Artificial Intelligence-enabled Autonomous Plant operations at CEMEX, with Petuum Industrial AI Autopilot

Rodrigo J. Quintero, CEMEX
Prabal Acharyya, Petuum
Company overview

Business
CEMEX is a global building materials company that provides high-quality products and reliable service to customers and communities in more than 50 countries throughout the world.

A global industry leader
• Annual sales of US$13.67 billion
• One of the leading cement manufacturers, ready-mix and aggregates in the world
• One of the world's top traders of cement and clinker

About the Presenters

- Rodrigo J. Quintero
- Operations Digital Technologies Manager
- CEMEX

- Prabal Acharyya
- Head of Industrial AI
- Petuum
Agenda

• Artificial Intelligence (AI) Potential for Cement Industry
• Cemex: How we got started on the path to AI
• Petuum and Petuum Industrial AI – An Overview
• Autopilot with “Autosteer” for Autonomous Cement Plant Operations at Cemex
  • Cooler, Kiln, Pyro Process, Vertical Mill, Ball Mill examples
  • Fuel Mix (Alternative Fuels), Emissions, Benchmarking, Energy Management
• Petuum Deployment Architecture with OSIsoft PI
• Next Steps
Industry 4.0: The Digital Transformation Journey

- **Digitization**
  - Computerization
  - Connectivity

- **Seeing & Understanding**
  - Visibility
  - Transparency

- **Autonomous**
  - Predictability
  - Adaptability

What's next?

What is happening?
Why is it happening?

What will happen?
Can we adapt automatically?

Connected 1  Prescriptive 2  Autonomous 3
Why Artificial Intelligence?

Artificial intelligence holds the key to future growth and success

In cement operations, artificial intelligence assisted operation can help our plants realize manufacturing process improvements and achieve strategic goals in:

- Safety performance
- Operational Efficiency
- Energy efficiency and alternative fuels substitution
- Quality Assurance and product design
Artificial Intelligence in Cement Operations

Why is AI so crucial for manufacturing? There are multiple potential applications in:

- Failure prediction (operative and corrective failures)
- Production processes optimization
- Predictive Maintenance
- Remote operation & digital twins
- Product design and quality; smart supply chain

“If you don’t have the capability to digitalize the manufacturing processes, your costs are probably going to rise, your products are going to be late to market, and your ability to provide distinctive value-add to customers will decline.”*

How can we test the technology, its capabilities, and how to take advantage from it?

PETUUM and CEMEX pilots

CEMEX AI Pilot: On an Industry 4.0 Journey

CEMEX Autonomous kiln 2022

- Increased Efficiencies
- Reduced fuel & energy consumption
- Better Quality
- Reduced Costs
- Improved Decision Making

Key Figures

Autonomous Manufacturing

We know how to do it better.
Predictive
We know what we know.
Preventive
We know what we don’t know.
Cognitive
We don’t know what we don’t know.
Reactive

Product/Process Optimization
Operational Excellence
Process Stabilization
Metrics and Measurements
Why Petuum AI Autopilot with Autosteer

• Collaborative approach/engagement

• Phased approach:
  • **Predict**: Real time forecasts help boost understanding
  • **Prescribe Only (Autosteer OFF)**: Prescriptions can be validated by operators before updating the setpoints.
  • **Autosteer ON**: Supervised controlled autopilot operation integrated with plant control systems
Use Case: Clinker Cooler Optimization

The cooler transfers the heat from clinker to combustion air to:

- Increase heat recovery
- Obtain clinker at a temperature suitable for grinding
- Maximize clinker potential strength through rapid cooling

**Goal**
1) Maximize 2\(^{\text{nd}}\) air heat
2) Maximize 3\(^{\text{rd}}\) air heat
3) Minimize Cold Clinker heat
4) Minimize exhaust gas heat

**Controllable variables:**
- Fan flow
- Undergrate pressure

**Key factors:**
- Chemistry
- Feed rate
- Burning zone temperature
- amps (others)

**Note:** Variables and key factors full list depends on use case complexity; typically contains 40+ variables
Phased Development

Phase I: Forecast prediction in real-time (Mode: Prediction)

- Identify output variables for AI model to predict behavior 5 to 15 minutes in advance
- Allows kiln operators to take actions if they identify issues before these occur
- Forecast can predict values
- Forecast can predict change in slope

All actionable items rely on kiln operator's knowledge, experience and intuition
Phased Development

Phase II: Prescriptive Recommendations in real-time (Mode: Prescription)

- The AI model can recommend setpoints for the control variables in real time
- Operators need to validate if recommended setpoints are within operating range before making a decision
- Kiln operator has to accept and input manually the prescriptive recommendation into the control system

All actionable items support kiln operator’s knowledge and experience to improve performance
Phased Development

Phase III: Auto-pilot operation of kiln’s cooler section (Mode: Autosteer)

• The AI model submits setpoints for the control variables in real time to control system via PI
• Operators can monitor in real-time if auto-pilot operation is aligned to normal operating parameters
• Kiln operator can engage-disengage autopiloting the control system in case of process disruptions (i.e.- power failure, kiln push, blockages, etc.)

