Ridge National Laboratory

Application of Subtractive Rapid Prototyping for RSP Tooling, Cleveland State University, Finkl Challenge Grant

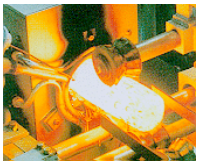


Best in Class Practices of Forging Design and Process Simulation Program, Forging Defense Manufacturing Consortium

Characteristics of Materials Used for Forging Dies and Surface Modification Techniques to Extend Die Life, Precision Forging Consortium

Characterization of Internal Defects in Open Die Forgings, Colorado School of Mines, Finkl Challenge Grant

Comparison of Mechanical Properties in V and V+Nb Forging Steels, Colorado School of Mines, Graduate Fellowship



Design of Robust Temperature Specifications for Billet Induction Heating, Pennsylvania State University, Graduate Fellowship

Development of Hybrid Rapid Infrared Furnace for Treatment of Aluminum Alloys, Ohio University, Finkl Challenge Grant

Development of Hybrid Rapid Infrared Superheating Furnace, Oak Ridge National Laboratory

Development of Next Generation Heating System for Scale Free Steel Reheating, Department of Energy

Diagnostics and Control of Natural Gas Fired Forging Heat Treat Furnaces via Flame Image Analysis, University of Missouri

The Effect of Forging on the Tensile Properties and Microstructure of Magnesium Alloys, Case Western Reserve University, Graduate Fellowship

Effect of Nickel Content on Thermal Processing and Grain Growth Characteristics of 4330 Alloys, Illinois Institute of Technology, Graduate Fellowship

Effect of Prior Microstructure and Heating Rate on Austenite Formation Kinetics in Three Steels for Induction Hardened Components, Colorado School of Mines, Graduate Fellowship

Effect of Prior Microstructure on Austenite Decomposition and Associated Distortion, Illinois Institute of Technology, Finkl Challenge Grant

The Effects of Prior Microstructure on Spheroidizing Treatments for Enhanced Cold Forgeability, Colorado School of Mines, Graduate Fellowship

Experimental Investigation on the Use of Welded Preforms to Produce Novel Forgings, Marquette University, Finkl Challenge Grant

Fatigue Performance Comparison and Life Prediction of Forged Steel and Ductile Cast Iron Crankshafts, University of Toledo

Fatigue Performance of Forged vs. Competing Process Technologies: A Comparative Study of Steering Knuckles, University of Toledo

Flow Stress Measurement, Rensselaer Polytechnic Institute, Graduate Fellowship

Forging Process Monitoring and Control through Feature Extraction of Tonnage Signals, University of Michigan, Graduate Fellowship

Heating Response of Different Starting Microstructures and Their Relationships with Important Forging Process Parameters, Colorado School of Mines, Finkl Challenge Grant

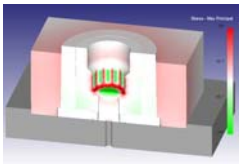
HotEye™ Automatic Inline Surface Inspection System for Steel Rod and Bar, OG Technologies

Hybrid Infrared Forging Stock Heating System, Oak Ridge National Laboratory

Improving Fatigue Performance of Aluminum Alloy Forgings using Rapid Infrared Thermal Processing, Ohio University, Finkl Challenge Grant

Infrared Heating of Forging Billets and Dies, Oak Ridge National Laboratory

Innovative Die Material and Lubrication Strategies for Clean and Energy Conserving Forging Technologies, Ohio State University, Finkl Challenge Grant



Innovative Rapid Tooling Technology, Forging Defense Manufacturing Consortium

Investigation of Friction Measurements at CSM for Hot Steel Forging Applications, Colorado School of Mines, Finkl Challenge Grant

Investigation of Workability & Mechanical Properties of Welded Preforms, Marquette University, Graduate Fellowship

Material & Energy Optimization of the Ring Gear Forging Process, Ohio University, Finkl Challenge Grant

MPLUS Program to Determine When Phase Change Occurs on Heating of Large Billets, Oak Ridge National Laboratory

Scholarships The Foundation has awarded 65 Finkl Scholarships since the program began in 2004. These students have gone on to graduate school and to find employment in the forging, steel and customer industries.

