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Implementation of Digital Twin for Three CNC Machines Consisting of Loading and Unloading Operations using a Cobot

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Abstract:- A collaborative robot is something of growing interest for companies in the manufacturing industries to implement. However, a collaborative robot is quite new in today's market. An issue that arises is that no implementation process for collaborative robots exists today, as well as no requirement guide for skills, as well as actors, has been defined.

The aim of this project was to examine how an implementation process of collaborative robots in manufacturing companies could look like. Focusing on charting the integration process steps of a collaborative robot, and identifying the actors as well as skills needed for successful cobot integration, with the aim achieve the goal of this thesis by answering the research questions. The thesis had the following research questions:

Keywords:- *Collaborative Robot, Cobot, Human-Robot Interaction, Human-Robot Collaboration, Development Strategies, Automation, Industry 4.0.*

I. INTRODUCTION

This manual indicates information and message for an operator to verify troubleshoot, learning to operate a cobot and how to overcome the error(s). Here, the JAKA Cobot (Zu12) with its PLC controller will communicate with each other to perform a machine tending process. This manual tells an operator what to do and what not to do. Read every instruction carefully and must check every condition. Be safe by following the safety rules.

This manual has every device information which are used in this application, the information are attached, follow the step by step procedure. In case of error or accident read the trouble shooting chapter that briefs how to solve the problem. An operator must follow the instruction which is given in operation manual chapter. An operator operates the cobot step by step as given in operating sequence chapter. Read this manual to operate the cobot in a proper manner.

II. BACKGROUND

Today, the industry is the part of the economy producing materials and goods, where the production strives to reach a highly mechanized and automated. Since the industrialization, technological developments have resulted in paradigm shifts, so-called "industrial revolutions" (Lasi, et al., 2014). Currently, the industry is boarding a new industrial revolution commonly referred to as Industry 4.0 (Mohamed, 2018; Wang, et al., 2016), and the manufacturing plans of the future have already been envisioned (Mohamed, 2018).

Industry 4.0 promises smart factories involving autonomous production systems where machines, human operators and other resources will be able to communicate with each other and products will be manufactured in a smarter way in the sense of knowing how to be manufactured (Isikli, et al., 2018). In the smart factory, software driven systems will be monitoring the physical processes and duplicate the physical environment by creating a virtual copy. Based on self- organization mechanisms these software-driven systems will make decentralized decisions (Smit, et al., 2016). However, Industry 4.0 does not only focus on separate factories but comprises the integration of production facilities, service systems, and supply chains to achieve value-added networks (Salkin, et al., 2018). Industry 4. 0 has a lot of different driving key factors, one factor is traditional industrial robots that have over the years, gotten further flexible, productive as well as collaborative. Ultimately, these robots will be able to integrate with humans as well as work side by side with them due to the greater abilities from the greater range that will be developed (Othman, 2016)

Traditional industrial robots were presented around 1938 and have since then been commonplace in some of the industrial enterprises (Matthias, et al., 2011). A traditional industrial robot is defined as a reprogrammable, automatically controlled, flexible manipulator that is programmable in three or more axes. The robot can either be fixed or movable, for use in the industrial automation (Bolmsjö, 2006). The traditional industrial robots have since implementation been a major reason for improvements especially when it comes to safety, time and ergonomics. Traditional industrial robots have performed work that is not ergonomic for the operator due to heavy weights etc. In addition, robots have also been used in industrial environments that are classified as unsafe for the human worker (Matthias, et al., 2011). A traditional industrial robot is intended to manage items by assembling, polishing and milling. It is also designed to interact with the current environment around the robot (Garcia, et al., 2007).

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Issac Asimov has created four different laws, that were mentioned in his novel, in order to keep the robot to serve the human. These laws should be followed in order to ensure that the human is in control (Bolmsjö, 2006).

- *Rule number 0:* A robot cannot ever hurt humanity or even allow humanity to get hurt. This law is prioritized compared to the rest of the laws.
- *Rule number 1:* A robot must not harm a human being or fail to help a human being who has been injured.
- *Rule number 2:* A robot must always obey a human being unless it does not clash to the first rule.
- *Rule number 3:* A robot must protect itself from damages unless it does not clash with rule number one or two (Bolmsjö, 2006).

Currently, one of the main focuses of benefit from a traditional industrial robot is providing higher quality, especially regarding welding, milling, drilling, grinding and polishing. The reason is that robots are more precise and capable of working for longer periods, and more tirelessly compared to the operator (Bolmsjö, 2006). The challenges today are the introduction of automation in the industry (Zafarzadeh & Jackson, 2013). The underlying reasons for the challenges are mainly focused on the time-consuming planning of the automatization, difficulties in the visualization and complexity regarding maintenance and interaction between humans and machine (Frohm, 2008). Another common challenge within automation is education, technical feasibility, and qualifications. Education is an important part due to a challenge that is the lack of competence of operators due to the fact that they come from an industry that is not automated (Winroth, et al., 2007). Other challenges are for instance when changing the production process from manual to automated, or vice versa. It is also claimed by a few industries that time is a challenge. When it comes to planning or training the staff, it could require a longer time period. If the staff is untrained, it can generate a decrease in quality, competence, and maintenance work (Zafarzadeh & Jackson, 2013).

