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Canadian Centre for Occupational Health and Safety Centre canadien d'hygiène et de sécurité au travail

Safety Hazards

Robots and Cobots

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What are robots and cobots?

Robots and related devices are common in some workplaces, but technological advances have begun to allow for a greater diversity of robotic systems. Innovations in safety assurance mechanisms and intuitive interaction technologies are allowing closer robot-human interactions than ever before.

Industrial robots include powerful, heavyweight automated arms that perform tasks such as welding, painting, or assembling components within a physical enclosure such as a cage. Robots offer considerable safety benefits by performing tasks that are dangerous or undesirable for human workers. For example, robots perform tasks that are repetitive or require awkward motions or postures, protecting workers from being exposed to risks of developing musculoskeletal injuries. Robots also work in environments that are hazardous to humans, such as cleaning up chemical spills.

Collaborative robots, or cobots, also perform these types of tasks, but they have built-in safety mechanisms that allow them to work more closely with humans. Cobots can assist with complex tasks that cannot be fully automated. Human-cobot interactions could involve workers handing off parts and materials to cobots, or workers “teaching” the cobot by guiding it through a desired motion, which the cobot then repeats. Collaborative robot systems allow robots and humans to use their strengths – robot’s power, precision, endurance, and consistency, and human’s creativity, intelligence, adaptability, dexterity, touch sensitivity, and problem-solving ability.

Are there safety standards for robots and cobots?

Robots and cobots are subject areas that are still growing. Currently Canada's CAN/CSA-Z434-03 (R2013) standard “Industrial Robots And Robot Systems - General Safety Requirements” applies to the manufacture, remanufacture, rebuild, installation, safeguarding, maintenance and repair, testing and start-up, and personnel training requirements for industrial robots and robot systems.

International safety standards for industrial robots include ISO 10218-1 and -2, “Robots for industrial environments – Safety requirements Parts 1 and 2”, and ANSI/RIA R15.06, “Industrial Robots and Robot Systems – Safety Requirements”. These standards describe hazards associated with industrial robots and provide guidelines for eliminating or reducing risks associated with those hazards.

International safety standards for cobots include ISO/TS 15066, “Collaborative Robot Safety”; and ANSI/RIA R15.606, “Collaborative Robot Safety”. These standards provide important information on how to implement a collaborative robot system in a way that maintains safety for the human collaborator.

Some jurisdictions have also included requirements for robots in their health and safety legislation. For example, Alberta's Occupational Health and Safety Code requires industrial robot systems to comply with CSA Standard CAN/CSA-Z434-03 (R2013) and sets specific employer duties for when a worker is teaching (or programming) a robot.

What hazards and concerns are associated with robots and cobots?

Potential hazards associated with using robot systems include:

Impact, collision, or other “struck by or caught-between” hazards: unexpected movements, malfunctions, or program changes could result in contact between the robot system and workers, which may lead to injuries depending on the force of contact.

Crushing and trapping hazards: parts of a worker's body can be trapped within or between components of a robotic system.

Struck by projectiles hazards: mechanical failure of the robot system could cause parts to be released, gripper mechanisms to fail, or power tools to malfunction, leading to projectile objects.

Hydraulic and pneumatic hazards: rupturing of hydraulic and pneumatic lines can create dangerous high-pressure cutting streams and whipping hoses that can cause physical injury. Ruptures and leaks can also result in exposure to hazardous fluids that may be toxic or flammable. Pressure losses due to ruptures or leaks could also result in struck-by or crushing hazards if a component of the robot system falls onto or swings into a worker.

Electrical hazards: the robot system's power supply and cords could be a source of electrical hazards such as arc flash, electrical shock, or fire.

Slipping, tripping, and falling hazards: spills or leaks, equipment, power cables, and hoses can all be tripping and falling hazards.

Other hazards: Other hazards could stem from systemic issues such as mechanical failures, power system malfunctions, or faults within the robot control system due to errors in software or electromagnetic or radio frequency interference. Hazards could also be caused by human error when integrating or programming the robot, improper assembly and installation, unauthorized access to the robot area, exposure to environmental factors such as water and dust, and time constraint and other workplace pressures.

Additional hazard considerations for collaborative robots:

Whereastraditional industrial robots are physically separated from human workers to prevent contact, collaborative robots, or cobots, can work in close proximity with workers, sometimes even making contact with workers as part of their normal functions. Cobots have built-in safety controls to prevent hazardous contact. For example, a cobot could be designed to slow down or stop when it detects a worker nearby to prevent injury.

