

Review on Collaborative Robot in Welding Application

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ABSTRACT: Welding is a manufacturing process in which two pieces of metal are joined usually by heating and fusing. Traditional manual welding is now replaced by robotic welding in industry. Robot to robot cooperation used in industrial production is discussed. As two or more than two robots cooperate with each other, the same way collaboration between a robot and the human called the Human Robot Collaboration is explained in this paper. A collaborative robot, also known as a cobot, in its most basic definition is a robot which can safely work directly alongside human workers to complete a task. The rapid evolution of collaborative robots is bringing advanced automated solutions to welding production lines. The cobot industry has previously only been involved with material handling and other basic tasks on the assembly line; it has yet to be introduced into the welding world...until now. Collaborative robots in welding applications can be the ones to complete the dangerous, repetitive tasks; without any fear of working right alongside human workers. Robotic manufacturers such as ABB, Universal Robots, KUKA, FANUC, and Motoman, continue to create brilliant, responsive robots within the collaborative market. The purpose of this paper is to provide a comprehensive literature review on current status and development of Use of Collaborative Robot in Industrial Welding. Specific attention is given to programming time required for the welding operation.

I. INTRODUCTION

Welding is a manufacturing process in which two pieces of metal are joined usually by heating and fusing. Welding forms an essential part of advanced manufacturing and robotic welding is the main symbol of present welding technology.[1] Technical innovations in robotic welding have facilitated manual welding processes in severe working conditions with enormous heat and fumes to be replaced with robotic welding. Robotic welding is most productive when completing high-volume, repetitive welding tasks. The robotic welding has greater capability to control robot motion, welding parameters and enhanced wrong detection and wrong correction. The most common forms of robotic welding are Arc welding, Spot welding, Laser welding, MIG welding, TIG welding, Plasma welding. These forms of welding are most commonly deployed across the industrial sector for various applications. Robot to robot cooperation is most widely seen in automobile industry in which the robot is totally safeguarded with fences and controlled from the computer outside the safeguard. To make these robots more user friendly, robot manufactures came with concept of Collaborative Robot. Collaboration between human and robotic workers is gaining traction in manufacturing. [2] Both humans and robots have some advantages regarding the specific tasks they can accomplish.

Collaborative Arc Welding Robot is first type of such welding robot which is working alongside human. Current Industrial manufactures of Collaborative Welding Robot like KUKA, UNIVERSAL ROBOTS, ABB, etc. are developing these Cobots to another level. As robotic welding is programmed based and to make it work precisely with safety, the programmed is to be properly installed and it will take some time. So, a case study of comparison of programming and working times for the three considered scenarios: fully automated, collaborative and fully manual operation was done.

Industrial Robotic welding is done by taking care of human safety. Robot is 360 degree safeguarded with fences and monitored with lot of sensors and controllers. Organizations like ISO, IRF, VDMA have set different standards of safety. In case of collaborative robot or Human Robot collaboration (HRC), safety is major concern as there are no safeguards or fences. Safety Regulations and Safety Standards are set by ISO specially for collaborative robots used in any application.

II. ROBOT TO ROBOT COOPERATION IN INDUSTRIAL PRODUCTION

We are convinced that co-operating robotics is one of the core technologies meeting the demand for diversity and short life cycles in industrial production. Expensive, single-purpose transport equipment is removed from the shop floor and replaced by standard robots. Figure 1. shows the principle of a flexible cooperating robot work cell. An incoming part

is taken by a robot. The second robot can execute the process during the transport phase while, at the same time, the transport robot may maximize dexterity. A third robot takes the part from the first robot and supplies it as a transport robot to another production process. The cooperating robot approach offers:

- Maximum flexibility w.r.t. part volume, capacity and type of parts processed.
- Cycle time optimised production flow.
- Increased availability through collision avoidance.

