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Designing Arc Welding Application Using Yaskawa Robot

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Abstract - Welding is the process of joining two pieces of metal using heat and pressure, it is necessary for manufacturing. Arc welding is a welding process that is used to join metal to metal by using electricity to create enough heat to melt metal, and the melted metals when cool result in a binding of the metals. The process of welding put humans in hazardous environments of extreme heat and toxic fumes. Instead of manpower, robotic welders are used in hazardous environment to avoid from fumes and extreme heat. it creates high-quality, precise welds, and they boost productivity on an assembly line. These robots save manufacturers money in production in labour costs because of their speed, ability to work without breaks, and their ability to reduce errors and increase safety. YASKAWA Electric Corporation, Japan is one of the leading manufacturer of industrial robots. Their Motoman robots are heavy duty industrial robots used in welding, packaging, assembly, coating, cutting, material handling and general automation. Simulation modeling solves real-world problems safely and efficiently. In this project we use MotoSim EG-VRC (Motoman Simulator Enhanced Graphics – Virtual Robot Control) software to develop an Arc welding application. The language used in this software is INFORM III.The environment required to run MotoSim EG software is, OS must be windows 7 or above with .NET framework 3.5.

INTRODUCTION

An industrial robot is an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. The field of industrial robotics may be more practically defined as the study, design and use of robot systems for manufacturing (a top-level definition relying on the prior definition of robot).

Typical applications of industrial robots include welding, painting, ironing, assembly, pick and place, palletizing, product inspection, and testing, all accomplished with high endurance, speed, and precision. The most commonly used robot configurations for industrial automation, include articulated robots, SCARA robots and gantry robots. In the context of general robotics, most types of industrial robots would fall into the category of robot arms.

CLASSIFICATION OF ROBOTS

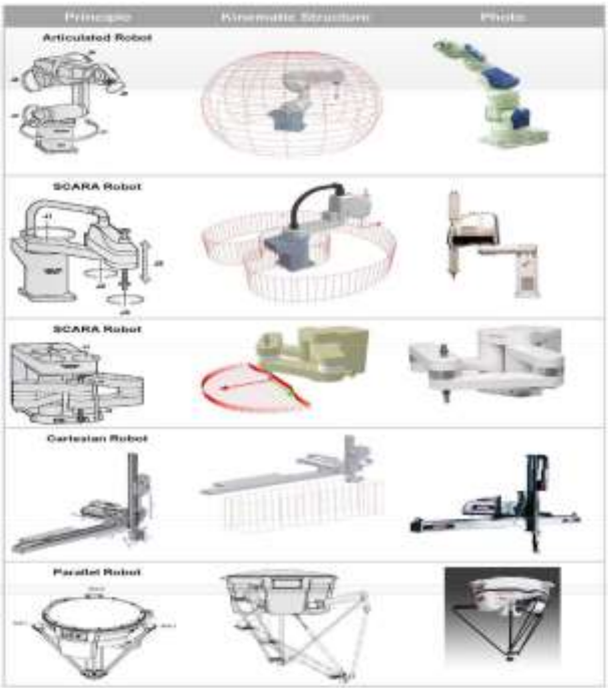


Fig 1. Classification of industrial robots by mechanical structure

I. Welding

Welding, technique used for joining metallic parts usually through the application of heat. This technique was discovered during efforts to manipulate iron into useful shapes. Welded blades were developed in the 1st millennium CE, the most famous being those produced by Arab armourers at Damascus, Syria. The welding technique—which involved interlayering relatively soft and tough iron with high-carbon material, followed by hammer forging—produced a strong, tough blade.

ROBOTICS IN WELDING

I. Examples of welding robots

In this section, a few examples of current welding robots are provided.

KUKA**:** Their versatility and flexibility make the KUKA KR 6-2 and KR 16-2 our most popular robots. These masterful movers have a payload of 6 or 16 kg and, thanks to their design, are ideal for all space-saving, cost-effective system concepts. That's why they are used virtually everywhere – both in the automotive components industry and in non-automotive sectors. With minimized disruptive contours and a streamlined robot wrist design, these high- precision multi-talents offer outstanding accessibility, even in confined spaces. For cleanroom requirements or environments with a high degree of fouling and high temperatures, the KR 16-2 is also available in the special variants Cleanroom (CR) and Foundry (F) .

FANUC: The FANUC F-200iB is a six degrees of freedom servo-driven parallel link robot designed for use in a variety of manufacturing and automotive assembly processes. The F- 200iB is engineered for applications requiring extreme rigidity and exceptional repeatability in a compact, powerful package.

Panasonic: Panasonic Perform Arc C Series are dedicated customized robot systems, made 100% on customer request. Some of the important features of these robots can be summarized as follows.

- High quality welding with high production rate
- Torsion-free design for easy transportation with no programming correction, and for program exchanges between the robots for production expansion
- All from one solutions reduce interfaces from different supplies and increase productivity.


Fig 2 (a) KUKA KR 6-2 robot and (b) FANUC F-200iB robot

Fig 3 Panasonic Perform Arc robot

MOTOMAN**:** Motoman is extending the success of its arc welding robotic arms with the introduction of the first 7-axis arc welding robot. The flexibility of the VA1400 model can be used to reduce floor space and achieve higher robot density for increased production. The unique "elbow" axis of the arm also allows the robot to reach around tall parts or reach into boxy parts.

CLOOS**:** Due to the modular product design, the new generation of CLOOS QIROX welding robots (Figure 5) can be optionally equipped with a seventh axis. The off-set axis mounted in the robot base permits horizontal movement of the robot up to 550 mm. The welding of complex work pieces is simplified and accelerated thanks to the considerably increased range. The setting and positioning efforts are considerably reduced because, thanks to the eccentric movement, the welding head can be much easier moved around corners or into niches, for example.

Daihen**:**The Daihen FD-V6 is suitable for virtually all MIG, MAG, CO2, and TIG welding applications, and Air Plasma Cutting applications. The FD-V6 may be used for common

materials such as mild steel, stainless steel, aluminum, titanium, as well as other exotic metals.

Fig 4 (a) MOTOMAN VA1400 robotic arm (b) CLOOS QIROX welding robots a n d (c) The Daihen FD-V6 robot

ROBOTICS IN DIFFERENT WELDING TECHNIQUES

I. *Spot welding*

Spot welding is widely used among the automotive industries as the efficient joining of metal sheets. Classify under te resistance welding, spot welding acts by generating heats with use of a high current, approximately about 1000A – 100,000 A. The welding guns are the main part of the welding. It comes with 2 different kinds but the important is these guns do similar function as to make a close loop circuit, connecting the power supply to the weld spot.