An automation strategy model by Granlund and Friedler (2012) has presented and is used for the processes to integrate a traditional industrial robot in a production system. The first step of the project development guideline is planning. Each phase of this automation strategy is focusing on the primary objective of each phase, working methods, deliveries, requirements needed for decision-making as well as templates and tools that might be of use, in time to complete the phase (Granlund & Friedler, 2012). Considering the Industry 4.0 revolution and the increase of competitiveness in today´s business environment (Bayram & Gökhan, 2018; Isikli, et al., 2018), it is important for manufacturing companies to manage technology investments (Isikli, et al., 2018) to establish intelligent and communicative systems (Salkin, et al., 2018). One technology considered important is collaborative robots (cobots). Cobots have the ability to work side by side with human operators and to support the human operator when needed (Gualtieri, et al., 2018).

Until today, traditional industrial robots have been applied to increase production efficiency and to replace human operators in the case of heavy, repetitive and unsafe work tasks (Huber, et al., 2008). The traditional robot requires an isolated robotic cell to avoid physical contact with human operators and is limited to a fixed position with a fixed work task (Gualtieri, et al., 2018). Compared to the traditional robot, a cobot has the ability to work side by side with humans accomplishing common tasks (Wang, et al., 2015) and therefore, presents an interaction between human and robot. This technology also introduces a new concept of workplace design. The human-robot collaborative work cell can be described as a shared and hybrid workspace, where the cobot has to adjust its movements to accommodate the human operator. The communication between cobot and human must be realized in order to fulfill safety requirements (Gualtieri, et al., 2018). Since cobots are new in today's industry and are also the developed version of current traditional industrial robots, some problems do exist. For instance, there is no guide to implementing a cobot, which creates difficulties of how a cobot can be implemented in a company. One reason for this problem is that misperception arises since companies are unaware of what skills are needed which creates uncertainty in the implementation process. These factors create an urgency of developing and inserting a guide for the required skills and actors in the implementation process. Considering that the implementation of cobots is occurring more commonly, this study will try and combat these challenges.

III. SPECIFICATIONS

Machine tending operation on Cobot: JAKA ZU12 with six-axis has a Gripper on the end flange. As there are multiple variants available for the operation and pass the associated signal to the existing PLC. Then the PLC will send the corresponding signal to the robot controller, As Robonetics already programmed the Robot for different variants, based on the signal's received from the controller the robot program will execute and perform the intended action Note: The Cobot proceeds to start the operation when it is in auto mode. During manual Mode, the Machine tending operation can be started manually by start button in the control panel. Robot motor ON, Start, Hold, Continue, reset etc. can be controlled externally in a Remote mode.

➢ *Robot Specifications:*

Make	JAKA
Model	ZU12
Max-Reach Horizontal / vertical	1327 mm
Payload (kg)	12
Repeatability (mm)	±0.03
Mass (kg)	41

Table 1 Robot Specifications

➢ *Controller Specifications*

Model	JAKA ZU12
Power Requirement	100-240VAC
Phase	SINGLE-phase
Frequency	50/60 Hz (±2 %)
W*D*H mm	410x307x235（mm）(WxHxD)

Table 2 Controller Specifications

IV. EXPERIMENTAL WORK

- Input concept changed from Rotary to Horizontal Slider
- POKE YOKE FOR Input variant – Sensors planned at Gripper to detect component reverse/Flipped position loading by an operator.
- Same sensor can be used to identify the component availability in fixture, if not available cobot will skip the actions and move on to next immediate position and the operation will repeat until it find the component.
- Air-blow Provisions provided at gripper
- Spring mechanism provided at gripper.
- Output System changed from rotary to Conveyor
- Under the conveyor brush provisions will be provided to clean the belt.
- Conveyor will be partitioned as two so that combination-1 (OP10-1 & OP20) & combination-1 (OP10-2 & OP10-2) can be separated in conveyor which will helps to identify the component defect from which machines to an operator.
- Buffer for Every machines to identify. – Will be placing the buffer tray during the installation.
- Stand for Final Process such as Oil dipping, Quality checking and Packaging - Will be finalizing the dimensions during the installation.