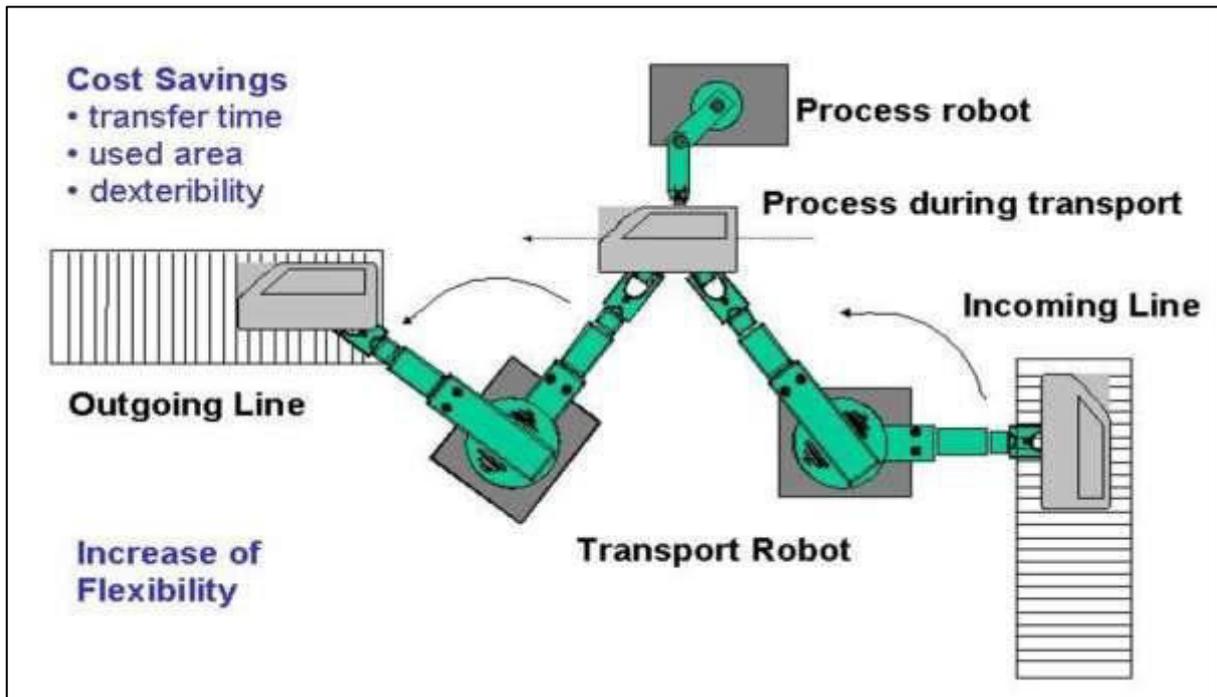


Figure 1: Cooperating Robots in production line [5]

A cooperating robot group is controlled by several standard controllers exchanging the following signals:

- Motion data
- Synchronization signals (clock synchronization)
- Safety signals

Cooperating Robots applications imply the following main features:

- A. **Workspace Sharing:** Workspace Sharing consists of defining critical sections of the application program that are logically common on all relevant controllers.
- B. **Motion Synchronization:** The motion synchronization feature allows multiple machines in the cell to begin and end a motion command at the same time. This requires that all involved programs wait until having arrived at their respective motion statements. The synchronized motion time will be limited by the slowest motion, such that no robot exceeds its programmed speed. Because clock synchronization is used between controllers, such motion synchronization can be carried out with very good precision.
- C. **Program Synchronization** This feature allows setting synchronization points in programs running on different robots. Their effect is that all robot programs wait at these synchronization points until all other

programs have reached this point as well. This is a necessary prerequisite for performing linked and time-synchronized motions.

- D. **Linked Motion** Linking is what enables multiple machines to handle a part simultaneously in a geometrically coordinated fashion. Linking occurs when one machine is programmed to move its tool to a position that is relative to a frame of reference on another machine. For two machines to share a load, one “dependent” machine would be stationary with for the frame of reference defined by the other “independent” machine. For “process relative” motions, one dependent machine carries out a process relative to the other independent machine.

Robots cooperating each other is most commonly seen in automobile industry. But some operations require the intervention of humans so in order to make robot more user-friendly industries are developing and manufacturing collaborative robots for different applications. This intervention of human or cooperation of human with robot is called collaboration.

III. COLLABORATION

As per defined by ISO 10218,

Collaborative operation (Part 1, 3.4) – the state in which purposely designed robots work in direct cooperation with a human within a defined collaborative workspace.

