Technical articles

Safeguarding Robots and Robot Cells

Protect personnel working directly with or around robots.

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Robots offer a means to simplify and improve efficiency with a process and can complete tasks that pose too great of a hazard to be handled by human operators. This, however, does not remove all hazards from a machine or process, yet it creates new unique hazards which must be guarded to protect personnel while working directly or around the robot.

Relevant standards for robots

As with any industrial piece of equipment, the first steps to safeguarding a robot or robot cell is understanding the relevant safety standards associated with robots.

This allows safety requirements to be aligned with the hazard identification process of your risk assessment. Being able to understand what typical hazards exist as described within harmonized standards such as **ISO 10218** (robots and robotic devices — Safety requirements for industrial robots) will provide guidance on recognizing gaps and deficiencies related to the safety of new and existing robot applications.

One important concept to take away from such standards is that hazards (the potential source of harm) and risks (the degree of potential exposure and consequence of the hazard) are not reserved for the robot itself, but also for the surrounding areas such as the end-of-arm tooling, material being processed, and the auxiliary equipment used in conjunction with the robot application (conveyers, lifts, etc.). **ISO 10218** being harmonized means that that these fundamental baselines for robot safety are shared globally as seen with **ANSI/RIA 15.06** and **CSA Z434**

Relevant robot standards:

USA

- **ANSI/RIA15.06** - Industrial Robots And Robot Systems - Safety Requirements
- **ANSI/RIA15.08** - Industrial Mobile Robots - Safety Requirements: Requirements For The Industrial Mobile Robot
- **RIA TR R15.306** - Task-Based Risk Assessment Methodology
- **RIA TR R15.406** - Safeguarding
- **RIA TR R15.506-2014** - Applicability of ANSI/RIA R15.06 For Existing Industrial Robot Applications
- **RIA TR R15.606-2016** - Technical Report - Industrial Robots And Robot Systems - Safety Requirements - Collaborative Robots

Canada

- **CAN/CSA-Z434-14** - Industrial Robots And Robot Systems

International

- **ISO10218** - Robots and robotic devices - Safety requirements for industrial robots
- **ISO/TS15066** - Robots and robotic devices - Collaborative robots

Aside from understanding the safety requirements, it is important to understand the robot functionality and limitations.

Risk Assessment

A thorough risk assessment should be performed on the application, based on the standards. The risk assessment should focus on the robot application as a whole as well as the individual specific tasks associated when interacting with the robot.

For example, reasonably foreseeable hazards and risks should be evaluated on the materials being handled, the type of end-effector being used and its operating speeds. This same approach is needed when looking at tasks such as teaching, setup, maintenance and even troubleshooting. Where the hazards associated with the robot as a whole can affect all personnel, the task-based hazards are associated with specific personnel such as operators, technicians, and maintenance, performing a specific task.

Workers inspect the end tooling of a industrial robot

Stop time analysis

If the plan is to use non-separating guarding, then the robot application should have stop time analysis performed. It is important to know how quickly the robot will cease hazardous movement once a stop signal is sent. This is particularly important information needed to calculate the appropriate placement of non-separating guards. Since these type of devices do not prevent personnel from entering the hazardous area, they must detect personnel and bring the system to a safe state before the hazard can be reached.

Spacial mapping

Another crutial element to define is the space criteria, which is the three-dimensional area through which the robot can move. It is broken down into three sectors:

- **Maximum space** is the actual reach the robot is cable of, including the end or arm tooling.
- **Restricted space** is an area within the maximum space, restricted by limiting devices that establish limits which will not be exceeded be the robot, such as limits created by hard stops or programming.
- **Operating space** is the area that the robot has been programmed to work in.

It is important to understand the robot's space criteria, especially if soft stops (predefined program limits) or hard stops (physical end-stop to restrict moment) are not in use. It may be helpful to create a space mapping, designating the maximum, restricted, and operating spaces, like in figure 1.

