Sensors to Revolutionize Manufacturing

DOE Sensors & Automation
2007 Annual Portfolio Review

ROBOTICALLY ENHANCED ADVANCED MANUFACTURING CONCEPTS TO OPTIMIZE ENERGY, PRODUCTIVITY, AND ENVIRONMENTAL PERFORMANCE

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Project Description

- **Need**
  Early in 2004, the Robotically Enhanced Manufacturing Line (REML) was conceived for the production of small lots of tapered roller bearing races. REML was seen as an opportunity to utilize Timken steel tubing with microstructures optimized for REML processes, to reduce energy consumption, improve productivity, reduce health and safety risks, and reduce environmental impact when compared to conventional, low volume industrial bearing manufacturing lines.

- **Project Description / Goal(s)**
  Construct an advanced, low-volume manufacturing line for the production of industrial bearing races.

  The line consists of processes for cold working and green machining, for thermal treatment, and for finishing and inspection of the bearing races.
Project Description – REML green cell

sawn slug, rolled blank, green machined race
Project Description – REML thermal treatment cell

green machined race, hardened race, tempered race
Project Description – REML thermal treatment cell
Project Description - REML finishing cell

heat treated race, finish machined race
The operating power consumption of the light weight, high speed gantry robot is about one-half that of the conventional gantry robot.
Project Description

- **Core Technology & Transformational Elements**
  
  Energy-efficient induction heating processes, which operate on demand, replace continuously heated, energy over-sized furnaces. Robotics which tend the processes thereby reducing manual labor and repetitive labor. CAMotion Inc. low-mass, high-speed gantry robot in the finishing cell which relies on sensors not structural rigidity for positioning accuracy “brains not brawn”.

- **Key Project Deliverable(s)**
  
  Analysis of potential
  1. for energy savings for bearing races and other heat treated, metal products
  2. for productivity increases
  3. for reduction of environmental impact, health and safety risks as compared to a conventional, low-volume bearing race manufacturing line (low-volume manufacturing line or cells for other heat treated, metal products)
Project Description

- Industries for Application
  The REML technologies will in general be extendible beyond bearings to the manufacture of many types and forms of heat treated and finished machined metal parts.

- Crosscutting Applicability
  Industrial Heating Equipment
  Heat Treating
  Industrial Materials
  Robotics
Energy Savings

- **How energy is saved**
  
  Use of energy-efficient induction heating processes, which operate on demand, replace continuously heated, energy over-sized furnaces.
  
  Use of multi-function finishing assets which replace multiple, single-function finishing assets.

- **Measuring line annual energy savings**

  1) The energy consumption of all energy consumers within REML was measured while processing the baseline part and while at idle. Energy forms included electricity, natural gas, process gases, compressed air, and water (chilled, tower, city). Human energy was not included.

  2) The energy consumption of all energy consumers of the conventional baseline, low volume line while processing reference-sized parts and while at idle. These measurements were made at a Timken industrial bearing plant in Canton, Ohio.

  3) Duty cycles (processing versus idle times) were measured for all producing assets of the REML line and the conventional line while producing the baseline part.

  4) Line annual energy consumptions were computed and comparisons were made assuming equivalent annual line production of approximately 51,000 races per year.
Energy Savings

The REML line in its current state of development has been measured to be about 22% (338,000 kVA-hrs per year) less energy intensive than the baseline conventional low volume line assuming equivalent annual production volume of bearing races. Additional savings are possible if flow through green cell is batch rather than single piece flow.
Anticipated Economic Impact and Value Proposition

- **Annual energy cost savings per REML line**
  
  \[
  (338,000 \text{ kVA-hrs/yr}) \times \left( \frac{0.06}{\text{kVA-hrs}} \right) = 20,300 \text{ / yr}
  \]

  Additional savings are possible if flow through green cell is batch rather than single piece flow.

  Generally extendible to manufacture of metal parts in the US (gears, sleeves, rods, any ring geometry)

- **Productivity improvement**
  
  Reduced labor content
  Reduced flow time
  Reduced unit cost
  Make to order with low run volumes
Other Important Metrics

- Productivity (lower energy cost, dramatically reduced flow time, reduced labor content, lower unit cost for small run volumes)
Other Important Metrics

- **Environmental Impact Reduction**
  REML would result in an estimated annual reduction of emission of approximately 43,780 lbs CO₂ of and approximately 220 lbs of un-combusted methanol vapors into the air. Eliminates hazards and wastes associated with periodic removal and replacement of insulating bricks in conventional furnaces.

- **Health and Safety Risk Reduction, Ergonomics Improvement**
  Health and Safety Risk Assessments were completed for each asset by a Timken Health and Safety and Environmental Compliance Analyst.
  Compared to the conventional line, the REML line substantially reduces the risk of ergonomic injuries (musculoskeletal disorders) as a result of the robotic machine tending and other forms of automation which eliminate or reduce the need for human / machine manual interaction, repetitive motion and frequent material handling.
Project Status Timeline

2004

Specify and purchase major assets

2005

Integrate thermal treatment and finish cells with robotics. Acquire secondary assets.

2006

Asset optimization. Trial production runs. Improvement estimates.

2007

Process additional steel grades in thermal treatment cell. Deploy green and finish assets to production. Cell and line SCADA.

2008

Deploy thermal treatment cell or assets to production. License technologies to non-competitors.
Next Steps & Commercialization

- All current contract milestones are completed.
- Ongoing effort to optimize and qualify inductive heating and tempering efficiency and post-heat treat metallurgical properties of new steel grades, new (larger) part sizes and new part geometries and features (flanges, holes, slots, grooves).
- Complete an associated investigation of opportunities for deployment of the thermal treatment cell into Timken’s Industrial Bearing Business.
- The Timken Company and its supplier of induction heating equipment will investigate licensing of induction heating technology to non-competitors of The Timken Company. The Timken Company will be the point of contact.
- CAMotion Inc. will promote and offer low-mass, high-speed gantry robotics, similar to that featured in the REML finish cell, to industry.
Commercial/Technical Risks Remaining

- Achieving induction heating processes which achieve the required control over temperature uniformity across full range of part diameters, widths, and cross sections.

- Marketplace acceptance of non-conventional materials and manufacturing processes. (Employ existing customer notification, acceptance, and approval practices).

- Production service reliability especially of machine tending robotics. High technical sophistication of line assets, robotics and systems. (Development of Total Productive Maintenance TPM programs, Condition Monitoring).
Summary

10 REML Lines per Year Beginning 2007
240 Conventional to REML Conversions by 2030

1% Cost of Energy Increase per Year

CUMULATIVE REML SAVINGS POTENTIAL IN US

Year’s energy output of 100 Mega Watt Power Plant