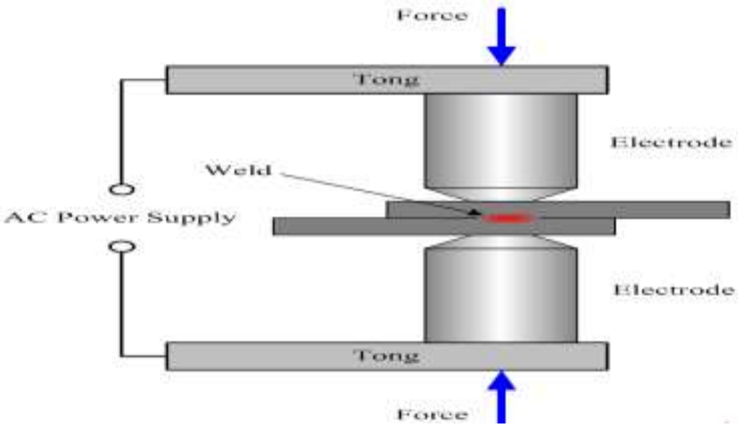


Fig 5 Process of spot welding

The commonly used equipment in spot welding can be divided into two main categories; welding equipment and robotize equipment. The main equipment in robotic spot welding is the spot- w e l d i n g robot in order to have the spot welding to be automated. This robot is available in various sizes which is classify according to how much is the maximum load the robot can manipulate, how far the robot can reach for welding and number of axes can the robot to work on. The welding gun is attached to the end effector of the robot. It is designed to fit the assembly process which come in 2 types; C-type, which is to be the cheaper than X-type. These guns are operated by means of pneumatic actuator which is provide uniform electrode force and hydraulic actuation which is often used when high pressure is needed at a small or limited space (Figure 7). However, technology allows people to discover better solution for problems. A new servo gun was invented which adopt servo motor to operate the gun. This gun has more accurate electrode force control compared to pneumatic gun.

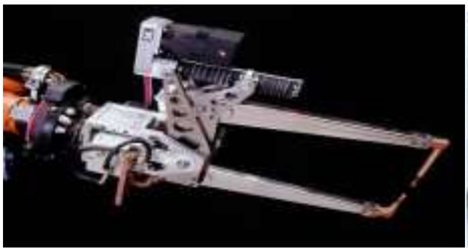


Fig 6 C-type welding gun

Fig 7 Tip dresser

Basically, welding gun applies appropriate pressure and current at the welding spot. This means the gun will be exposed to heat and pressure that will cause deformation of the welding electrodes. Automatic tip dresser is used to sharpen the electrode . This is due to soft electrode material, high welding current and pressure. The dressing is done after each working cycle which takes about 1 to 2 second. But to maintain the good contact surface of the electrode is important yet it is defined how good the quality of the welding is. In addition, maintaining proper electrode geometry can reduce the production downtime and utility cost. One main problem encountered during the welding process usually is the cables and hoses which are tend to cause limitation of robot movement. Swivel is used to provide compressed air, cooling water, current and signal within single rotating unit.

Swivel greatly improves the efficiency installation of robotic welding. It maximizes the utilization of access to spot-weld areas. It fits directly onto the robot's end effector without any hoses or cables and ensures the quality of the spot weld to be the highest. An automated spot welding needs to initiate and time the duration of current. A spot weld timer is used to control welding time when spot welding, and the current as well as sequence and time of other parts of the welding cycle.

II. *Arc welding*

Father of robotics, George Charles Devol has created the first industrial robots in 1954. I n d u s t r i a l robot continued to evolve and is directly influenced by the development of computer and massive production demand. At this time, development of arc welding robot in terms of design, control system and sensing ability are seen among engineers as potential areas because it will give highly positive impact to the whole production. Design is in general defined as the establishment of a new algorithm wherein mathematical equation describes the physical parameters setup of the robot [48]. The most important part in arc welding process is the arc itself. Welding process consists of two types of control system which are manual control and automatic control [48]. There are a lot of differences between using automatic control and manual control in welding process that influence primary things such as in product quality level, number of productions, error occurrences, hazardous working environment and total production costs.

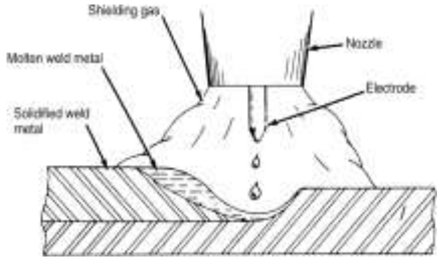


Fig 8 Arc welding

Fig 9 RRX4 Mobile Welding Robot

Another important consideration in improving arc welding robot system is sensing ability. Sensor that is integrated in the central welding system will convert the information from parameters involved into quantitative data such as digital signal, voltage and current.

FRICTION STIR WELDING (FSW)

In the relatively short time since its invention, the new welding process has found potential applications in a number of industries including aerospace (military/civilian aircraft, aircraft parts, fuel tanks, rockets), land transportation (tailored blanks, truck bodies, armor plate vehicles, wheel rims, engine and chassis cradles, fuel tankers, motorcycle and bicycle frames), railway (tankers and wagons, container bodies, underground carriages and trams), shipbuilding and marine (panels for decks, sides, bulkheads and floors, helicopter landing pads, offshore accommodation, hulls and superstructures, aluminum extrusions), construction (aluminum bridges, window frames, aluminum pipelines, heat exchangers, facade panels), electrical (bus bars, electrical connectors, electric motor housings, encapsulation of electronics), and gas (tanks and cylinders) .

Unlike fusion welding processes, for example arc welding, electron beam welding, and laser welding, the FSW process takes place in the solid phase below the melting point of the materials being joined . Advantages that have been cited for the process include the ability to weld alloys that are difficult to weld by fusion welding processes, excellent mechanical properties, low distortion and shrinkage, no fume, porosity or spatter (frequently associated with arc welding), energy efficient, and ability to be used in all positions . Additionally, FSW uses a non-consumable tool, requires no filler wire, or gas shielding, and is tolerant of thin oxide layers.

