Understanding Collaborative Robot Safety

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Introduction

The current popular trend in industrial robotics is the emergence of collaborative robots. In a previous article, "Putting Collaborative Robots to Work," the increasing use of collaborative robots (cobots) was discussed along with what benefits they provide to the end users. That paper briefly touched upon the safety aspects of cobots. This paper provides an overview on more detailed safety considerations. Please note, this article is not sufficient to cover everything needed to know about cobot safety. It presents safety topics that likely require further consideration and study.

Applicable Safety Standards (The Rules)

Going back over 10 years ago, there were two different safety standards specifically surrounding robotic safety: the ANSI/RIA 15.06 American National Standard for Industrial robotics and the ISO 10218 International Safety Requirements for Industrial Robotics. The ISO standard was the first standard to cover collaborative robot applications. The adopted 15.06-2012 standard came from the revision of the ISO 10218 standards. The reader is encouraged to get more detailed information by reading the following:

- ISO 10218-1:2011 and ISO 10218-2:2011
  - Part 1: Robot only (manipulator and controller)
  - Part 2: Robot system/cell and application
- ISO TS 15066 is a Technical Specification on collaborative robots
- ANSI/RIA R15.06-2012 North American Safety Standard for Industrial Robotics (an adoption of ISO 10218-1:2011 and ISO 10218-2:2011)
- ANSI/RIA TR R15.306-2016 Task Based Risk Assessment Methodology

What is "Collaborative Robotics"?

Based on current safety standards (ISO-10218-1:2011 part 1 section 3.4) a collaborative operation is a state in which purposely designed robots work in direct cooperation with a human within a defined working space as in the photo below. In the simplest terms, a collaborative robot is defined as a robot that can be used in a collaborative operation. The next section (3.5) defines a collaborative work space as a working station within the safeguarded space where the robot and human can perform tasks simultaneously during production operations. So, what does this mean? It means any robot can be collaborative in terms of safety standards, and it is the task undertaken within the space that defines "collaboration."

Kawasaki Duaro press tending of automotive drive train parts (courtesy of Ohashi Giken)

Different Types of Robot Collaborations

To understand the limits of new cobots it is necessary to understand further the current safety standards. In the ISO standard Part 1 section 5.10 it is stated that robots designed for collaborative operation shall comply with one or more of the following categories:

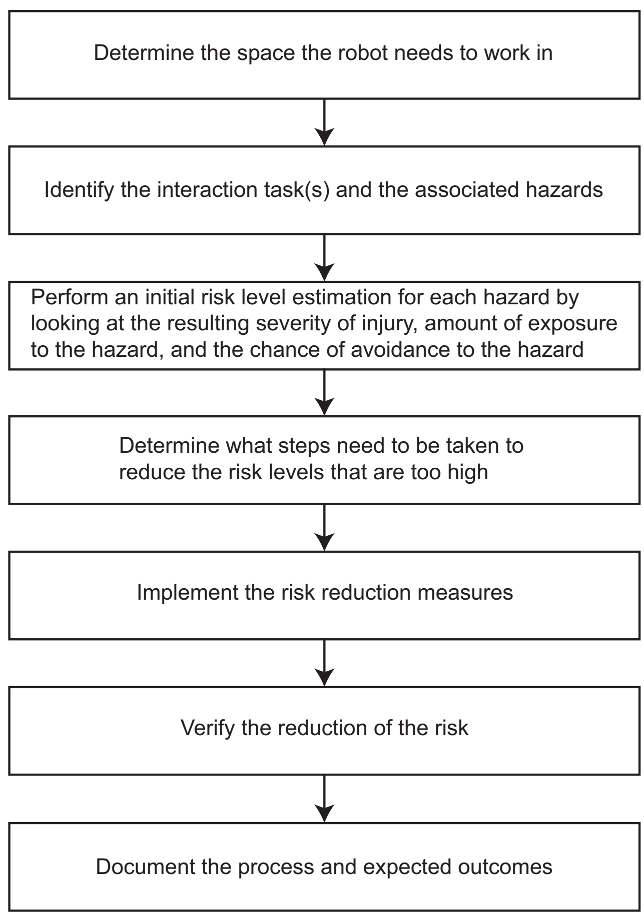
- 5.10.2 Safety Rated Monitored Stop – In the presence of an operator, motion is stopped. Drive power, however, remains on and motion resumes after the operator leaves the protected space.
- 5.10.3 Hand Guiding – While in automatic operation, the robot stops when the operator arrives (see 5.10.2). The operator grasps the enabling device allowing motion. Robot motion responds to the operator commands until the operator releases the enabling device. The non-collaborative operation resumes when the operator leaves the collaborative work space.
- 5.10.4 Speed and Separation Monitoring – The robot speed reduces when an operator is detected. Robot speed directly correlates to separation distance-zones dictate allowable speed. A robot stop condition is given if direct contact distance is achieved. There are specific calculations to determine the speed zones.
- 5.10.5 Power and Force Limiting – Accidental contacts initiated by the robot are limited in energy to avoid causing the operator harm. The forces the robot can exert are limited, the robot package design (including robot add-ons) eliminates pinch points, sharp edges, etc. The robot has to know contact has been made and react accordingly.

