Turkish Journal of Computer and Mathematics Education Vol.12 No.11 (2021), 5042-5047
Research Article

Application Of Industrial Revolution 4.0: An Overview On Biodegradable Polymer Production

Tang Tung Hau[1],Han Jun Hoong[2], Ooi Chia Sian[3], LK Chng[4], Chan Mieow Kee[5]

[1]Centre for Bioprocessing Engineering, SEGi University Malaysia
[2]Centre for Bioprocessing Engineering, SEGi University Malaysia
[3]Centre for Bioprocessing Engineering, SEGi University Malaysia
[4]Centre for Bioprocessing Engineering, SEGi University Malaysia
[5]Centre for Bioprocessing Engineering, SEGi University Malaysia

Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 10 May 2021

Abstract: Industry revolution 4.0 represents the future technological capability of an industry that can be achieve through extensive research on linking digital database with mechanical equipment. This initiative is primarily designed to digitize the structure of the manufacturing process, allowing the control on variables in a plant and also improve accessibility of crucial information that is useful for operators to improve the performance of the process. Some examples of Industrial Revolution 4.0 technologies are Smart Equipment, drone with high resolution cameras and predictive sensors, all linked through the Internet of Things (IOT), allowing access into the massive data, churned out by intricate software, which operators can analyze to implement suitable solutions based on the feedback. This paper also presents how the process of producing biodegradable polymer can benefit should if Industrial Revolution 4.0 is implemented. Also, the contribution and skills required by chemical engineers to practice Industrial Revolution 4.0 is discussed. This paper mainly represents an overview on how Industrial Revolution 4.0 affects the industry market and what engineers need to navigate through this new era.

1. Introduction

Nowadays the industrial production sector need to handle the complex and dynamic market request with a fast pace. The complexity of these requirement can be tackles by advance techonology. Therefore Industrial revolution 4.0 (IR 4.0) will be a great approach to tackles and integrate the company's business and manufacturing process.IR 4.0 was firstly introduced during Hannover fair in the year 2011 in order to intergrate the current business and manufacturing process. Industrial Revolution 4.0 introduce the concept of Cyber-Physical System (CPS) and Internet of Things (IoT), CPS will be the building blocks of the system and enable the system to collecting and exchanging real time information in order to optimizethe production process(Nagy et al., 2018). In order to have a seamless system network a third party software would be needed, Enterprise Resource Planning and Manufacturing Executive System (MES) would be necessary for these requirement(Ren et al., 2017).The enourmous amount of data will be stored in a cloud storage and the incoming "raw" data will be undergoes a sieving or analytical process to becoming a valueable information. With the help of these system the manufacturing process will be able to self-optimizing the process without much hassle.

This paper will focus on the implementation of IR 4.0 to the manufacturing sector of Production of Cellulose-based Biodegradable Poymer,the roles and skills needed for a chemical engineer in order to be a part of IR 4.0.

2. CHEMICAL ENGINEERING AND IR4.0

Asset Management

The financial outlook of chemical industry are usually based on their available assets and liabilities. The stability of the financial status grants mobility for the industry to navigate through the market, constantly finding new ways to earn revenue and stay relevant on the market.

Depending on the company, the sheer amount of work and effort is needed to ensure that assets of the industry are managed effectively while optimizing their performance. Merging Internet of Things (IOT) with digital technologies allows companies to help optimize their expenditure, safeguarding the status of their assets. With this, efficacies of utilizing assets may be able to be done through predictive asset management (Man et al., 2015). For example, continuous stream of data from operating equipment such as heat exchangers and condensers can be collected through intricate network of software technologies which is then utilized to predict and diagnose possible errors or problems down the road (Mattera et al., 2018). Technological advancements resulted in existence of SMART technologies which essentially helps to remedy the problem or provides near-instantaneous signal to operators in charge. As the timing improve, operators can catch the problem early on, evolving the traditional See-

