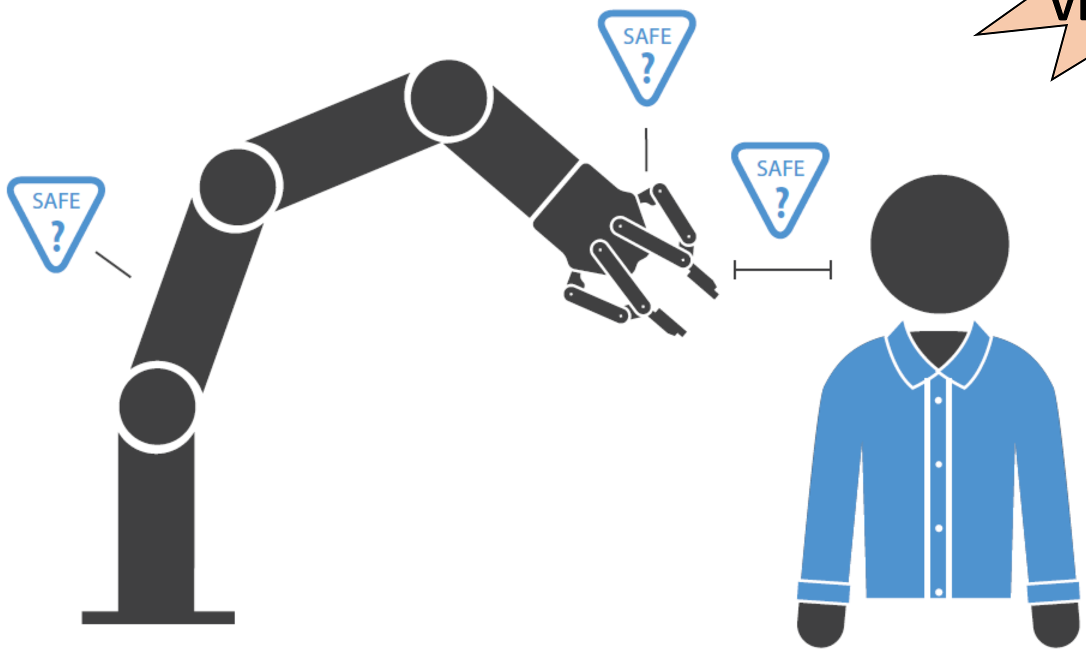
COLLABORATIVE ROBOTS

RISK ASSESSMENT, AN INTRODUCTION

UPDATED VERSION



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INTRODUCTION

A new kind of robot, called a ‘collaborative robot’, has made its way into the industry changing our preconceived ideas about robots and humans sharing a workspace. Having a robot to work safely alongside humans can improve the production flow, while allowing for the automation of new processes by using the best of robots and the best of humans. There is a lot of talk about these robots in the industry, but what are they really?

Robots without safety guarding? From the beginning of industrial robotic history, robots have been designed to be strong, powerful and enduring, they were designed to do heavy tasks and it wasn't a good idea to be in the path of this gigantic piece of steel. Collaborative robots are now designed to work alongside humans without any fencing. So what allows the robot manufacturer and robot integrator to introduce robots without this protection?

With all these new robots, technologies and the different standards concerning robotics, the recurrent theme is safety. To make a long story short, there is a certain very low level of acceptable risk which has been deemed acceptable when a robot is in the same environment as a worker. This level is set by different parameters related to the severity and the occurrence probability of injury for a human worker. The robotic system and its environment, must meet certain levels of safety, before it can be considered safe enough to be collaborative.

So, how to determine if a potential hazard exceeds acceptable standards for safety or not? Well the only way is to carry out a risk assessment. If you have been around the robotic world, you have no doubt heard the term “risk assessment”. In fact, even though this term is frequently used, what we have come to realize is that especially for people just coming into the robotic market, they may not have experience with this concept or may not fully understand its meaning or the purpose of a risk analysis. This is why we have put together this eBook, we hope that it will help you to better understand just what a risk assessment is. We will essentially focus on collaborative robots since they are becoming more and more popular.

But, please remember that we are not a risk assessment firm and that this information is provided as a guide and to instigate discussion. To perform a proper risk assessment you should validate and apply the regulations or standards for your particular region and company. For more relevant information specific to your particular situation you should contact your local robot integrator or industry association who should be able to direct you.

