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TECHNOLOGIES

AI EMPOWERMENT THROUGH MANUFACTURING EXECUTION SYSTEMS (MES) IS PROVEN TO DRIVE OVERALL MANUFACTURING OPERATIONS MANAGEMENT (MOM) IMPROVEMENT

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IT'S LOGICAL THAT ACTIONABLE INSIGHTS WHICH LEVERAGE REAL TIME DATA WOULD DRIVE OPTIMIZED FACTORY PERFORMANCE. INSTANT NOTIFICATION OF PROBLEMS, ROOT CAUSE ANALYSIS, PREDICTIVE ANALYTICS, AND SCENARIO-BASED PRESCRIPTIONS WILL RESULT IN IMPROVED THROUGHPUT, INVENTORY, AND OPERATING EXPENSE WHILE DELIVERING ON ASSET UTILIZATION, OEE, LABOR EFFICIENCY AND ORDER FULFILLMENT.

Data remains the constant need for all predictive analytics, especially the newer AI/ML based approaches to predictive analytics. AI also includes process automation where predictions can be served up to an operator to interactively resolve issues on a workbench or served up to an automated decision-making process. And the new kid on the block, generative AI, can drive value in various ways including structured queries to customize work instructions along with NLP support for certain query types on the factory floor, such as inventory positions.

MES, MOM AND SMART MANUFACTURING

First, we must understand how to generate and access actionable data. MES is the core systems capability suite that enables "smart manufacturing" which is an operating framework that integrates multiple factory systems (such as those that track lots, processes, scheduling, and distribution) to improve data quality, communication and real time decision making.

Through MES, factory level machines and assembly stations transmit data which is then leveraged by connecting people who don't normally work with data generated directly from machines or assembly stations. Smart manufacturing solutions integrate data from multiple sources and make it easily accessible to all users via dashboards and interactive workbenches.

Collaboration is enabled across the plant floor, manufacturing sites, and the company. This is the first step in effective AI deployment - understand both the available data as well as the man/machine interface and then orchestrate the decision making that then merges AI insight with human insight - the man/machine interface. These early AI capabilities really change the game as follows;

Real Time Insights

Digital information derived from real-time insights leads to better use of resources and optimized factory performance. Real-time line operating performance—including instant notification of problems and their root causes – enables improved problem solving, less downtime and greater productivity.

Insight into equipment and process state empowers you to predict issues like unplanned downtime. Predictive and prescriptive maintenance would then enable you to plan optimized maintenance intervals. Systems can identify problems, notify stakeholders, recommend, and execute effective interventions. Speed of decision making is critical to improving quality, scrap, OEE, efficiency, planned volume, and planned product mix. MES driven smart manufacturing delivers overall quality through the integration of systems, real-time data, and user-friendly interfaces to enable faster decision making. Historical data identifying trends is also leveraged providing the framework for long term continuous improvement.

Business Value

Profitable throughput of high-quality products is the goal for manufacturing and assembly. Accurate, on-time delivery with better insight and control over cycle times, machine or assembly station output, and resource utilization will result in accurate delivery schedules promoting increasing customer confidence and satisfaction. Key is to deploy a full-service MOM solution which incorporates a powerful MES capability.

MES directs labor, resource and material activity providing the right information at the right time, guiding the operator in the production or assembly tasks to be done, collecting genealogy data as products are produced, and collecting production data in real time. This data makes it possible for companies to optimize production activities from product creation to final production. The primary purpose of MES is to monitor, manage, and optimize the day-to-day processes inside a facility using data. This includes production tracking, work instructions, and machine connectivity.

MOM is an expansion of MES and includes all activities that support production including quality management, plant logistics, materials management, order management, time and labor, maintenance, calibration, and more. Significant value is driven through a unified MOM solution that operates as a highly configurable suite of manufacturing capabilities. Users can manage and execute enterprise-wide manufacturing operations processes, including those associated with production, quality, internal logistics, warehouse, maintenance, labor, and the supply chain.