Then-Do response into a predictive mechanism where they can diagnose the probability of the recurring issue long before the incident and hence, provide strategically sound response against the problem (Komljenovic et al., 2017). Also, data of similar equipment from different operating sites can be gathered for analyzing purposes for future improvement on newer facilities (Popkova at al., 2019). The reliance of chemical industry on IR 4.0 allows massive collection of data as each component of the manufacturing line is registered to a data cloud which can be then processed by individuals that may be able to interpret those data for usage(Fisher et al., 2018). For example, Caterpillar, a construction machinery and equipment company based in USA recently formed a partnership with Uptake, an industrial analytical company to form a predictive analytical platform which can greatly benefit their customers as they are able to adopt a “Repair before Failure” method towards industrial issues (Kritikos and Barreiros, 2016).

Process Instrumentation and Control System

Earlier days saw petrochemical industries operating on an analog-based system, which means that there are specific controls and mechanisms that needs to be activate manually to bring about the desired effect. Such procedures are often confusing and complicates the works of the operator, especially during emergency (Fernando & Zailani, 2008; Li, 2016). IR 4.0 allows data to be collected from each sections of the manufacturing plant through intricate network system built which is then passed along to the operator digitally, allowing easier access to the conditions of the process, for faster response and better performance (Rojko, 2017). Besides that, putting cutting-edge technology such as real-time analytics and automation equipment together with data access system allows faster predictive response and higher quality assurance (Noam, 2018). There are number of sub processes that can benefit from such improvement such as internal conditioning of the manufacturing line, controlling of specific conditions of production and even the expiry conditions of certain equipment. Analysis of the data obtained can help predict the patterns or any deviation from the norm of the process before occurrence, ultimately improving the quality of the final products (Titler, 2008).

Energy Utilization

One of the accountable cost of running a plant is the energy expenditure. Energy usage significantly affects the production cost of a manufacturing plant. Energy is spent throughout the entire plant, from production to servicing of equipment (Kermeli et al., 2011). In chemical engineering, engineers usually are required to maintain optimum condition for the process so as to produce desired quality of product. As there are numerous procedures and steps involved in the plant, it is quite hard for engineers to determine the best operating condition for the process, resulting in large expense of costs in terms of energy. IR 4.0 encourages development of model or simulation in which operators may determine the conditions and simulate the entire process before bringing it into actual practice (Petrillo et al., 2018). Modelling of the condition enables operators to take multiple variables into accountability such as fouling period, fluctuation of surrounding temperature and variation of products required and hence, minimizes the waste of energy and resources for production (Kermeli et al., 2011). Augmentation of the condition in combination of automated machinery helps to fine-tune the process in which helps to reduce energy waste while maximizing the performance of the equipment (Schimek, 2016). Specific requirement such as liquid level in tank, pressure in piping and flowrate of solutions in plant can be incorporated into IR 4.0 technologies that can optimize the procedures(Barlev, 2011). Certain instruments such as sensors can add additional input about the conditions of the process which can establish an approximate value so as to avoid malfunction or deviation from the intended result. IR 4.0 can help incorporate sensors with digital software which can provide more accuracy towards the probability of such events occurring while providing control over certain variables that ultimately improve energy efficiency (Nagy et al., 2018).

OSHA and HAZOP

Chemical industry often involves sensitive components which requires specific conditions to operate or else, results in failure or even harm to the workers. In this sense, chemical companies are required to have certain protocols or built-in mechanism to help protect their assets, which is the employees. Level of security towards the safety of their plants can also help ensure the faith of stakeholders towards the company’s performance. IR 4.0 can help relieve certain issues such as human error as traditional method of providing safety is through diligent monitoring of process which involves manual works. Also, human reactivity during events also affects the level of safety in the industry (Schilter et al., 2003). Continuity is the key in providing a safe environment in the chemical industry. IR 4.0 combines data analytic systems with production equipment to help in predicting any events that has not occur but will eventually. This provides operator sufficient time to access the situation to provide the most suitable solution to handle the event. Also, continuous monitoring of the equipment can help predicting the efficiency of the equipment while adjusting the suitable time for maintaining the equipment (Lee, 2018; Lee et al., 2019). Moreover, certain plants are relatively large in size and it can be quite difficult for workers to identify certain hard-to-reach areas for checkups. Certain technology such as drones or sensors placed strategically can help resolve these issues against the traditional method of reaching these areas such as ladders. Also, these technologies are equipped with high resolution technologies in which provides better imaging of the area, allowing better efficiency for accessing the problems (Yang et al., 2017).