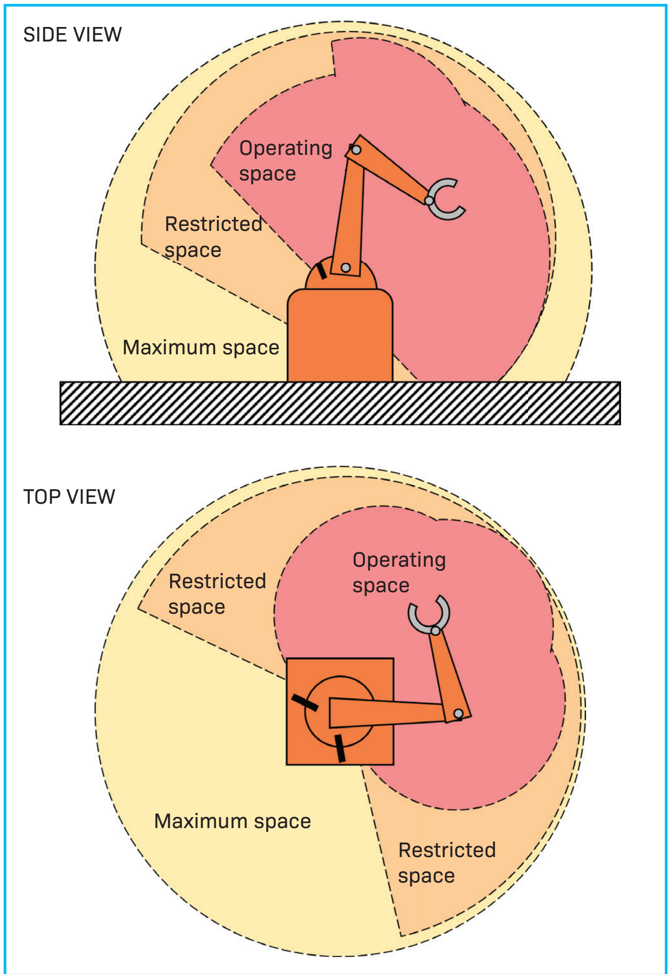


Figure 1: Side and top view of robot arm space mapping

Typical methods of safeguarding robots

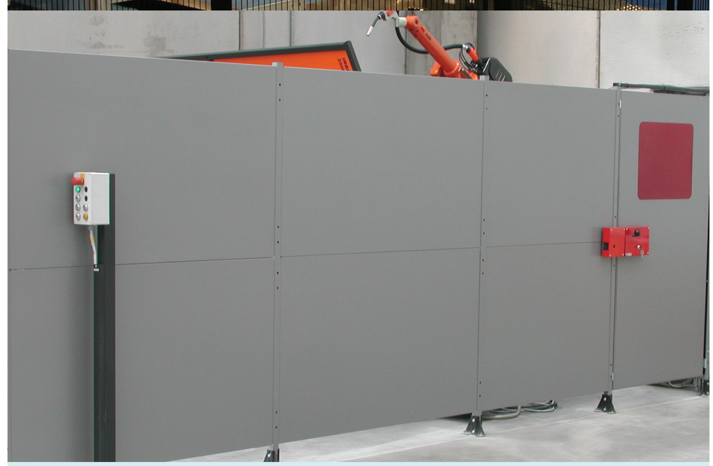
The risk assessment, stop time analysis, and spacial mapping will help determine what types of safeguards should be used and where they should be placed in relation to the robot.

Physical barrier

The most common means to protect personnel walking or working near the robot and robot cells is by using hard guards such as fencing. As with any safeguarding measure, certain considerations and requirements must be observed for the safety solution to be effective.

When implementing physical barrier to safeguard against robot hazards, it is important to understand the programmed robot operating space and the potential reach due to a failure of the robot safety controls. Again, the terms reasonably foreseeable must be considered during this evaluation. If proper safety controls are not in place to adequately reduce the chances of the robot from entering a restricted space, physical guarding that can withstand the impact of the robot to prevent it from entering the restricted space may be needed.