Continuous improvement is accelerated through improved tracking and reporting coupled with an operational agility that is delivered through faster and easier process change. Just like ERP is an extension of MRP delivering an expanded value prop to the enterprise, MOM is an extension of MES delivering expanded value both within and across factory operations.

AI POWERED MOM, MES, AND IIOT SOLUTIONS

In today's complex manufacturing and assembly operations, the key to deploying an AI powered MOM solution is gauging what level of AI based automation is appropriate to maintain competitive margins while also enabling users to be more effective. One of the more promising applications of AI and ML in MES is **Predictive Maintenance**, which is the ability to anticipate and prevent equipment failures before they occur. Predictive maintenance uses ML algorithms to analyze historical and real-time data from various sources, such as sensors, logs, and inspections, to detect patterns and anomalies that indicate potential faults. By using predictive maintenance, you can reduce downtime, repair costs, and waste, as well as extend the lifespan of your assets.

IIoT makes it possible to integrate machine data into MES, use MES data for contextualization to predict failures, and run predictive maintenance analytics. The architectural approach for doing this can either be behind the firewall or have a system at the edge to collect the data locally from machines without exposing data sources to the cloud. Machine learning models can be built and trained on prem or in the cloud and deployed on site or at the edge. MES can use these ML inference results to schedule activities like maintenance and assign priority. Evolving applications include the following;

Process Automation

Process automation is an evolving AI capability which includes applying reinforcement learning, optimization algorithms, and simulation to learn from data and optimize process parameters, settings, and strategies for production. For example, AI and ML can help MES to adjust the speed, temperature, and pressure of machines, balance the workload and inventory, and schedule the orders and deliveries to maximize output, quality, and profitability.

Digital Twins

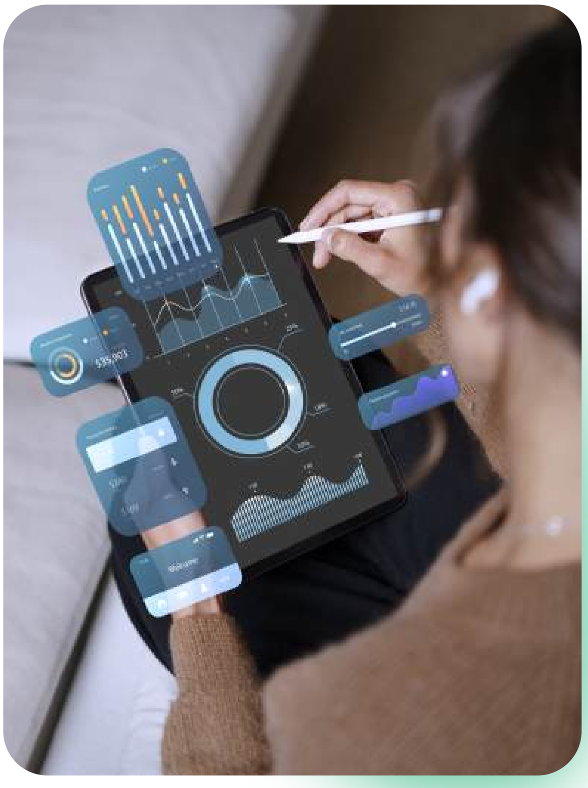
Model Predictive Control (MPC) techniques have produced mixed results in the past, but with the usage of reinforcement learning techniques, they are becoming a reality for process control.
In terms of Process Optimization, a primary use case has been the growth of Digital Twins to be able to simulate various scenarios for process optimization. Digital twins are virtual representations of physical assets, systems, or processes. Digital twins can use AI and ML technologies, such as data

fusion, cloud computing, and edge computing, to integrate and synchronize data from multiple sources, such as sensors, models, and databases, and create a dynamic and realistic simulation of the real-world counterpart. By using digital twins, you can monitor and control your production remotely, test and validate new designs and scenarios, and gain insights into your performance and outcomes.