With the recent release of the technical specification ISO/TS 15066, an updated version of the ‘Risk Assessment for Collaborative Robots’ was required. Since certain previous parameters have been adjusted or new ones established based on this tech spec, this revision has incorporated this information. Still we must remember that safety requirements are a work in progress and periodic revision is a necessity.

SCOPE

The main focus of this eBook is to help you understand the nomenclature/vocabulary and give you tools to achieve a risk assessment for collaborative robots. However, to make things clearer, when most people are talking about 'collaborative robots', they mean force limited robots (See Section 2.4). As this kind of robot is becoming more popular and are marketed as being safe, it is important to recognize the substantial safety concerns that come with the introduction of these types of robots in a workshop. With this eBook, we want to give you tools that will help you to start to develop an internal knowledge of risk assessments in relation to force limited robots, so that you will feel more at ease when introducing them to your workshop.

With the introduction of tech spec ISO/TS 15066, a lot of data, calculations and methodologies have been developed to make sure your collaborative robot application is safe for use alongside humans. However, the technical specification has no effect on the certification of the robot and its application. This is why robot manufacturers will still use third parties to accredit their robots. This means that according to some designated external safety body, the robot under certain given conditions is certified as being safe as a tool. This does NOT means that the application will automatically be safe. So, this means that the application in its entirety requires a risk assessment. This is why you should build an internal knowledge in terms of safety, so you can use your past experiences to build a new risk assessment for any given situation.

1 WHAT IS A STANDARD?

Standards are guidelines that are determined by non-governmental organizations in the region where you are located, or if you are selling internationally in the region where your sales are located. One organization that manages standards is the International Organization for Standardization (ISO). This organization manages a huge quantity of norms that treat almost everything, from pharmaceuticals to robot safety. They provide guidance on the design, use or performance of materials, products, processes, services, systems or persons. Since the range of applications is very wide, here's a general definition that covers the entire literal meaning of "standard".

''A standard is a document outlining specific or minimum working conditions to be fulfilled, and its development is the result of a particular consensus or standardization effort.

If the standard has been consulted upon within the <according authorities> and forms part of collective agreements, it holds the title of "directive".

Safety standards are designed to provide measures which are considered necessary or appropriate for the prevention of accidents and injuries, and also for protection against exposure to unhealthy environmental or occupational factors.

Safety standards are developed with the intention of protecting personnel from the hazards of their employment, and are conceived so as to exercise the minimum restriction or interference with operations or levels of service.'' [1]

Standards ensure consistency of essential features for goods and services, such as quality, ecology, safety, economy, reliability, compatibility, interoperability, efficiency and effectiveness. So this is basically a guide that should be followed in order to produce things within the safety guidelines for a particular product or production process. However, a standard is not legally binding, though in reality they often have the effect of law. The fact is that even though standards are not laws, they can be used to complement laws and are often thereby incorporated into them. So if a governing organization is promulgating a law, it will probably refer to some standard, ISO or other, which is already established by world experts instead of reinventing a whole new standard. This might then unify different existing laws and reduce the complexity of the law, since it might refer to standards that are already being followed. You should notice that there could be organizations other than ISO that could provide standards relative to your robotic cell, like the International Electrotechnical Commission (IEC) that also establishes standards.

[1] Treasury Board of Canada, consulted on July 15th.

Here's a short list of some organizations that promulgate standards:

ISO: The International Organization for Standardization is an international standard setting body composed of representatives from various national standards organizations. The organization promotes worldwide proprietary, industrial and commercial standards.

OSHA: The Occupational Safety and Health Administration is an agency of the United States Department of Labor. Their mission is to "assure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance".

ANSI: The American National Standards Institute is a private non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the United States. The organization also coordinates U.S. standards with international standards so that American products can be used worldwide.

CSA: The Canadian Standards Association, a division of CSA Group, is a not-for-profit standards organization which develops standards in 57 areas. CSA publishes standards in print and electronic form and provides training and advisory services. CSA is composed of representatives from industry, government and consumer groups.