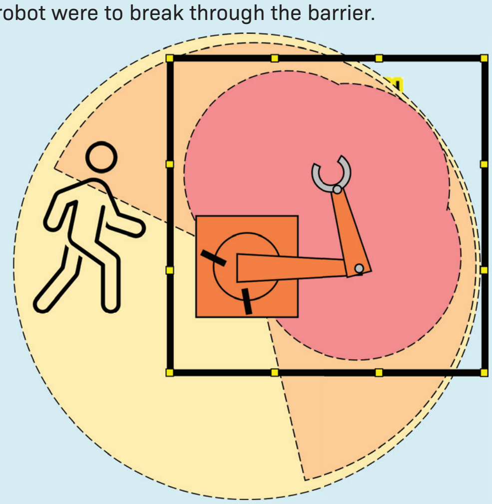
Other attributes of the physical barrier to consider is the viewing capability. Operators may need to see the robot function to confirm a process, or to teach the robot a new function or perhaps maintenance require visual access for troubleshooting. The easier it is for personnel to see past the physical barrier the less likely the chance of bypassing the guarding is.



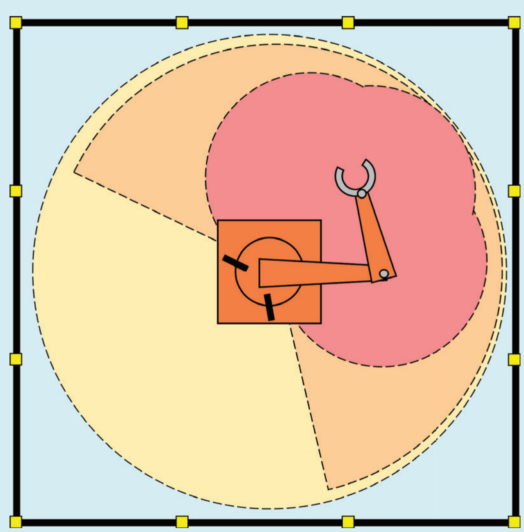
Top: safety fencing provides a good view of the robot cell
Bottom: A robot cell with a opaque barrier.

Placement of physical barrier

In this example the physical barrier guard has been placed around the operating space only. It does not consider the potential reach of the robot to extend within the restricted or maximum space in the event of a failure with the robot safety controls. Workers would be exposed to the hazards of the robot and potential hazards within the robot cell, if the robot were to break through the barrier.



Here the phsyical barrier has been placed outside the maximum space, restricting access to the hazardous area.

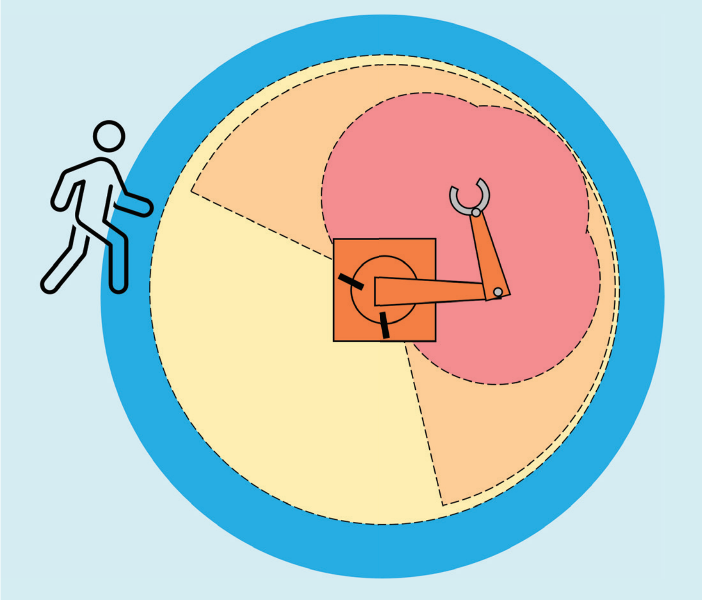


Non-Separating guarding

Safety light curtains, safety pressure mats, and safety laser scanners are safety protective devices that can detect the presesnce of personnel approaching or within the robot cell. They are considered “non-separating” since they do not provide a physical barrier.

