Implementation of Digital Transformation in Business & Leveraging AI in Product Development and Manufacturing Process

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Abstract- The swift evolution of digital technologies and artificial intelligence (AI) is transforming industries across the globe, as organizations harness these advancements to streamline operations, improve customer interactions, and expedite product development. This research investigates the role of digital transformation in businesses, particularly focusing on the incorporation of AI in product development and manufacturing processes. As companies aim to maintain their competitive edge in a progressively digital marketplace, the integration of AI and other digital solutions presents substantial opportunities for enhancing efficiency, lowering costs, and promoting innovation. This study analyzes the application of AI in critical phases of product development, including design, prototyping, and testing, as well as its contribution to optimizing manufacturing through predictive maintenance, quality assurance, and supply chain management. By showcasing best practices and focusing on a case study for the manufacturing industry for Digitally Transforming Piling/Drilling Rigs, this paper offers essential insights into how organizations can effectively navigate the digital environment and utilize AI to improve their product development and manufacturing processes, ultimately supporting sustained growth and competitiveness.

Indexed Terms- artificial intelligence, digital transformation, drilling, piling, technologies, manufacturing, industry

I. INTRODUCTION

In today's business landscape, digital transformation has become essential for organizations aiming to remain competitive, foster innovation, and adapt to changing customer expectations. The adoption of cutting-edge digital technologies, including Artificial Intelligence (AI), the Internet of Things (IoT), cloud computing, and data analytics, has significantly transformed business operations. Notably, AI-driven advancements in product development and manufacturing processes stand out as some of the most impactful applications of these technologies. By utilizing AI, companies can improve their design processes, optimize production, enhance product quality, and shorten time-to-market, all while ensuring cost-effectiveness and operational excellence. Product development and manufacturing are pivotal sectors where digital transformation can deliver considerable advantages. AI has the potential to transform conventional workflows by automating repetitive tasks, refining decision-making, and facilitating more accurate and adaptable systems. For example, in product development, AI technologies such as machine learning and generative design can expedite the design process, foster innovative solutions, and improve customization. In the manufacturing realm, AI's abilities in predictive maintenance, real-time monitoring, and automated quality control contribute to heightened efficiency, minimized downtime, and a more agile supply chain. While the benefits of digital transformation are significant, implementing these technologies poses considerable challenges. Organizations must navigate the integration of new digital tools with existing legacy systems, address workforce skill gaps, and prioritize data security and privacy. Furthermore, effectively managing change and cultivating a culture of innovation are crucial for successful implementation.

II. ENABLING TECHNOLOGIES OF DIGITAL TRANSFORMATION

Applying digital transformation in the manufacturing industry stays one of the critical indications of the success of Digital Transformation process in the digital technology field.

The research describes different technologies that are utilized in the Digital Transformation process reference to the firm's field (De Carolis et al., 2018).

In this paper, the digital technologies used in the manufacturing firms has been shown in Figure 2.4. These technologies are connected together to gain an effective Digital Transformation (Bai et al., 2020; Osterrieder et al., 2020), and one of the best technologies which triggers Digital Transformation in any firm is the artificial intelligence (Demirkan et al., 2016; Hartley & Sawaya, 2019; Qi & Tao, 2018; Ulas, 2019).
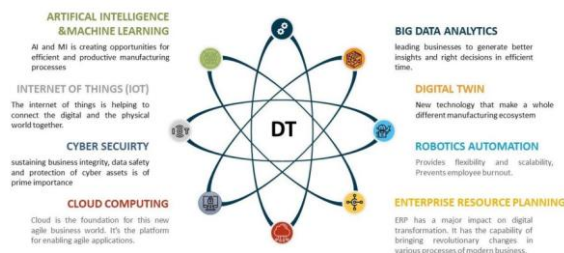

Fig 2.4 Enabling Technologies of Digital Transformation

By Digital Technology and Machine Learning, equipment turns to be more efficient and more effective when operating since they will be knowing the process and the mechanism of a self-learn approach with solving any problem that may arise during the production (Hartley & Sawaya, 2019). In fact, the IoT technology triggers businesses to combine the physical world with the digital world and it assists manufacturing firms to collect more data from machines and equipment which aids a lot in understanding the manufacturing problems and the ways to solve them in an efficient and more productive way in operations (Borangiu et al., 2019; Cachada et al., 2019; CasteloBranco et al., 2019; Gökalp et al., 2017).

Getting closer to the piling/drilling industry where it is the point of focus in this paper as a case study, the following review of literature confirms that enhancing the piling machines and equipping them with the latest technologies and artificial intelligence as well as the sharing of the data through the Internet of Things (IoT) which is a system of physical devices having sensors, software, and network connections which have the ability to gather and exchange data and Digital Twin (IBM, 2024) is a need worldwide which is really leaving its positive impacts and taking the construction industry to a very positive and interesting place which is keeping in enhancement in the coming years and playing a crucial role in the business economy worldwide. (Piling Experts, 2024)

In addition, it discusses the pathways of fully transforming the piling rig machines to autonomous machines adding to the precision in drilling, better productivity and time saving. The call of action was heeded by researchers who started to study the enhancement of piling and drilling machines in the whole world and to test the positive effects they are leaving in the industry.

III. ARTIFICIAL INTELLIGENCE EXPANSION IN THE DRILLING FIELD

Abdo (2023) shed light on the digital revolution entering the industry 4.0, along with the IoT, Machine Learning and Artificial Intelligence that play an important role in the energy industry nowadays. In this study, the concentration is on the drilling field and the possible ways to digitalize the same using computers and IoT communication to add an amazing change and a next level of proper enhanced work and operations that is leaving a visualized positive impact on cost reduction.