Based on the first three categories, standard industrial robots can be used with additional safety devices added to the robot cell, or additional safety monitoring of the robot in the form of separate safety processor of some form. The first three categories require more third-party equipment purchases beyond that of the robot itself. This will also require more integration time to make sure all the systems are installed safely.

In the last category, the robot must be designed to specifically monitor itself and limit the amount of energy transferred on a collision. This can be in the form of software force feedback controls or mechanical compliance built into the arm. It's this fourth category that is allowing a new wave of robots to come to the market at a reduced system cost to the end user.

Thinking through the Robotic Cell Safety

How do these collaborative scenarios that relate to the robot cell safety? Whenever a robotic cell (collaborative or not) is being conceived or designed, the system designer and end user have to think through all of the interaction tasks for that cell, the hazards associated with those tasks, and measures that have to be taken to reduce those hazards. This general thought process is called a *risk assessment* with a methodology defined in in Document ANSI/RIA TR R15.306-2016 Task Based Risk Assessment. An overview summary of this process might follow this thought path:



By old standards, the only way to make a robot safe was to put some form of guarding around it. If an operator wanted to enter the space, the safeguards would have to be removed bringing the machine to a stop in some form or another. With the new standards and new robots, the initial risks are much lower due to the control on the energy transferred and the slower speeds at which the robots are moving.

Safety of the New Collaborative Robots

New cobots on the market require a focus on the fourth category of the new safety specifications, Power and Force Limiting. A new technical specification (ISO TS 15066) has been created to help guide collaborative robot users in determining safe and unsafe forces for power and force limitations. The technical specification contains the calculations needed to determine the energy being transferred during a collision. The calculations are based on the mass and velocity at the point of impact of the robot arm or an object being carried by the robot. The technical specification also contains tables that define the limit of forces that can be applied to different areas of the bodies without causing harm. Having calculated the forces that will be applied based on the list of hazards, the operator can cross reference the table and determine what limits need to be set up in the robot controller system.

Testing the Universal Robot force settings

Of course, doing the calculations is not enough. Not only do the applied forces have to be determined, it is also necessary to verify that the forces at the point of impact, after the settings have been changed, are safe and acceptable. This may mean taking some form of force gauge and measuring the predicted points of impact. Once this has been verified, then it can be truly said the robot is safe. Although the new robots bring cost-saving benefits, additional time may be required for determining the safety of the system.

***Mike Garman** has worked in industrial automation for more than 20 years. He has extensive experience in the design and implementation of specialty automation systems along with strong robot programming capabilities. As a Senior Engineer, he supports advanced automation development projects at EWI's Buffalo Manufacturing Works facility in western New York.*