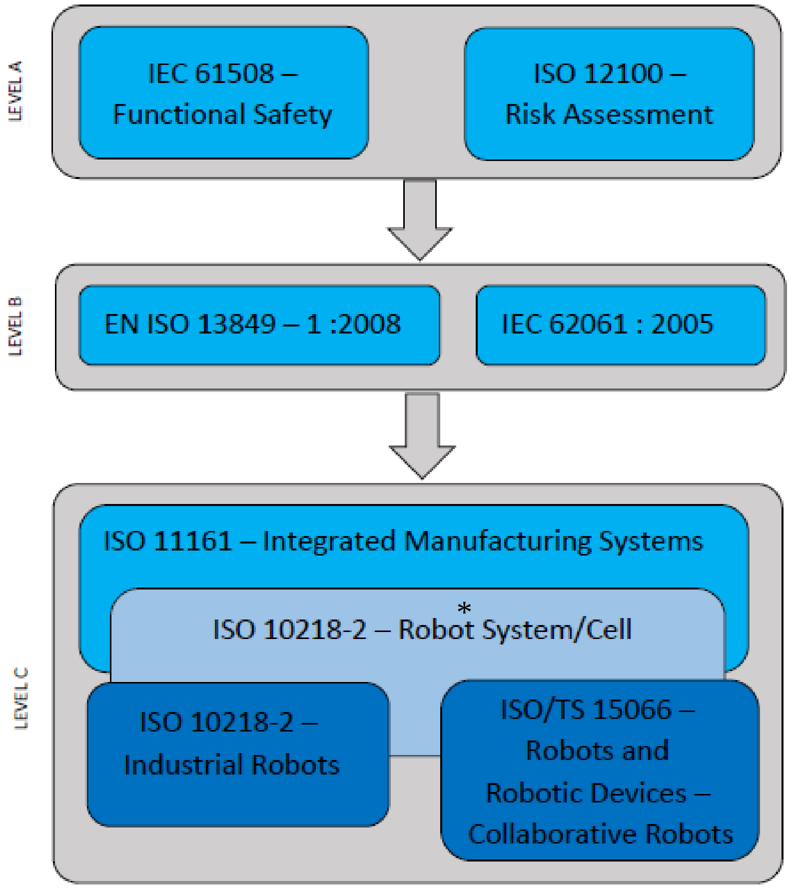
And the list goes on and on, each country or region can decide which standard it will use for its laws or regulations. However, other organizations, such as the *Conformité Européenne* (CE), apply directives for the whole European Union. This type of organization is not writing standards, but it is using them to provide legal guidelines to products that are manufactured or imported in European Union countries. Notice that the CE accreditation is done by the product manufacturer themselves.

1.2 How Does it Work?

ISO standards are constructed in a way so that the Top Level standard is the first reference. As you go down the standard level, you get to the most specific safety standard that applies (in this case) to robots or robotic devices.

Essentially, the A-level standards are the highest level standard. They apply to fundamental safety knowledge, basic design features and general machine aspects. The B-Level standards are more specific to particular devices that can be found on different types of machines. It is still a general standard, but it goes into specific safety features. C-Level standards are specific safety requirements for a specific kind of machine, a robot for example. As you go down the diagram illustrated in Table 1, you get more and more specialized or refined for your product or process. For example, *ISO 12100 - Safety of machinery* defines different basic concepts such as risk assessments and risk reduction for all types of machines. But, the *ISO 10218 – Robots and robotic devices* is written specifically in terms of robotics and uses robotic examples for detailing safety requirements for industrial robots. Both standards pretty much provide the same function, i.e. machine safety, but since *ISO 10218* is specific to robots, this is a more direct way to communicate. *ISO 13482* was issued in 2014 and is specific to Personal Care Robots which allows close human robot interaction and even human robot contact. This is another category altogether from those robots that are used in manufacturing products, but it is totally possible that the different categories will be blurred in functionality and practice.

Table 1: Standard Levels



The revised *ISO 10218 standard Parts 1 and 2* and the *ISO/TS 15066 Technical Specification*, define the safety requirements for the sphere of robots and especially collaborative robots. Besides the robot itself, the collaborative robot in this context includes its end effector; (i.e. the tool attached to the robot arm with which the robot performs tasks); the objects moved by it; its environment; and all its potential interactions. Close or direct contact between the collaborative robot and the operator gives rise by definition to the possibility of collision. The robot manufacturer's risk assessment must therefore also cover the intended industrial workplace. The basis for this risk assessment is *ISO 10218 Parts 1 and 2*, as well as the Machinery Directive.