Another study confirming the same is what was done by Ahel (2012). It left stamps in the oilfield in which he has designed several electronics for downhole drilling equipment used in the closed loop automation. His oilfield career started in 2012, designing and qualifying electronics on projects for high-shock, high-pressure, and high-temperature downhole drilling tool applications. In his study, he concentrated on the improvements the AI is leaving on drilling that can happen by a lesser input from drillers, so that the machine can do the task given to it. The aim is to educate the machine to do the requirement at its own.

Moreover, AI is functioning as the link between automation and optimization where this study explains how to change the previous mentality by the use of this AI in technology and the often than not, automation and optimization are independently addressed where

AI can help in predictive analysis to protect drilling un proper functions, lessen downhole vibration, control drilling pressure which can lead to save energy. The accuracy of the data resulting from AI can drive accurate analysis of sensor data. Besides, AI will elevate safety levels where a lesser number of people will participate in the process. (Piling Experts, 2024)

Moreover, optimization will occur by lessening the drill pipe wear, automation for drilling decision, measurement during drilling, increase in the ability for managing pressure, enhancement in programs for mud, benefits on casing during drilling, interference in rig operations and elevation in production with a precise target, alongside with reduction in drilling time. He also addressed the fear of the manpower replacement by AI, and confirmed that AI will not affect human force and it is opening forces like accountants who can be engaged in model computations, (Nunoo, 2018)

To do the same and make the idea clearer, Drillmec, a data management system was used, developed and installed being the most important point to the Real Time Operation Center (RTOC) in which the system depends on the IoT that uses machine learning for analyzing the data generated from the sensor data of the rig machines. This system uses IoT technology that applies machine learning to analyse rig sensor data. Going more deeply, the ProRig system plays a vital role in transforming the drilling rigs and their equipment into smart devices integrating energy industry in the digital age. Compared to other data management systems, DMS which is used in Soil Mec Italian Machines, ensures the excellence of the Drill Rig that uses a similar concept. (Soil Mec, 2019)

Digging more in AI applications to the drilling machines, to make the idea clearer the drilling in the oil and gas sector is an important field to discuss as it is always loaded by drilling operations with the use of drilling equipment. In addition, the computational intelligence is a very crucial line which helps the drilling operations. Hence, the below study done by the author from the Center for Petroleum and Minerals and the Research Institute which belongs to the King Fahd University for Petroleum and Minerals that was founded in Dhahran in the Saudi Arabia, along with his experience in computational intelligence discussed the work done that concentrates on the capabilities of two hybrid models as Computational Intelligence tools to predict two important oil and gas reservoir properties, the porosity and the permeability depending on the power of AI techniques which can be related to functional networks in addition to the fuzzy logic system Type 2 along with support vector machines. The hybridization was done in a way that gives permission to one technique to assist in improving the other. (Abdulraheem, 2011).

Hence hybridization is quite necessary, and results showed that the hybrid models will be the pioneer in giving a best practice and AI is not limited to a single approach. This will result in an increased production of more crude oil and hydrocarbons to satisfy world's demand that is increasing gradually. Going deeply through the results, the same show that the hybrid models perform better with a higher level of correlation coefficients when compared with individual techniques if used alone for the same group of data. This work has demonstrated a very successful application of the hybridization of mixed Artificial Intelligence techniques in one of every day's problems that was applied in oil and gas production in which a high quality of data and accurate predictions are requested for better and more efficient exploration (Abdulraheem, 2011). Compared with other studies which relates the drilling machines productivity, this falls in the same concept since it is increasing output.

Digging deeper in AI enhancement and achieving the demand of operating and analyzing parameters through AI instead of using simple sensors while drilling that are spread in common drilling machines, (Mohammed M Al-Rubaii, 2023) showed how much it is important to regulate the formation pressure and prevent kicks while drilling. The same can be done by regulating the equivalent circulation density (ECD), that becomes very important in the presence of elevated pressure and when the temperature in wells rises. In addition, ECD is too much essential in the formation when the pressure of the pore and the fracture are very near, however the already existing ways to measure the ECD is very expensive using the down holes sensors and at the other side it is sensitive to elevated pressures and limits its function in such mediums.

Hence, to be successful and face this obstacle, two novels are used, $ECD_{effc.m}$ and $MW_{effc.m}$ to be able to predict ECD and the mud weight (MW) straight from the parameters of the surface drilling including the standpipe pressure, rate of penetration, drill string rotation, and mud properties. Therefore, by coming up with an artificial neural network (ANN) and a support vector machine (SVM), ECD resulted with a correlation coefficient of 0.9947 and an average percentage error of 0.23%. Moreover, another model is decision tree (DT) and it was performed to get the MW with a correlation coefficient of 0.9353 with an average absolute percentage error of 1.66%. Then a comparison is done for the two approaches with artificial intelligence (AI) techniques and the same are evaluated. The results proved that there was an additional accuracy in both models by the value obtained from the pressure while drilling (PWD) tools.

Hence, a good use of these models in the well design stage and in the drilling phase can happen to do a fair analysis and assessment for the weight of the mud and equal circulation density that can lead to a super saving in terms of cost and money without engaging any expensive downhole equipment and any commercial software (Al Rubai, Al-Shehri, Al Shangabi, Minaev, 2023). This study compared to other AI studies related to drilling reveals that AI is very necessary in our lives to take us to the required desired level of accuracy and cost savings in time, resources, and money.

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