Typically these presence sensing devices are implemented as a secondary measure, used to ensure personnel are not within the robot cell prior to re-initiation. Additionally, non-separating guarding may also be used to allow material to enter or leave the robot cell while preventing personnel from entering and reaching hazardous parts or conditions. This can be achieved by utilizing safety functions such as muting, most commonly seen with conveyor applications.

They can be used as a primary safety function, such as a virtual cell created by light curtains and deflecting mirrors. There are special considerations to this application - since these devices must detect personnel and bring the system to a safe state before the hazard can be reached, they may need an additional detection distance beyond the “maximum area”. Proper placement of these devices requires a safety distance calculation which takes factors into account such as the type of device being used, the manner in which is mounted, the approach speed of the body (or limbs) and the total stopping time of the system (from the stop time analysis). ISO 13855 is a safety standard which provides guidance on conducting a safe minimum distance calculation.



Many applications become ineligible because the calculated minimum safe distance for placing these devices is impractical. Traditional industrial robotics applications which consist of large payloads and high speeds generally have longer stoppage time and may need a greater distance than is feasable.

Controls

Many of today’s robot controllers allow for an easy integration of safety systems which may be required. This includes a safety rated two-channel redundant input for an emergency stop function (used for an E-stop) and a separate safety rated two two-channel redundant input for an interlock safety function (used for a laser scanner).

Additional considerations relating to the robot functions and limitations is the potential for full body access. In other words, is there a possibility to access a robot cell and possibly be trapped by the closing of a guard? Robotic safety standards such as ANSI/RIA 15.06 require an emergency egress bypass of locks on access doors. This must allow personnel to escape from within the robot cell regardless of the lock condition of the safety interlock.

This door lock has an emergency release handle inside the robot cell.

Restart controls should be positioned so that operators can see that entire hazardous area is clear. If personnel could be present but unseen in the hazardous area, then a double reset function should be introduced. This would require actuation of a pushbutton within the hidden hazard area, acknowledgement of egress (guard closure or light curtain interruption) and then actuation of a second pushbutton outside, all within a limited timed period.

Animation of a double reset. The second pushbutton is mounted outside the cell. The process includes interupting the light curtain.

Safety Considerations for Collaborative Robots

A collaborative robot differs from an industrial robot in the sense that the collaborative robot is designed to be inherently safe. This is primarily because human contact with a collaborative robot is both allowed and expected if both are working within the same operating space.

However, an inherently safe-by-design collaborative robot does not mean that a collaborative robot application itself is safe. The harmonized safety standard **ISO/TS15066** (robots and robotic devices — collaborative robots) provides guidance on establishing a safe collaborative robot application.

As with any industrial machine, a risk assessment should be performed. The focus should be on the cobot application as a whole including the environment, scope of work defined for the robot and human operator, and material being handled.

ISO/TS15066 states that a collaborative operation may include one or more of these safeguarding techniques:

Safety-rated monitored stop
A safety-rated monitored stop will bring the collaborative robot to safe condition, allowing personnel to access restricted and unauthorized operating spaces. However, if the collaborative robot were to experience an unexpected movement or condition while the monitored stop is enabled, an emergency stop function would be initiated.

Hand guiding
Hand guiding allows an operator to utilize a hand-operated controller, or even hand moving the robot directly, to initiate motion commands commonly seen during a collaborative teaching process.

Speed and separation monitoring
The speed and separation monitoring function allows a person to be in the collaborative space while robot motion is running as long as there is a separation of a defined protective distance from coming in contact with the robot.

Power and force limiting
Lastly, applying Power and Force Limiting is used if the robot system may come into direct contact either intentionally or accidentally with a person. Limiting the power and force to a safe level reduces the risk factors. Safe levels are determined by the body area(s) expected to be in contact with the robot which have predefined thresholds to follow called out by harmonized collaborative safety standards.

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