1.1 What is a Technical Specification?

A Technical Specification represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 66% of the members of this committee. The content of the technical specification is a *normative document representing the technical consensus within an ISO committee* (source: ISO website).

In other words, this is a precision on an existing standard. In the case of collaborative robots, *ISO/TS 15066* was released to give further data and support for *ISO 10218* that did not have a lot of information directly relating to collaborative robots. It has the TS (Technical Specification) nomenclature because more application knowledge and data need to be analyzed before accrediting it as a standard, i.e. it is still a work in progress. Important data such as acceptable pain levels and body part inertia have to be considered in the design of any future standard to establish a force/energy/speed limit for collaborative robots.

Note also that *ISO/TS 15066* specifically clarifies the four different types of collaboration: Safety Monitored Stop, Hand Guiding, Speed & Separation Monitoring and Power & Force Limiting. As these different types of collaboration were already present in *ISO 10218*, the new tech spec clarifies points particularly concerning the maximum speed and the maximum pressure and force values allowable to achieve a safe human robot collaboration.

2. RISK ASSESSMENT

2.1 What is a risk assessment?

The literal definition of a risk assessment is: *The identification, evaluation and estimation of the levels of risk involved in a situation, their comparison against benchmarks or standards and the determination of an acceptable level of risk.* In the robotic world, a risk assessment is used to evaluate potential risks – and afterwards mitigate them to achieve acceptable levels – of potential risk of harm to a human worker during the operation of a robotic system.

To conform to the ISO standard, all machines must pass through a risk assessment in order to make sure it is safe. As cited in previous sections, some devices have already been approved by their manufacturers or a third party and this simplifies the risk assessment process since you don't have to verify the safety level of certain parts, the robot actuator, for example.

Photo Source [SME Robotics]

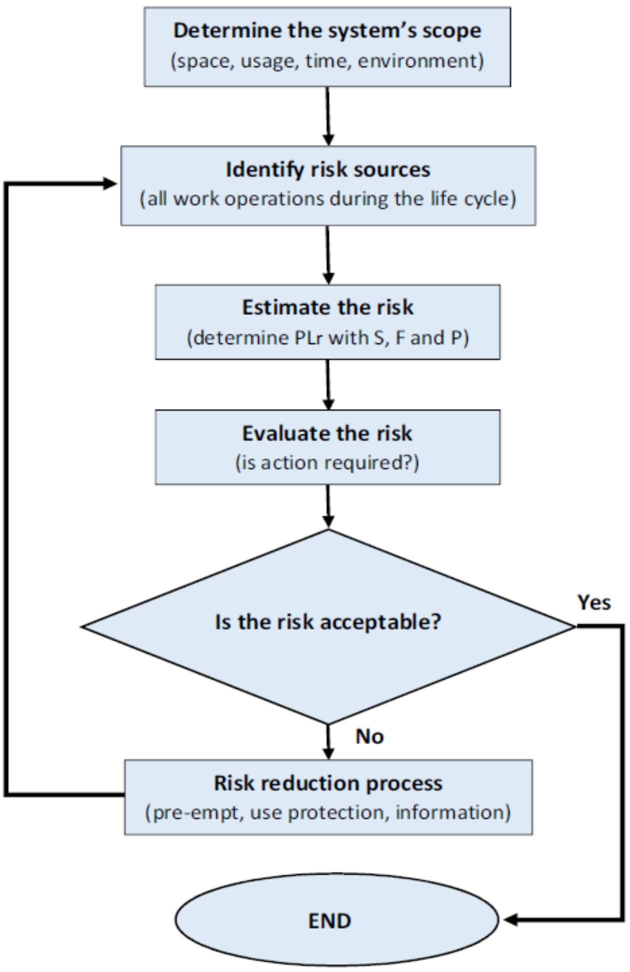
However, even if the robot's internal components and software have been certified, this doesn't mean it is safe relative to its surrounding environment. Especially in the case of industrial applications, usage is so varied that it is impossible for a part manufacturer to approve any given process. This is where the risk assessment comes into play. Another way to look at this is that you need to evaluate each industrial application as a whole and not each device separately. If you take the example of a sharp part or a knife being manipulated by a certified robot, this does not mean that the application is safe, even if each part is safe in and unto itself.

