

INTRODUCING A MANUFACTURING EXECUTION SYSTEM AT HAPPY PEN INC.*

Knowledge Dimension:
Technology

Teaching Notes
06 2019

*Fictional company name

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Funding

This work is supported by the Interreg CENTRAL EUROPE Programme funded under the European Regional Development Fund (ERDF).

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Teaching Notes¹: Happy Pen

1. Explain the circumstances that made Happy Pen's manager think of introducing a manufacturing execution system. What other drivers can you think of?

The current production at Happy Pen consists of separate machines that each provide different process steps within the production of pens (e.g. injection moulding machines for producing the plastic housings). Since all these machines are treated as separate units, there is no connection between them or any higher IT-System. This means the manager of Happy Pen can only track individual information about the production, such as OEE, by manually gathering it. However, to get combined information about the complete production line and to derive the right actions out of these numbers regarding a potential improvement of the production (e.g. identifying bottlenecks), intensive calculations would be needed. To do this by hand would be very time consuming and could only be done in very large time intervals, which prohibits any kind of quick reactions of the production control.

Due to a lack of such information and calculations, it is unknown, if the current production system works at optimal efficiency. The teaching case states *“export is an important field of growth in order to maintain the annual growth rate of 4-6%”*, so production needs to become as efficient as possible. In contrary it would also be possible to keep the production management as it is and just add more machines to compensate for growth, but this would not be the most cost efficient way to reach those numbers. The fact that the pen-market is very cost competitive due to prices where every cent counts, makes this kind of approach even less attractive.

A Manufacturing Execution System (MES) that is connected to all those separate machines and can gather and process the necessary information, could make the production more efficient and help to further improve the machines capacities. Happy Pen does also describe a batch-size 1 oriented strategy due to the general trend towards individualised mass-production with the statement: *“Over the years, Happy Pen has increasingly developed its business model towards the production of more individualised products which should be competitive at the price and delivery time of mass products.”* This goal does also support the implementation of

¹ Exemplary results from the regional Basic Trainings and insights from theory



a MES, since it could process required information needed for producing individual products with a high machine output.

2. What is MES? What are the advantages of such a system? What could be the risks in introducing such a system?

As stated in the Teaching Case: “MES are computerised systems for manufacturing that allow the tracking of the production process from the raw materials to the finished goods. This is not only important in terms of quality management, but also makes optimisation decisions much easier. It supports resource scheduling, downtime management and overall equipment effectiveness (OEE). It should furthermore reduce the failure rate and re-work, increase uptime, provide more accurate cost information and reduce inventory. As it works in real time, it enables to control all the elements of the production process. The introduction of MES can also be seen as an intermediate step to further integrate upstream and downstream processes into the production process.”

In terms of risks, Happy Pen has to consider that MES can be very expensive themselves and their tool kits often have high cost ratios in terms of licence-to-service, often up to 1:5. That means that it for every 10.000€ spent on licence, you may actually spend 50.000€ in services. This especially applies for custom build MES solutions, while “Commercial-off-the-Shelf” (COTS) MES might only have a licence-to-service ration of 1:2 but require more implementation effort and expertise by the end user. Since no MES is currently implemented at Happy Pen and all the machines have different connectivity protocols, a COTS MES would require great efforts within the company in an unknown field and therefore present a high financial risk.

3. What are Happy Pen’s specific requirements for such a system? Which connectivity technology does Happy Pen prefer? What other issues can make the implementation of such a system difficult?

Happy Pen faces the challenge that many different generations of machines with completely different communication protocols are currently used in production, which makes connecting them to an MES quite difficult. The requirement is not only to provide connection with legacy machines but also to be prepared for future IoT-Standards. The system has further to be highly scalable.



In terms of future connectivity technology, OPC UA is the preferred standard. It has already a high dissemination in the domain of mechanical engineering and will be implemented in future machine generations. This is especially the case for injection moulding machines, which are the one of the most important machine type for a pen manufacturer and already have the Euromap OPC UA Specifications.

One of the main issues is the connectivity strategy for existing machines. While Happy Pen could chose a MES that can handle current legacy connectivity protocols as well as OPC UA, the number of protocols needed would strongly restrict the selection of a suiting MES provider. This could be compensated by a custom MES, which integrates all those different protocols, instead of a COTS MES with only selected ones. However, this would lead in strongly increased service costs as mentioned in question two.

The other possibility would be retrofitting all existing machines with an OPC UA interface, which would make it the only required connectivity technology for the MES and therefore drastically increase the possible providers. Since Happy Pen has currently no experience with OPC UA, this kind of approach represents a high risk. It is unknown how such a retrofitting can be realised. The most cost effective way would be to do it with internal resources, but without any prior knowledge, this is nearly impossible. If an external service provider is involved, there might be no financial benefit of only using OPC UA instead of multiple protocols. In this calculation, the future development of OPC UA also needs to be considered.

Another difficulty might be management and respectively staff commitment. If either are not 100% on board with implementing this new system, the whole endeavour might be a lot more difficult than it needs to be. Happy Pen Inc. needs to find healthy balance between applying gentle force to convince overly sceptical employees and positive encouragement.

4. What are advantages and disadvantages of the preferred protocol?

The biggest advantage of OPC UA is a unified communication protocol as well as the possibility to provide an information model directly within the interface itself. It uses “Standard-Ethernet” known from the office and enables therefore high interoperability with all layers of the classic “automation pyramid”. In terms of dissemination, OPC UA is one of the most popular communication standards and highly recommended by different organisations for being the standard protocol in the Industrial Internet of Things. Currently most of the bigger vendors of industrial automation components (e.g. Siemens) have fitted their products with OPC UA connectivity, which further improves its dissemination.



