DOE Sensors & Automation 2006 Annual Portfolio Review

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

The Timken Company, Canton Ohio

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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.

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Project Description

- **Project Description/Goal(s)**

  Construct an advanced, low-volume manufacturing line for the production of industrial bearing races.

  The line will consist of processes for cold working and green machining, for thermal treatment, and for finishing and inspection of the bearing races.

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Project Description – REML green cell

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Project Description – REML green cell

sawn slug, rolled blank, green machined race

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Project Description – REML thermal treatment cell

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Project Description – REML thermal treatment cell

green machined race, hardened race, tempered race

Project Description – REML thermal treatment cell

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Project Description- REML finishing cell

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Project Description – REML finishing cell

heat treated race, finish machined race

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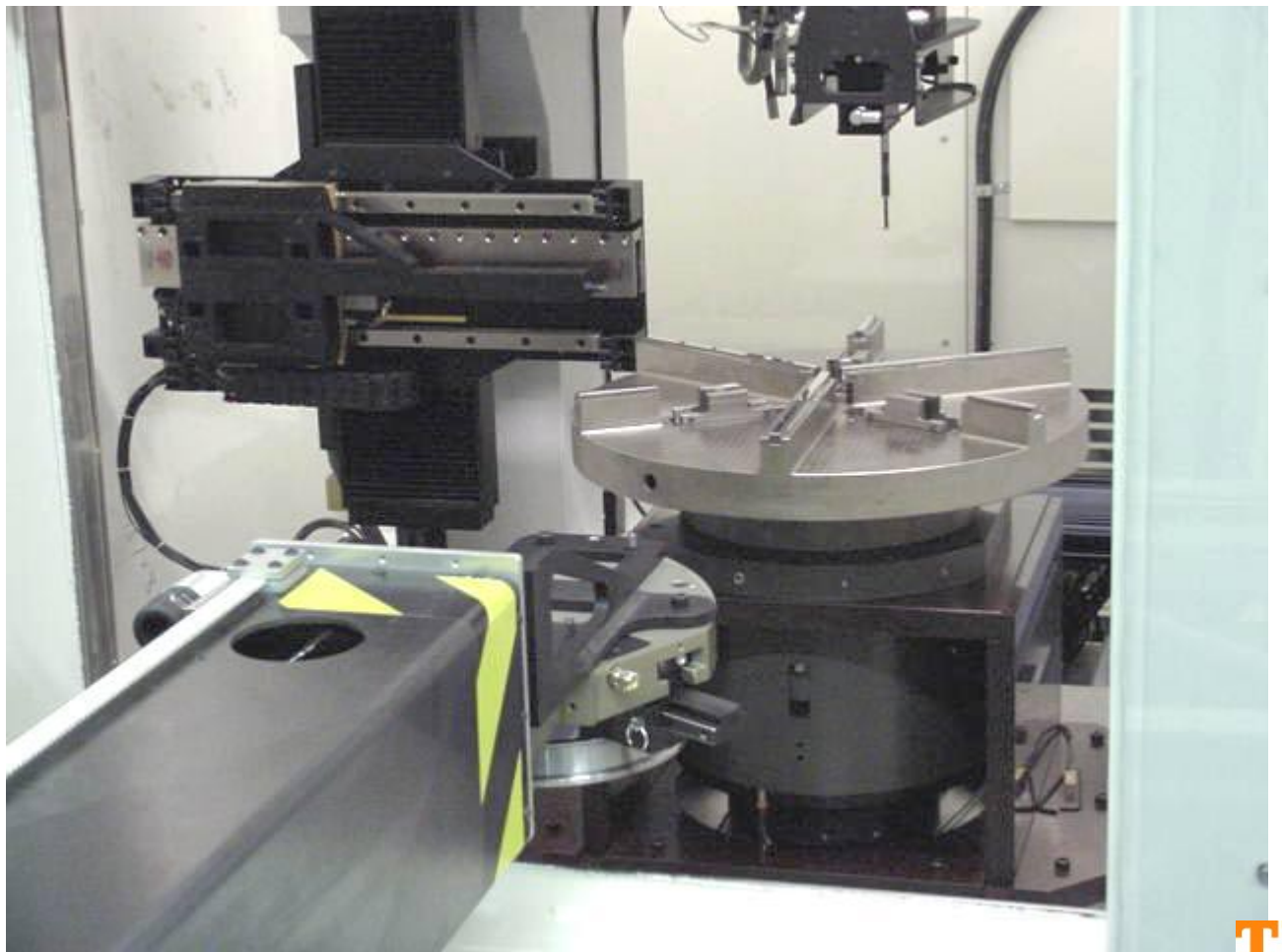
Project Description – REML finishing cell