Collaborative workspace (Part 1, 3.5) – workspace within the safeguarded space where the robot and human can perform tasks simultaneously during production operation. [6]

Figure 3. gives clear idea about collaborative workspace and operating workspace.

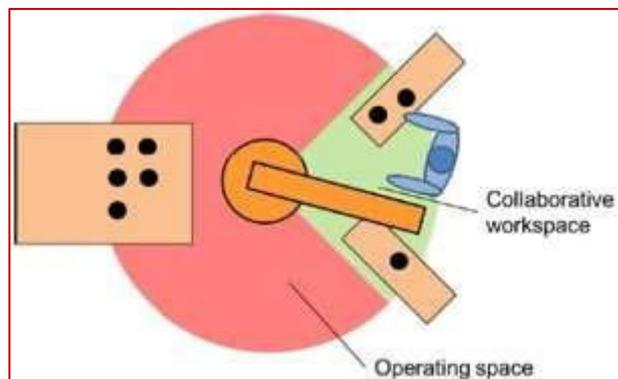


Figure 2: Example of Collaborative Workspace. [6]

The definition of collaboration is *the action of working with someone to produce or create something*. Which is the exact purpose of collaborative robots? However, the misunderstanding is not about the purpose of use of the robot, but its functionality or more precisely how it works. There are various types of collaborative robots and that only, uniquely, one type of collaborative robot can be used without any additional safety features

IV. TYPES OF HUMAN-INDUSTRIAL ROBOT COLLABORATION

Human-Robot co-operation is achieved when a human and robot share the same workspace or interact directly. According to IFR (International Federation of Robotics), the most common collaborative robot applications are shared workspace applications where robot and operator work alongside each other, completing tasks sequentially. Often, the robot performs tasks that are either tedious or unergonomic – from lifting heavy parts to performing repetitive tasks such as tightening screws. Applications in which the robot responds in real-time to the motion of an operator, for example, altering the angle of the gripper to match the angle at which a worker presents apart, are the most technically

challenging. Figure 3. shows types of collaboration with industrial robots. Since the robot needs to adjust to the motion of the operator, its movements are not completely predictable and therefore the end-user must be sure that the full parameters of its potential scope of motion meet safety requirements. Examples of responsive collaboration in industrial settings are unlikely to appear soon in most manufacturing sectors, which rely on precision and repeatability to achieve productivity gain.

