Collaborative Robots in a Manufacturing Environment

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Abstract - *Collaborative robots, also referred to as cobots, are a new age form of technology, allowing workers and robots to work together in a safe and productive work environment. Between the increased productivity and the support from those on the manufacturing floor, the addition of cobots should be high on the list for manufacturing companies. In this research we hypothesized that human and robot collaboration will increase productivity, and overall morale in the workplace. The research shows that rather than having a fully automated robot, the cobot is able increase performance, and employee appreciation, all while costing less than a fully automated robot.*

Key Words: *cobot, human-robot cooperation, manufacturing, technology, employee.*

1. INTRODUCTION

Today's marketplace is continuously changing the dynamics of manufacturing. The speed of business is accelerating, and competition has increased dramatically. Expectations for the consistency and quality of products have reached unprecedented levels. Labor itself is problematic, less from a cost perspective than from demographics and capability. Employers are finding themselves in need to fill new positions, especially as the older skilled workers retire [1].

With the ever changing, ever evolving manufacturing market, the process of manufacturing must also evolve. The once common high volume, low mix model of manufacturing is rapidly relinquishing to lower volumes and higher mix product. Agility in manufacturing is key when operating in this environment. The future for factories will be small, flexible, and movable. In order to comply with the demands of the modern manufacturing environment, equipment must meet these essential requirements [1]:

- Quick and easy setup
- Flexibility
- Compact and Lightweight
- Low cost
- High reliability
- Fast

In the pursuit of fulfilling these requirements, the evolution in the world of robotics in today's manufacturing automation is extensively increasing. A close cooperation between the worker and an automated system is an emergent strategy to address the challenges stated previously. To achieve a better productivity, the high degree of dexterity and cognitive capabilities of humans, combined with the strength and efficiency of robots are combined [2].

Robotic systems are used in many applications today, such as painting, welding assembly, hazard handling, inspection, and many other applications. These tasks are monotonous and can be in an environment not suited for humans [3]. New human/machine interaction approaches are being developed in the form of collaborative robotic systems, also known as cobots. By using the robot and human in conjunction, the human is able to focus on the decision making aspect, while the robot fills the role of strength, endurance, and precise repetition. The cobots are designed and operated as a tool, aiding in the manufacturing for human workers [4]. The idea of designing a robot that would work directly with a human was born back in 1995 as part of a research project by the General Motors Foundation [5].

When robots were first planned to be introduced to the manufacturing floor, the thought of a fully autonomous system was the general consensus. Although this can be achieved, the cost, setup time, lack of mobility, and other factors make it less appealing than investing in the cobot market. A recent review by Campbell concluded the advantages of traditional robots and cobots, as seen in Table I [6].

2. TRADITIONAL ROBOT

A traditional manufacturing robot is one that does not interact with humans. It is designed and built with automation, production, and efficiency in mind. Traditional robots have been used in hazardous, tough, and dirty working conditions [7]. Originally, manufacturing robots were caged to allow humans to interact with them safely, and parts were fed from outside the cage [1].

Once assembled and programmed the only human interaction with a traditional robot while in motion is that of maintenance and turning the machine on and off. The shielding required for a traditional robot is very different than the shielding required for a collaborative robot. Due to the lack of impact sensors, and possible dangerous motions, traditional robots must be contained in an enclosure. This is to prevent the introduction of a human while the robot is in motion [8]. When cobot detect an impact, it stops immediately. When a traditional robot is in motion and something is in its path, due to the lack of safety sensors, it will try and push through the object that is blocking it [4].

Table I. Traditional vs. Collaborative Robot

	Traditional Industrial Robot	Collaborative Robot (Cobot)
Ability to easily redeploy robot to different processes/tasks		X
Ability to program and set robot up in-house		X
Very high-volume in high-speed production (exceeding 1m/s)	X	
Payload exceeding 16 kg (32 lbs)	X	
Reach exceeding 1300mm (51.2 ins)	X	
Minimal changes to existing production layout		X
Human workers to enter the robot cell to complete their tasks		X
Integration options with other machines and robots	X	X
Low initial cost and payback in under a year		X
Ability to run processes with few or no employees	X	X
Automation of processes or products that won't change over time	X	X
Very quick un boxing and setup		X

Sixty-five percent of traditional robots are installed in the automobile industry, and it takes 200 hours to program and reprogram them [3]. This is a result of the many pieces that need to be individually programmed in order for the robot to function. Major headings are to be column centered in a bold font without underline. They need be numbered. "2. Headings and Footnotes" at the top of this paragraph is a major heading.

3. COLLABORATIVE ROBOT"COBOT"

A comparison of cobots and traditional robots, illustrating the advantages of cobots, is seen in Table II [3]. A collaborative robot, or cobot, is a robot that is designed to be used with human interaction in a shared space [9]. Cobots are now a $100 million segment of the industrial robotics market with continued growth projected at more than 50 percent per year [10]. Cobots have piqued the interest of many corporations from automotive and aerospace OEMs to small and mid-sized businesses [3]. Cobots were designed to be lightweight and easy to use, while also being powerful industrial tools, integrating with existing machinery and other robots through PLCs and programming software [6].