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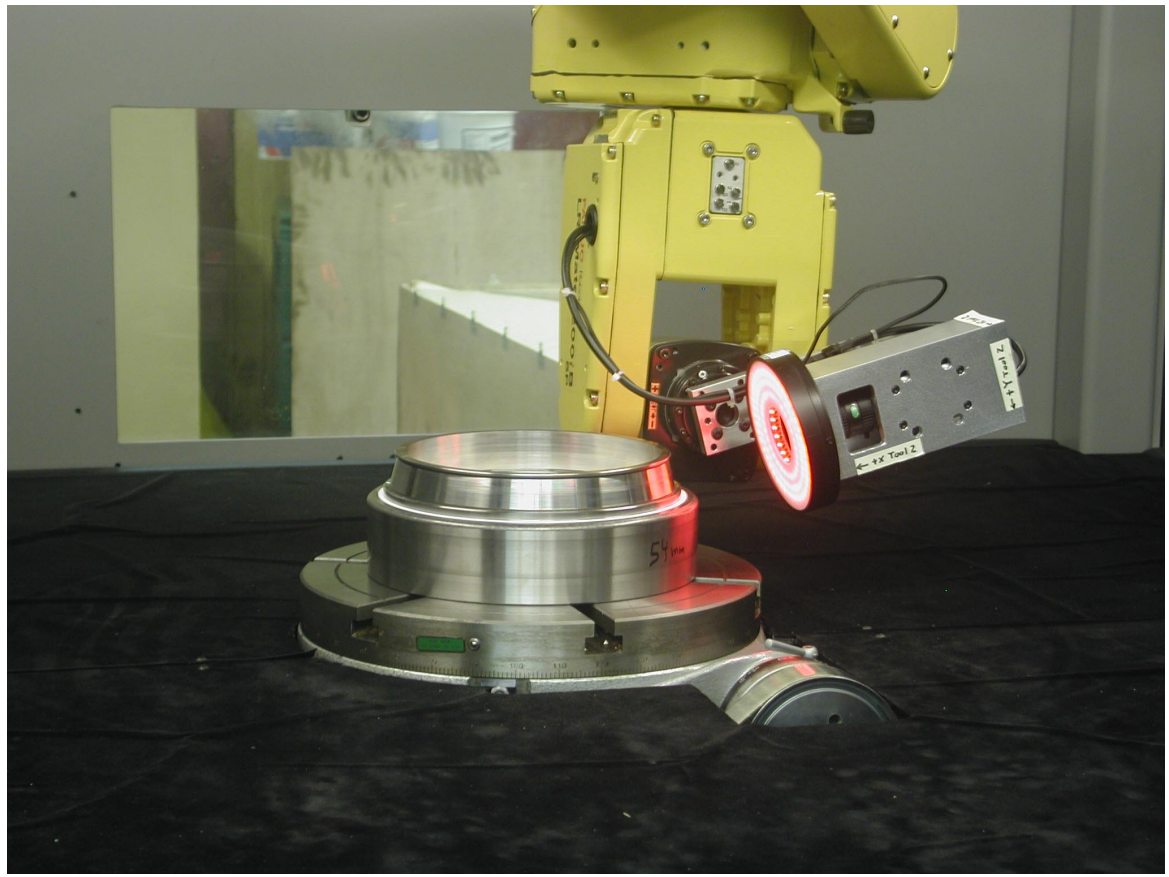
Project Description – REML finishing cell



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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”.

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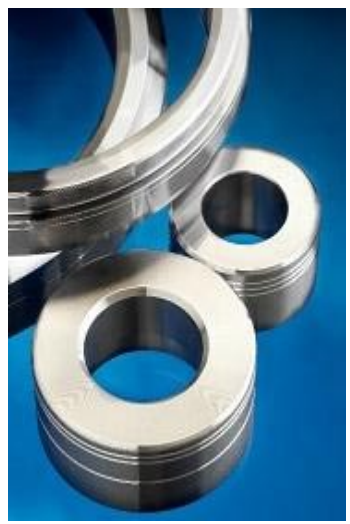
Project Description

- **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.



