Industrial Revolution 4.0 Contribution of chemical engineer

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Abstract— The fourth industrial revolution is (IR 4.0) or in other words 'Smart Industry' that refers to technological evolution from automation of manufacturing processes to customized and flexible mass production technologies**.** Industrial revolution 4.0 is benefits chemical engineering by integrating combination of physical and digital technology into manufacturing chemical industries. By this combination, the productivity of the manufacturing plant can be improved and risks of the process can be reduce which enhance the business operation. In order to integrate "what" into industrial revolution 4.0, chemical engineer is required system thinking which is understand on entire process and system of the chemical plant and make decision accurately, generate idea and troubleshoot the incident happened. Chemical engineers contribute to IR 4.0 by using smart manufacturing techniques to enhance productivity and expand revenue by R&D, smart products or services. In an enzymatic process, the process can be improved by introducing advanced analytic program to predict the optimum utilization of the machine and equipment.

Keywords— industrial revolution 4.0 ; chemical engineering ; contribution in IR 4.0 ; enzymatic hydrolysis

1. Introduction

The fourth industrial revolution (IR 4.0) or in other words 'Smart Industry' that refers to technological evolution from automation of manufacturing processes to customized and flexible mass production technologies (reference). These machines have the ability to operate independently to collect data, analyse it, and advise upon it or cooperates with humans to create a customer oriented production field. IR 4.0 is made of 4 basic components such as Cyber-Physical Systems (CPS), Internet of Things (IoT), Smart Factory, and Internet of Services (IoS). CPS are actually computers and networks that are used to monitor the physical process of manufacturing at a certain process. The -IoT enables the objects and machines such as mobile phones and sensors to communicate with each other to find solutions. Moreover, the IoS simplifies the manufacturing processes through connected devices. On the other hand, the Smart Factory is where CPS communicate over the IoT and assist people and machines in the implementation of their tasks.

Please provide objective of the paper and the information of IR 4.0 to your study.

2. Literature Review

IIa. Needs of IR 4.0 in chemical engineering

By applying IR 4.0, manufacutring data can be collected from the physical world and assembly from digital database which allow operator able analysed and revise. However, a huge amount data will be collected and assembled for a chemical manufacturing plant (Jung, E. 2018), such as ….. Hence, the huge amount of amassed data is converted into actionable information and store inside storage platform which the data is ready to be analysed and shared. By integrating digital technology, it will benefit the next generation which a complete data of the process is shared and able revise easily.

Besides that, IR 4.0 can maximize the machine utilization and minimize the possibility of the equipment breakdown via predictive asset management which analysis of the data collect from the sensor on the critical machine such as reactor and compressor. After the pattern and flow of the readings be analysed, the possibility of the equipment breakdown can be predicted therefore reduce the risks of incident happened during the manufacturing process (Alaloul, W. S, et al 2018). Heating or cooling is required a huge amount of energy to achieved the desired temperature and it will result in high plant cost is required (Zhou, K., etal 2015). By integrating data modelling and plant stimulation, it able to develop an optimum condition operating for a chemical plant with lowest cost by accounting various factor such as plant conditions, environment temperature and fouling problem

IIb. Skill required for chemical engineer in IR 4.

Integrating of IR 4.0 into manufacturing plant is popular in nowadays which IR 4.0 is benefited to manufacturing industries which is able to improving the productivity of the product by using combination of physical and internet technology. On the behave of a chemical engineer, some skills are needed and required to be part of IR 4.0 such as system thinking, data savvines, computer and communication skill and adaptability. System thinking is also know as analytic skill which is process of understanding on overall ecosystem of the chemical plant which is able to make decision accurately, generate ideas and troubleshooting on plant issue (Jung, E. 2018). A chemical plant is combination from various sub-system and each of sub-system may affected other sub-system and it is required valuable insight and perspective across the value chain which to reduce plant costs, plant issue and improving product quality.

Besides that, operator or researcher is required be savvy when collecting data and readings during the process and needed to analysed the assembly data accurately which operator or researcher is required analysed and characteristic the problem and potential risks based on the system or process (Reis & Gins 2017). After analysed the collected data, engineer should be able to identify the problem and generate ideas to resolve the problem. Moreover, engineer is required adept at the digital network and technology skill in order to adpat the revolution of the industries. And also, chemical engineer is able communicate to other discipline on the digital system and internet technology which is easier to understand and able to give instruction clearly. Due to evolving rapidly of the digital technology on the manufacturing industries, chemical engineer or other discipline is required to training continuously and willing to learn the new innovation knowledge which to improve and enhance the personal ability and keep up with the pace of times.