Operators can supervise auto-pilot operation while concentrating on other kiln parameters (similar to a car’s cruise control).
Autosteer delivers Immediate Results

As soon as “Autosteer” picks up driving the asset operation, immediate results are achieved.

• Secondary Air Temp for K1 Cooler (black line), resulting in energy savings as soon as the Autosteer is switched ON by the Operator.
Achievements

Phase I: Forecast prediction in real-time

✓ Successfully predicted Clinker and Air temperatures and trend slope changes as outputs of cooler up to 15 minutes in advance

✓ AI Prediction model showed better results compared to previous POCs using linear modeling to forecast clinker quality (free-lime modeling)

Phase II: Prescriptive Recommendations in real-time

✓ Relayed recommendations to kiln operators. Model improvements introduced additional constrains to make recommendations reasonable and actionable

Phase III: Autosteer operation of kiln’s cooler section

✓ Successfully ran kiln cooler using artificial intelligence

✓ AI-supported kiln cooler is obtaining higher exit air temperatures when auto-pilot is engaged
Petuum Industrial AI Autopilot Architecture

Customer Internal Network

ASSET 1
- Prescriptions
- Control System
  - Process
  - Autosteer ON / OFF

ASSET 2
- Control System
  - Process
  - Autosteer ON / OFF

Petuum Industrial AI Autopilot

Distributed PI Infrastructure
- Plant and Corporate
  - Model Dynamic Constraints (AF Analytics with Petuum Service)
  - Petuum Industrial AI Autopilot Data Collectors (bi-directional) Through OSIsoft PI System
  - Autopilot Engage / Disengage through OSIsoft PI AF (Edge)

Petuum Industrial AI Autopilot (SaaS)

(Streaming) Sensor Data from CEMEX to Petuum

(Streaming) from Petuum to CEMEX Prescription

OSIsoft PI Cloud Connect

OBJECTIVES

ASSET 1
- Prescriptions

ASSET 2
- Control System
  - Process
  - Autosteer ON / OFF
Petuum Industrial AI Autopilot
About Petuum

Industrialize AI technology
Turning it from black-box artisanship into standardized engineering process

AI as “Civil Engineering”

10-20% White glove services
Transform building blocks to completed software

Pittsburgh, Pennsylvania
Home to Carnegie Mellon
#1 AI University in the US

Silicon Valley, California

All-Inclusive AI
Petuum enables and orchestrates AI for the enterprise with vertical industry solutions. Our solutions deliver ready-to-use AI in numerous verticals, pre-built with the right context and templatized for minimal customization by sub-segments.

- 150+ employees and growing
- 30+ Ph.Ds, over half from CMU AI research program
- Majority of employees in product, engineering, and AI research. Multiple best publication, Ph.D dissertation & industrial AI awards
**Petuum Industrial AI Autopilot**

**CUSTOMER NETWORK**
- Streaming
- Control Systems
- Structured Databases
- Time series
- Historians
- Unstructured
- Video

**Operations data**
- Secure bi-directional sharing
- Edge
- Cloud
- Predictions, Prescriptions

**Petuum Industrial AI Autopilot**

- Predictions
- Prescriptions
- Autosteer

**AI Algorithms**
- Model 1
- Model 2
- Model 3
- Model 4
- Continuous Self-Learning

**Petuum AI Symphony Platform**

**Predictions**

**Prescriptions**

**Autosteer**

**Petuum Industrial AI Autopilot**

- Asset Autopilots
- Process Autopilots
- Operational Excellence

**Petuum AI Symphony Platform**

**OSIsoft PIWorld SAN FRANCISCO 2019**

©2019 OSIsoft, LLC
Cooler Asset Autopilot - Deployed

**OBJECTIVES**

- **DEEP PAN CONVEYOR CLINKER TEMPERATURE**
  - MINIMIZE

- **TERTIARY AIR TO CALCINER TEMPERATURE**
  - MAXIMIZE

**INPUTS**

- PI
- SAP

**DATA FLOW**

**CONTROLS**

- FAN 01: 21.067
- FAN N: 31.049
- GRATE SPEED: 24.185

**CONSTRAINTS**

- Predictions
- Prescriptions
- Autosteer

**COOLER AUTOPilot**

Site: Line

**COOLING**

- FAN 01
- FAN N
- GRATE SPEED
Petuum | OSIsoft Integrations

1. PI Web API
2. PI Connectors and Interfaces (e.g. PI OPC Read-Write)
3. Asset Framework and Asset Analytics
4. PI Vision including custom controls
5. OSIsoft PI Cloud Connect

