Energy Savings Initiatives

The Timken Company’s Steel Business
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Energy Savings Initiatives
The Timken Company’s Steel Business

Outline of Topics to be Discussed

• Overview of Energy Savings at Timken over the Years
• Heat Treat Furnace Energy Savings Projects
  1. Reducing the number of burners
  2. Installing high velocity burners
• Rotary Furnace Energy Savings Projects
  1. Tuning on-line billet temperature model and level 2 control system
  2. Optimizing on-line billet temperature model and level 2 control system
  3. Replacing conventional burners in the high fired zones with regenerative ones
  4. Redesigning recuperator by adding more surface area
  5. Increasing oxygen enrichment
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Alloy Steel - US
MCF per Shipped Ton

1980s ~ 40% improvement  
1990s ~ 17% improvement  
2000s ~ 45% improvement (excl. 2009)

Faircrest Steel Plant
HSP Continuous Caster
HSP Continuous Mill
CI
Heat Treat Furnace Energy Savings Projects

- Historically the furnaces were designed for production & quality
- Energy efficiency was not the primary driver
- Team of Manufacturing, Process Improvement, Combustion, & Met QA was formed
Heat Treat Furnace Energy Savings Projects

An idea was generated that we may be able to reduce the number of burners.

Numerous trials were run monitoring temperature profiles of the product and the furnace.

Product samples were cut and examined to assure no impact to the product properties.
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Trials supported reducing burners in the soak zones

Results:
- No impact to product quality
- Significant fuel savings
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Reducing the number of burners

This control chart shows the Results

Net reduction of 25%
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One of our car furnaces had lower velocity 1950 vintage burners

Another car had a higher mix 1979 vintage burner
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These two car furnaces at GSP were rebuilt with high velocity burners to improve throughput in addition to energy.
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Installing high velocity burners

As high as 33% savings for some heat treat cycles
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Other projects:
- Reduced Cycle Times
- Improved Furnace Pressure Control
- Shut down Zones
- Added Insulation
- Better Control of Air/Fuel
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Key factors for success:

- Projects needed dedicated resources
- Finite element analysis knowledge was essential
- DOE (Design of Experiment) expertise was required
- Commitment from operations for the trials was needed
- Trials were designed to run within standard operating ranges
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Tuning on-line billet temperature model and level 2 control system

• True knowledge of billet temperatures allows optimum pre-heat conditions to be set
• Scale layer minimized so mill yields increase
• Areas of non-uniform heating that cause eccentricity of tubing identified
• Vital information for verification of mathematical furnace models
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**Tuning on-line billet temperature model and level 2 control system**

Making Thermod billet temperature calculation closer to actual temperature. Attaching a logger to the billet with thermocouples recording temperatures every 5 seconds.
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Tuning on-line billet temperature model and level 2 control system
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Tuning on-line billet temperature model and level 2 control system
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Tuning on-line billet temperature model and level 2 control system

<table>
<thead>
<tr>
<th>NO.</th>
<th>TC LOCATION</th>
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<tbody>
<tr>
<td>1</td>
<td>TOP, MIDDLE</td>
</tr>
<tr>
<td>2</td>
<td>CENTER, MIDDLE</td>
</tr>
<tr>
<td>3</td>
<td>BOTTOM, MIDDLE</td>
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<td>4</td>
<td>TOP, END</td>
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<td>7</td>
<td>SIDE</td>
</tr>
<tr>
<td>8</td>
<td>ZONE</td>
</tr>
</tbody>
</table>

SECTION A-A (ENLARGED)

TC #1, #3, #4, AND #6 ARE LOCATED 1/4" INSIDE THE SURFACE
TC #8 IS LOCATED 1/4" OUTSIDE THE SURFACE
TC #7 IS LOCATED 3/4" INSIDE THE SURFACE

TIMKEN
THERMOCOUPLE LOCATIONS
DRAWING IS TO SCALE
BY NATHAN ABOUD 6/14/02
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Tuning on-line billet temperature model and level 2 control system
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Tuning on-line billet temperature model and level 2 control system
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Tuning on-line billet temperature model and level 2 control system

**INPUTS**

ZONE TEMPERATURE  
TIME  
BILLET OD  
SPACING  
VIEW FACTOR  
EMISSIVITY  
MATERIAL TYPE  
CONDUCTIVITY  
HEAT CAPACITY

**MODEL**

**OUTPUTS**

CALCULATED BILLET TEMPERATURE
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Tuning on-line billet temperature model and level 2 control system

• Design of experiment goal was to run a minimum number of trials to identify the variables causing the most amount of error between calculated and actual billet temperature.