Table 2. Comparison of Standard Characteristics Between Traditional Industrial Robots and Cobots

Traditional Industrial Robot	Collaborative Robot (Cobot)
Fixed Installation	Flexible Location
Periodic, Repetitive Tasks; Infrequent Changes	Frequent Task Changes; Task Infrequently Repeated
On- and Off-Line Programming	Online Instruction, Supported by Offline Methods
Difficult to Teach	Easy to Teach
Rare Direct Interaction with Worker	Frequent Interaction with Worker, Including Force/Precision Assistance
Worker and Robot Separated by Fence	Workspace Sharing with Worker
Cannot Interact Safely with Worker Directly	Can Interact Safely with Worker Directly
Profitable Only with Medium to Large Size Lots	Profitable at All Lot Sizes (Including Small)
Small or Large Size, Fast	Small Size, Slow as Needed
Cannot Reduce Cost and Footprint to Justify New Applications	Can Reduce Cost and Footprint to Justify New Applications
No Risk Assessment if Properly Enclosures	Requested Risk Assessment
Usually 6 Axes, Last 3 Intersecting in Wrist	Usually 6 or 7 Axes, Many Offsets

The human worker should be part of the production process when required, but by working with the cobot, they can concentrate on other tasks to improve the overall system performance [2].

Due to the novelty of this technology, operational efficiency is usually measured considering different aspects when compared to traditional robots. Other adoption criteria can be difficult to measure monetarily. Assisting the employee with physical and mental workloads, improved quality, and improved flexibility. Even without having the exact monetary benefits documented, these are considered important reasons to adopt this technology [2].

The cobots, when linked together, are able to detect their physical relationship between the other robots. This ensures that the robots do not collide with each other, which could result in damage of the parts being handled [11]. Cobots, specifically those produced by Universal Robots, can communicate with each other via a TCP/IP socket connection on each other's dashboard servers. This essentially plays and pauses each other as needed, letting the other know when it is safe to move. TCP/IP is popular because the connection is via Ethernet. An industry standard, MODBUS protocol, can also be used by itself for robot-to-robot communication [12].

3.1 Cost

When searching automation options, cobots are hard to ignore. Since the introduction of cobots nearly a decade ago, the accessibility and affordability of cobots, for many companies, is an attainable concept [6].

A popular cobot used in manufacturing is the Universal Robots UR5e. Universal Robots has five models of robots, each with varying payload, reach, footprint, and weight. The UR5e is sold for around $35K USD. It has a payload of 11 lbs and a reach of 33.5 ins. With the UR5e, Universal Robots includes a teach pendant where all the programming can be done. Accessories will need to be purchased in addition, and can be purchased from Universal Robots [13].

The average employee on the manufacturing floor makes ~$18/hr. We all know that wage is not a direct representation of how much it costs the company to employ someone. A good rule of thumb is to add 30% to the wage of an employee. This percentage covers tax, healthcare, vacation time, and other benefits that are available to an employee [9].

Table III compares the cost over one year of both purchasing cobot, and having a human employed. Table IV breaks down the cost of having a human ran station at a business that has three shifts per day. Table V uses the data that was calculated in Table III and in Table IV to create a chart representing the possible net gain if a company were to use cobot, instead of a human, to run a station.

Table III. Comparison between Cost of Cobot and Human [9]

	Cobot	**Human**
Initial Cost	$35K	0
Salary (40hr/week)	0	$37K
Additional costs (Hardware and services/ 30%)	$10K	$11K
Total (Overall/Yearly)	$45K	$48K

Table IV. Current Situation: Cost to Run a Station [14]

Labor Costs (per hour)	$18
Hours (per shift)	8
Shifts (per day)	3
Days operating (per week)	5
Weeks Operating (per year)	50
Operators (per shift)	1
Yearly Running Costs	$108K
Monthly Running Costs	$9K

Table V. Net Gain [14]

Break Even (months)	5
1 Year Savings	$ 63,000
1 Year Savings	$ 171,000
1 Year Savings	$ 279,000
1 Year Savings	$ 487,000

The cobot is the ideal employee. It does not come in late, take vacations or sick days, nor does it have slow days. Utilizing a cobot is like employing a highly skilled laborer for only $0.75/hr that can work 24 hours a day, 7 days a week, for 52 weeks a year, without needing breaks [15].

3.2 Customization

An appealing attribute of cobots is the flexibility and customization that can be achieved with numerous attachments. Cobots are capable of, but not limited to, the following tasks:

- Screw driving
- Painting
- Sanding/Polishing
- CNC
- Welding
- Part Transfer

Not only are cobots customizable due to the many physical additions available, but they can also be mounted in various orientations. Depending on the application it may be necessary for the cobot to be mounted to a wall or an overhead structure. By having a small footprint and compact configuration, this can easily be achieved [11]. If a cobot is needed in another area on the manufacturing floor, it is done so without disturbing workflow. Reprogramming and reconfiguration is easily achieved with clear interfaces and easily configurable add-ons [8].