3. SKILL REQUIRED FOR CHEMICAL ENGINEER IN IR 4.0

Technical Skills

Chemical engineer is required to have technical skills in IR 4.0 such as job-related knowledge, production line simulation and coding skill which may bring the benefit to the company. Technical skills can be acquired through learning and practicing from industry field. Those technical skills can combine with multiple sources of data to validate the existing knowledge and to generate new ideas to improve the manufacturing design in term of operating condition, cost, quality as well as quantity(Grzybowska & Łupicka., 2017; Teles et al., 2018).

Managerial skills

The managerial skills are one of the important skills that need to posses for chemical engineer in IR 4.0 as it included for all skills and abilities for general problem solving as well as decision making. Chemical engineer should possess the analytical and creative skills to compare, evaluate and make the decision to select the best method to solve the problem based on the data generation from various sources to improve the decision making(Grzybowska & Łupicka, 2017; Sitek & Wikarek, 2016).

Social Skills

Chemical engineer must possess with social skills which included time management, interpersonal communication, ability to work with other discipline, to work in a team and ability to transfer the knowledge. Teamwork is often the focus of social skills as engineering project will collaborate and communicate with other discipline such as mechanical engineer, civil engineer as well as electrical engineer in production line for industry 4.0(Fitsilis et al., 2018; Grzybowska & Łupicka, 2017).

4. ROLE OF CHEMICAL ENGINEER IN IR 4.0

Big Data Analytics

Chemical engineer can utilise and interpret from Big Data which collected in continuous feed of data from sensor to predict and diagnose possible breakdowns for equipment such as turbines, compressors and extruders. With those supporting data, the smart equipment can send the message to production engineer to notify any required maintenance and potential breakdowns of equipment. Thus, the production line can escape from unplanned downtime due to the failure of the equipment. Unplanned downtime of the production line may lead to the loss of production, scrap and overtime labour. Therefore, the continuous feed data from sensor is needed to maximise the asset utilization and minimise unplanned downtime (Chan et al., 2017; Ferreiro et al., 2016; Thienen et al., 2016)

Real time Monitoring

Chemical engineer can monitor the real-time data streaming from Supervisory control and dataacquisition (SCADA) to ensure the production line conditions such as temperature, pressure and flowrate are between the desired range in order to produce the consistent quality of products. The corrective action can be taken immediately when the chemical engineer noticed the abnormal condition from SCADA so that the quality of the product will not be affected due to the condition of the production line. With the complete database from production line, the chemical engineer can calculate to scale up or scale down the quantity of the products accurately based on the customer requirement (Simon et al., 2018; Thienen et al., 2016).

Research and Development

Chemical engineer can involve in research and development department by utilizing the facilities of smart factory to improve the quality of the product, to develop the new product as well as to replace those high cost raw materials or unsustainable materials. With the advance of laboratory automation in experiment, huge data sets can be provided. By using the informatics methods, chemical engineer can accelerate the progress of the R&D and to provide more reliable experiment results for the research(Chiang, 2017; Peil et al., 2004; Thienen et al., 2016).

5. BIODEGRADABLE POLYMER AND IR 4.0

The process of production of cellulose-based biodegradable polymer consist of pre-treatment, extraction of cellulose, neutralization process and casting process. Firstly, the raw material need to undergoes pretreatment to remove impurity that might affect extraction of cellulose process. There are several ways to process the raw material in order to extract cellulose out from it but overall it consist of acid-hydrolysis process and alkaline treatment. Acid-hydrolysis process will dissolve lignin and hemicelluloses and help to reduce the overall crystalinity of the fiber . Alkaline treatment will swell up the cell wall and release the trapped cellulose (Soom et al., 2009).

