Smart Manufacturing Benefits to Small and Medium Size Manufacturers

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POSTECH
Crisis in Korea’s Manufacturing

MFG Operation Ratio 2011-2017

- 2011: 80.5%
- 2012: 78.5%
- 2013: 76.5%
- 2014: 76.1%
- 2015: 74.5%
- 2016: 72.6%
- 2017: 71.9%

MFG Operation Ratio = Production/Capacity x 100
(Statistics Korea)

World-class Product 2011-2017

- 2011: 38
- 2012: 54
- 2013: 46
- 2014: 42
- 2015: 38
- 2016: 34
- 2017: 27

① Top 5 or 5% in market share or
② Estimated best product in 7 years
(KOTRA)

CIP: The Competitive Industrial Performance Index
(UNIDO Statistics Data Portal)

2014-2018

(Rank)
This talk is about our experiences to help SMEs get some benefits (value) from smart manufacturing.

Target of upgraded smart factory

<table>
<thead>
<tr>
<th>Year</th>
<th>%</th>
<th># of total smart factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>21%</td>
<td>~8,000</td>
</tr>
<tr>
<td>2019</td>
<td>22%</td>
<td>12,000</td>
</tr>
<tr>
<td>2020</td>
<td>23%</td>
<td>18,000</td>
</tr>
<tr>
<td>2021</td>
<td>24%</td>
<td>24,000</td>
</tr>
<tr>
<td>2022</td>
<td>25%</td>
<td>30,000</td>
</tr>
</tbody>
</table>

30,000 x 25% = 7500

However

- Focus only on “The Number” of smart factories
- Ambiguous definition of smart factory maturity
- SMEs do not want to spend over government’s subsidy

Hence

- Various fragmented systems installed incrementally
- Misunderstand that having systems is enough for smart manufacturing
- Interoperability lacks and therefore more work needed
Definition of 4M+1E

**Machine**

- Equipment, Mold, Jig, Tools, ...
- (Temperature, Pressure, Vibration, Energy, Production outputs ...)

**Material**

- Supplier, Arrival date, Weight, Volume, Humidity ...

**Method**

- Recipe (Process), Guide, Specs, Tolerance ...

**Environment**

- Temperature, Noise, Dust, Humidity, ...

**Man**

- Role, Employment duration, ...

**Connectivity**

- Sensory
- Physical
Smart Factory consisting of 4M+1E

Applications
- Sensor, Actuator
- Barcode, RFID
- SCADA, PLC, HMI
- Monitoring, Control

KPI Improvement & Innovation
- Quality ↑
  - R&D Quality
  - Production Quality
  - Market Quality
- Cost ↓
  - Productivity
  - OEE
  - Yield
- Delivery ↘
  - Production Lead Time
  - Ramp-Up
  - R&D Lead Time

Platform
- Big Data

Edge
- Process, Control, Monitoring for manufacturing with no scheduling
- Device, Process

Connectivity
- Sensory
- Physical

Man
- Forming
- Injection
- Cutting
- Casting
- Sewing
- Bonding
- Machining
- Assembly
- Inspection

Connectivity
- Sensory
- Physical

Big Data
- Applications
- KPI Improvement & Innovation
- Platform
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Process, Control, Monitoring for manufacturing with no scheduling
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Connectivity
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- Assembly
- Inspection
Operation Management

- Support Mold inspection after 300 cycle
- Support Optimal plan to maximize machine utilization
- Support Documenting defects after outgoing inspection
- Support Gathering production amount
- Support Sequence production to meet demand
- Support Delivery control of raw materials

Byproducts: Data

Asset Management System (AMS)
Quality Management System (QMS)

Master Planning/Factory Planning (MP/FP)
MES

Advanced Planning & Scheduling (APS)
ERP/SCM

Byproducts: Data

Big Data
Data Engineering & Analytics

- Tracing customer’s returns
- Quick Search for Past defects
- Vision inspection of final products
- Extending use of mold by prediction of wear
- Process optimization to maximize quality
- Extraction of CTQ from customer’s review data

Use of Data

<table>
<thead>
<tr>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum OEE by predictive maintenance</td>
<td>Predictive production by demand forecasting</td>
</tr>
<tr>
<td>Quick cost estimation</td>
<td>MES Data Analytics</td>
</tr>
<tr>
<td>Maximum yield by predicting quality</td>
<td>Energy optimization</td>
</tr>
</tbody>
</table>

Use of Data

- Edge
  - Process, Control, Monitoring for manufacturing with no efficiency
    - SCADA, PLC, HMI (Monitoring, Control)
    - Sensor, Actuator, Barcode, RFID
    - Device, Process

- Big Data
  - Connectivity
    - Sensory
      - Physical
    - Man, Material, Machine, Method, Environment
    - Forming, Injection, Cutting, Casting, Sewing, Bonding, Machining, Assembly, Inspection