Project Description

- **Crosscutting Applicability**

  Industrial Heating Equipment
  Heat Treating
  Industrial Materials
  Robotics

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Project Description

- **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)

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Barriers and Pathways

- **Technical Barrier(s) Being Addressed:**

  Achieving induction heating processes which do not require part-specific tooling while achieving the required control over temperature uniformity across full range of part diameters, widths, and cross sections.

  Sensing and robotic gripping of hot parts (bearing races) without causing geometric distortion. Optimization of gripper actuation forces. Speed of robotic transfer of parts, minimization of heat transfer from heated product to the grippers and ambient air. Robotic positioning of parts in assets which require high positional accuracies while the assets function in harsh, metal-removal environments.

- **Project Pathway:**

  Design of experiment test matrix is establishing induction heating recipes and processing parameters which yield optimized cycle times and metallurgical properties for full range of product geometry.

  Optimization of gripper actuation forces and minimization of heat transfer from heated product to the grippers and ambient air by use of skeletized grippers and thermal barriers. Optimized transfer speeds. Positional accuracy of robotics found to be generally acceptable.

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Energy Savings

- **How will energy be 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.

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Energy Savings - Assumptions used in calculation

- **The approach to measuring line annual energy savings was as follows:**

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.

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Energy Savings

- **Consumptions were computed as follows:**

Asset Energy consumed per part = Σ (processing power) *(processing time) + Σ (idle power)*(idle time)

Asset Annual Energy Consumption = (Energy consumed per part)* (Annual production volume)

Line Annual Energy Consumption = Σ Asset Annual Energy Consumptions

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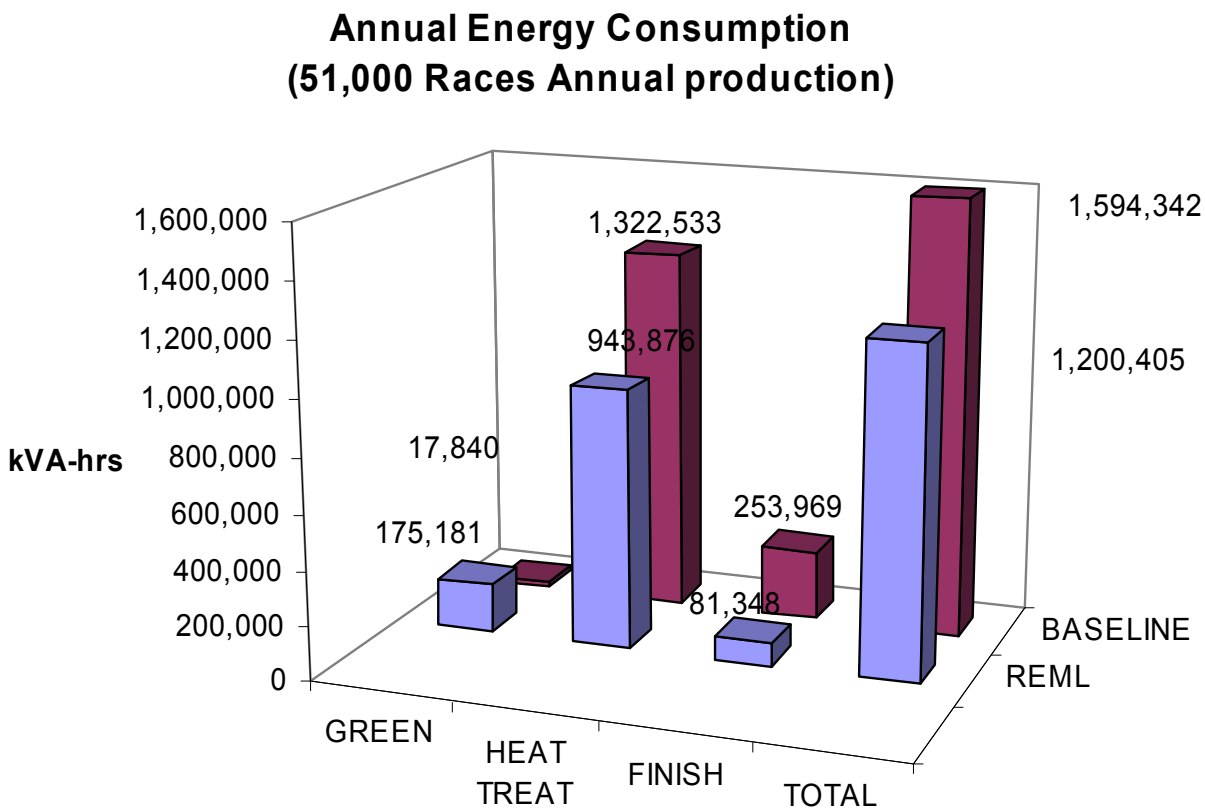
Energy Savings - How much energy

