

University of Wales Trinity Saint David

Introduction to Industry 4.0 (ACPA7004)

Assignment A - A review of Penderyn Distillery's Mashing Process and the Introduction of Industry 4.0 Technologies

Submitted to: Mahesh Kannath

Submitted by: Bethan Morgans

Date of submission: 27/07/2022

Word Count: 1535

Abstract:

Employing industry 4.0 technologies within breweries and distilleries has become more popular over recent years. Whisky manufacturing is considered a traditional Scottish industry which has incorporated conventional techniques for many years. Recently, whisky distilleries have been opening all over the world forming a new whisky category 'New World Whiskies'. The modern way of whisky making means that industry 4.0 technologies are being employed within the industry to improve productivity. The mashing process at Penderyn Distillery was reviewed, highlighting target areas within the process where industry 4.0 technologies could be employed to reduce mashing time and increase throughput. Discrete event simulation was considered the most suitable technology to mitigate the issue of bottleneck within the process. The addition of multiple criteria decision analysis was also considered to be incorporated to the DES model, in order to identify problems and help decision makers through use of documents, personal knowledge and business models.

Aims & Objectives:

The purpose of this report is to assess the efficiency of the mashing process at Penderyn Distillery and highlight any development opportunities which may be implemented within the organisation to reduce overall process time. The aim is based on the theory that employing industry 4.0 technologies within the organisation would help reduce overall mashing time or increase throughput.

Introduction

A data driven exercise was conducted using information collected from the mashing and distillation processes of one complete batch of malted barley consisting of 18 separate mashings (Malt batch reference 02-2021). The total mashing process time for each of the 18 mashings were plotted to analyse the utilisation of the mash tun (Appendix 1). The average time taken to complete the mashing process was 407 minutes with the shortest (minimum) mashing time being 360 minutes. The difference between the minimum achieved time and the average was 47 minutes.

The process times for each stage of the mashing process were analysed. Five key stages were identified as 'time limiting' within the mashing process. The process duration for each of the key stages was calculated, which allowed the theoretical minimum, average and maximum mashing time to be calculated for each. Reducing the duration of the mashing process from the current average of 407 minutes to the achieved minimum duration of 360 minutes, a total of 47 minutes would be saved on each mash. With the distillery operating 24 hours, 7 days a week, and completing two mashings per day, this would save 32,336 minutes per year, the equivalent to 89 extra mashings per year.

The data used for this analysis is already captured and manually recorded by operators. Discrete event simulation software could utilise this data to create a digital simulation of the distillery processes. This model could be interrogated to identify the system's bottleneck, the bottleneck could then be targeted, which in turn could reduce mashing time.

Background Research

Discrete event simulation (DES) is defined as a method that can simulate events occurring in sequences making it possible to include the influence of one event on other events (Khetwal et al,

2022). This approach has many capabilities, one main advantage of DES is that it has the ability to represent a number of processes or events and their complexities and independencies. For this, DES models are used widely in computer networks, business processes, vehicle manufacturing as well as many other applications (Khetwal et al, 2022).

Arena software was developed by Rockwell automation, this simulation software enables food and beverage companies to increase throughput, identify process bottlenecks, improve logistics and evaluate potential process changes (Rockwell Automation, 2022). Arena software offers an automated brewing software designed specifically for the brewing industry, aimed at reducing the time spent on managing equipment and processes. With the mashing process being a common process in brewing and distilling industries, the Arena software has the capabilities to address cost, quality, and flexibility to meet demand, from grain handling through waste treatment and packaging. Although this report covers the requirement for DES within the mashing process, the Arena software could target other processes or activities elsewhere within the Penderyn Distillery organisation, making it more cost effective.

DES allows decision makers to fully understand and respond to the behaviour of the variables of the system (Barros Brito et al, 2011). By employing DES within the mashing process, Penderyn Distillery's management can closely observe the system and respond to certain elements in a timely manner. For instance, certain bottlenecks within the process can be predicted early on, allowing management to utilise resources promptly. This would be useful where there has been delays in the mashing or fermentation processes, having a knock-on effect on the stills. The decision can be made to carry out maintenance or cleaning regimes on the stills whilst they experience downtime due to a bottleneck. Without DES, it is difficult to predict the impact a delay may have on the process due to the complexity of the system, which means opportunities to utilise resources in other ways can easily be missed.

A multiple criteria decision analysis (MCDA) may be incorporated into the DES model to expand the capacity of the model as a decision-making tool. According to Barros Brito et al (2011), the DES and MCDA combined methodology has been shown to be effective as a complex logistics problem decision-making support tool, which can enhance the interaction between model development and users. The combination of both models can be considered a hybrid DSS model as it combines the techniques of each model (Barros Brito et al, 2011).