Data Engineering & Analytics

- Q
  - Tracing customer’s returns
  - Quick Search for Past defects
  - Vision inspection of final products
  - Extending use of mold by prediction of wear
  - Process optimization to maximize quality
  - Extraction of CTQ from customer’s review data

- D
  - Predictive production by demand forecasting
  - MES Data Analytics

- C
  - Maximum OEE by predictive maintenance
  - Quick cost estimation
  - Maximum yield by predicting quality
  - Energy optimization

- D
  - Predictive production by demand forecasting
  - MES Data Analytics
Tracing Customer’s Returns

Company A - “Tracing customer’s returns by achieving systems interoperability”

Synopsis

• Data Reliability
  ▪ Shipped products marked “under production” in ERP
• Data Consistency among Systems
  ▪ Mold repairs not synced among YMMS, ERP, QMS, EAM
  ▪ MES data not synced to ERP, so data in ERP only fixed later
• Different key by different systems for the same query
  ▪ To search ERP with “plan no” for production outputs, MES with “work order no.”

Approach

• For every customer’s return, the workers walk through all related systems to sync data manually
• Develop use cases and document the requirements to achieve interoperability

1) YMMS: Yeonwoo Mold Management System
Quick Search for Past Defects

Company B - “Adding any defects and their correction to Chat Bot, the workers search Chat Bot for similar defects”

**Synopsis**

- No document for response to defects
- No learning effect for repair

**Approach**

- In case of defects occurring, take pictures and/or video and share them to the Chat Bot
- Given past data, quickly search for images similar to current defects

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**Diagram**

1. **Defect A** (No Document)
2. **Defect B** (No transfer)
3. **Defect C** (No transfer)

**Build a Model**

- Adding any defects and their correction to Chat Bot, the workers search Chat Bot for similar defects.
Vision Inspection of Final Products

Company C - “Labor intensive inspection needs replacing with Vision”

Synopsis

- Manual inspection incurs costs and bottle neck
- Tired workers spend more time and perform less accurate inspection
- How to use image-based inspection?

Approach

- Data deficiency in building Deep Learning
- Data collection from prototype at R&D stage
- Learning at the ramp-up stage and then being used at mass production
Maximum OEE by Predictive Maintenance

Company D - “Instead of Off-line Laser-based measurement, data (vibration, power consumption) driven wear prediction”

**Synopsis**

- Cutting tools replacement based on the time being used
- In order to save the costs of less wear tools, laser-based measurement is used
- This loses OEE

**Approach**

- Predicting tool wear using data (vibration, power consumption ...)
- Save costs and increase OEE

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**Tool Supplier** → **Tool Life** → **Cutting Tool A**

**AI System**

- Vibration
- Current
- Temperature
- Motor
- Spindle
- Lubricant

**NC Machine**

**Wear**

0 40 80 120 160 200 240 260

**As-IS** → **Longer Life** → **To-Be**

**Threshold**

**Life time**

**Predicted Wear**
Quick Cost Estimation

Company E - “Upon receiving design data from OEM, how to conduct quick cost estimation”

Synopsis

- Transform design to mfg process
- For each process, measure standard work time to estimate labor costs
- Many efforts and costs

Approach

- Feature engineering for shoe product to build a learning model
- Direct labor cost estimation from feature extraction of a new product
- Other costs can be estimated from past similar products

Diagram:

1. Define Process
   - Measure ST
   - Labor Costs Calculation
   - Other costs Calculation
   - Team Meeting
2. ST Prediction
   - Labor Costs Simulation
   - Other costs Estimation
3. Finding similar products

Cost

Less Efforts
Company F - MES Data Analytics

Hourly production amount from MES

<table>
<thead>
<tr>
<th>WORK_DATE</th>
<th>LINE_NAME</th>
<th>MINI_LINE_NAME</th>
<th>HOUR_08</th>
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<tbody>
<tr>
<td>20180901</td>
<td>B-1</td>
<td>Zoom Fearless</td>
<td>288</td>
</tr>
<tr>
<td>20180901</td>
<td>B-1</td>
<td>Zoom Elevate</td>
<td>252</td>
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<tr>
<td>20180901</td>
<td>B-2</td>
<td>Odyssey React Knit</td>
<td>253</td>
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<tr>
<td>20180901</td>
<td>B-3</td>
<td>Free TR 3 Knit</td>
<td>248</td>
</tr>
<tr>
<td>20180901</td>
<td>B-3</td>
<td>Free RN Knit 2018</td>
<td>291</td>
</tr>
<tr>
<td>20180901</td>
<td>B-4</td>
<td>Odyssey React Knit</td>
<td>291</td>
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</tbody>
</table>