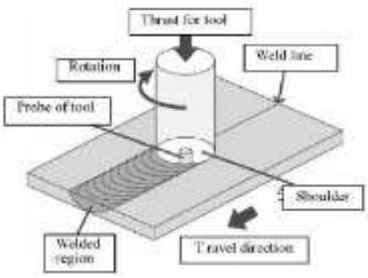


Fig 10. Principle of Friction Stir Welding

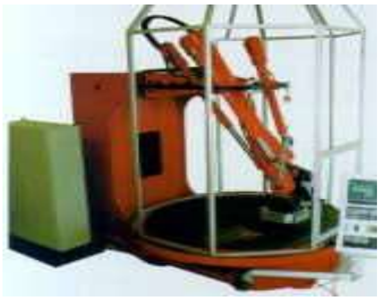


Fig 11. Neos Tricept Robot

FSW applications can be expected to expand substantially when industrial robots are used more in place of currently employed heavy-duty machine tool equipment. This will permit welding three-dimensional contours, with the robots offering the advantages of greater flexibility and availability, and relatively low cost. It was not until the Friction Stir Welding Symposium in Gothenburg, Sweden in 2000 that the first robotic FSW application was demonstrated. Two research groups were presented successful welding in aluminum where one group was using a serial kinematics robot and the other using a parallel kinematics robot. The work by C. Smith was initiated in 1997 with internal feasibility studies at Tower Auto-motive and could be seen as the first investigation of robotic FSW.

The most common for industrial robots is serial kinematics design. It is widely adopted in the automotive industry and has been tested in the area of FSW by several research groups in the past. However, alternative systems have also been demonstrated using parallel kinematic robot. Such robot systems have a much better stiffness but lack the large workspace that serial kinematics robots offer and are far more expensive. A serial kinematics robot has great advantages but has the limited stiffness. A robot also consists of many components with certain flexibility. Inaccuracies in robotics are mainly caused in the joint by torsional flexibility in the gears, bearing deformation and shaft windup.

Since 1996, efforts have been put into creating a robot based FSW technology. Early in the development of friction stir welding, it was recognized that FSW had many advantages over other joining processes for aluminum in numerous applications. However, it was often concluded that FSW was uncompetitive in many of these applications for a couple reasons. First, the high forces that FSW requires caused the need for expensive custom-built machinery. These custom-built machines also created relatively high productivity losses in many applications, due to the inability to achieve high duty cycles (‘on time’). These two factors made FSW uncompetitive, especially where robotics is currently employed. To overcome this issue, the robotic FSW solutions were developed.

Neos Tricept type robots have a parallel kinematic structure, which yields a significantly stiffer structure than the serial structures typically used with other industrial robots (Figure 14). This parallel kinematic structure has definite advantages when attempting to develop robotic FSW systems. However, these types of robots have rather limited working envelopes when compared toserial kinematic structures. Additionally their cost has been significantly higher than standard serial kinematic robots.

Since the welding procedures do not call for widely varying operating parameters, stable robust force feedback control can be readily implemented with properly sized industrial robots. For example, Smith have reported a robotic FSW system based on the use of an ABB IRB 7600 articulated robot arm. This robot has a 500 kg payload. The spindle and motor drive for rotating the pin tool are attached to the end plate of the manipulator. The spindle is designed to accept the forces (both axial and radial) required for FSW and it additionally contains force sensing for force feedback control. Smith have shown that the system is capable of maintaining constant axial force even under conditions of a programmed 3mm change in component surface height over the length of the weld. Furthermore, these robots are stiffer than the previous serial kinematic robots. Another important advancement with these new robots is the modern, more powerful control systems that allow for significant improvements in the force control system capability.

MOTOMAN YASKAWA ROBOTS

I. *Introduction*

Founded in 1989, Yaskawa Motoman is a leading industrial robotics company in the Americas. With more than 400,000 Motoman industrial robots, 15 million servos and 26 million inverter drives installed globally, Yaskawa provides automation products and solutions for virtually every industry and robotic application; including arc welding, assembly, coating, dispensing, material handling, material cutting, material removal, packaging, palletizing and spot welding.

II. *Yaskawa Robot*

An industrial robot consists of “manipulator” which moves and performs tasks, “controller” which actuates and controls the manipulator, and “programming pendant” which teaches the manipulator movement. Yaskawa Electric develops and produces all these core components.

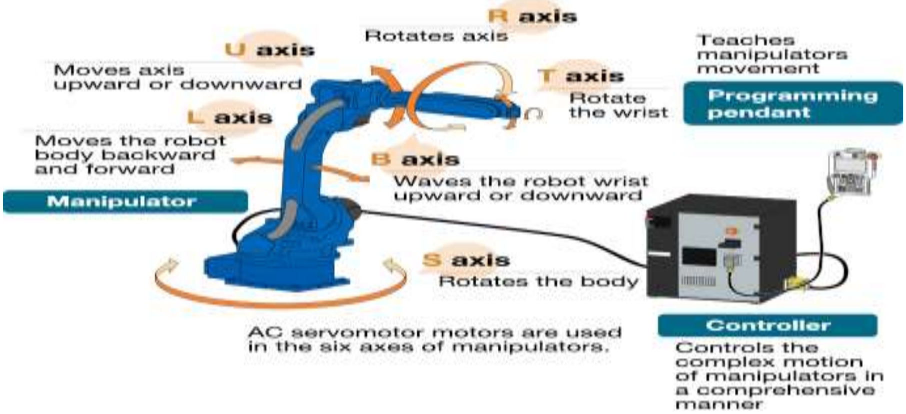


Fig 12. Yaskawa Robot Connections

Yaskawa Arc welding robots

These arc welding robots Offers the highest payload, fastest speed and highest wrist allowable moment in their class, six-axis AR-series robots optimize productivity. These high-performance arc welding robots are compatible with the easy-to-use Universal Weldcom Interface (UWI) pendant application that enables full utilization of the advanced capabilities of select welding power sources without putting down the robot programming pendant. There are different series of Yaskawa arc welding robots. In this project DX100 controller is used to control the arc welding robot by using teach pendent.

III. Manipulator (AR1730)

The six-axis AR1730 robot provides fast and accurate performance for a range of arc welding applications. While a slim profile allows for high-density robot placement, a contoured arm gives easy access to parts in close spaces, avoiding potential fixture interference. An extensive robot reach accommodates a wide variety of parts. The AR1730 has a patented double-yoke upper arm, and it utilizes a symmetric wrist with a substantial range, providing equal torch access to both sides of a part. A 50 mm thru-hole reduces cable wear and interference.