In ISO/TS 15066:2016 "Collaborative Robot Safety" (R2019), the International Organization for Standardization requires collaborative robots to use one of four safety measures:

1. **Speed and separation monitoring**: This safety feature uses sensors tell the cobot that a worker is nearby. Depending on its proximity to the worker, the robot may slow down, change direction to move away from the worker, or stop completely.
2. **Hand-guided controls**: This safety feature allows the cobot to move only when it is under an operator's control. For example, a worker can guide the cobot to grasp and place a heavy box onto a vehicle. In this case, the cobot will not move without the worker pressing a hold-to-run control device and physically directing its movements.
3. **Power and force limiting**: This safety feature limits the pressure and force that can be applied when the cobot makes contact. Limiting speed, force, and power of the cobot allows physical contact between cobots and workers. These limitations also reduce the amount of force cobots can exert if they strike a person unintentionally. Cobots with power and force limiting functions are typically much slower and handle lighter objects. These cobots also tend to have rounded edges and softer surfaces to reduce the risk of injury when there is contact.
4. **Safety-rated monitored stop**: The cobot will stop moving when it senses a worker enters its workspace, similar to approaches used with more traditional industrial robots.

“Speed and separation monitoring” and “power and force limiting” technologies are commonly used together so cobots can function at high speeds when workers are not in the area but slow down when workers enter the area so contact can happen without causing injury.

While these internal features facilitate safer robot-human interactions, it is important to keep in mind that collaborative robots are not inherently safe. How the cobot is configured, programmed, and used in the workplace can create potential hazards. For example, a cobot could be tasked with picking up objects or components that are sharp, which could injure workers if contact is made. A cobot’s interaction with other equipment or robots can also present additional hazards. Therefore, it is crucial to assess the hazards and risks associated with cobot and also how it will be used in the workplace.

Research has shown that introduction of human-robot collaboration has the potential to both positively and negatively affect the stress level and workload of workers. Workers may also feel pressured to keep up with the cobot’s pace and level of productivity, potentially leading to musculoskeletal risks. Increased collaboration with robots may also reduce workers’ contact with their peers and impact their social support at work. This isolation may have a negative impact on workers’ mental health.

What should be considered when assessing the hazards and risks of robots and cobots?

To ensure the safety of everyone involved, hazard identification and risk assessments should be performed for each stage of the process, including integrating, operating, and maintaining the robot. A good time to conduct a comprehensive hazard analysis and risk assessment is when the robot is first integrated into the workplace. Individuals who are responsible for integrating and programming the robot should have thorough training and knowledge of what needs to be programmed, how to interface with the robotic system, and the control functions of the robot and associated equipment. Therefore, they would be an asset to the risk assessment team.

A task-based approach to the risk assessment is recommended. Identify all the tasks that will be performed as part of programming, operating, and maintaining the robotic system. Then, identify the hazards and assess the risks associated with each task.

When assessing risks and hazards of a robot system, the Occupational Safety and Health Administration’s (OSHA’s) Technical Manual on Industrial Robot Systems recommends considering:

- Tasks that will be programmed
- Start-up and command or programming procedures
- Environmental conditions
- Location and installation requirements

- Possible worker errors
- Scheduled and unscheduled maintenance
- Possible robot and system malfunctions
- Normal mode of operation and procedures
- Emergency conditions and procedures
- All worker functions and duties
- Hazards typical of the specific robot application

Similar robot systems in the same workplace should each have their own risk assessments. Though the robot is identical, they may be working on different parts or processes. Additionally, their physical placement in the facility may introduce unique hazards (e.g., a particular robot may be next to a wall, while another otherwise-identical robot is next to a walkway).

Risk assessments for robotic systems should be conducted by leaders and workers with knowledge of workplace process operations, the specific robotic system, and risk assessment techniques. Workers and third-party consultants with relevant specialized expertise should also be invited to participate.

Worker involvement in the hazard and risk assessment is especially important for collaborative robots. Operators have insights into how they will be using the cobot system so they may be able to identify hazards that would be otherwise missed.

Additional risk and hazard assessment considerations for collaborative robots

Risk and hazard assessment for cobots must also consider instances where the worker and robot come into contact. Determine when the contact may happen, which part of the body might be affected, the type of contact, and the allowable force for that type of contact. For each of contact type, ANSI/RIA standard R15.606-2016 provides a permissible biomechanical limit for force and contact pressure based on the body part being contacted. These limits are intended to avoid pain during contact events.

Consider hazards involved in both transient and quasi-static contacts.

Transient contact occurs when the worker’s movement is not restricted at the time of the contact.
Quasi-static contact occurs when a part of the worker’s body cannot move at the time of the contact because it is being restricted (e.g., trapped or pinched between the robot and another object).

What are some possible control measures for robots and cobots?

Hazard control measures can vary based on industry, robot type, work process, and work practices. Each risk reduction measure has its own benefits and limitations. However, effective control measures will align with the hierarchy of controls . This hierarchy help workplaces prioritize control methods from the most effective level of protection to the least effective level of protection. Workplaces will likely need to use a combination of different control measures including safeguarding devices, regular inspections and testing, standard operating procedures, education and training, and personal protective equipment.