Implementation Methodology

The core concepts of DES are entities, attributes, events, resources, queues, and time. Entities are objects that have attributes, experience events, consume resources, and enter queues, over time (Karnon et al, 2012). In this example, the malted barley, water, yeast and unfermented wash would be treated as entities. Attributes are features specific to each entity that allow it to carry information (Karnon et al, 2012). During mashing, the temperature and volume of the water and the original gravity of the unfermented wash would be considered to be key attributes. These attributes can be modified at any time during the simulation. Events are broadly defined as things that can happen to an entity or the environment in which it is in (Karnon et al, 2012). In this case, the mixing of the water with the malted barley, the filling of the fermenter and the addition of the yeast would be considered as key events. Typically, a resource is an object that provides a service to an entity, which may require time (Karnon et al, 2012). The mash tun and the fermenting vessels as well as any ancillary pipework would act as the resource in this example. If the resource is full when an entity

requires it then this would form a queue. For example, if the fermentation has exceeded the target time of 68 hours, then the start of the next mash would be delayed as the next 1.5 tonne of malted barley would form a queue due to there being a lack of available fermenters.

Due to time being a key component of DES, it is possible to track interim periods. There were five key stages of the mashing process which were highlighted as 'time limiting',

- Process Start → Start Fermenter Fill
- Start Fermenter Fill → End Fermenter Fill
- 3rd Water Start → Drain Start
- Drain Start → Drain End
- Drain End → Mash Complete

Use of the existing equipment along with new working practices, in combination with an iterative simulation process could significantly increase productivity by targeting the time limiting stages.

According to Barros Brito et al (2011) the methodology and development of DES can be broken down into three main stages:

- Conception: definition of the system and its objectives, as well as data collection and conceptual modelling.
- Implementation: preparation of the computer model itself, verification and validation
- Analysis: simulation runs and sensitivity and results analysis

The introduction of DES into the Penderyn Distillery production would follow the above stages in order for successful programming and commissioning.

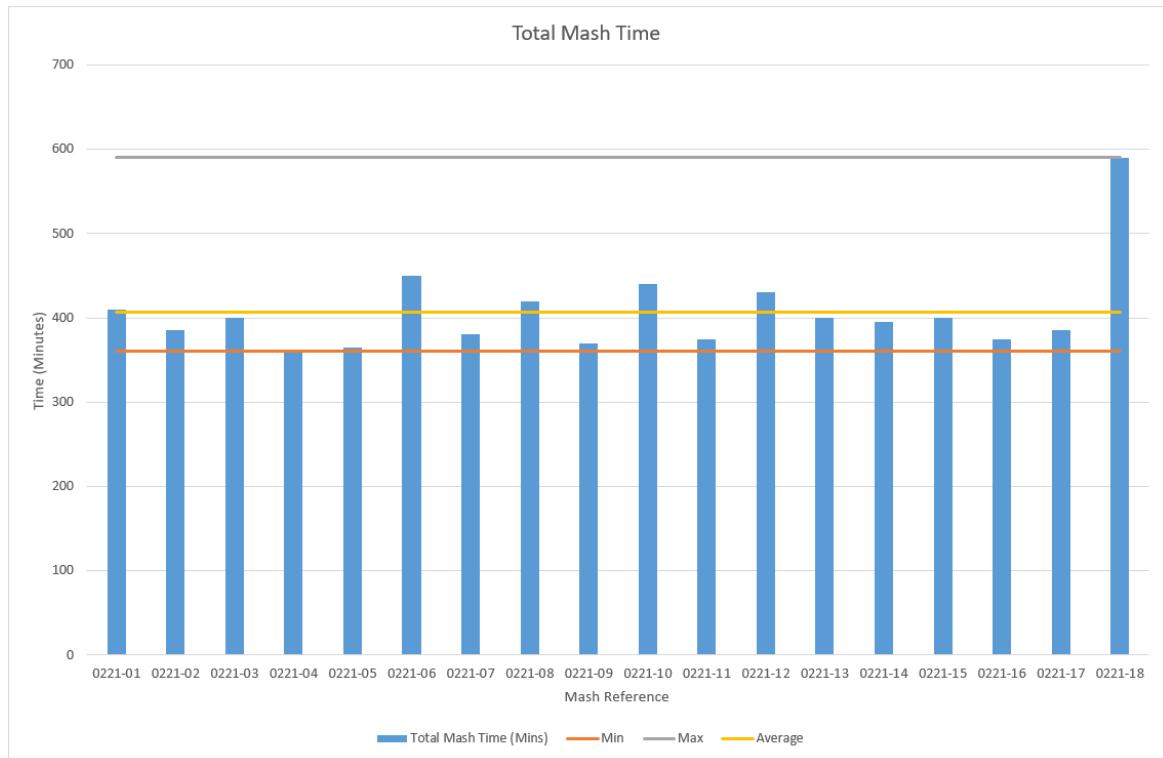
If opting for the addition of the MCDA model, the scenario planning (SP) methodology would be used. This would utilise hypothetical future scenarios to assist decision makers with developing coping mechanisms for the main uncertainties they are most likely to face. However, as the SP is an additional support tool and an extension to the MCDA model, this may be considered an excessive addition to the DES technology for the mashing process alone. The SP and possibly the MCDA model would be better utilised across the whole operations or added at a later date if DES alone was not sufficient.

