OPTIMIZATION & ANALYTICAL OPPORTUNITIES IN THE STEEL INDUSTRY

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Agenda

- Context
  - Tata Steel
  - Integrated Steel Plant Operations Background

- Areas for Optimization in the Steel Industry
  - Process
  - Logistics
  - Capacity

- An unsolved problem

- Challenges

45 Minutes
Tata Steel Limited

- 5 MT fully integrated steel plant
- 40,000 work force
- Key Segment: Automotive and Construction
- No. 1 Steel Company in the world - World Steel Dynamics 2006
From dirt to door panels

Inbound:
- Iron
- Coal
- Limestone
- Scrap
- MRO
- Energy

Outbound:
- Distribution Center
- Service Center
- Tier 1
- Automotive Assembly
- OEM
- Appliance

OEM
Into the Steel Plant
An integrated steel plant is a complex industrial system in which LIMITED materials flow through VARIOUS routes to generate NUMEROUS products through DIFFERENT series of production units.
Areas of Optimization
OR  or or or

Optimization
Illustrative Scope of Optimization

<table>
<thead>
<tr>
<th>Process Modeling</th>
<th>Capacity balancing</th>
<th>Logistics optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Blend optimization of coal mix, sinter charge, Blast Fces.</td>
<td>• Load balancing on each work center</td>
<td>• Design transportation network to reduce freight cost.</td>
</tr>
<tr>
<td>• Heat and mass balance for steel make operation</td>
<td>• Modeling demand</td>
<td>• Raw Material movement and storage.</td>
</tr>
<tr>
<td>• Modeling blow pattern in BOF</td>
<td>• Product Mix optimization</td>
<td>• WIP flow balancing</td>
</tr>
<tr>
<td>• Modeling of decarburization in RH-degasser</td>
<td>• Inventory optimization</td>
<td>Etc…</td>
</tr>
<tr>
<td>• BAF filling factor</td>
<td>• Design buffer</td>
<td></td>
</tr>
<tr>
<td>Etc…</td>
<td>• Scheduling each work center</td>
<td></td>
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<td>Etc..</td>
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Process Modeling
Optimal allocation of Electrical energy

• Problem
  – Energy in steel plant is a scarce and expensive resource.
  – Typically eastern part of India the gap between the supply and demand is very high.
  – In steel plant some of the units are considered as essential power consuming units (such as BF CO etc..) requires fixed units of power.

In case of shortages in the power supply, how the consumption to be distributed most profitably.

• Model Objective
  – Maximizing Profit contribution
  – Minimize the cost of production
  – Maximize the Throughput.

• Model used
  – Linear Programming with Power as a limiting constraint.

Edelman Recognized
Problem:
A model to predict the heat transfer from the reheating furnace atmosphere to the surface of the slab and from the slab surfaces to the core of the slab.

Heating profile of the reheating furnace depends on

- Target drop out temperature
- Entry temperature
- Different thermal properties for different grades of steel
- Operational fluctuation in the down steam processes

Model Objective:
- Understand the thermal model
- Understand the operational requirements
- Calibrate the model parameters

Model Used:
- Mathematical functions using basic heat transfer equations.
Online Slab Temperature Calculation and Control

Basic parameters:

Reheating furnace of walking beam type of effective thermal length 39 meters with max operating temp 1350°C.

The furnace divided into 12 operating zone
- Recuperative (top and bottom)
- Preheating (top and bottom)
- Heating (top and bottom)
- Presoaking (top and bottom)
- Soaking right (top and bottom)
- Soaking left (top and bottom)

Assumptions:

- Heat transfer mode is primarily radiative.
- Insulating effect on heat conduction due to scale formation is negligible
- Heat transfer in the slab is only from the top and bottom surfaces, mode being conduction
- Shadowing effect due to skid layout is small
- Temperature throughout the horizontal plan in the slab is uniform.