Fig 13. AR1730 Arc welding Robot

IV. Overview

This chapter describes the procedures from cell construction to job creation. An arc welding application is used as an example to illustrate the creation of workpieces for fillet-welding and a welding torch for tool, and then to teach a welding path.The following sections aim to create a robot, a workpiece and a stand like the ones prepared in "Arc_samp_NX" sample cell shown in the figure below.

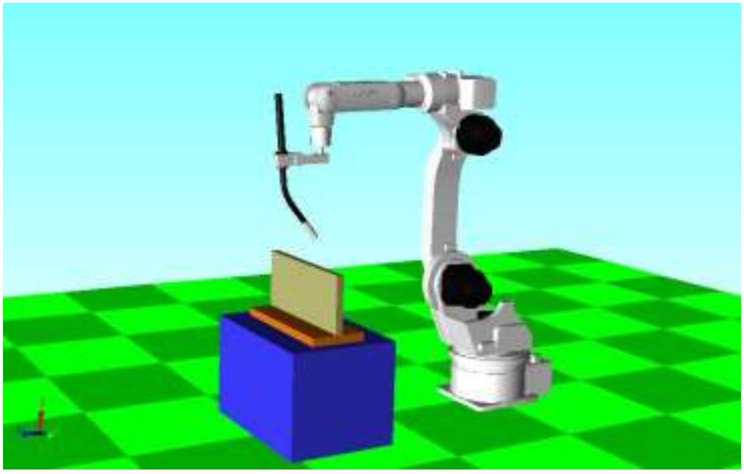


Fig 14. Arc welding sample

V. Creation of models

Follow the flowchart below to create a workpiece and its stand.

