Inside a Smart Foundry: Digitalized Operations Management

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Abstract: This article seeks to demonstrate some of the principles, features, benefits, and challenges of digitalized operations management inside a "smart foundry". A three-stage approach was used to achieve this digital transformation.

Specific digital use cases relevant and unique to the sand casting industry will be presented, including: end-to-end traceability and quality control by the MES system's automated data acquisition; predictive tooling manage-ment that reduces waste and improves OEE; preventive safety measures powered by IoT and computer vision; cross-platform data integration to achieve granular cost transparency and control, etc.

Keywords: smart foundry; digital transformation; mes system; operations management

1 Introduction

Digital transformation has swept across many traditional manufacturing industries in recent years, where advanced technologies including robotics and automation, IoT, and Big Data / AI have been used to elevate decade-old operations management best practices such as Lean, Kaizen, TQM, TPM, JIT and Six-Sigma (See Table 1 for explanations of all acronyms). Playing a fundamental role in this digital transformation is the MES, a software platform that connects the shopfloor to the broader business context [1].

However, the millennium-old sand casting industry has been slow to adapt to the digital transformation overall, despite being under pressure from other competing metal fabrication technologies like forging, die casting and 3D printing [2]. This is due to a combination of factors: the intrinsic long and complex chain of processes in sand casting that involves various types of equipment (e.g., Figure 1), the often high-mix low-volume nature of casting products, and financial constraints – in 2022, all US foundries averaged $26.7 million in revenue but only 57% of them were profitable [3]. It is therefore of paramount importance that foundries develop and adapt digital tools to their specific needs in pursuit of operational excellence.

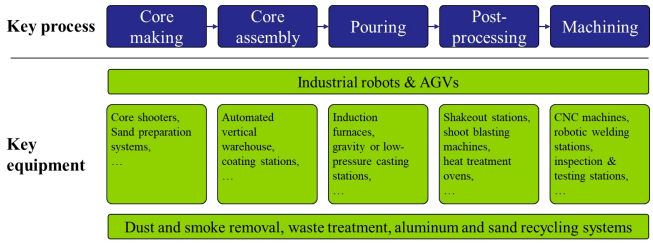

Figure 1 Overview of MZT's modularized aluminum casting process (non-exhaustive)

2 Methodology

Suzhou Mingzhi Technology Co., Ltd. (MZT) developed the digital technology platforms inside and around its highly automated and modularized aluminum casting factories in three stages:

- Stage 1: Independently developing IT platforms and their data infrastructure, including the MES, QDAS, WMS, ERP, PLM, etc. In the case of the MES system, Figure 2 illustrates how operational data is acquired and aggregated in a number of ways.
- Stage 2: Linking IT with OT in order to analyze, extract insights, hence gain value from the data, by developing specific use cases such as TQM and TPM. Examples of such use cases are described in the following sub-chapters.
- Stage 3: Bridging the information flow across different IT platforms developed in stage 1 to enable holistic data-based operations management beyond just the production lines, as shown in Figure 3. For example, depending on the business context, the optimal tradeoff between delivery, quality, and cost may vary, hence specific operational decisions would differ accordingly across products and over time.