2.2 Why Do a Risk Assessment?

Ensuring your worker's safety is your responsibility. The risk assessment is a tool to achieve worker safety. In some areas of the world, local laws and regulations impose doing a risk assessment for any machinery installed on the factory floor. Not all governing regions will require you to respect standards, but most safety institutions will have laws incorporating or referring to safety standards. This also applies to large corporations that usually have their own safety guidelines. So you will most likely have to comply with some standard, ISO or other, when integrating and designing your robotic cell in order to respect the laws in your region and ensure worker safety. The risk assessment is then based on whatever standard you have chosen; either for your region or perhaps an even a higher standard to insure workplace safety at a global level. If you want to assure the safety of your robotic cell, you will need to perform tests and adjust your cell in accordance with all the points required by the standards you have chosen. You should also document your cell's performance in accordance with this standard. For more detailed and specific information, contact your local robot integrator or go to your local employee safety organization.

2.3 The Risk Assessment Process

As most devices that are used in robotic cells will already have a given performance level, the risk assessment for the end user or the integrator will mostly be about the application itself. To have an overview of the process of a risk assessment, check out the following diagram.



Determine Scope

This part of the risk assessment is a description of the context of the use of the machine. Where will the robot be used? Which tools will be used? What objects will be a part of the operation? You also need to list data such as maximum robot speed and acceleration, effective mass (robot payload), part weight, etc. This will give you all the necessary information that you will need further on in your risk assessment.

Identify Risk

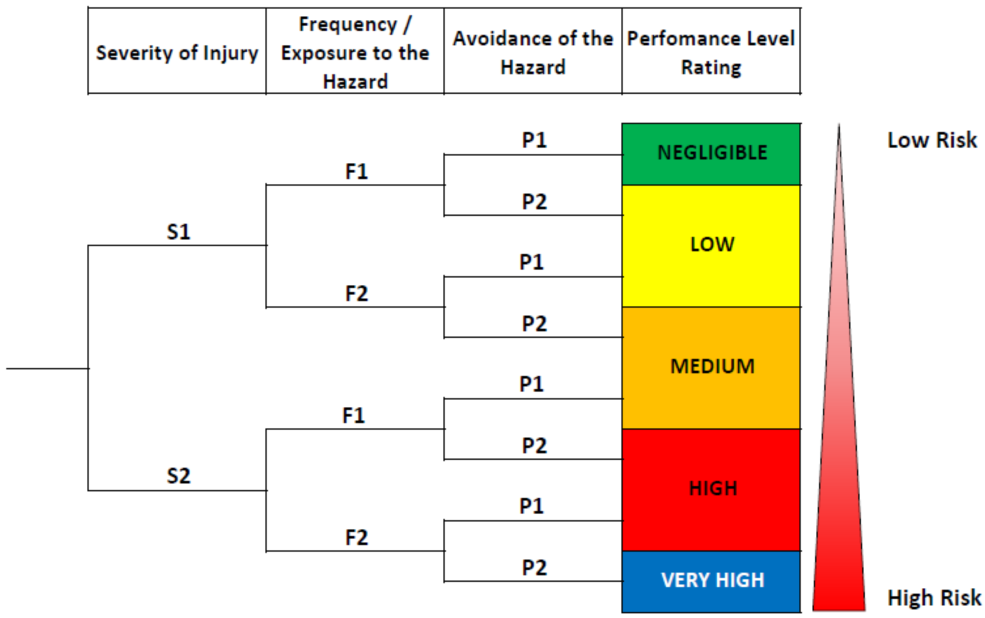
You then need to identify all the operations that involve any kind of danger. These operations include not only the robot operation, but everything from the moment the robot is delivered off the truck to the moment you decommission it. This part of the analysis might seem a little exaggerated, but it can also sometimes be underestimated. Earlier last year, the media was full of a tragic case where a robot crushed a worker to death during the installation process. So a risk assessment will analyze the different motions and actions of the robot throughout its lifespan and simply divide each operation for further analysis. This process is called task based risk assessment.