Digital twin use cases typically drive specific business outcomes, such as predicting the behavior of a physical system based on real-time and historical data remote monitoring. In manufacturing environments, MES data adds context to data captured from sensors, devices, and machines. For example, a machine may produce data such as running speed, process parameters, and sensors might give ambient temperature and humidity. When you combine this data with MES data such what product is running on that machine, who is operator, what is the raw material and when this combined data is contextualized and imposed on immersive 3D or 2D image then it gives the complete picture to the user. Gen AI has enabled the rise of Copilots in supervisor guidance which shows how previous knowledge can be encapsulated into an AI bot that can guide and assist in supervisory decision making, or to customize and filter work instructions to users.

Problem Detection and Automated Decision Making

AI based automated control includes the ability to create personalized views of production operations, from configuring logical representations of facilities to configuring the resources within the factories. By monitoring and tracking everything from inventory and serialized production units to people and equipment, users can focus on execution strategies and continuous improvement by utilizing numerous MES out-of-the-box operations for starting and stopping equipment, collecting critical data, consuming material, and predicting issues and root cause through statistical process control.

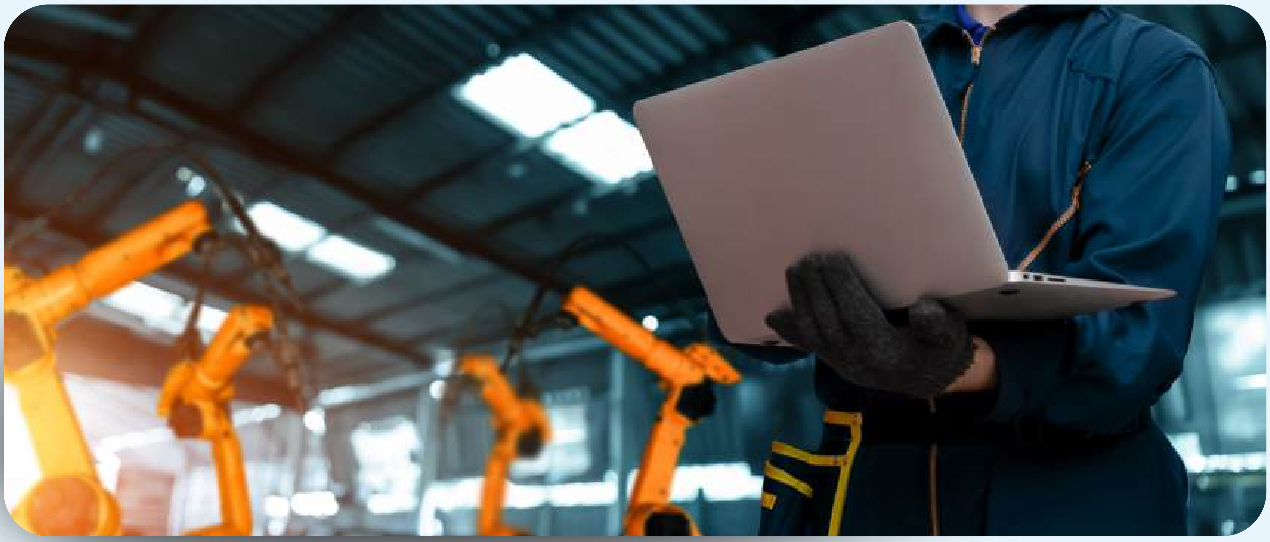


Problem detection is configured through the event manager to automatically respond to conditions within the facility. Production information is fed forward for AI based auto decision-making on unit-specific processing parameters. Real-time inventory changes are monitored and responded to using the key performance indicators with built-in auto-alerts.