Conclusion

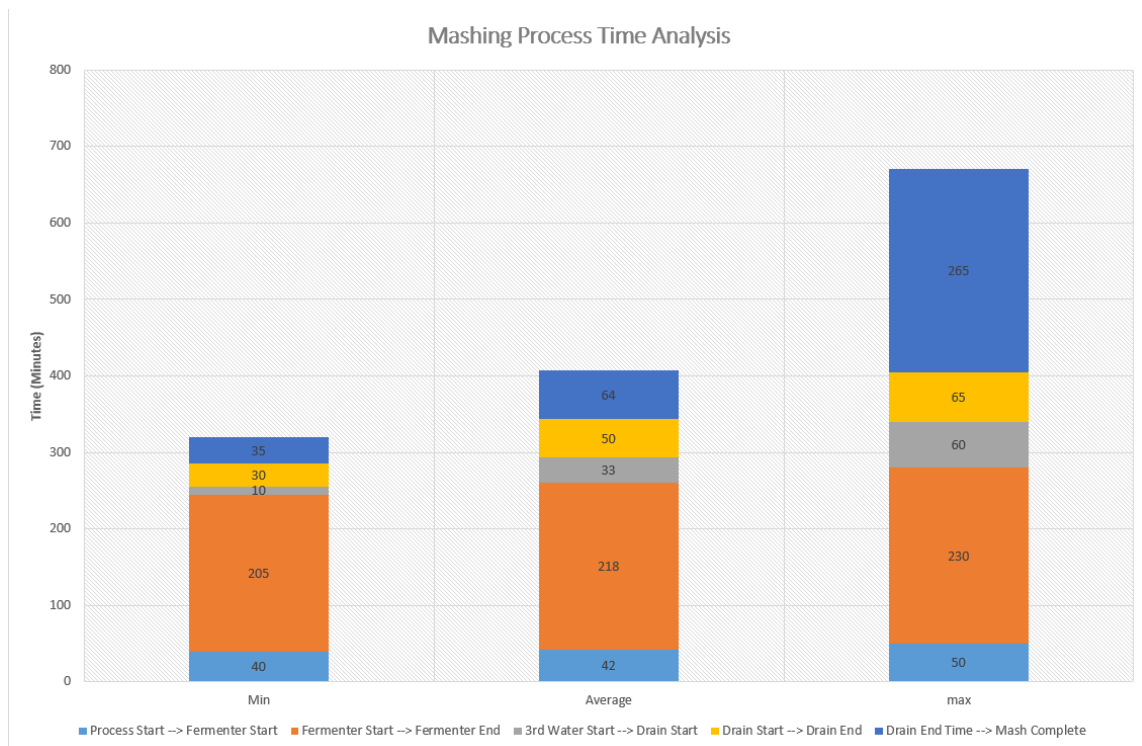
DES provides a useful framework in order to replicate a multitude of manufacturing processes, highlighting key problems and target areas. This report has reviewed the main attributes of the DES software and how it can be implemented within Penderyn Distillery to target bottlenecks and increase throughput. The implementation methodology has considered the best practice for DES within the organisation in order to increase transparency and value of the software within production in order to optimise the decision-making process and trade-offs. The DES model can be combined with MCDA to provide a more robust interactive software-based system, designed to provide decision making support.

Appendices

Appendix 1



Appendix 2



Bibliography and References

Babulak, E., Wang, M., 2010, 'Discrete Event Simulation: State of the Art', in A. Goti (ed.), Discrete Event Simulations, IntechOpen, London. 10.5772/9894.

Barros Brito, T., Santos Silva, R., Trevison, E. and Botter, R., n.d. *Discrete Event Simulation Combined with Multiple Criteria Decision Analysis as a Decision Support Methodology in Complex Logistics Systems*.

Gajsek, B., Marolt, J., Rupnik, B., Lerher, T. and Sternad, M., 2019. Using Maturity Model and Discrete-Event Simulation for Industry 4.0 Implementation. *International Journal of Simulation Modelling*, 18(3), pp.488-499.

Gilchrist, A., 2016. *Industry 4.0 The Industrial Internet of Things*. 1st ed. Apress L.P.

Huynh, B., Akhtar, H., and Li, W., "Discrete Event Simulation for Manufacturing Performance Management and Optimization: A Case Study for Model Factory," *2020 9th International Conference on Industrial Technology and Management (ICITM)*, 2020, pp. 16-20,

Karnon, J., Stahl, J., Brennan, A., Caro, J., Mar, J. and Möller, J., 2012. Modeling using Discrete Event Simulation: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force-4. *Value in Health*, 15(6), pp.821-827.

Khetwal, A., Rostami, J. and Nelson, P., 2022. Introducing uniform discrete event simulation (CSM2020) for modelling the TBM tunnelling process. *Tunnelling and Underground Space Technology*, 125, p.104502.

Rockwell Automation *United Kingdom*. [online] Rockwell Automation. Available at: <<https://www.rockwellautomation.com/en-gb/company/about-us.html>> [Accessed 27 July 2022].