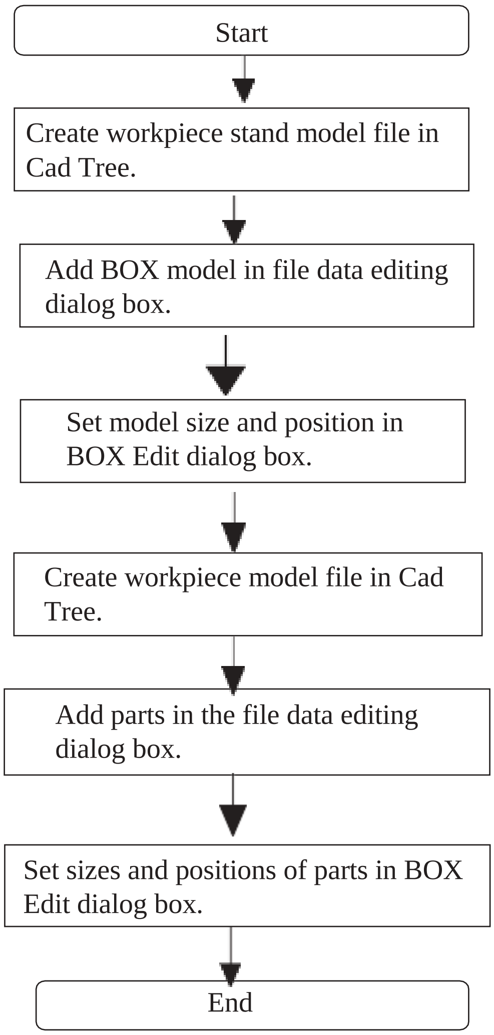


Fig 15 flowchart to create a workpiece and its stand

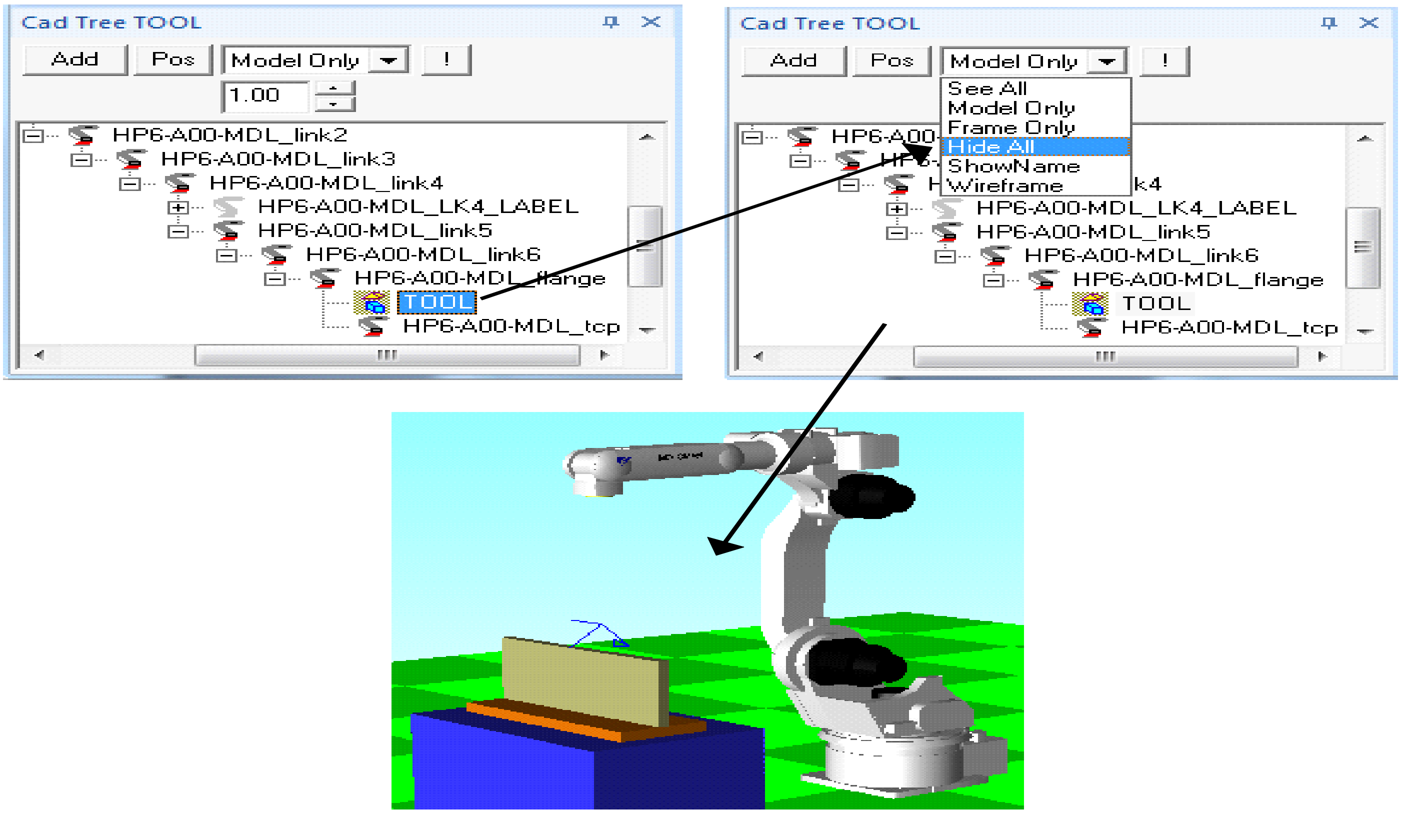


Fig 16 Adding tool in HSF model format

Reading the HSF Format Model

This section describes how to add a tool model which is provided as an HSF format (*.hsf).

If the tool model has been already added in the previous section " Creating and Adding a Tool Model with the CAD Function ", select "TOOL" from the Cad Tree and select "Hide" to hide it.

1. Select "HP6_tcp" in Cad Tree and click [Add] to display the Add Model Dialog dialog box, then enter "TOOL2" in the Name edit box.

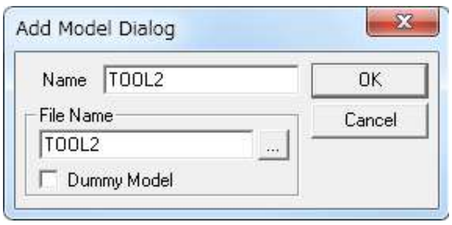


Fig 17 Adding Tool name

2. Click the [...] button of the file name and select "Torch.hsf" file in the folder "MODELS"; click the [OK] button.

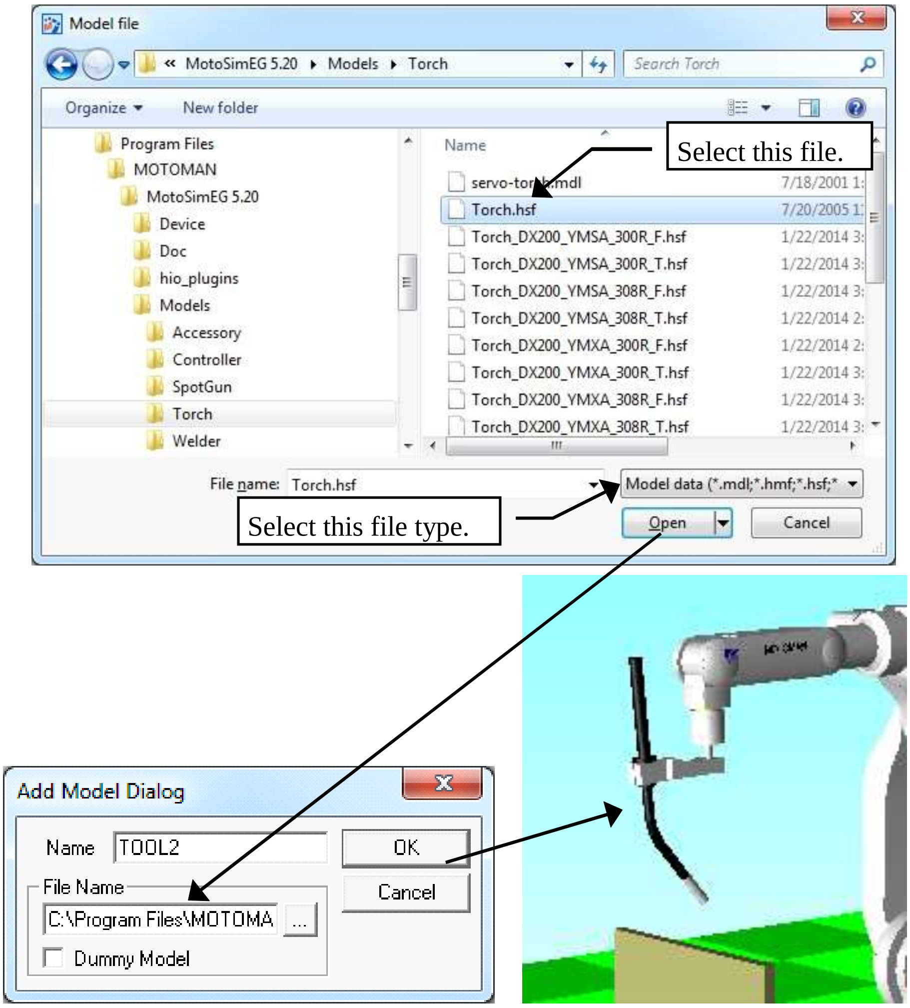


Fig 18 Adding Torch to Robot

Setting of Target Points (AXIS6 Model)

This section explains on how to add an AXIS6 model before starting to teach. This procedure is not necessarily required; however, it makes future teaching easier.

AXIS6 is a model composed of only X, Y and Z-axis frames. Set AXIS6 as target points for the following two steps which will be teach late.

1. On the [Home] tab, in the [Teaching] group, click the [OLP] button to display OLP dia- log as shown below. Select the [Teacher] radio button in the "Operation Object" sec- tion, check the [OLP Pick] check box.

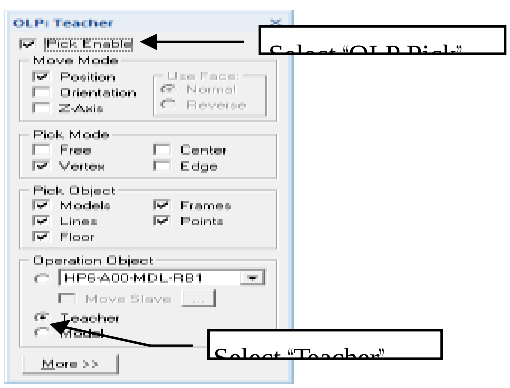


Fig 19 Selecting options

2. Set the Teacher to the welding start position of Step 3: click the welding start position with [OLP Pick] checked.

3. Set the Teacher to optimum angle for the tool welding position: in the following exam- ple, welding is performed at an angle of 45° to the welding position. Select "Teacher" from the Cad Tree and set Rx, Ry and Rz as shown below using the [Pos]button.