IIc. Contribution of chemical engineer to IR 4.0

Chemical engineers can contribute to IR 4.0 via predictive asset management, process control and production simulations in supply chain. Predictive asset management can be done by chemical executives if smart equipment is installed in chemical industries. Sensors can collect data from critical equipment such as turbines, compressors, extruders and advanced analytics tools that able to identify patterns and predict possible breakdowns. Hence, if smart equipment is installed it will send message about required plant maintenance and breakdowns, performance optimization and enables manufacturers to evolve from scheduled repairs to predictive maintenance (Sniderman et al,2016). For an example, a global chemical company had to face unplanned downtime due to malfunction of extruder for more than 90 times a year. Hence, sensor was installed to collect and analyse the data from extruders as well as maintenance records from other sources to develop a failure-prediction model that creates alerts on the extruder performance which reduced the unplanned downtime and operational expenditures (Thienen et al, 2016). Moreover, another example is chemicals major BASF is currently using connected systems and advanced analytics to collect data for predictive asset and process management to improve operations and increase yield. BASF automated the production of liquid soap at its pilot plant that enables mass customization without human involvement. Once the orders have been placed for customized soaps, the RFIDs tags on the soap containers will send composition and packaging to the equipment on the production line using wireless network connections. On the other hand, process management and control involves collecting structured and unstructured data using sensors from few other sources such as lab, alarms and process equipment. In modern control rooms, data are collected through connected systems and presented to operators digitally which prevents the need of manual reviews and also saves the time and effort of operators. But with Industry 4.0 technologies such as analytics and automated control actions supports prediction, alerts and prescriptive responses which in return enables greater control over batch consistency and quality. Analytic models are used to identify patterns and deviations that arises in chemical process before it occurs hence it reduces production risks. Besides, when process management and control is implemented by chemical engineers, energy efficiency is also improved with help of industry 4.0 technologies. The chemical industries usually have high degree of automation and common standard variables such as temperature, flows, tank levels and pressure are monitored to obtain optimum plant conditions. With use of technologies such as soft or virtual software sensors, the data points can be augmented and the nonstandard process variables are controlled for better energy management (Kaneko and Funatsu, 2014) For an example, one of the leading manufacturer Borealis AG uses data mining and modelling to develop dynamic target values for energy consumption of a plant for factors such as current conditions of plant, outside temperatures, fouling of the systems and aging of the catalyst. (Sniderman et al,2016 ; Thienen et al, 2016).

Furthermore, chemical engineers can contribute to IR 4.0 by aiding revenue growth through development of new products or enhance existing products via research and development or smart products and services. R&D is the critical stage in supply chain because it shapes how the products are manufactured and plays a key role in improvements of the products (Sniderman et al,2016). In the R&D department, advanced analytical tools help the researchers use the available date to comprehend the properties of available materials and produce new materials with desired properties according to specific customers. There are few tools are used in R&D such as addictive manufacturing, advanced analytic to test or develop new products. Addictive manufacturing which is known as 3D printing uses the information from the digital realm to create a physical product, encapsulates the IT/OT transition, and helps the chemical companies to save cost in R&D process. Furthermore, it allows the designer to custom build a reactor according to specific geometrical configurations, reaction kinetics or residence time of chemical reactions. For an example, researchers from University of Glasgow contributed to IR 4.0 by developing 3D printed polypropylene reactor which served as alternative to stainless steel reactor. This plastic reactor performs same as the traditional reactor but managed to reduce operating costs of chemical labs and helps additional experiments that lead to innovation of new chemical compounds (Thienen et al, 2016). A leading manufacturer also contributed to IR 4.0 by developing stretchable and screen printable electronic inks to use in smart clothing. These inks can be used to embed sensors like electrocardiogram to collect data through smartphone applications (Conor, 2014). Whereas, advanced analytics on the other hand helps the chemical companies use digital information to create new physical materials. As an example, researchers at University of Illinois contributed by developing a molecule-synthesis machine that produces new drugs and agricultural chemicals that works by breaking down complex molecules into basic building blocks which later recombined to produce new compounds. Advanced analytics also helps to build databases that store information on available materials, its properties and presents new material combinations with desired properties which leads to advances in material genomics. (Thienen et al, 2016).

Other than that, chemical engineers contribute to IR 4.0 by developing product intelligence and by creating new data services. Usage of advanced technologies like IoT, it allows chemical industries to add intelligence to the existing products and provide better customer services. When technical recommendations are provided through applications or software it helps customer to determine the right choice of chemical products hence this combination of chemical and technology become a smart solution in terms of products and service offerings. As an example, Eastment Chemical company developed online solvent comparison tool and web-based resin calculator for their coating customers that helps them to compare and choose resin and solvent according to the properties. Whereas the resin calculator act as tool that generates resin solubility charts for varieties of resins sold by Eastman and other manufacturers which helps the customers to have an understanding on stoichiometry of resin polymerization in coatings and adhesives application. Moreover, this model also proposes a resin product that meets the required parameters when range of raw materials and resin parameters are entered. Hence, both tools provide formulators together with technical intelligence that helps to develop coatings that serves the needs of performance as well as cost efficiency. Furthermore, chemical companies also have the opportunity to make use of their collaborative knowledge to integrate within their customers' operation. If IR 4.0 connectivity, monitoring and analytics are implemented chemical industries, the companies can have direct visibility and interaction with their customers operations and also provide real time recommendations on optimization of the operations as well as enhance the water treatment facilities. This will directly help the industry to create new revenues. For an example, Ecolab provides water treatment as a service as well as monitoring customers operations and assets with advanced analytics that will recommend reviews on usage of water, reuse and recycle. (Sniderman et al,2016 ; Thienen et al, 2016)