- **How much energy will be saved?**



The REML line in its current state of development has been measured to be about 25% (390,000 kVA-hrs) 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.

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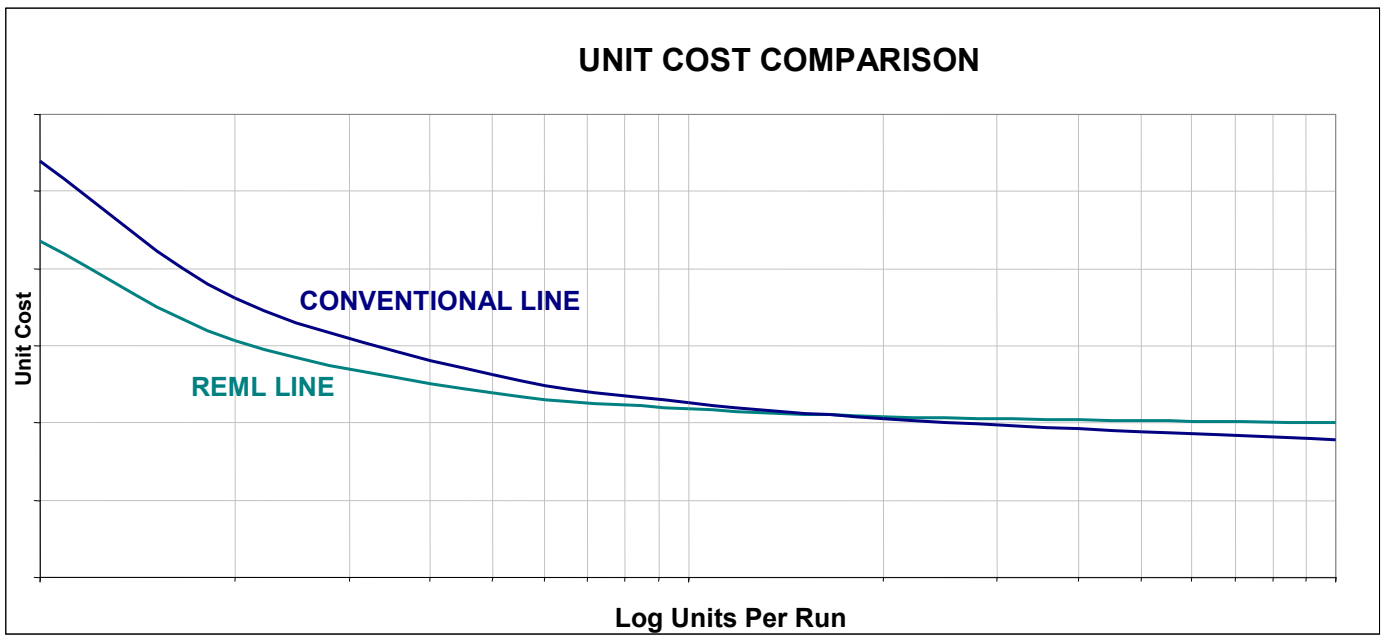
Other Important Metrics

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



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Other Important Metrics

- **Environmental Impact Reduction**

  The conventional line employs carburizing furnaces wherein methane and methanol are the carburizing gases. REML does not employ a carburizing process.

  Based on an annual production of approximately 50,000 bearing races and an estimated combustion efficiency of 99.5%, it is estimated that REML would result in an annual reduction of emission of CO_2 into the air of approximately 43,780 lbs and approximately 220 lbs of un-combusted methanol vapors. These are estimates which have not been verified by sampling stack gases.

