The advancement in surface quality assurance for hot rolled steel bars

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Project Description

- This SQA program is to solve the major surface quality problems for the US special quality steel bars and rods industry and their customers.
  - The problem accounts for roughly 50% of the rejects.
  - The sporadic nature cannot be addressed based on sampling techniques.

- The goal is to develop & demonstrate an SQA™ prototype that
  - Enables efficient steel bar rolling process control of surface quality;
  - Is capable of automatic accurate-marking of the residual surface defects for downstream removal.
Project Description

Core Technology:

- In-line, real-time imaging based visual inspection;
- Modal based vibration reduction;
- Advanced data analysis for process signatures and root cause identification;
- Predictive process control to prevent surface defects;
- A new business paradigm based on defect detection, marking and removal.
Project Description

- **Initial Application:**
  - Steel bar/rod rolling mills

- **Key Project Deliverable(s)**
  - A reliable and accurate HotEye™ surface inspection system.
  - An effective, non-contact vibration reduction device.
  - A methodology for rolling process signature identification.
  - An integrated prototype of an on-line automatic root cause identification system.
  - A system for automatic defective segment removal.
Barriers and Pathways

**Barriers**
- Lack of a reliable surface defect detection system;
- Lack of a means for accurately registering/tracking defects, and
- Lack of the comprehensive knowledge of the complex rolling process.

**Pathways**
- Improved in-line surface defect detection capability;
- Integrated database systems (mill operation + surface defect data);
- Advanced pattern extraction models;
- New logistics for steel bar delivery; and
- Intensive on-site test and refinement.
Energy Savings

- Energy be saved through reduced steel mill scrap
- Based on the assumption that the surface defect scrap rate can be reduced by 80% in the special bar quality production,

The advancement in technology from 2003 expects to save
- 749,000 MMBTU / Year by 2010
- 5,800,000 MMBTU / Year by 2020
Other Important Metrics

- Decrease defect detection false positive accuracy to 2%, from ~20% prior to the project.

- Improve the capability of inspecting small bar to φ5 mm (φ13/64”, state-of-the-art rolling capability), from φ8 mm capability.

- Improve the defect position registering (speed measurement) accuracy to 0.2%, from ~2%.

- Decrease the surface defect caused rejection rate to 2.5%, from ~5% as in 2003.
Accomplishments to Date

- Achieved the target surface detection accuracy of the in-line surface detection system.
- Demonstrated the target speed measurement accuracy on rods as small as $\phi$9 mm.
- Demonstrated the capability of in-line pattern identification for selected surface qualify faults.
Surface Defect Detection Accuracy
Surface Defect Detection Accuracy

Ability to detect and differentiate:

• Seams/laps
• Slivers/scabs/checking
• Overfills
• Scratches
• Roll cracks (periodic)
• Fluttering (periodic)
• Tool marks

Seam  Roll cracks  Overfill  Scratch  Heat crack
Speed Measurement Accuracy

- Base technology: Laser Doppler Velocimeter
- Issue: Difficult to maintain perpendicularity to the surfaces of long products
- Solution: Special signal processing to extract the good measurements
- Tested accuracy: 0.02% of the speed

Part made and turned on a CNC lathe
In-line Repeating Pattern Identification

**Ideal Case**

In-line Images

Repeating Pattern

Autocorrelation

Symptom / Problem Location

Roll Pass Parameters
In-line Repeating Pattern Identification

Real Case

In-line Images

- Contact/non-contact in subsequent rolling stands
- Quantization error due to fast computing needs
- Signals from multiple repeating sources
- Localized noise sources

Roll Pass Parameters

Repeating Pattern

Autocorrelation

Symptom / Problem Location
Next Project Steps

For each technology developed,

- Proof of on-site stability with a 6-month trial of production usage at beta site.

- Integration of the developed technologies into the base HotEye™ sensor system.

- Documentation of performance and benefits.
Future Milestones

- Demonstrated surface detection capability for wire (smaller than $\phi 8$ mm, or $\phi 5/16”$) rolling lines by 12/31/2005.
- Demonstrated off-line process diagnosis for rolling process faults that result in surface defects by 12/31/2005.
- Demonstrated near-real-time on-site process diagnosis for rolling process faults that result in surface defects by 12/31/2006.
- Demonstration of surface defect marking, tracking, and removal by the end user of the steel bars by 12/31/2006.
- Demonstration of 80% surface defect reduction (baseline defect rates prior to this project) by 12/31/2007.
The technology developed will be marketed directly.

In fact, the following items are already integrated into the base sensing product:
- Accurate surface defect detection algorithms
- In-line repeating defect pattern identification

More development may be necessary for other applications
- Planned project blocks to lower entry barrier
- Seeking possible matching funds
Value Proposition for End User

- Improved productivity
- Improved quality
- Improved efficiency
- Expected payback of at least $1M / year
- Example Case:
  
  The developed technology has helped a mill reduces its monthly average mill setup rejects from ~150 tons to ~10 tons.
Commercialization Plan

- Current market status
  - Steel industry is in its best period for years
  - No competing imaging technology in the long product sector

- Marketing objective
  - Solution provider to long product rolling mills for surface quality

- Marketing activities
  - Nine steel companies visited the project host site since March 2004
  - Exploring next step with a rolling equipment provider
  - More than 10 outstanding business proposals

- Current market position
  - The only proven in-line seam/overfill detection system for bars and rods
  - Close cooperative relation with most US SBQ mills
  - Seeking worldwide patent protection
  - Established market in Asia

- Broaden Applications
  - Started a contract for rail inspection
  - Negotiating a contract for billet inspection
Commercial/Technical Risks Remaining

- **Complex causal relationship for sporadic defects**
  Results to date are not intuitive and yet to be further delineated.

- **Uncertain on-site schedule**
  The test hosting sites are running their production schedule, which always takes the priority.

- **Global market**
  Such global appearance is a good opportunity, with a potential risk to OGT.

- **Potential steel price instability**
  Decreased profits may prohibit the bar mills to limit their investment on capital equipment.

- **Difficult 1st sales into the secondary applications**
  The industry has a special sense of “risk” when it comes to adopting new technologies.