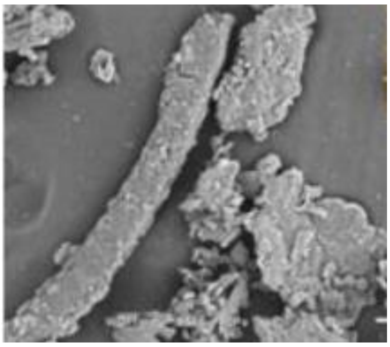

Fig 1 Before treatment(Herawan et al., 2018)

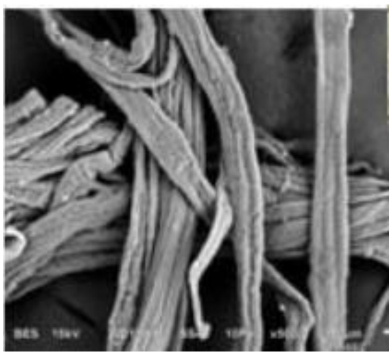

Fig 2 After treatment(Herawan et al., 2018)

In Fig 1 the surface of the fiber is rough that indicate the present of lignin and hemicelluloses. After undergo acid-hydrolysis process and alkaline treatment process the surface of fiber Fig2 is smoother compared to Fig 1. After post acid hydrolysus process and post alkaline treatment process, neutralization process will be introduce into the process flow to ensure the remaining acid or base will be fully remove and won’t interfere the next process.

Currently the process is conducting in lab skill to ensure the process flow is feasible and able to implement into industrial skill. During acid-hydrolysis process, acetic acid and distilled water was mixed and used to remove lignin and hemicelluloseand sodium chloride will be introduce into the vessel together at the same time for bleaching process to occur, the mixture will be heats under reflux condition for 4 hours and neutralization process was performed. For alkaline treatment, 1M sodium hydroxide (NaOH) solutions was used for the treatment process, the mixture was heated under reflux condition for 1 hours.The extracted cellulose will be the filling or medium of the polymer in order to increase the physical properties(Isroi et al., 2017). The cellulose will mix with solvent and obtain a viscous liquid and the liquid was casted on a flat plate and let to air dired.The following process was proven by theoretically and practically feasible in lab scale and it may implement in industrial scale.

Different ratio between cellulose and solvent it can produces different quality and product accordingly. Therefore with the aid of IR 4.0 the manufacturing process of the production of biodegradable polymer will ensure the amount of raw material will be precise, increase product quality and reduce man power. Manufacturer can obtain the data from cloud storage and precisely prepare the amount of raw material without much hassel(Saldivar et al., 2015; Simon et al., 2018), this is due to the supervisory control and data acquisition (SCADA) will be use at the same time for collecting data for future production purpose.

By using wireless connection between the user and machine it help the manufacturer to control the quality of the product in real time and able to collect data at every point of the production(Simon et al., 2018), this will help manufacturer to check which of the changing of condition will affect the quality of the products.Processing the real time data manufacturer can precisely identify when to perform maintenance on machinery before problem occur tharequires more man power compare, alsowire-less controlling also can reduce the frequency of worker steps into hazardous area such as acid and base treatment area to check on the pH level.

6. Conclusion & Recommendations

Chemical engineering has vast opportunity to implement IR 4.0 into its structure. Safety and productivity may be interpreted as de facto recognition of the core of chemical engineering but incorporating IR 4.0 enchances the full potential of chemical engineering to be more sustainable while being effective in managing its asset to maintain the economical standview of the respective company. Chemical engineer should continuously educate and upgrade themselves to be familiar with the language of this new era to ensure IR 4.0 transform the future of this industry.

7. Acknowledgment

Special thanks to SEGi University for the funding given.