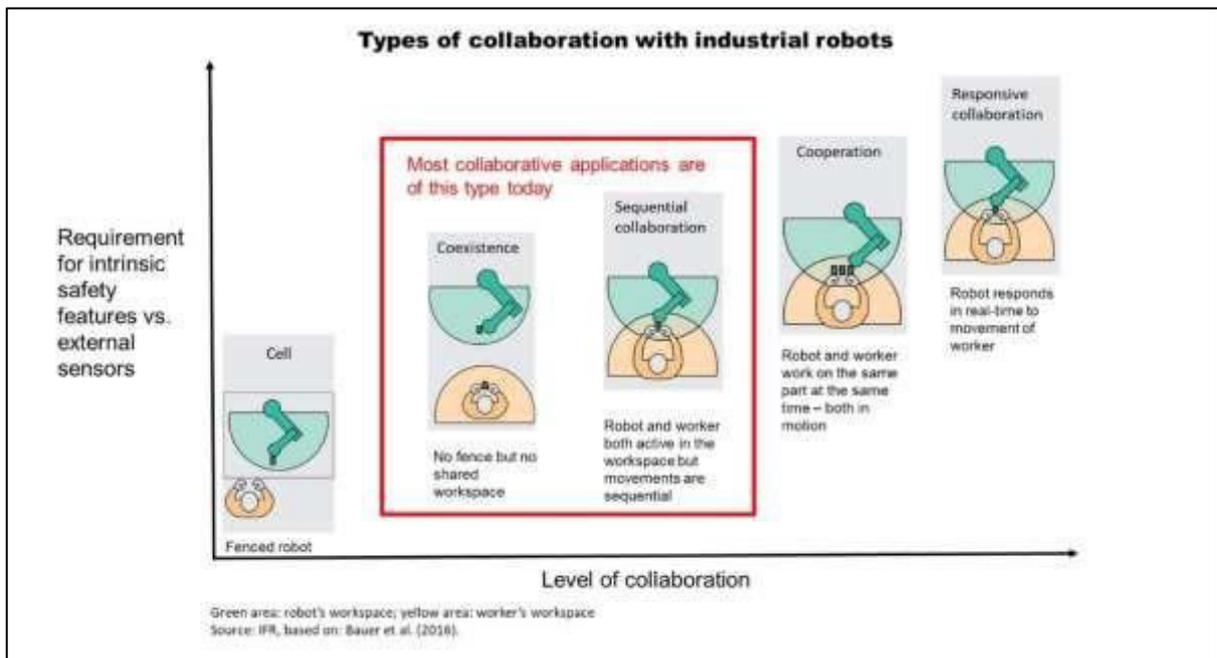


Figure 3: Types of Human-Industrial Robot Collaboration [7]

With collaborative robots, manufacturing companies will see:

- An increased rate in their production rate
- No errors that are otherwise seen in their human counterparts
- An improved work quality with high-level uniformity, and a reduction in wastage.

V. INDUSTRIAL MANUFACTURES OF COLLABORATIVE

Different manufactures of Collaborative Welding Robot are as follows:-

- Universal Robots
- Fanuc
- Kawasaki Robotics
- Yaskawa
- ABB

- Scott Automation
- KUKA

VI. COLLABORATIVE ARC WELDING ROBOT

Collaborative Robotic Arc Welding uses a consumable wire electrode (i.e., in MIG welding) with an automatic wire feeder, welding with non-consumable tungsten electrodes with shielding gas (i.e., in TIG welding) is also in use. In Arc Welding, the robot uses the welding gun as a tool. Consumable electrode, which provides the filler material, is in the form of a wire (coiled on a drum) of the same composition as the material to be welded. The wire is automatically fed by a motor with the adjustable speed at a present rate that is determined by the arc voltage. The wire feed increases with an increase in the voltage applied between the work and the electrode. This voltage can be monitored and used to maintain a constant arc length by varying the speed of the motor which feeds the wire. To keep the electrode cooler and permit higher currents to be used, the shielding gas flows in a tube along the electrode. The tube is terminated in a nozzle at the end of the gun from which the gas flows into the arc region. Welding robotic systems sometimes use water-cooler guns.