Next: OCS
Benefits of Petuum Industrial AI

<table>
<thead>
<tr>
<th>INCREASED YIELD</th>
<th>REDUCED COSTS</th>
<th>ACHIEVE OPERATIONAL EXCELLENCE</th>
</tr>
</thead>
</table>
| Increased operator and equipment productivity through autopilot operation of:  
  - Cooler  
  - Rotary kiln  
  - Pre-heater  
  - Ball mill  
  - Vertical mill | Cut energy costs for pyro process while maintaining high quality through:  
  - Optimal usage of renewables in the fuel mix  
  - Minimize energy consumption with access to real-time log data, pyro images, timeseries sensor data | Improve sustainability through reduced emissions  
Increase asset utilization through:  
  - Extended kiln campaigns for benchmarking across lines  
  - Fleet management of equipment  
  - Optimized field services for preventive/predictive maintenance |

Est 2-5% savings in energy costs and >2% higher overall yield
CEMEX

LEVERAGING THE PI INFRASTRUCTURE & PETUUM INDUSTRIAL AI AUTOPILOT WITH AUTOSTEER TO DRIVE AI-ENABLED AUTONOMOUS OPERATION

CHALLENGE
Predictable, repeatable “golden day” operations – high yield, high quality at low cost sustainably

• Prove AI / ML capabilities to optimize production processes
• Complex, highly variable operations
• No real time prediction, reactive operator actions

SOLUTION
• Petuum Industrial AI taps into PI system and other sources to deliver real time forecast of process variables, prescriptions for operator actions and a supervised auto-steer
• Integration with OSIsoft suite of products for configuration, data streaming and visualization
  • PI Cloud Connect, PI WebAPI
  • PI AF, PI OPC Read-Write
  • PI Vision incl. Custom Controls

RESULTS
Expected yield and energy improvements in the range of 2-7% from combined use cases

• Reduced process variability
• Increased throughput
• Cost reductions from increased energy recovery:
  • Secondary Air ΔT: +100 °F
  • Tertiary Air ΔT: +15 °F
  • Clinker Temp ΔT: +5 °F (did not decrease; acceptable)

“This is a giant step in digital transformation towards safe, highly standardized operations, that will help us strengthen our high-quality products portfolio while also ensuring we meet our operational and sustainability goals, and minimize costs.” – Rodrigo Quintero, CEMEX
Lessons Learned

☑️ Company commitment from both corporate and plant leadership is key to successful implementation of new technologies
  • Initial implementation took about 2-3 months, go-Live (27-Nov-2018).
  • Now, we are working with Petuum to deploy Autopilot with Autosteer at multiple sites and use-cases.
  • Subsequent implementations reduced to weeks.

☑️ AI is not magic: Autosteer mode initially started to run only under stable conditions; it is being expanded to other conditions with different dynamic and static modes.
  • SME input to improve modes of operation
  • Reliable sensors and data are critical

☑️ Change Management is critical: Autosteer started with engagement only when plant supervision is available (day-shift only).
  • Our goal is to run Autosteer round the clock as plant operators take full ownership of the process.
  • Support is key: CEMEX’s C3 / Center of Excellence to provide process support, and Petuum’s Live Tracking & Alerting 24x7 to achieve continuous operation.
  • A good change management process can make transition to new technologies faster, easier.
Questions?

Please wait for the **microphone**

State your **name & company**

Please remember

TO DOWNLOAD APP, SEARCH OSISOFT

[Download on the App Store] [Get it on Google Play]
THANK YOU

转谢
KEA LEBOHA
TAGADH LEIBH
고맙습니다
MISAOTRA ANAO
شكرا
SALAMAT
DANKJE
GRACIAS
TERIMA KASIH
DANKON
TANK
TAPADH LEAT
MULȚUMESC
FAAFETAI
ESKERREK ASKO
HVALA
HVALA
XBALA BAM
TEŞEKKÜR EDERIM
GRAZIE
DI OU MÈSI
ＤＡＫＵＪＥＭ
MATUR NUWUN
MULĆUSI
PAKMET CIŽGE
GRACIAS
MERCI
RAHMAT
HATUR NUHUN
CAM ON BÁN
WAZVIITA