References

1. Bishop, K., & Said, I., (2017). Challenges of Participatory Qualitative Research in a Malaysian and Australian Hospital. Asian Journal of Environment-Behaviour Studies, 2(4), 1-11.
2. Chan, H. K., Subramanian, N., & Abdulrahman, M. D.-A. (Eds.). (2017). Supply Chain Management in the Big Data Era: IGI Global.
3. Chiang, L., Lu, B., & Castillo, I. (2017). Big Data Analytics in Chemical Engineering. Annual Review of Chemical and Biomolecular Engineering, 8(1), 63–85.
4. Collado, S., & Corraliza, J., A. (2017).Children’s Perceived Restoration and Pro-Environmental Beliefs. Journal of ASIAN Behavioural Studies, 2(2), 1-12.
5. Grzybowska, K., & Łupicka, A. (2017). Key competencies for Industry 4.0. 250–253.
6. Ferreiro, S., Konde, E., Fernández, S., & Prado, A. (2016). INDUSTRY 4.0: Predictive Intelligent Maintenance for Production Equipment. 8.
7. Fernando, Y., & Zailani, S. (2008). The Determinant Factors of Safety Compliance at Petrochemical Processing Area: Moderator Effects of employees Experience and Engineering Background. 11.
8. Fisher, O., Watson, N., Porcu, L., Bacon, D., Rigley, M., & Gomes, R. L. (2018). Cloud manufacturing as a sustainable process manufacturing route. Journal of Manufacturing Systems, 47, 53–68.
9. Fitsilis, P., Tsoutsa, P., & Gerogiannis, V. (2018). Industry 4.0: Required personnel competences. (3), 4.
10. Herawan, T., Rivani, M., Halimatudahliana, H., & Irawan, S. (2018). Oil Palm Based Cellulose Esters as Raw Material for Environmentally Friendly Bio-plastic. Majalah Kulit, Karet, Dan Plastik, 34(1), 33.
11. Isroi, Cifriadi, A., Panji, T., Wibowo, N. A., & Syamsu, K. (2017). Bioplastic production from cellulose of oil palm empty fruit bunch. IOP Conference Series: Earth and Environmental Science, 65, 012011
12. Kermeli, K., Worrell, E., & Masanet, E. (2011). Energy Efficiency Improvement and Cost Saving Opportunities for the Concrete Industry. Lawrence Berkeley National Lab.(LBNL), 120.
13. Komljenovic, D., Loiselle, G., & Kumral, M. (2017). Organization: A new focus on mine safety improvement in a complex operational and business environment. International Journal of Mining Science and Technology, 27(4), 617–625.
14. Kritikos, K. & Barreiros, J. (2016). Business model innovation to explore data analytics value; A case study of Caterpillar and Ericsson.
15. Lee, S. M. (2018). Innovation: From small “i” to large “I.” International Journal of Quality Innovation, 4(1), 2.
16. Lee, S. M., Lee, D., & Kim, Y. S. (2019). The quality management ecosystem for predictive maintenance in the Industry 4.0 era. International Journal of Quality Innovation, 5(1), 4.
17. Li, D. (2016). Perspective for smart factory in petrochemical industry. Computers & Chemical Engineering, 91, 136–148.