Contd..
Online Slab Temperature Calculation and Control

Radiative heat Transfer from the furnace to the slab surface

- Nodal point at each Zone (maximum temperature) were identified
- Measured temperature by the TCs nearest to the nodal points used as primary radiation data.
- An offset (fixed and variable) was added to the measured temperature for absorbing the effect of the convective heat transfer
  - Fixed part- Additional heat transfer for the standard fuel flow at each zone
  - Variable part- Deviation in convective heat transfer due to changes in fuel flow w.r.t. standard.

Calculated nodal point temperature was extrapolated throughout the furnace length to provide two continuous radiation curves
  - Along the ceiling
  - Along the floor

This continuous temperature profile used as higher temperature and the slab surface as a lower temperature in the Stefan-Boltzman's radiation equation.

This calculates the heat flux density of the slab.

\[ j^* = \sigma T^4 \]
Online Slab Temperature Calculation and Control

Conductive heat Transfer from the slab surface to the core of the slab

- The model used one dimensional Fourier’s heat conduction equation.
- The temperature and heat flux equations were solved using finite element technique.
- Slab thickness was divided into 7 layers each at 35mm apart.
- Top and bottom surface temperature calculated from the radiation equations was used as boundary value.
- Physical properties (such as thermal conductivity, specific heat etc..) of the plain carbon steel were taken from standard table.
- Interval between successive calculations was taken one minutes.

PI control for achieving required slab temperature

\[
\frac{\Delta Q}{\Delta t} \sim kA \frac{\Delta T}{\Delta x}
\]

- Calculated slab temperature from the 7 layers then processed as average upper half and average lower half temperature and compared with the respective slab target temperature.
- The deviations were averaged for all the slabs in a zone.
- This was used as feedback to PI control loop which calculates the temperature set point for all Level 1 system thermocouples.
- Out put down loaded to Level 1 system.
- This dedicatedly tries to maintain the set point by regulating the fuel flow rate.
Cost optimized executable dispatch plan

• **Problem**
  – Transportation of the finished good in steel industry is a complex and expensive operation.
  – Typically eastern part of India the infrastructure is not favourable for the industries.
  – Resources such as transportation modes are not well organised.
  – Most of our movements are away from Eastern zone.

*How to use the resources optimally at the lowest cost*

• **Model Objective**
  – Minimize the cost of finished goods movement per ton.
  – Minimize the congestions of finished goods at each nodes.
  – Maximize the material movement.
  – Predict budget allocation requirement.

• **Model used**
  – Linear Programming.
Cost optimized executable dispatch plan

PARAMETERS:

Products
- HR / CR coils/ Sheets& Plates /
- WR coils, Rebars, Billets,

Routes & Costs
- Mother Mill
- Rail siding
- EPA
- St.Yd/Hub

Transport Mode & Costs
- Rail
- Road
- Container
Annual Sales Plan
Product group/ volume/ destination

Annual Shutdown Plan
Each major resources

Detailed Annual Business plan
Product group/ Volume / Destination

Total Delivery System Cost
Product group / Route / Destination / Mode / Cost data

Transport Capacity Constraints

L P model
for Cost Optimization

Rework with Shipment execution constraints

Matrix developed on XL spreadsheet.

Cost-optimized & executable Dispatch Plan
Product group / route / mode / destination / volume / cost
Capacity Balancing
### Problem

- Limited ability to proactively fulfill rapidly-changing customer demand.
- Infeasible supply plans due to inability to model all relevant supply chain bottlenecks.
- Low asset utilization due to inability to get a single global view into entire supply chain.
- Sub-optimal costs and lost sales due to limited analytics and optimization.
- Inability to allocate limited product supply through sales channels.

### Solutions

- Maximize customer responsiveness by integrating supply planning to strategic planning and forecasting processes.
- Gain global visibility into extended supply chain by modeling all relevant production and distribution bottlenecks.
- Increase feasibility of detailed plan by representing them in global supply plans.
- Simultaneously optimize entire supply chain in a real world fashion by considering real costs and multiple goals.
- Allocate limited supply as ATP reservations.