• These trials were later analyzed and used to refine the model and reduce the error.
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Tuning on-line billet temperature model and level 2 control system

- Assuming:
  - The error from factor interactions is negligible
  - Only diameter spacing and time are the main factors
- DOE half factorial predicts the main effects of 3 control factors with a total of 6 runs

<table>
<thead>
<tr>
<th>RUN</th>
<th>DIA</th>
<th>SPACING</th>
<th>TIME (MPI)</th>
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<tbody>
<tr>
<td>1</td>
<td>10.5</td>
<td>1.25</td>
<td>15</td>
</tr>
<tr>
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</tr>
<tr>
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<td>6</td>
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<td>15</td>
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<tr>
<td>6</td>
<td>6</td>
<td>0.25</td>
<td>25</td>
</tr>
</tbody>
</table>
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Tuning on-line billet temperature model and level 2 control system

- Zone temperature range is 1700°F to 2350°F. It varies within the same run. Thus, its effect was captured.
- Time usually varies from 15 MPI TO 25 MPI. Only 6” billet was tested at 15 MPI and 25 MPI. The 10.5” billet cannot be tested at 25 MPI due to Datapaq limitations.
- View factor is a function of spacing. Only spacing was tested.
- Emissivity varies with scale thickness and scale thickness varies with time. Only time was tested.
- According to DEFORM model already developed, material type has negligible effect.
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Tuning on-line billet temperature model and level 2 control system

Material type effect is negligible
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Tuning on-line billet temperature model and level 2 control system

Predicted temperature was off by over 400° F at times
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Tuning on-line billet temperature model and level 2 control system

New view factors were calculated to account for furnace geometry and billet spacing variations

Furnace thermocouples were relocated to reflect true zone temperature

Difference between actual billet temperature and calculated billet temperature was significantly reduced
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Quality

Production

Energy Savings
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Optimizing on-line billet temperature model and level 2 control system

If the billet temperature is non-uniform, the tube is eccentric. Eccentric tubes often result in an out-of-tolerance wall size.
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Optimizing on-line billet temperature model and level 2 control system

Furnaces are slightly pressurized in order to reduce cold air infiltration

Cold air infiltration negatively affects billet temperature uniformity
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Optimizing on-line billet temperature model and level 2 control system

- Billet spacing
- Zone #4 excess air
- Zone #5 excess air
- Enthalpy Profile
- Furnace pressure

Responses were:

Eccentricity (P)
Fuel Consumption (S)
Productivity (S)
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Optimizing on-line billet temperature model and level 2 control system

- A resolution 5 fractional factorial design of experiment with center points was conducted using JMP
- Ran a four month trial
- Towards the end of the trial, results started to show that lower eccentricity can be achieved with increased spacing, increased excess air, and higher furnace pressure
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**Optimizing on-line billet temperature model and level 2 control system**

- The trial was augmented with additional settings in order to determine the optimal settings for this process.
- The trial was continued to completion with these additional runs.
- Optimal spacing was determined (Greater than normal practice)
- We optimized excess air (which was a higher setting)
- Furnace pressure was not changed
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Optimizing on-line billet temperature model and level 2 control system

Eccentricity Percent from IMS gage

Control Chart
Rotary Furnace Energy Savings Projects

Optimizing on-line billet temperature model and level 2 control system

• In Summary:

• A design of experiment using JMP (statistical software) was conducted to optimize furnace settings and achieve uniformly heated billets.

• Since then, eccentricity has been at a record low. Tubes concentricity significantly improved allowing us to process new orders with a tighter wall size tolerance.

• Monitoring fuel, we did see a reduction in fuel.

• Productivity was maintained
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Regeneration uses a pair of burners which cycle to alternately heat the combustion air or recover and store the heat from the furnace exhaust gases.

- Replaced 21 burners with 9 burners at #4 Rotary in 2006

- Air preheat temperatures within 300°F - 500°F of the furnace are achieved resulting in exceptionally high thermal efficiency.

- Result was 32% in natural gas saving
Replace conventional burners in the high fired zones with regenerative ones.
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Replace conventional burners in the high fired zones with regenerative ones

Regenerative Burners Cycle B

Media

Courtesy of Bloom Eng.
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Redesign recuperator by adding more surface area

A recuperator is a special purpose counter-flow heat exchanger used to recover waste heat from exhaust gases. Optimization of heat recuperator size for heat recovery applications is extremely significant in order to get maximum savings from these systems.

Courtesy US Department of Energy Efficiency
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**Increase oxygen enrichment**

Substitution of commercial oxygen for combustion air, which contains only 20.9% O2, reduces the volume of heat-absorbing nitrogen flowing through the combustion process and therefore reduces the flue gas loss.

2005: 3% enrichment  
2006: 7% enrichment

Result was 10% in natural gas saving
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Other projects:
- Shut down Zones
- Added Insulation
- Better Control of Air/Fuel
Questions?