Sensor-based Prognostics and Predictive Control for Hot Deformation Processes, Collaborative Project headed by University of Michigan

SmartSmith System to Check Surface Quality and Dimension of Hot Forging in a Closed Loop Control System, OG Technologies

Stress Analysis and Optimization of Crankshafts Subject to Dynamic Loading, University of Toledo

Study of Premium H-13 for Improved Toughness and Temperature Resistance, Rensselaer Polytechnic Institute, Finkl Challenge Grant

Tempering Behavior of Hot Forging Die Steels, Colorado School of Mines, Finkl Challenge Grant

Use of Nano Testers to Evaluate the Surface Mechanical Properties of Hot Forging Die Steels, Colorado School of Mines, Finkl Challenge Grant

Process Heating Assessment and Survey Tool" for Induction, Infrared and Resistance Heating - Help process heating equipment users assess how much energy their furnaces, ovens, and heaters use, and model different ways to improve individual unit performance and manage bottom-line costs. This is available on line from the DOE-ITP website.

"Collaborative Research in the Forging Industry" pamphlet has been published to provide an easy to understand introduction to the process.

Five forging companies (FormTech, SIFCO Industries, Jernberg, Utica Forge and Citation Corporation) have received Plant Wide Energy Assessment awards from the **Department of Energy or local utility companies.**

Appendix B

FIERF Fellowships

2008
R. Allen Schaneman, Colorado School of Mines, “The Effects of Prior Microstructure on Spheroidizing Treatments for Enhanced Cold Forgeability”

David Poerschke, Case Western Reserve University, “The Effect of Forging on the Tensile Properties and Microstructure of Magnesium Alloys”

2007
Rodrigo Caliz. Department of Industrial and Manufacturing Engineering, Pennsylvania State University, “Design of Robust Temperature Specifications for Billet Induction Heating”

Chris Kaschner, Illinois Institute of Technology, “Effect of Nickel Content on Thermal Processing and Grain Growth Characteristics of 4330 Alloys”

Ran Jin, Department of Industrial and Operations Engineering, University of Michigan, “Forging Process Monitoring and Control through Feature Extraction of Tonnage Signals”

2006
W. Scott Lemoine, Metallurgical and Materials Engineering Department, Colorado School of Mines, “Comparison of Mechanical Properties in V and V+Nb Forging Steels”

Peter Hale, Materials Science and Engineering Department, Rensselaer Polytechnic Institute, “Flow Stress Measurement”

Rodrigo Caliz, Department of Industrial and Manufacturing Engineering, Pennsylvania State University, “Design of Robust Temperature Specifications for Billet Induction Heating”

Three Forging Fellows at Ohio State University – Die Material and Lubrication Strategies for Clean and Energy Conserving Forging Technologies

2005
Kester Clarke, Metallurgical and Materials Engineering Department, Colorado School of Mines, “Effect of Prior Microstructure and Heating Rate on Austenite Formation Kinetics in Three Steels for Induction Hardened Components”

Megan Shaefer, Manufacturing Systems Engineering Department, Marquette University, “Investigation of Workability & Mechanical Properties of Welded Preforms”

Three Forging Fellows at Ohio State University – Die Material and Lubrication Strategies for Clean and Energy Conserving Forging Technologies

2004
Three Forging Fellows at Ohio State University – Die Material and Lubrication Strategies for Clean and Energy Conserving Forging Technologies

2003
Three Forging Fellows at Ohio State University – Die Material and Lubrication Strategies for Clean and Energy Conserving Forging Technologies

213,000 (OSU)
100,000
$313,000