18. Man, L. C. K., Na, C. M., & Kit, N. C. (2015). IoT-Based Asset Management System for Healthcare-Related Industries. International Journal of Engineering Business Management, 7, 19.
19. Mattera, C., Quevedo, J., Escobet, T., Shaker, H., & Jradi, M. (2018). A Method for Fault Detection and Diagnostics in Ventilation Units Using Virtual Sensors. Sensors, 18(11), 3931.
20. Mehdi K., & Koorosh, A. (2015). Achievement to Environmental Components of Educational Spaces for Iranian Trainable Children with Intellectual Disability. Procedia - Social and Behavioral Sciences, 201, 9-18.
21. Nagy, J., Oláh, J., Erdei, E., Máté, D., & Popp, J. (2018). The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain—The Case of Hungary. Sustainability, 10(10), 3491.
22. Noam E.M. (2018) Technology Management in Media and Information Firms. In: Managing Media and Digital Organizations. Palgrave Macmillan, Cham
23. Ren, L., Zhang, L., Wang, L., Tao, F., & Chai, X. (2017). Cloud manufacturing: Key characteristics and applications. International Journal of Computer Integrated Manufacturing, 30(6), 501–515.
24. Peil, K. P., Neithamer, D. R., Patrick, D. W., Wilson, B. E., & Tucker, C. J. (2004). Applications of High Throughput Research at The Dow Chemical Company. Macromolecular Rapid Communications, 25(1), 119–126.
25. Petrillo, A., Felice, F. D., Cioffi, R., & Zomparelli, F. (2018). Fourth Industrial Revolution: Current Practices, Challenges, and Opportunities. In A. Petrillo, R. Cioffi, & F. D. Felice (Eds.), Digital Transformation in Smart Manufacturing. InTech.
26. Popkova, E. G., Ragulina, Y. V., & Bogoviz, A. V. (2019). Fundamental Differences of Transition to Industry 4.0 from Previous Industrial Revolutions. In E. G. Popkova, Y. V. Ragulina, & A. V. Bogoviz (Eds.), Industry 4.0: Industrial Revolution of the 21st Century (Vol. 169, pp. 21–29). Cham: Springer International Publishing.
27. Rojko, A. (2017). Industry 4.0 Concept: Background and Overview. International Journal of Interactive Mobile Technologies (IJIM), 11(5), 77.
28. Saldivar, A. A. F., Li, Y., Chen, W., Zhan, Z., Zhang, J., & Chen, L. Y. (2015). Industry 4.0 with cyber-physical integration: A design and manufacture perspective. 2015 21st International Conference on Automation and Computing (ICAC), 1–6. Glasgow, United Kingdom: IEEE.
29. Schilter, B., Andersson, C., Anton, R., Constable, A., Kleiner, J., O'Brien, J., … Walker, R. (2003). Guidance for the safety assessment of botanicals and botanical preparations for use in food and food supplements. Food and Chemical Toxicology, 41(12), 1625–1649.
30. Schimek, R. S. (2016). IoT case studies: companies leading the connected economy. American International Group.
31. Simon, J., Trojanova, M., Zbihlej, J., & Sarosi, J. (2018). Mass customization model in food industry using industry 4.0 standard with fuzzy-based multi-criteria decision making methodology. Advances in Mechanical Engineering, 10(3), 1-10.
32. Sitek, P., & Wikarek, J. (2016). A Hybrid Programming Framework for Modeling and Solving Constraint Satisfaction and Optimization Problems. Scientific Programming, 2016, 1–13.
33. Soom, R. M., Aziz, A. A., & Hassan, W. H. W. (2009). SOLID-STATE CHARACTERISTICs of Microcrystalline Cellulose from Oil Palm Empty Fruit Bunch Fibre. Journal of Oil Palm Research, 8.
34. Teles dos Santos, M., Vianna Jr., A. S., & Le Roux, G. A. C. (2018). Programming skills in the industry 4.0: Are chemical engineering students able to face new problems? Education for Chemical Engineers, 22, 69–76.
35. Titler, M. G. (2008). The evidence for evidence-based practice implementation. Patient safety and quality: An evidence-based handbook for nurses. Agency for Healthcare Research and Quality (US).
36. Thienen, S. V., Clinton, A., Mahto, M., & Sniderman, B. (2016). Industry 4.0 and the chemicals industry Catalyzing transformation through operations improvement and business growth. Deloitte University Press.
37. Yang, G., Liu, J., Zhao, C., Li, Z., Huang, Y., Yu, H., … Yang, H. (2017). Unmanned Aerial Vehicle Remote Sensing for Field-Based Crop Phenotyping: Current Status and Perspectives. Frontiers in Plant Science, 8, 1111.