While Ethernet-based unified connectivity could have also been achieved with legacy standards like ProfiNET, the addition of a browseable built-in information model based on executable standardised services (read, write, method-call, subscribe, etc.) is the biggest advantage of OPC UA. While the standard itself only specifies the tools for building an information model, it is also possible to specify additional “Companion Specifications” with domain and machine type specific standardised information models, which are created by working groups from the respective manufacturers. This is especially relevant for Happy Pen with its injection moulding machines for producing the shells of their pens. Association for European Plastics and Rubber Machinery (Euromap) created one of the first companion specifications, which describes the connectivity between injection moulding machines and a MES. This means that future generations of this machine type will most likely have standardized OPC UA connectivity. While the use of standard Ethernet is an advantage in terms of connectivity, its TCP/IP-based architecture prohibits any real time communication, which is a hard requirement for any controlling applications within the shopfloor. The use of the proprietary UA-Binary communication protocol over TCP with its client-server architecture makes it also slower than UDP-based MQTT.

5. Which other connectivity technologies can you think of? What are their advantages? What are their disadvantages?

One of the biggest contender of OPC UA is the MQTT (Message Queuing Telemetry Transport) protocol. In contrary to the TCP/IP-based UA-Binary protocol of OPC UA, MQTT uses UDP, which allows a faster transfer of packages with less overhead. This is possible by using a publish/subscribe interaction pattern instead of client/server. The “payload” of messages transmitted with MQTT is usually described as a JSON-file. While JSON is a standardized notation format, it doesn’t specify which information is described within, which is a big disadvantage of MQTT. It is therefore not comparable to the highly standardized Companion Specifications of OPC UA with its domain specific information models. A pub/sub-based interaction pattern does also not allow any kind of browsing, so the information that is received needs to be known to the subscriber beforehand.

6. What is the future of OPC UA and comparable technologies?

For many years, dozens of different fieldbus and industrial Ethernet protocols have been state of the art on the shopfloor and anytime a new standard from a company was created to unified



communication, they only created another parallel one. What makes OPC UA special is the fact, that the OPC Foundation created it and not a company, so it appears as a “neutral” protocol. For the first time, there is a real chance to end the jungle of protocols currently in place and the already very high dissemination of OPC UA speaks for this development.

Not being able to communicate in real-time limits its current applications mainly to data collection, the benefits of having a unified interface with built-in standardized information models are huge. This leads to the use of OPC UA as a second communication channel for use cases related to data analysis next to its primary communication for real-time control.

For the realisation of a truly fully connected and interoperable industry, it would be necessary to have only one communication standard and data semantics. For many applications real-time processing is a necessity, especially when machine control is involved. The connectivity standard of the future would have to meet this demand. In the case of OPC UA, there are developments to meet these requirements. Since it is not only an interface, but rather an architecture (UA = Unified Architecture), it is possible to change the underlying communication protocol as well as the interaction pattern. While standard client/server-based OPC UA transmits over UA binary, it is also possible to include the pub/sub-interaction pattern into the architecture with the use of protocols like UA Multicast, AMQP or MQTT. This also means the use of UDP as network protocol and therefore a much slimmer and faster communication. This can be combined with the layer-2-technology Time-sensitive Networking (TSN), which is collection of different sub-standards that allow real-time communication over standard Ethernet. TSN and OPC UA are independent from each other and using TSN means a convergence of all the different networks with its individual switches to only one physical Ethernet network. This is the first step for a future Industrial Internet of Things and will further be improved by also harmonising the protocols that are transmitted.

At last, a general development will be the orientation of such intelligent communication standards towards “plug-and-produce” capability. This should be similar to the USB principle known from consumer electronics. Companies want to be able to connect different machines (old, new, different manufacturers, etc.) with each other without having to worry about interfaces. This group does believe though, that OPC UA will establish itself as the communication protocol to use. It fulfils many of the requirements, listed to be important to companies, already.



7. Which steps should Happy Pen take to come up with a final decision? Are there issues they currently overlook?

Currently there are many unknown factors regarding the implementation of an MES. The biggest issue is no internal experience with MES or OPC UA. Happy Pen should therefore setup a project-team, which is responsible for evaluating and implementing the new MES with a possible OPC UA connection. This team should record the project goals and time-line in a document and also define Happy Pen Inc.'s requirements in a specification catalogue. Afterwards they should obtain quotations of at least five different IT-consultants or software developers. They should narrow it down to the best 2-3 offers and gather references from these companies. Maybe even speak with other companies who purchased similar services and inquire about their experiences with said consultant. After the best companies has been chosen, the project team and the contractor should come together and discuss the entire process. Possible issues that might be overlooked is the maintenance of the new system. Maybe they would have to hire somebody or train their IT-department. The other possible option would be to set up a maintenance-contract and outsource this responsibility.

8. What could be the next steps after the implementation of a MES?

Next to obvious next steps regarding the MES itself, such as maintenance and continuous improvement, the now established connectivity should be explored further. Within the I4.0-initiative, there are many use cases that can be realised with interoperable interfaces. Especially the use case of mass customized products should be evaluated further and the requirements should be checked with the current possibilities of the OPC UA interface. Another use case would be a faster “plug-an-produce” setup of new machines by using this standard. With the implementation of the MES, Happy Pen also has to think about which organisational aspects need to be altered in order to have the most benefit out of this investment.