Safeguarding devices

Safeguarding devices reduce risks by physically separating workers from robot systems during automatic operations. When the robot is in automatic mode, all safeguarding devices should be activated, and at no time should human operators have access to the area.

Examples of safeguarding devices include:

- Presence-sensing devices such as light curtains, safety mats, safety scanners, and safety vision systems
- Fixed barrier or perimeter guards such as fences
- Interlocked barrier guards

In most cases, the robot is programmed to automatically assume a safe state such as stopping when a worker enters the safeguarded space. However, there are some circumstances in which workers need to interact with a robot that is still active (e.g., when a worker is programming or teaching the robot, or during the testing phase after maintenance or repairs). When this interaction must happen, the industrial robot should be on manual mode where its movements are completely controlled by the worker inside the safeguarded space through an enabling device, and the robot will operate at a reduced speed to decrease the likelihood of contact and minimize injury potential.

Awareness devices can be used with safeguards by visually alerting workers of zones with higher hazards. Typical awareness devices include fencing, chain or rope barriers with supporting stanchions, flashing lights, signs, whistles, or horns.

Inspections, maintenance, and testing

Regular inspections, maintenance, and testing of the robot system should be performed to verify that robot conditions and programming are operating as desired. The robot’s safety function settings, automatic stop ability, and the appropriateness of the robot's safety distances should also be verified and tested regularly.

When creating an inspection program, consider the hazards and risks identified in your assessment and the manufacturer’s recommendations. As with all inspection and maintenance activity, it is important to apply appropriate lockout/tagout procedures to maintain worker safety.

Keep a record of the maintenance activities as well as tests and inspections performed and their results. This record can help workplaces track the safety performance of the robotic system and flag any leading indicators of new hazards.

Don’t forget to conduct pre-operation tests as required and appropriate. For example, site acceptance testing is usually performed to confirm the robot is operating as expected after being integrated into the workplace.

Operating procedures

Develop programs and procedures for each robot system in your workplace. At a minimum, procedures should be written for:

- Activities that must be done in a specific sequence to maintain safety such as entering and exiting the safeguarded robot area.
- Activities that can create unusual or significant hazards such as start-ups, shutdowns, or emergency events.
- More complex activities such as equipment programming, maintenance, testing, and lockout/tagout procedures.

Make sure to communicate and provide training for the program and procedures.

Education and training

Employers and workers involved in setting-up, operating, and maintaining robot systems should have knowledge of the system and applicable safety standards. Everyone involved should also understand not only the nature and severity of potential hazards, but also how these hazards are addressed. Everyone involved should also be able to demonstrate competency to perform their jobs safely. Workplaces can develop and implement a robot safety training program to help workers develop relevant skills before they perform robot-related work.

Personal protective equipment

Workplaces should select appropriate personal protective equipment (PPE) based on the hazards and risks identified in the assessment. PPE may include:

- Hardhats
- Hand protection for the intended use (sharp edges, heat, cold)
- Safety glasses
- Protective footwear
- Hearing protection
- Arc-flash protection
- Respirators

Confirm control measures

Lastly, it is always important to make sure that the control measures do not create new hazards. For example, make sure safeguards selected will not impede the vision of workers if a clear line of sight is necessary for safety. If viewing is important but the safeguard cannot be modified without compromising safety, the workplace can consider using a camera system to enable viewing from a distance.

Additional risk reduction considerations for collaborative robots

Following the hierarchy of controls principle, first consider whether human-robot collaboration is necessary and to what extent. For example:

- Can the process be performed without a human collaborator?
- Does the human and robot need to work on the same item simultaneously?
- Does the human need to be in physical contact with the robot or the item being worked on while the robot is in motion?

Because of hazards that could result from robot-worker contact, only use human-robot collaboration if it is truly necessary.

If human-robot collaboration is necessary, make sure the robot used is designed for collaboration. More specifically, make sure the robot has the appropriate safety features for the task, such as speed and separation monitoring, hand-guided controls, power and force limiting, or safety-rated monitored stop.

The cobot may need additional control measures to reduce risks, including:

- Rounded corners and edges
- Padding on sharp corners and edges
- Eliminating projections on surfaces
- Compliant elements such as springs that limit force
- Smooth protective covers

Workplaces can also use administrative control measures such as clearly marking the collaborative space where workers may come into contact with robot systems. Signs that warn workers that they are about to enter a robot collaborative space can also be used.

Potential psychosocial hazards of introducing human-robot collaboration can be mitigated by involving workers (and unions if applicable) in the planning and implementation process. Build trust by being clear about why the organization is bringing in cobots and provide everyone with a chance for input. Encourage worker acceptance by providing education about how the cobot can benefit their safety or job quality, and make it clear that the cobot is not going to replace workers. More information on this topic can be found in the OHS Answers on Introducing New Technology at the Workplace.

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