Other Important Metrics

- **Health and Safety Risk Reduction, Ergonomics Improvement**

Based upon Health and Safety Risk Assessments were completed for each asset by the asset leader and 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. It is difficult to accurately quantify the reduction of ergonomic injuries that would result from implementing REML. In a future phase of this program, it may be possible to assess the ergonomic injury risk using a software program, HumanTech Risk Priority Management (RPM), to compare the risk the REML line versus a conventional line.

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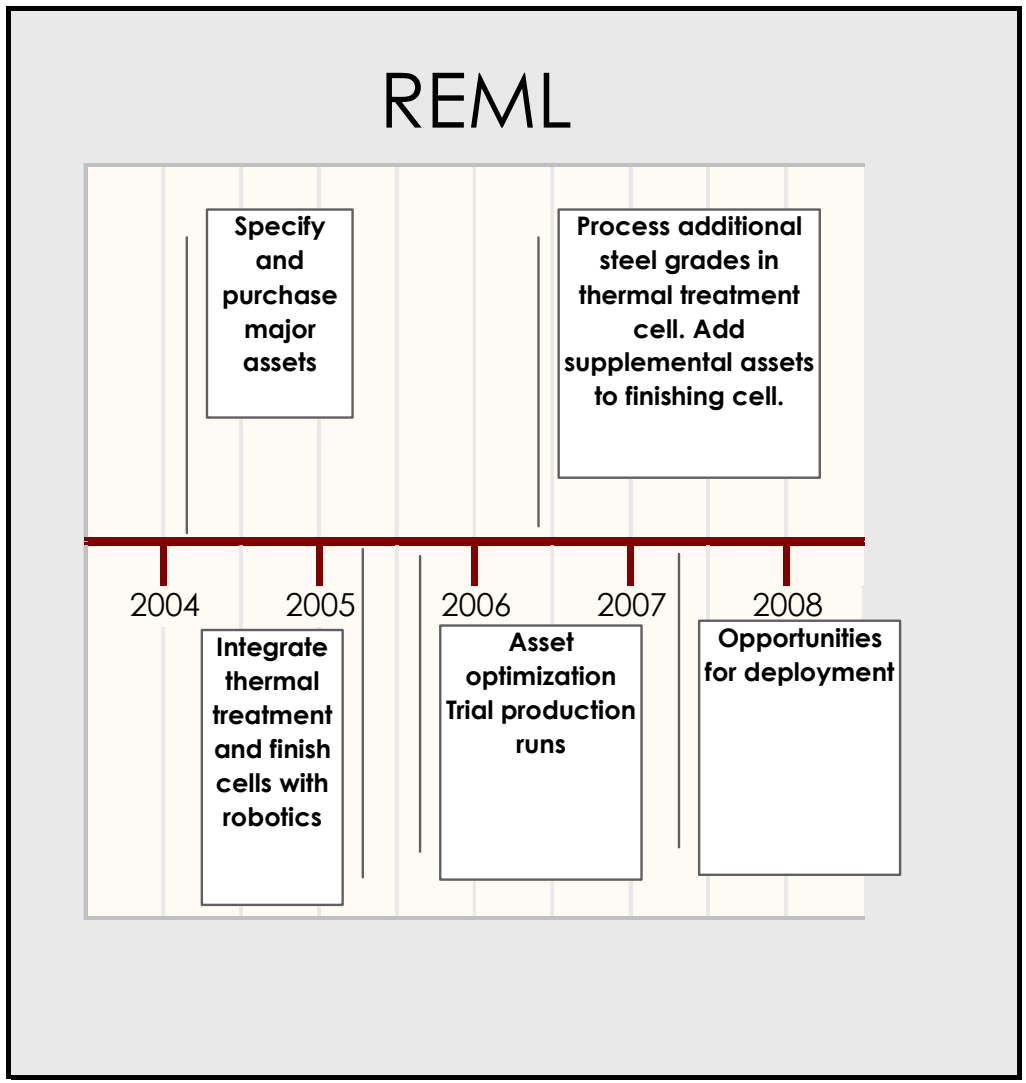
Project Status Timeline



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Accomplishments to Date

- **Completion of installation of major assets**
- **Purchase and installation of secondary and support assets**
- **Integration of thermal treatment cell assets with commercial gantry robot**
- **Integration of finish cell assets with low-mass, high-speed machine tending robot**
- **Completed improvement estimates**
  - Energy Consumption Reduction
  - Productivity Improvement
  - Health and Safety Risk Reduction, Ergonomics Improvement
  - Environmental Impact Reduction
- **Completed trial runs of major production assets across the entire line**

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Next Project Steps & Future Milestones

- **All current contract milestones are projected to be completed by the end of the contract June 29th, 2006. An extension is being contemplated to expand the benefits. Those expanded milestones include:**

  Conclude development of the green cell. Complete an investigation of opportunities for deployment of the green cell(s) into Timken's Steel Parts Business and into the Timken's external supply chain of green races by January 2007.