4. Double-click the "WORK" model in the Cad Tree and add AXIS6 in the file editing dia- log box.

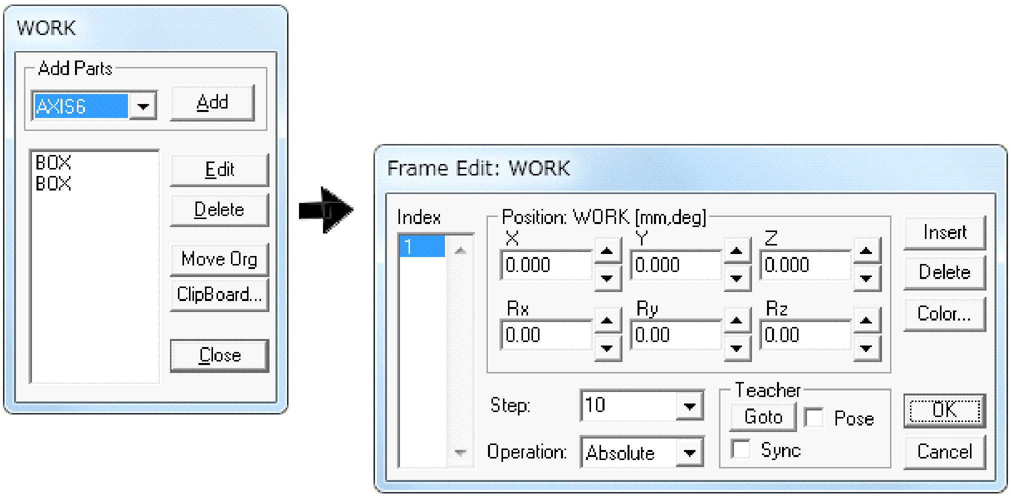


Fig 20 Frame Editing

5. Click on [Add] and verify that the number "1" has been added to the Index list box. Then, check the [Pose] check box in the Teacher group and click the [Goto] button. With this operation, the teacher frame color in the cell window changes, which means that AXIS6 has been set to the teacher coordinate and orientation and now overlaps it.

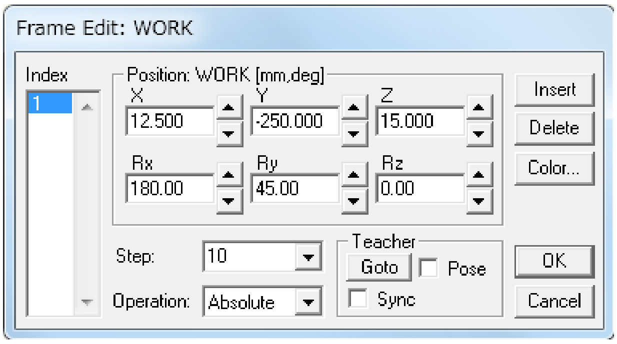


Fig 21 Coordinates

6. Set AXIS6 to the welding end point by performing steps 1 and 2 again, however, since the welding end point is to be set this time, be sure to click the part shown below in then OLP function. (Since the teacher angle has already been modified in the 3rd step, the angle modification is not necessary here.)

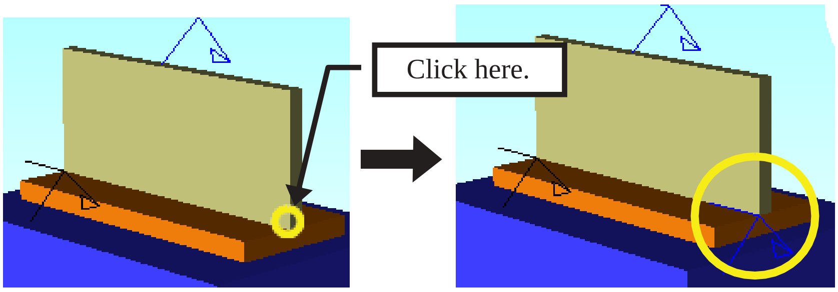


Fig 22 Selecting Coordinates of model

7. Add frame number 2 by clicking the [Insert] button in Frame Edit dialog box for AXIS6 which has been previously set; verify that the [Pose] check box is checked and click on [Goto]. When AXIS6 is set, click on [OK] to complete the setting.

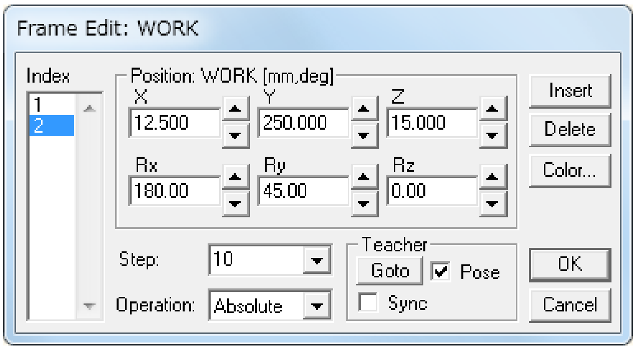


Fig 23 Inserting new coordinates

Teaching the Welding End Position

1. Enable the OLP function and click on AXIS6 which has been set to the welding end point to move the tool to the welding end point.

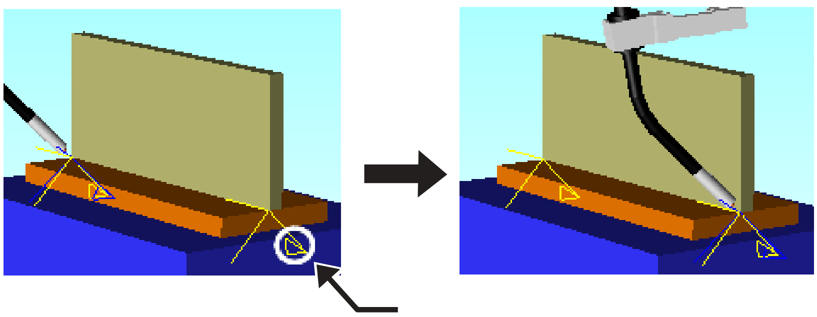


Fig 24 Welding edge point

2. Click the [Move...] button to display Interpolation dialog box.

   Set MOVL (linear interpolation) for the motion type and 93 mm/s for the speed.