Technicians can monitor the availability of consumable resources as well as available spare parts and the consumption of material is automatically performed and decremented against its source location. Spares are tracked with a complete history and current location. Customer views can be created in seconds, building upon out-of-the-box reports, Overall Equipment Efficiency (OEE), Mean Time Before Failure (MTBF) and Mean Time To Repair (MTTR) are just a few reports which keep the key personnel apprised of any critical operational signals that may need attention. These and other reports are easily created, printed, exported, and reviewed using configurable screens and filtering agents. For example, OCAP extends the automation intelligence in the factory with embedded AI functions, such as context pattern matching (CPM) and other types of data pattern analysis to help guide users in their decision making.

Real Time Dispatching

Real time or advanced dispatching provides an AI capability through configurable rules, filters, and conditions to prioritize material processing at equipment or workstations for each step of a manufacturing route/build order. The real-time conditions are evaluated when an operator or automation rule requests the system to advise which material should be processed next. The dispatcher can incorporate many configurable criteria for a location/equipment ID to aid decisions that are otherwise difficult for people, Material Control Systems (MCS), Automated Material Handling Systems (AMHS), and Automated Storage and Retrieval Systems (ASRS) due to competing priorities such as meeting due dates, changing customer priorities, avoiding bottlenecks, and optimizing equipment and material utilization.



Quality Management

A comprehensive quality model can be deployed through AI/ML advancements. Predictive quality based on vendor lots, human resources, machine availability, past performance, and environmental conditions is now a possibility. Quality inspections are typically carried out manually or through disconnected machines. The results of those inspections are fed to MES either through point interface or manually to report the final good product count. Automated inspection can help remove this disconnect between execution or inspection. The AI/ML inference results can be directly fed to MES, resulting in faster corrective and preventive action.

The primary advantage of using AI/ML for automated quality inspection is that it helps increase the frequency of quality inspection, reducing errors and costs associated with the human element. Essentially, it closes the analytics gap from postproduction to real time production. Alerting to an out of spec condition as soon as possible to minimize waste/rework drives material value.

MES is the critical component given it takes a significant amount of data to tune these alerts for any given product. Typical application would be the high-volume production of quality critical items. Containing a defective batch or lot in an earlier step of manufacturing reduces downstream cost, rework and timeline delays. Machine learning has shown promise in being able to crunch multiple variables and create correlation models between quality of intermediates early in a multi-step process and the quality of the final product, thereby enabling early intervention and remediation.

SINGLE SOURCE OF THE TRUTH

The MOM MES application framework provides a single source of the truth for AI based planning prioritization. Live visibility of schedule adherence – early warnings of issues prevent the need for the typical chase heroics we find daily in manufacturing. And scenario planning and "what-if" analysis to predict the business impact of any changes to demand, production, deliveries, shift patterns etc. Real-time dashboards and alerts trigger action before problems escalate.

"What-if" scenario analysis takes the guess work out of production planning as planners can model the potential impact to the business with changes to, for example, shift patterns, manning levels and forecast demand. Knowing manufacturing can fulfill every new order along with when delivery commits can be made is essential for customers' satisfaction. Dynamically plan and schedule people, time, materials and equipment. Constantly evaluate and optimize factory floor performance using real-time analytics.

ERP INTEGRATION FRAMEWORK

Manufacturing-related operations are constantly communicating with each other in real-time to create an organization capable of instantly reacting to changing business needs. For instance, when inventory drops below target levels, the AI based automation and integration framework keeps the MES transacting with the ERP system to generate requisitions for more materials automatically.
Or, as high volumes of product are manufactured, connections between MES and QMS/CAPA ensure that issues get flagged and quality managers are alerted the instant a problem is detected.

The framework includes distributed Bills of Material (BOM) and inventory management capabilities with complete traceability down to the source vendor lot and/or unit level. History of all activity including splits, merges, reworks, batches, and usage of materials, durables, and equipment is maintained for 100% traceability and is easily accessed for the full spectrum of reporting needs. With mobile access to real-time alerts, KPIs, and dashboard drilldowns, personnel can quickly make informed decisions.