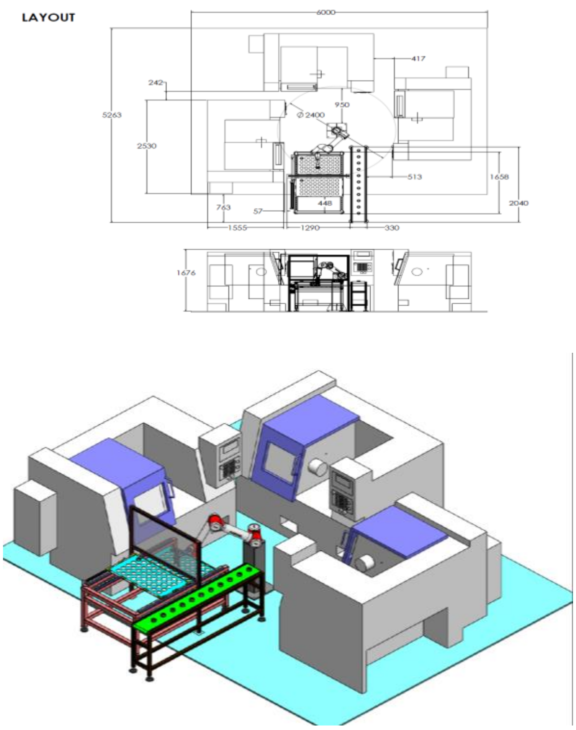

Fig 1 Layout

V. RESULTS AND DISCUSSION

Different steps in the process are presented, and all of the steps are completed by different actors.

The initial contact is performed between the developer as well as the customer, the customer could both be the integrator or the user directly. This is where the first contact between the developer as well as the integrator/ user is done.

The proof of concept is performed by the user to be able to know if it is possible to invest in a cobot or not, it is important to know if a cobot is a right choice to implement. This is all decided regarding what the user is looking for in a robot.

The requirement specification is performed by the user in order to get what is wanted from the production through the implementation of the cobot.

The preliminary study is performed by the integrator. The user states what the requirement needed is necessary for the cobot that is going to be implemented.

The investment analysis is performed by the developer in order to create an assessment of the potential values of implementing in a cobot.

The ergonomics and quality are also performed by the developer, this is where the ensuring of quality, productivity is made as well as the ergonomics.

The risk and safety are performed by the developer is the last step where the involvement of the developer is in this process, the last step of the developers is vital due to the fact that the cobot is tested before being placed in the production. Safety risks are estimated and challenges that could occur in the user's site can be prevented at an early stage.

The build of the workstation is performed by the user, and this is the stage of the building of the cobot depending on where it will be placed, different adjustments might be performed. The station, fixture, gripper as well as the palette is assembled.

The cost analysis is also performed by the integrator, it is important to determinate if the investment is profitable for the users. The cost of the robot is the significant factor in this step questions to ask could be if the tasks can be performed by the cobot be performed by a traditional industrial robot? If yes, would costs be lowered? Is the production line being improved? Is the cobot improving the production line due to the benefits of the cobot.

The programming is performed by the integrators, in this stage, all of the programming of the cobot is completed, the movement of the robot, strength, reach repetition as well as the capability in force. It is important in this step to ensure safety as well as benefit from the cobot to all it has to offer.

The conducting and assembling are the last step performed by the integrators; this is where the cobot is assembled as well as conducted. The robot is mounted, incorporate the finished programmed software is incorporated and the conducting of the gripper is done. The grippers design is depending on the work tasks and needs.

The education of employees is the final and last step of the process itself as well as the user is to educate the employees. The employees need to be prepared to work with a robot that is not fenced, which is something new in the production today, and they will learn how to handle the cobot. The ensuring of the safety of the employees will be achieved as well as the employees learn that the cobot is not implemented to take over the job of the operator, it is here to support the operator.

➢ *Comparison between implementing cobots and traditional industrial equipment*

There are at this point in time very few differences separating the respective implementation processes. However, the ones that do exist are quite pivotal regarding the cobot implementation. The biggest differences are the risk and safety assessment and the education of operators. An example of why the stage of educating employees is both important and quite complex is that the usual approach to industrial robots is to keep away from them since they carry plenty of risk to the human. Since there is usually some sort of safety equipment which puts a distance between robot and operator, it is hard to adjust the mindset of the employees to interact with the cobot in a close manner. To enable building a trust in the employees toward the cobot, they need to know plenty about how it operates and its capabilities.

The second pivotal stage in the implementation process is risk and safety which differs a lot from the traditional equipment. The reason is coherent with the education stage since it involves the safety assessment. Since the cobot works freely without any physical barriers, the safety assessment needs a different approach. There is limited knowledge at the moment about cobots in general which creates more difficulties. What is done in this stage at present might not be the process in the future, because it is fairly new in the industry.

Another factor that separates the two implementation processes is the installation at the customers' enterprise since there is no need for major alterations of the workstation in order to incorporate external safety equipment such as fences or robot cells. Most cobots, when delivered, are programmed to perform the tasks needed and only require a power source to be deployed in production. This could in the long term allow more users to perform the installations themselves, assuming the cobot is the version that is easy to use. This also includes the programming. If the programming could be made simpler, it will, with provided education, allow the user to perform it themselves**.**

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