Thyssenkrupp Industrial Solutions
Coke Plant Technologies

The value of engineering for reduction of CAPEX and OPEX as well as for optimizing the performance of coking plants

25 Anniversary of Polish National Cokemaking Conference
Koksownictwo 2017

engineering.tomorrow.together.
Development of coke plant technologies

~ 1980s
- Large number of coal mines and coke plants in Europe
- Rapid development of coke plant technologies
- Innovations constantly implemented on new plants
- Speed of innovation slowing down from 1980s

1990 ~ 2003
- Constant reduction of steel and coke production in Europe
- Supply of low cost coke from China
- Reduced number of projects for new plants
- Sharp reduction of specialists for design / R&D projects

2003 ~ 2012
- Enormous increase of coke price
- Boom in constr. of new and replacement of aged plants
- Copies of existing designs with little innovation
- Low number of R&D projects and design specialists

2012 ~ now
- Over-supply of steel on world market => low profits
- Very few projects for new plants
- Main buying criteria is lowest price (of engineering)
- Value of technology and design is not respected
Development of coke plant technologies

Example: increase in oven dimensions:

- Demand for larger production capacities.
- Limited area available for installation.
- Reduction of emissions due to smaller number of charging/pushing actions and oven closures.
- Desire to decrease manpower for operation and maintenance.

<table>
<thead>
<tr>
<th>Year</th>
<th>Width (m)</th>
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<tbody>
<tr>
<td>1900</td>
<td>2.5</td>
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<tr>
<td>1915</td>
<td>3.0</td>
</tr>
<tr>
<td>1925</td>
<td>4.2</td>
</tr>
<tr>
<td>1928</td>
<td>6.0</td>
</tr>
<tr>
<td>1970</td>
<td>7.1</td>
</tr>
<tr>
<td>2003</td>
<td>8.4</td>
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Development slowing down
Development of coke plant technologies

Requirements for future sustainability of coking industry

Optimization of
➢ operational safety and plant performance
➢ environmental plant performance
➢ working conditions in the plant
➢ cost for operation and maintenance (OPEX)
➢ plant service life

Combined with reduced cost of investment (CAPEX)!

How can that be achieved ??
Reduction of NOx-content in waste gas

Combiflame® heating system

Combination of air staging and internal flue gas recirculation
Reduction of NOx-content in waste gas

Combiflame® heating system

Combiflame® 2.0 heating system

Largely reduced NOx-formation
Reduction of NOx-content in waste gas

Combiflame® 2.0 provides for:
- Reduction of NOx-formation at constant heating flue temperatures
- Improved heat distribution over the height of heating flues

Example from a recent project:
Production capacity 1,600,000 tons/year
Limit of NOx-content in waste gas < 150 ppm
Copy of an existing design requires 128 ovens
Average heating flue temperature 1,250°C

Optimized design concept requires 120 ovens
Average heating flue temperature 1,290°C
Reduced number of ovens minus ~ 6.5%

With much more potential after validation of present calculations
Optimized oven dimensions

Methodology of main process engineering steps:

1. SUGA-value (>100 hPa)
2. Chamber length L
3. Coal-H₂O
4. Max. heat flue temperature (NOₓ< xxx mg/Nm³)
5. Coal-vm, ash
6. Oven pitch, chamber width W, chamber height H, roof thickness
7. Oven volume
8. Bulk density
9. Net coking time
10. Coke yield
11. Coke production requirement
12. Oven number required
13. Maximum machine operating cycle (pushes/d/set)
14. Chamber width
15. Regenerator, corbel area
16. Concrete wall thickness
17. Overall battery dimensions
18. Overall battery dimensions

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Optimized oven dimensions

Methodology of cost estimates:

- Total refractory quantities are calculated precisely based on the dimension of the battery.

- The quantities of all other equipment were compiled from completed plants and current project proposals, approximated by means of correlations with the battery dimensions.

- Unit prices for equipment and construction can be adjusted case by case depending on the country of manufacture / installation.
Optimized oven dimensions
Chamber length

Enlarging the chamber length causes:

- linear increase of production capacity (or reduced number of ovens)
- linear increase in quantities of refractory
- almost no increase in mech. equipment & electric/instrumentation/automation
Optimized oven dimensions
Chamber length

Enlarging the chamber length causes:

- linear increase of production capacity (or reduced number of ovens)
- linear increase in quantities of refractory
- almost no increase in mech. equipment & electric/instrumentation/automation

➢ The most economical way of capacity increase!
Optimized oven dimensions
Chamber height

Enlarging the chamber height causes:

- almost linear increase of production capacity (or reduced number of ovens)
- increased oven pitch in order to keep the wall stability
- disproportionate increase in quantity of almost all equipment
Optimized oven dimensions
   Chamber height

Enlarging the chamber height causes:

- almost linear increase of production capacity (or reduced number of ovens)
- increased oven pitch in order to keep the wall stability
- disproportionate increase in quantity of almost all equipment

➢ The most costly way of capacity increase!
Optimized oven dimensions
Chamber width

Enlarging the chamber width causes:

- slight reduction of production capacity (or more ovens)
- reduction of numbers of pushes per day
- reduction of regenerator height
- reduction of corbel thickness
- reduction of sole flue height
- increase of oven pitch
- slight increase of material quantities
Optimized oven dimensions

Chamber width

Enlarging the chamber width causes:

- slight reduction of production capacity (or more ovens)
- reduction of numbers of pushes per day
- reduction of regenerator height
- reduction of corbel thickness
- reduction of sole flue height
- increase of oven pitch
- slight increase of material quantities

➢ Important factor for achieving the optimum number of coke pushes per day!
Optimum oven dimensions