With the move-to-learn function, changing the size of a part does not require a complete reprogram of the cobot, but a modification to the logic.

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4. EMPLOYEE APPRECIATION

The transition to incorporating cobots on the manufacturing floor can be intimidating to employees initially. To ensure the employees do not feel threatened, it is vital to ensure proper training and information is given. Taking into consideration the feedback given by the employees that are working directly with the cobot is essential. Design and testing should not be, nor was it meant to be, the end of the road for the engineer and robot. To create a better collaborative experience, and ensure efficiency, modifications to the cobot may need to be made [11].

"If you put a robot in front of an employee, tell them it will be better, and that they just need to trust you, you will not get a positive response. It would be like telling someone that they need to get rid of their car, and drive a tractor trailer to work every day, simply because it is what the company wants them to do. They will be resistant, and potentially not want to work there anymore [11]."

People do not like large changes in their work environment. With the stigma of robots taking over blue-collar jobs, presenting these cobots must be done in an interactive and in a non-threatening way. By doing this, employees will not dread, but embrace the motion of a cobot in their area [4].

Working with multiple size parts with the same cobot is the norm, as manufacturing companies are adapting to today's market. Employees are taught how to align and set the robot when part changes are made. This allows the employees to learn a portion of the software that is used to program the cobot. By allowing the employees that work with the cobot to do this, it keeps the human in control [2].

5. JOB SECURITY

A myth that is associated with cobots is that by implementing them into the manufacturing environment, cobots result in people getting fired. This is a myth that has gained a lot of traction with the population that does not fully understand the purpose of cobot. Before the impact Covid-19 had on the economy, the U.S. unemployment rate was sitting at 3.5 percent. This is the lowest unemployment rate since 1968. With thousands of baby boomer retiring every day, and few millennial interested in joining the manufacturing industry, cobots are not put in place to replace workers, instead they staff the repetitive tasks that companies cannot fill. With cobots, manufactures can reduce the number of human workers needed for repetitive or injury-prone tasks, and transfer them into higher-value jobs [6]. With the addition of cobots in a manufacturing environment, companies are able to hire more local people, and gain contracts with buyers by undercutting overseas competitors [3].

An interviewed industry leader stated, "We are having a hard time finding people willing to work. With the incorporation of cobots on the manufacturing floor we are able to relieve employees of the less complicated jobs and assign them to other tasks"[9]. Robots seem to threaten employment in the short term but will create many new jobs in the long term. This transformation will lead to a situation where the manufacturing industry will need fewer low-skilled workers performing mostly manual tasks, and will require a higher demand for workers with skills related to robot interaction [5].

6. RISK PREVENTION

During the risk analysis process, it is essential to carefully consider the zones for a human-operator and robot in the robotic workplace so that all risks for humans are eliminated. At the same time, it is important to ensure ergonomic requirements regarding the placement of control panels, safety barriers and locking systems. Robots significantly improve the overall ergonomics of workplaces as well as avoid strenuous and repetitive work operations. Substituting robots in hazardous operations and reducing stress from work with heavy loads reduces the emergence of occupational illnesses, accidents, and injuries [5].

In collaborative work, unwanted contact with the human and robot may occur not only during the production tasks, but also during set up, maintenance, and cleaning. The priority is the safety of the employee, while also avoiding interference in the cobots work [2].

In every automated application where humans are present, risk assessment is required. Once the assessment is complete; a collaborative application may still require safety mechanisms [6]:

- Safety mats
- Reduced robot speed
- Plexiglas shielding
- Informational lights

Although the cobots have impact sensors to tell the robot to come to an immediate halt, there is always a situation where simply having the sensors is not enough. To ensure there is not accidental contact with an employee that could result in an injury, small, but sufficient safety measures should be put in place as a precautionary measure [8].

7. CONCLUSIONS

Unlike many human workers, manufacturing cobots are content to do the same job over and over, for days and years on end. In addition, robots do the job the same way every time, aiding manufacturers increase production output, and improve product quality and consistency [14]. Robots are missing a requirement that humans are able to do without much effort, and that is having a creative approach. Robots lack the imagination and ability to invent new and better practices. Therefore, it is advisable to look at the cobot as a co-worker who can minimize the risk of work-related injuries [5].

With the ever-evolving manufacturing environment, it is safe to say that the world of robotics is at the beginning of its life. With cobots being introduced into manufacturing, opportunities will rise, as well as the companies utilizing the technology. Manufacturing jobs and opportunities are opening for operators and engineers.

Rather than humans and robots working separately, cobots have allowed a safe and efficient cohabitation in manufacturing companies. The reasonable cost of cobots, combined with the connectivity and customization for countless applications, enables exponential growth of manufacturing in the U.S. and many countries.

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