Production Plan (Sep. 2018~Feb. 2019) from APS

<table>
<thead>
<tr>
<th>Line</th>
<th>Model</th>
<th>9-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>Zoom Fearless</td>
<td>1.008</td>
</tr>
<tr>
<td>B-1</td>
<td>Zoom Elevate</td>
<td>1.008</td>
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<tr>
<td>B-2</td>
<td>Odyssey React Knit</td>
<td>2.004</td>
</tr>
<tr>
<td>B-3</td>
<td>Free TR 3 Knit</td>
<td>2.208</td>
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<tr>
<td>B-3</td>
<td>Free RN Knit 2018</td>
<td>2.800</td>
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<tr>
<td>B-4</td>
<td>Odyssey React Knit</td>
<td>2.208</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9.028</td>
</tr>
</tbody>
</table>

Production Rate = \( \frac{\text{Production Amount}}{\text{Production Plan}} \times 100 \) (%)

NOS B, LINE 1 HOUR_08 Production Amount : 288
NOS B, LINE 1 HOUR_08 Production Plan : 2016/8 = 252
NOS B, LINE 1 HOUR_08 Production Rate : \( \frac{288}{252} \times 100 = 114.2\% \)

NOS B, LINE 2 HOUR_08 Production Amount : 153
NOS B, LINE 2 HOUR_08 Production Plan : 2004/8 = 250.5
NOS B, LINE 2 HOUR_08 Production Rate : \( \frac{153}{250.5} \times 100 = 73.8\% \)
Hourly Production Rate for 6 Months

Why so low before going home? Early going home?
Patterns of Production Rate

Fast

As Planned

Slow
Factory NOS C

Rate

<table>
<thead>
<tr>
<th>Hour</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOUR_08</td>
<td>120</td>
</tr>
<tr>
<td>HOUR_09</td>
<td>100</td>
</tr>
<tr>
<td>HOUR_10</td>
<td>80</td>
</tr>
<tr>
<td>HOUR_11</td>
<td>60</td>
</tr>
<tr>
<td>HOUR_12</td>
<td>40</td>
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<td>HOUR_13</td>
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<tr>
<td>HOUR_14</td>
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<tr>
<td>HOUR_15</td>
<td>100</td>
</tr>
<tr>
<td>HOUR_16</td>
<td>80</td>
</tr>
</tbody>
</table>

- **Fast**: Red
- **As Planned**: Blue
- **Slow**: Green
Factory NOS J

Rate

Hour

- Red: Fast
- Blue: As Planned
- Green: Slow
Factory NOS E

Rate

Hour

- Red: Fast
- Blue: As Planned
- Green: Slow

Hour: 08 09 10 11 12 13 14 15 16
The last 1-Hour production rate depends on those of the other hours

Big gap between plan and production amount in most cases
  - Due to planning or execution?
  - If planning, all the factors including ST, Capacity should be considered

Further analysis
  - For slow production, overtime needs to be proved
  - High variance for the first hourly production amount needs to be proved
Advanced Manufacturing

- Touch Probe development for inspection
- Nondestructive testing for inspection
- New nano materials for easy manufacturing
- Co-robot for collaborative task
- 3D Printing,
- Truck + Drone combination for Last Mile Delivery

Byproducts: Data

Big Data

Byproducts: Data

Byproducts: Data
3 Pillars for Smart Manufacturing

**Advanced Manufacturing**

- **Process/Product Innovation**
  - Touch Probe development for inspection
  - Nondestructive testing for inspection
  - New nano materials for easy manufacturing
  - Co-robot for collaborative task
  - 3D Printing,
  - Truck+Drone combination for Last Mile Delivery

**Big Data**

**Operation Management**

- Efficient planning, control, and monitoring for large scale operation
  - Q ↑: Mold inspection after 300 cycle
  - C ↓: Documenting defectives after outgoing inspection
  - D ↓: Optimal plan to maximize facility utilization
  - D ↓: Gathering production output
  - D ↓: Sequence production to meet demand
  - D ↓: Delivery control of raw materials

**Data Engineering & Analytics**

- Extraction of Insight, Action Items from Data
  - Q ↑: Tracing customer’s returns
  - Q ↑: Quick response to defects
  - C ↓: Maximum OEE by predictive maintenance
  - C ↓: Quick cost estimation
  - D ↓: Predictive production by demand forecasting
  - D ↓: MES Data Analytics

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Postech IDEA
OM solutions do not guarantee any value from data

Data everywhere = Future asset
- From OM solutions: ERP, APS, MES, PLM, QMS, ...
- From 4M+1E

We can do a lot with data
- Diagnostics, Prognostics, Judgment, and decision making, etc.
- Data-driven management

Data thinking culture is important
- Senior managers should ask data driven proof
- Staff should be able to extract value from data