3. Click the [Enter] button to register this step.

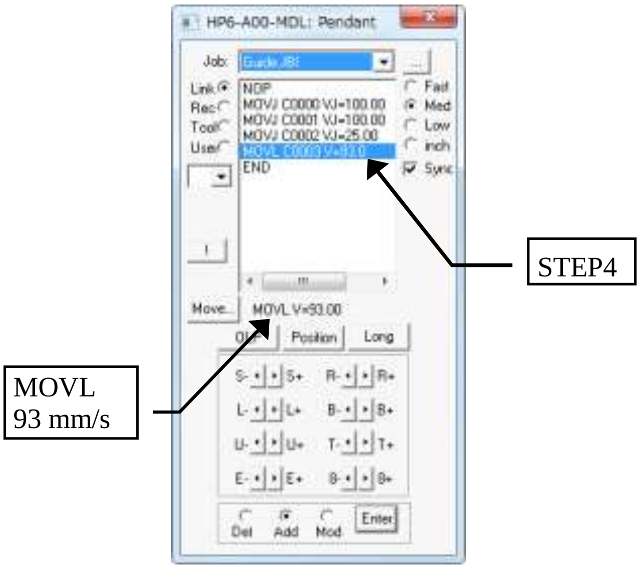
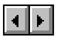


Fig 25 Adding teached coordinates

Teaching the Torch Retraction

1. Use the spin button  of the programming pendant dialog box to move the robot where it does not interfere with the workpiece.

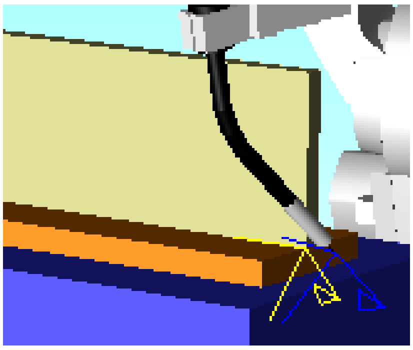


Fig 26 Teaching the torch retraction

2. Click the [Move...] button to display the Interpolation dialog box. Set MOVJ (link) for the motion type and 50% for the speed.

3. Click the [Enter] button to register this step.

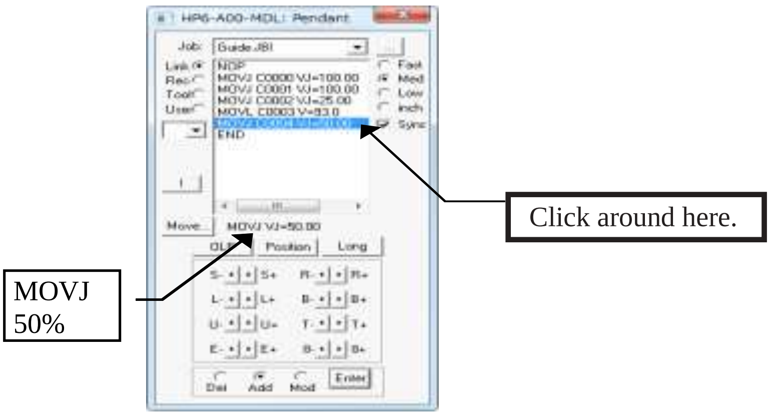


Fig 27 Adding final coordinates

Returning to the Standby Position

1. To move the robot to the same position as Step 1, check the step synchronization [Sync] check box in the programming pendant dialog box, then point the cursor to the instruction of Step 1 in the job display.

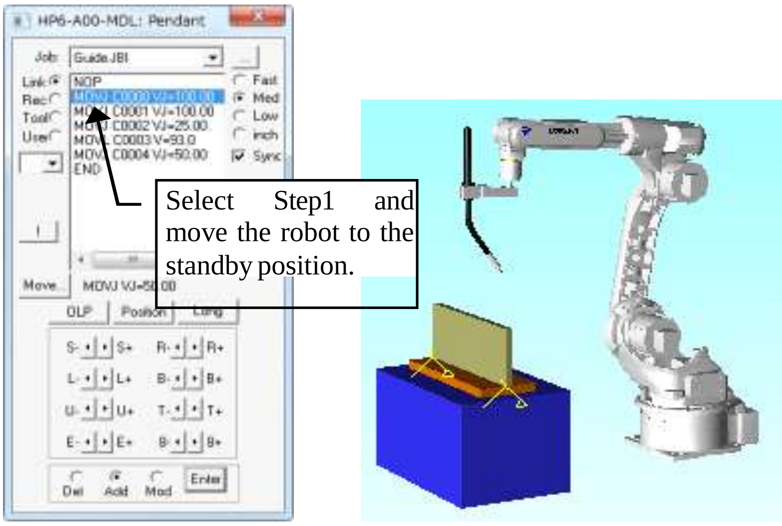


Fig 28 Returning to the Standby Position

Simulation

The simulation process in Motosim EG

Fig 29 Simulation Process

Playback	Job
Reset	Jumps to the top of the job execution line. Use this button to execute (or reset) a job from the beginning when job execution is interrupted.
Start	Executes the job currently selected. Use Select Job button to select the job to be executed.
Pause	Halts temporarily the job under execution. Use Start button to execute the rest of the job.
Stop	Interrupts the job under execution.
Back Step	Enables a job to skip backward step by step.
Next Step	Enables a job to skip forward step by step.
Stage Master	Display the Stage master. For details, refer to section " 7.3.3 Stage Master ".
Servo Emulation	To playback without considering the lag of servo.
Cycle Time	Display the Cycle time.For details, refer to section " 7.3.1 Cycle Time ".

APPLICATION USING MOTOSIM EG

I. Explanation

In this project we done simulation for Arc welding application using conveyor and jobs. We assumed jobs as the objects which we want to weld in the industries. In this simulation process we used conveyor and 2 robots which were teached using three teach-pendents. Here two robots collaboratively weld the job. Firstly, we fix a welding position on the conveyor. Later the robots are teached for edge points of the jobs. The process will continuously repeat whenever a new job arrives at the welding position.