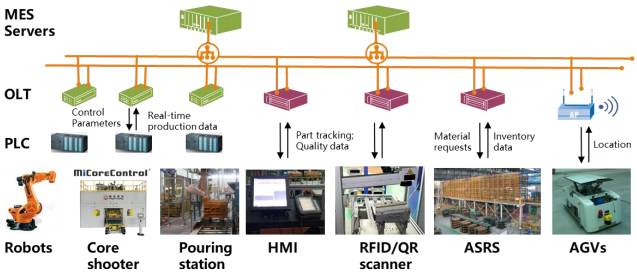

Figure 2 MES data acquisition from various sources

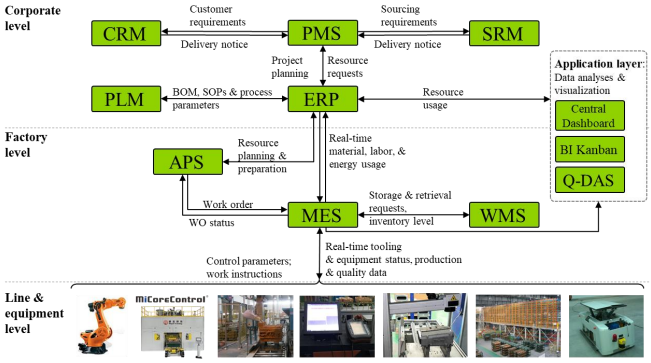

Figure 3 Blueprint of MZT's digital technology platforms

3 Use cases

End-to-end traceability and quality control

The aim of end-to-end traceability is to be able to track each individual casting part and to trace it back to its mold assembly or core package, or even each core, while linking the part to metadata like timestamps, batch number, operators IDs, testing results, and process parameters. At MZT, a combination of QR code printed on the casting, RFID-implanted core & core package trays, and computer vision are used to achieve this. The QDAS software will then analyze all the data to identify patterns and potential origins of defects.

Predictive tooling management

By collecting and storing the production data on the MES server, the spot-checks, maintenance, and replacement of various tooling (including molds, cutting tools, jigs and fixtures) can evolve from fixed-schedule to usage-based to predictive. I.e. prediction algorithms suggest whether, when, and what actions are required, based on the tools' usage and maintenance history. Over time, with more data gathered, the predictions will become more accurate, pushing the tools' utilization closer to limits, reducing the replacement cost and downtime, improving OEE.

Preventive safety features

At MZT, safety is always the highest priority, above delivery, quality and cost. IoT technologies are being used to implement even more preventive safety features. At the pouring station, one of the highest risk areas, only one operator who has been trained and certified can enter the designated area of the station at a time. If violated, all production equipment in the area will halt and alarms will raise. The operators are identified, marked and tracked by RFID chips planted in their helmet, as well as AI image recognition from the camera feed.

4 Challenges

The challenges in digitalized operations management at a foundry are nuanced. For example, with high-mix low-volume production, the processes vary across products, thus complex rules are required to accurately allocate resources and calculate costs (material, labor, energy and equipment) for each product. Another example is the APS - production and resource planning cannot be made fully automatically unless a certain level of process cabaility is achieved, as the optimization algorithm is sensitive to the process variabilities likely found in a foundry.

Table 1. List of acronyms

Acronym	Meaning
AGV	Automated Guided Vehicle
APS	Advanced Planning System
ASRS	Automated Storage & Retrieval System
ERP	Enterprise Resource Planning
HMI	Human-machine Interface
JIT	Just-in-Time
MES	Manufacturing Execution System
MZT	Suzhou Mingzhi Technology Co., Ltd.
OEE	Overall Equipment Effectiveness
OLT	Optical Line Termination
OT	Operational Technology
PLC	Programmable Logic Controller
PLM	Product Lifecycle Management
PMS	Project Management System
QDAS	Quality Data Analysis Software
RFID	Radio Frequency Identification
TPM	Total Productive Maintenance
TQM	Total Quality Management
WMS	Warehouse Management System

5 Result and conclusion

Transforming towards digitalized operations management at MZT has already brought measurable benefits across multiple dimensions. At one of its newer aluminum casting production lines for heat exchanger products, capacity (measured by pieces per shift) has increased by 58% whilest the number of operators has decreased by 70% since the beginning of the digital transformation, more than tripling the output per capita. In the meantime, average scrap rate went down from ~6% to ~2.5%, fastest turnaround time from 7 days to 0.5 days, and unit energy consumption down by 28%.

However, Kaizen is a journey with only beginning and no end. Along the way, there will always be new challenges to overcome and features to be developed. Furthermore, no matter how digitalized or intelligent operations management gets, people are still at the center of it. The data is meaningless unless the engineers and managers can derive the right insights and actions from it.

References

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