Figure 5: FANUC ARC Mate 100iD Arc Welding Robot

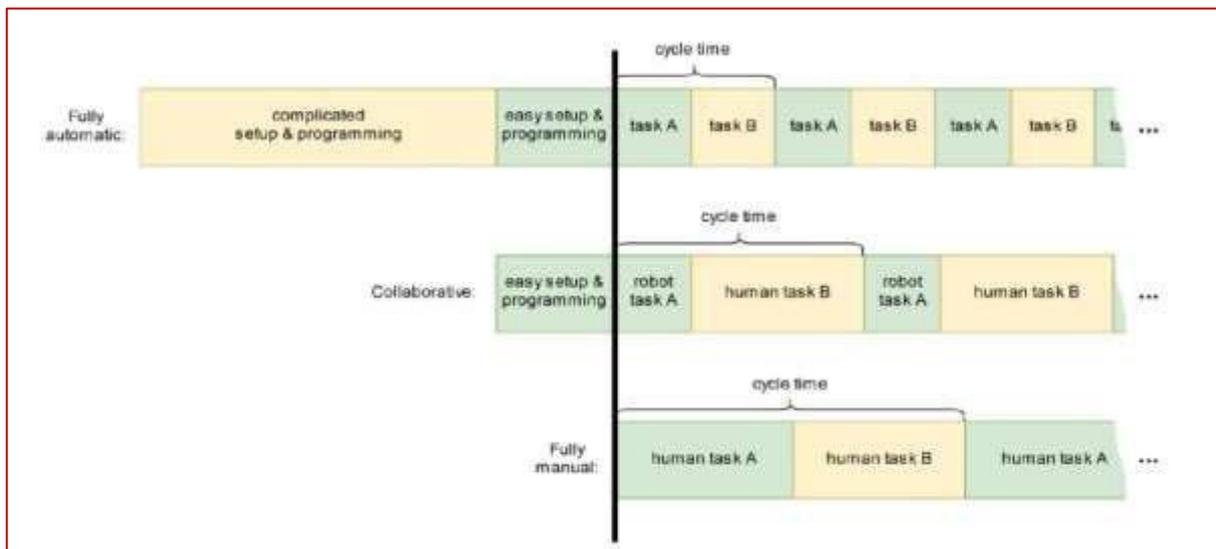
VII. COLLABORATIVE MIG WELDING ROBOT

The Collaborative Robot Welding developed by **ARC Specialties Inc. and Universal Robots** is a cobot-assisted, interactive welding system that can be deployed easily and flexibly in existing, manual welding booths, eliminating the need for costly new robotic cells. The welding system integrated with the UR robot is comprised of a Profax wire feeder and water-cooled torch enabling welds up to 600 amps, with torch bracket, all cables and hose packages included. The simplified programming is enabled through direct software integration into Universal Robots own programming environment through the, that will allow users to program advanced settings directly on the teach pendant that comes with the UR robot. Settings include features such as wire feed speed and burn back time, gas flow time, and crater fill time with instant feedback on welding volts and amps. [10]

VIII. CASE STUDY OF ROBOT PROGRAMMING TIME

Both humans and robots have some advantages regarding the specific tasks they can accomplish. While robots are superior at repetitive and simple tasks, humans are better suited for variable and complex operations, which are hard to be programmed in advance. Taking advantage of both factors employing human robot collaboration may reduce the total production time even in small batch production. We divided all manufacturing tasks into two kinds: the tasks which are easy to program and the ones whose programming is complicated. The time of programming is approximately proportional to the number of key points of the robot trajectory that must be recorded, thus the programming time of the easily programmable tasks is much shorter than the time required for complicated tasks. In

the same time, the complexity of the programming does not reflect the complexity of the manual execution. Sometimes, for humans, executing tasks that are easy to program can be difficult, while executing tasks that are complicated programmable can be easier (e.g., for a human worker it is more difficult to perform welding along a straight line than along a curved line). By considering these considerations, it is possible to find an optimal assignment of tasks to robotic and human workers. Let's consider three different scenarios of process execution: (i) fully automatic, where all tasks are entirely executed by a robot, (ii) fully manual, where all tasks are executed by a human worker, and (iii) collaborative, where some tasks are executed by a robot and some task by a human. Figure 8. graphically shows the differences between programming time and execution times for the three scenarios. In the fully automatic scenario, both easily programmable tasks (A) and complicated programming tasks (B) are executed by a robot. On the one hand, this implies a long programming time required before the batch execution can begin. On the other hand, we may expect that task execution times are as short as possible, so the cycle time is minimized. Fully automated execution also allows eliminating non-value adding operations, which are unavoidable in manual production. This scenario is the most efficient for large batch sizes, where the programming time is negligible for the batch execution time.



• *Figure 8: Comparison of programming and working times [7]*

In the fully manual scenario, no programming is required, but the cycle time is higher than for the robot. Thus, in small batch production, this scenario can be more efficient, because there is no time spent up-front. The collaborative scenario exploits the paradigm of assigning easily programmable tasks to the robot and the other tasks to the human operator. In this way, the programming time is noticeably reduced for the fully automated scenario. While the cycle time is increased for the fully automatic procedure, it should still be shorter than in the fully manual scenario. This scenario is the most efficient for intermediate batch sizes, depending on the programming and cycle time. In this discussion, we have implicitly assumed that the setup and programming times are dominated by programming. However, even in scenarios where setup time is not negligible, setup tends to be more complex for fully automated tasks because it may require designing and producing auxiliary equipment and developing new automation procedures. For the sake of simplicity, the analysis is focused on the case where the programming time dominates, and the setup is trivial.

IX. FUTURE DEVELOPMENTS

The market for collaborative robots is still in its infancy. Manufacturing companies and customers are still gaining experience in what works and don't in the design and implementation of collaborative applications. Technology developments in sensors and grippers hold promise for expanding the range of actions that the robot end-effector can perform. Programming interfaces will continue to become more intuitive, not just for Cobots, but also for traditional industrial robots.



X. CONCLUSION

Collaborative robotics is a paradigm shift where previously we separated the robot system from people, it allows more interaction & sometimes contact between the robot system and people. However, more research and improvements in programming and safety controls will make the collaborative robots more reliable, safe for use in applications like Welding.

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