  Undertake and complete expansion of capabilities of the thermal treatment cell for processing alternate steels grades and additional product sizes. Complete an associated investigation of opportunities for deployment into Timken's Industrial Bearing Business by August 2007.

  Complete the flexible finishing cell by adding supplemental finishing assets. Complete investigation of opportunities for deployment into Timken's Industrial Bearing by August 2007.

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Anticipated Economic Impact

- **Annual energy cost savings per REML line**

  (390,000 kVA-hrs/yr) * ($0.05 / kVA-hrs) = $19,500 / yr

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

- **Productivity improvement**

  Reduced labor content

  Reduced flow time

  Reduced unit cost

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Continuation after ITP-Sponsored Project

- Ongoing effort to optimize and qualify inductive heating efficiency and post-heat metallurgical properties of new steel grades, new (larger) part sizes and new part geometries and features (flanges, holes, slots, grooves).

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Value Proposition for End User

- Industry will analyze their specific business cases and will project that manufacturing costs will be less with the REML line (or REML stand-alone cells) than with the conventional line for low run volumes.

- The basis for lower cost in thermal treatment will be reduced energy consumption, reduced labor content, reduced flow time.

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Commercialization Plan

- The Timken Company will explore opportunities for deployment of the green cell(s) into the Timken external supply chain of green races.

- 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.

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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).

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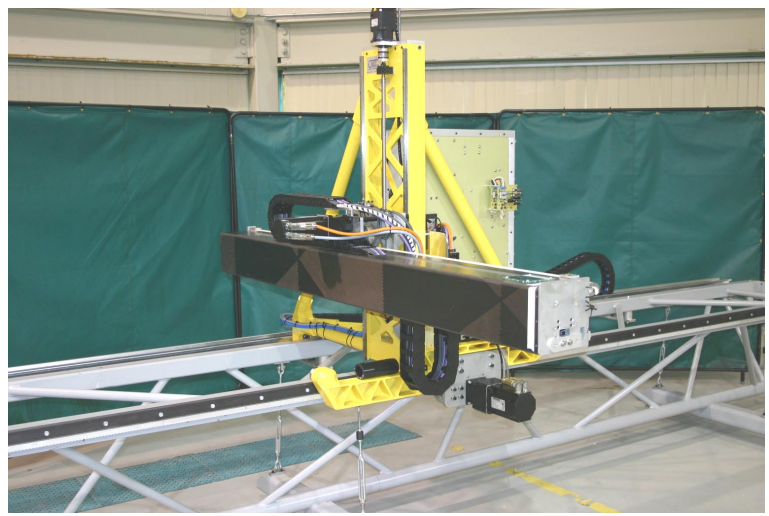
Showcasing Opportunities

Dr. Steve Dickerson, CAMotion, Inc.; Ai-Ping Hu, CAMotion; Inc, Joe Pack, Timken Co.

"A Large, High-Speed, Machine-Tending Robot",

Cleveland Exposition and Conference Emphasis on Flexible Manufacturing, Cleveland OH, June 7 – 9, 2005



Showcasing Opportunities

Department of Energy and Energy Industries of Ohio (EIO) Showcase Presentation
Cleveland OH, Sep 28, 2005

Showcasing Opportunities

Robotics in Manufacturing Technology Roadmap Workshop June 29, 2006 Baltimore, Maryland

Focused on identifying ways of furthering the development of robots and/or other manufacturing process equipment that reduce manufacturing costs and energy use. The output of the workshop will be a roadmap to be used by industry and DOE in advancing industrial robotic applications. Energy Industries of Ohio (EIO) is assisting in planning and conducting this workshop. Energetics Incorporated will provide facilitation for the workshop and prepare the overall documentation for the effort.

DOE Site Visit to REML Line 3Q 2006

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