INDUSTRY EXAMPLES

In semiconductors for example, both front end and assembly test and packaging deploy global dispatching rules alongside local dispatching rules and schedulers to improve productivity. Typically, the global rule ensures the due dates are met and bottleneck tools utilization is optimized by deploying line balance algorithms. These line balance algorithms have different parameters which need to be adjusted based on factory state for a given product mix. Today, these parameters are tuned manually, or though simulation. It's difficult
to compute the impact of these parameters for all the equipment and all products and process steps in a factory. Manually adjusting the parameters, therefore, could result in negative impact to factory KPIs, and it could take too much time to find an optimal set of parameters using simulation. This use case provides insight into how dispatching rule parameters can be tuned automatically through AI enabled workflow.

In pharma manufacturing, floor operators are constantly responding to process changes as they occur in real-time. Unfortunately, data analysis on the manufacturing floor isn't real-time, and it's difficult to understand which of the many production parameters is driving variation in performance. Often a reduction in quality or yield occurs without being anticipated and without a clear reason manufacturing teams can point to. Significant off-line data crunching must be done by manufacturing data scientists to interrogate historical data in the hopes of deciphering the cause. This analysis is only valid for that one point in time, not for any future events that may occur with the same equipment or processes. That's frustrating for operators as well as process science teams and has caused leading companies in the industry to look for a better way to perform real-time analytics.

Performing more sophisticated root cause analysis is a complex endeavor. Many pharma processes (especially in biologics manufacturing) aren't fully characterized, with multiple different process parameters – pressure, temperature, mixing speeds, settling velocities, etc. – simultaneously impacting critical quality attributes (CQAs). These parameters also interact in complex ways with equipment in a multivariate fashion, meaning it's often unclear how changing a parameter may be impacting output. All of this makes understanding and optimizing pharma manufacturing processes more complex, requiring advanced analytics and ML based tools to understand and characterize patterns in the data.

Most often, manufacturing data scientists today understand these patterns using offline and bespoke models in Python, Matlab or R. However, it is difficult to connect these programs to regulated, real-time manufacturing systems. The offline data available is often redacted and aggregated, meaning it's rare for analysts to gain enough insight to optimize the process. Ideally, manufacturing data scientists would be able to build a live analysis based off the current reality — and not the data that was collected months or years ago. Such an approach also enables continuous models that run frequently and can provide fresh insight second-by-second using the most up-to-date data. Expanding beyond SPC with medium size sample sets and subgroups, gradient boosted tree-based machine learning model have been shown to generate improved predictions.

SUMMARY

Manufacturing as a business is constantly driving toward improved productivity and product quality. AI, MES, MOM, and IIOT software-based solutions are a must have for every manufacturing company in today's competitive marketplace. Eyelit Technologies has deployed many of the capabilities outlined in this paper which have proven to generate 30% improvements in manufacturing cost, 15% improvements in labor efficiency, 20% improvements in planning efficiencies, 25% increases in plant throughput, and over 15% reductions in inventory positions across the Eyelit customer base. A partnership with Eyelit will ensure both current and future manufacturing performance.

ABOUT THE AUTHOR

Joe has been at the forefront of manufacturing operations management, process improvement, and data analytics for many years, having lead divisions at GE, GM, HP, Blue Yonder, Oracle, Brooks Automation, and Symphony IRI.

Many of the process innovations and mathematical solutions designed by Joe's teams in Semiconductor, Automotive, High Tech, Industrial Products, Medical Device, and Pharmaceuticals have been considered groundbreaking advancements. Joe is an alumnus of Harvard Business School, is certified in AI/ML from MIT Sloan, and has both a BS in Applied Mathematics & Statistics and a BS in Mechanical Engineering from UMass Amherst.

Joe holds patents in Supply Chain Planning, is the co-author of the business book "The Real Time Enterprise" and is a past award winner in the Mathematics Olympiad Competition.