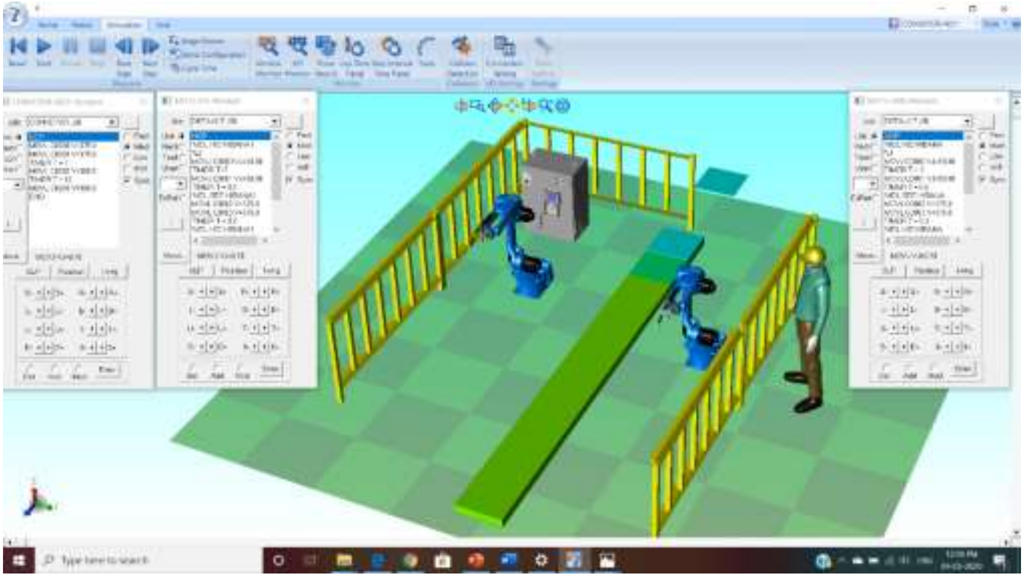


Fig 30 Arc welding robots in Motosim simulation software

Simulation Results

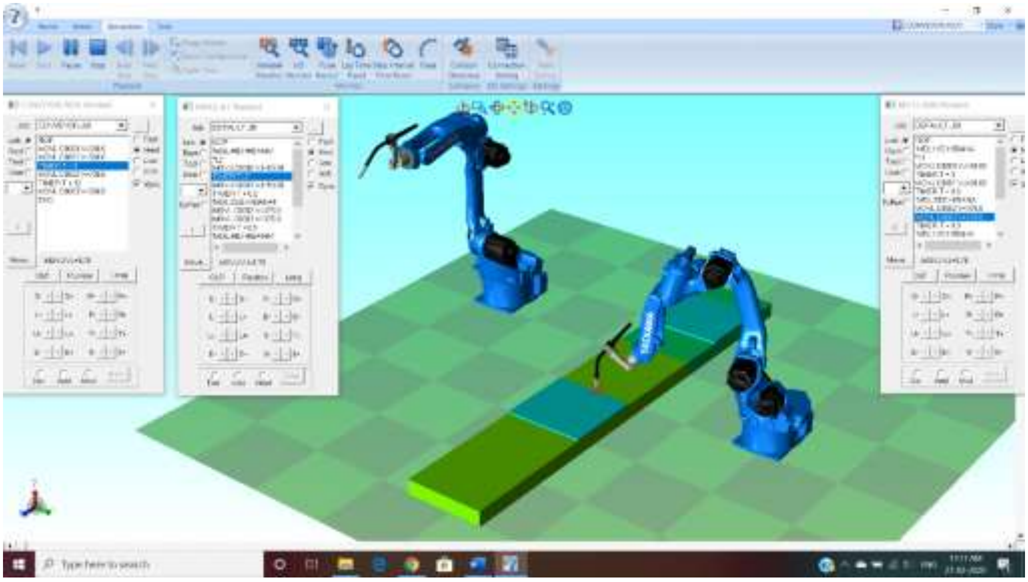


Fig 31 Welding a job

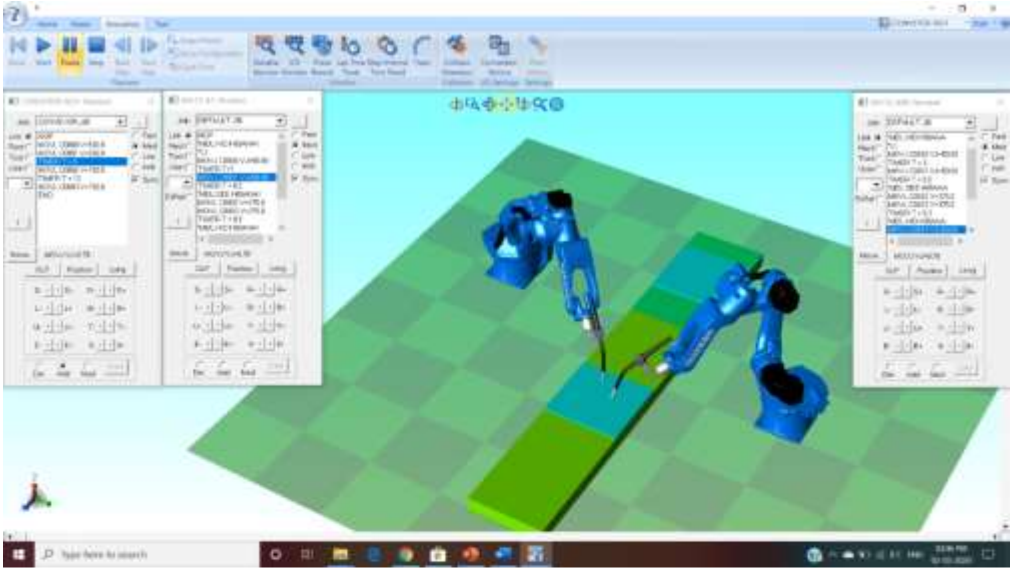


Fig 32 welding a job using Collaborative Robots

CONCLUSION

In order to fulfill modern day diversified requirements, significant improvements are needed for each element of welding robots. Robots must be able to integrate with their environment in order to produce optimum performance. People should provide robot with fully autonomous system rather than using panel to control them. Level of cooperation among robots is also important especially when solving complicated tasks.

Power supply is another issue that should be included in the discussion. Instead of using electricity, manufacturers could use renewable energy which maintain the energy sources. All of the mentioned elements will contribute to a major change in technology of welding robot.

FUTURE SCOPE

The automated welding techniques can be used for various numbers of applications. Further, it can be applied to do brazing and soldering applications. A robot can be designed for welding applications, which will minimize the human efforts and will increase the accuracy of the product to be welded. future robots will be mobile, able to move under their own power and navigation systems. Robot gripper design will be more sophisticated, and universal hands capable of multiple tasks will be available.

- Systems integration and networking robots of the future will be “user friendly” and capable of being interfaced and networked with other systems in the factory to achieve a very high level of integration.
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