Besides that, chemical engineers contribute to IR 4.0 by working together with organization of chemical companies ensuring that the company builds capabilities based on the solution layers of architecture in tend to achieve business operation and growth. Firstly, it is important to start with the areas where chemical companies have strong foundation. Organizational agility can be used to absorb changes in mature chemical processes, traditional products and supply chain operations where there is good visibility and move on to complex applications. This approach can be practiced and it will perform well because chemical industries have historical data related to mature products and processes that will be helpful to uncover new visions as well as identify new sources for betterment of operation or revenue growth. Secondly, chemical executives should form a cross functional IR 4.0 team to bring together competencies from different departments like R&D, manufacturing and commercial operations for revenue growth. On the other hand, chemical industries can contribute to IR 4.0 by building diverse capabilities in big data infrastructure, management, integration, validation as well as analytics in tend to deploy IR 4.0 applications. For that, chemical industries need to combine with technology vendors, analytics providers and also universities to optimise the operation of business in each layer. Next, one of the contribution of chemical engineers is that working together with organization in managing risk management policies and technologies with their ecosystem partners. This will aid to manage the risk related with retrofitting, assets and scalable automated systems that eliminate human involvement. (Sniderman et al,2016 ; Thienen et al, 2016).

IId. Starch hydrolysis and IR 4.0

Enzymatic hydrolysis is hydrolyse or degrade polysaccharides molecules such as starch or cellulose into monosaccharides or reducing sugar such as glucose by using enzymes (Betiku, E., et al 2013). Enzymes is biological catalyst used to fasten hydrolysis rate on the chemical bond linked inside the starch to form into monosaccharides molecules. By comparing to conventional acid hydrolysis process, enzymatic process is more preferable which is able to produce a high yield of glucose without generating a large number of by-products (Eom, I.-Y., se al 2015). The uses of enzymes in biochemical process is difficult due to the unstable of enzymes and additional separation process is needed to separate the enzymes after the process which will increasing the cost. To resolve this issue, immobilization of enzymes is introduced and there are three types of immobilization process such as covalent bonding or cross-linking, entrapment and physical adsorption (Nunes, et al 2009). An immobilization process of enzymes is attached an enzyme to an inert material which to enhances the enzymes properties and activity, simplify the downstream process.

Due to Malaysia is second leading of oil palm production in the world while it will result a huge amount of the oil palm biomass after replantation of the palm oil tree. Oil palm trunk consisting of a large amount of starch which has potential become raw material for the glucose production by undergo hydrolysis process. By undergo hydrothermal extraction method, starch is able extracted out and dissolved in the water under 100^{o}C for 20 minutes (Eom, I.-Y., se al 2015). After the extraction process, the enzymes are added into the solution under different factor such as different mass of substrate, stirring speed and time which to study the optimum condition for glucose production. As mentioned before, immobilization process is required in order to strengthen the enzymes properties and increase the reusability. Hence, the enzymes are immobilised before added into the starch solution.

This process may perform inconsistently which caused by human error or lack of data information about this experiment. By integrating IR 4.0, it is able improving the process operation manifests by improving the productivity and reducing risk during the process. The productivity and concentration of glucose is able improved by various smart internet technology such as predictive asset management and process control. Enzymatic hydrolysis is long period process which the process is implemented over 24 hours and the equipment may easily breakdown caused by overrun of the machine and equipment. By using predictive asset management such as advanced internet technology and advanced analytics which able to help in optimization of maintenance spend and improving the machine and equipment efficiency by using digital maintenance (Jung, E. 2018). The continuous feed of reading or data from the sensors on the equipment will collected and analysed by advanced analytics program to identify flow and shape of data in order to predict the possibility of the equipment breakdown. This program or tools is able to maintains consistent results and reducing the risks of incident happened. Besides that, the experiment and process is able improving the efficiency by integrating automation process management and control. By using modern technology, data or readings are collected from the sensor and connected to the systems inside the control room which presented digitally to the operator. If the parameter of process such as temperature or residence time is varying during experiment, analytic tools will identify the collected data and help in response to the deviation in order to reduce the production risks and maintain the final glucose concentration (Zhou, K., etal 2015).

3. Conclusion & Recommendations

As a conclusion, IR 4.0 can form a greater physical to digital connection and transform the chemicals industries by promoting strategic growth and operations. Advanced technologies such as the IoT, advanced materials, additive manufacturing, advanced analytics, artificial intelligence, and robotics enable widespread applications in chemical industries. By integrating IR 4.0 in Research Project, it improves the process operation by enhancing the productivity and reducing risk during the process. The productivity and concentration of glucose was optimised by various smart internet technology such as predictive asset management and process control.

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