### Benefits

- Reduced planning cycle time.
- Generation of feasible plan.
- Higher service level for key customers.
- Reduced Inventory costs.
- Reduced obsolescence cost.
- Improved profitability by allocating most profitable customer.

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**What does the Capacity balancing do to the business?**

- **Limited ability to proactively fulfill rapidly-changing customer demand.**
- **Infeasible supply plans due to inability to model all relevant supply chain bottlenecks.**
- **Low asset utilization due to inability to get a single global view into entire supply chain.**
- **Sub-optimal costs and lost sales due to limited analytics and optimization.**
- **Inability to allocate limited product supply through sales channels.**
Order Planner - Purpose

• The primary goal of Order Planner is to develop a feasible production plan for satisfying demand requirements placed on the Order (i.e., customer / forecast orders) respecting the due date promised.

• The production plan is developed with the simultaneous consideration of the following constraint types:
  – demand constraints: due dates and their tolerances
  – material constraints: materials availability (quantities and timing) – used for outsourced RM
  – capacity constraints: resources availability (quantities and timing)

• Order Planner is an intelligent decision support system for short-range and medium-range production planning.
An unsolved problem
Already Existing Body of Work

1. Modeling and Solution Approaches to Practical Scheduling Problems in Iron & Steel Industry by Dr. Lixin Tang, Dr. Jiyin Liu and Professor Zihou Yang
2. Steel-making process scheduling using Lagrangian relaxation by Lixin Tang, Peter B. Luh, Jiyin Liu and Lei Fang
3. A Survey of Mathematical Programming Applications in Integrated Steel Plants by Goutam Dutta and Robert Fourer
4. Utility and Stability Measures for Agent-Based Dynamic Scheduling of Steel Continuous Casting by D. Ouelhadj, P. I. Cowling, S. Petrovic

And there are many more mathematical models developed on this subject
Already Existing Software Solutions From…

1. Siemens
2. Rockwell Automation
3. IBM
4. Broner
5. i2
6. POSDATA
7. OM Partners

For instance, if caster and HSM are synchronized, then the impact on LH and RF are ignored.

How should the scheduling logic change intra-day if there is a change in hot metal quality?

Leaving aside many homegrown systems…

…But, the depth and breadth to cover for the variability of steel production as well as all the production steps remained a question ….
Melt Shop Scheduling

Steel plan depends on:

a) Downstream demand based on Order due date
b) Production constraints
   a) Technical constraints
   b) Shop Constraints
c) Dispatch constraints
d) Maximize capacity utilization at each resource
e) WIP reduction
Melt Shop Scheduling
Challenges
Critical Success Factors

- A large % of such initiatives don’t see the light at the end of the tunnel ……. Due to non-technical reasons

Because

“Technical problems are the easier ones to solve... The soft issues are always the hardest.”
What Kind of Project is this???

- IT?
- R & D?
- Process changes?
- Performance Improvement?
- Business Solution that will shape the future?
Who’s Project is this???

Understanding of Business

Academia

Collaboration

Business Practitioner

Source: Dr Brian Eck
Business Vision

• Clear understanding of problem definition
• Alignment with business strategy
• Identify and agree on direction
• Define critical success factors for the business and project
• Unify individual visions
Organizational Issues

- Business vision, strategy
- Top Management commitment
- Change Management
- Scope management
- User expectations
- Reporting issues
- Training
- Implementation timing
Manage Expectations

• Expectations, while necessarily ambitious, must be grounded in reality.
Compliance or commitment

Change can be achieved through

Commitment: "I want to do it this new way" and "I have to do it this new way"

Reaction: "I will react to this change if I must"

Avoidance: "I must avoid this change"

Positive perception: "I see the opportunity in this change" and "I will experiment with this change - and check that it really works"

Negative perception: "I feel threatened by this change" and "I must avoid this change if I must"

Engagement: "I see the implications for me/us" and "I will act to achieve this change"

Understanding: "I know what will change and why"

Awareness: "I am being told about something"

Change can be achieved through commitment or compliance
Discussion