Example from a recent project:

- Production capacity: 1,600,000 tons/year
- Copy of an existing design requires: 120 ovens, 105 pushes / day

Optimizations of chamber dimensions proposed by tkIS:
- Increase of chamber length
- Reduction of chamber width
- Reduction of oven pitch

Optimized design concept requires:
- 100 ovens, 104 pushes / day

Reduced weight of mechanical equipment minus 20%
Reduced weight of refractory material minus 10%
Design improvements
Design of wall protection plates

Design with wall protection plate of cast iron

Very heavy => high cost
High thermal deflection

Design with wall protection plate plus sealing membrane of mild steel plate

Light weight => low cost
Easy adjustment
Increased tightness
Design improvements
Location of regenerator sliding joint

Arrangement of sliding joint between fireclay and silica right above the sole flues:

- Less regenerator bracing
- Reduction of investment and erection costs
- Easier spring adjustment
Design improvement
Location of regenerator sliding joint

High level of sliding joint
Many springs, high cost, difficult adjustment

Low level of sliding joint
Less springs, reduced cost, easier adjustment, reduced strains on buckstay
Design improvements
Type of waste gas valves

Valve with 2 spindles
Leakages possible between air and waste gas

Valve with 1 Spindle
With better sealing between gas and waste gas (air between gas and waste gas)
Design improvements
Type of waste gas valves

Improved design
with 2 separate connection pieces between valve and sole flues
=> reduced cost for manufacturing
Design improvements
Oven pressure control system

EnviBAT 2.0

Simplified connection to DCS
Design improvements
Oven pressure control system

Current pneumatic cabinet

EnviBAT 2.0
New pneumatic cabinet with intelligent databus connection
Design improvements

Oven pressure control system

Merits of EnviBAT 2.0

- Simplified connection to DCS
- No RIO cabinets required
- Reduction of cables
- Simplified control cabinets

Resulting in reduction of:

- Equipment cost
- Erection cost
- Erection time
- Maintenance cost
Design improvements
Compensator between standpipe elbow and gas collecting main

Easy installation, exchange and maintenance, more flexibility
Less material cost than fixed connection
Design improvements
Charging car rail chairs

Heavy cast-iron rail chairs:
difficult alignment, expensive manufacturing

Simple, light steel rail chairs:
easier alignment, cheaper manufacturing
Design improvements

Example from a recent project:

Production capacity 1,600,000 tons/year

Copy of an existing design requires
- Weight of mechanical equipment 14,620 tons
- Weight of refractory material 60,070 tons

Optimized design concept requires
- Weight of mechanical equipment 13,470 tons
- Weight of refractory material 59,490 tons

Reduced weight of mechanical equipment minus ~ 8%
Reduced weight of refractory material minus ~ 1%
Effect of reduced NOx-formation, design improvements and optimized oven dimensions

Example from a recent project:

<table>
<thead>
<tr>
<th>Design concept</th>
<th>Number of ovens</th>
<th>Weight of mechanical equipment</th>
<th>Weight of refractory material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copy of existing plant</td>
<td>128</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>+ NOx-reduction</td>
<td>120</td>
<td>93.8%</td>
<td>93.8%</td>
</tr>
<tr>
<td>+ design improvements</td>
<td>120</td>
<td>86.4%</td>
<td>92.9%</td>
</tr>
<tr>
<td>+ optimized oven dimensions</td>
<td>100</td>
<td>74.8%</td>
<td>84.6%</td>
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</table>

Large savings on equipment and construction!
Effects on total investment costs (CAPEX)

Evaluation of cost factors:

- **Engineering**: 10% ~ 15%
- **Equipment**: 40% ~ 50%
- **Construction**: 35% ~ 50% (related to quantity of equipment)

- 85% ~ 90% of investment costs are related to the quantity of equipment

- **Reduction of equipment quantities is most important for optimization of investment cost!**
Further design improvements
Optimized design of regenerator walls

Previous design

New design with improved tightness due to larger staggering of joints
Further design improvements
Optimized design of regenerator faces

Previous design

New design with improved tightness

- Reduced energy demand and
- Reduced emissions
Further design improvements
Optimized heating wall quoin

Previous design

New design with improved tightness
Further design improvements
Optimized oven roof design

Previous design

New design with grouting joints for improved tightness
Further design improvements
Low emission bleeder system

- Safe ignition of the crude gas
- Complete, soot-free, combustion
- Low NOx-emissions
- Low thermal radiation
- Stable flame direction, i.e. no straying flames due to wind impacts
Further design improvements
Low emission bleeder system

Smokeless bleeder system in operation
Coke Plant Automation – The COKEMASTER® Suite


PCS = Pushing and Charging Supervision and Control
HQC = Heat Quantity Calculation and Control
DCS = Distributed Control System
MARCO = Evaluation Software for ManuTherm, AutoTherm, RamForce for Coke Ovens
MBT = Mean Battery Temperature for Heat Control
PLC = Programmable Logic Controller
Commissioning, plant adjustment and operator training

All system and design optimizations will only be effective if

- the construction is executed in accordance with the specifications
- the plant is well commissioned and adjusted
- the plant is operated and maintained properly

**Supervision of construction and precise plant adjustment are of high value**

**Training courses provide a high motivation to operation and maintenance personnel to use and maintain the plant well**
Resumee

An optimized technical concept considering the available design improvements will cause an increase in engineering cost, but has a large potential for improvement of the:

- operational safety and plant performance
- environmental plant performance
- working conditions on the plant
- cost of operation and maintenance (OPEX)
- plant service life

and for considerable reductions of cost for equipment and construction
Thank you for your interest in our technologies!

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