Estimate Risk

From the observations you have made during your risk identification analysis, you then need to rank the risk of given motions. There are various ways to monitor or rate a risk. To simplify the explanation, I will use the same example used in *ISO 13849-1: 2006*.

Risk is estimated using the Performance Level Rating (PLr) nomenclature. This analysis uses three different parameters: severity of injury (S), frequency of exposure to a hazard (F) and the possibility of avoiding the hazard (P). To simplify reading, I will use the S, F and P nomenclature.

So the basic way to estimate a risk would be to rate each parameter and go through a risk estimation tree to see what the risk level is. On the risk evaluation tree, the top case represents the lowest risk and the bottom case represents the highest risk.



To quantify the PLr, the following parameters have to be evaluated.

S: Severity of injury

- S1: Slight (normal reversible injury)
- S2: Serious (normally irreversible injury or death)

F: Frequency and/or exposure to hazard

- F1: Seldom to less often and/or exposure time is short
- F2: Frequent to continuous and/or exposure time is long

P: Possibility of avoiding hazard or limiting harm

- P1: Possible under specific conditions
- P2: Scarcely possible

Notice that some risk evaluation trees will have further choices to choose from. Some nomenclature will split the parameters into three or more different intensities instead of two. This will give a more precise estimation of the risk. In any case, the goal is to identify if the risk is too high for the robotic cell. Which brings us to the next step of the risk assessment: risk evaluation.

Evaluate Risk

What are the actions required to reduce the risk? Notice that there is a correspondence between the Performance Level Rating (PLr) and the overall Performance Level (PL) explained in section 2.1. To restate this, if you estimate that your cell or application has a high risk (PLr = high) you need to ensure that the safety features that will secure this application will have a Performance Level equal or greater than d (PL ≥ d). In this case d or e. This ensures that the risk will be monitored or secured by a device that will be able to accept the level of danger present.

PLr	PL
NEGLIGIBLE	a
LOW	b
MEDIUM	c
HIGH	d
VERY HIGH	e

Is This Acceptable?

The importance of this step is to ask the question: *Is this risk acceptable?* In most cases you want to be in the **low** to **negligible** category to make sure your employees are safe. If you are in this category, then you are done. If you are not, then further steps are required. So if your risk evaluation gives you a potentially high risk; you want to focus on these risks and reduce or eliminate them. As the risks are reduced, you need to go back up the risk identification chain for the risk assessment and complete the whole process again in order to make sure that the risk that has just been reduced does not create another risk.

Let's say you are integrating some guarding to prevent collisions, but this guarding increases the severity and the possibility of crushing an employee during maintenance operations, then you have to evaluate the configuration of this guarding and you may want to relocate or change the configuration of this guarding. Remember that after any change you have made to your application you need to reevaluate your application again.

Risk Reduction Process

As cited in the last section, you need to make sure the risk elimination, reduction or avoidance does not come into conflict with other aspects of the robot cell or does not create a bigger risk for the workers somewhere else in the robot cell application. This process is really iterative and needs to be done very carefully by considering and reconsidering each potential risk as you go back up the chain.

2.4 What is a Risk Assessment for Collaborative Applications?

There are four types of collaborative applications: safety monitored stops, hand guiding, speed & separation monitoring and power & force limiting. To make things clear, it is not because the robot is collaborative that the application is collaborative and vice versa. In fact, for many collaborative applications, regular (industrial) robots can be used (only if they meet Part 1 of *ISO-10218-1: 2011*).

Safety Monitored Stop

In other words, the robot stops when the operator enters the collaborative space. So let's say the robot is monitored by a laser scanner, safety switches or a vision system that detects the presence of a human, the system will then shut down all robot motion to make sure the human cannot be harmed. Notice that the robot is not completely shut down, in fact, it has simply stopped all its robot motors though it is still monitoring all their positions. In order to prevent an accident, a processor is analyzing if the robot is where it should be (Safety Level 3). This kind of collaboration can be used if the robot has to be in close proximity to a worker, for example if a robot has to lift something heavy and a worker has to do a second operation on the part. Notice that the robot is usually stopped before the operator enters the collaborative workspace.

Hand Guiding

In this case, the robot's motions are only possible using the direct input of the operator. So you literally teach the robot where to go. Notice that all robots using this kind of collaboration need a device that will allow it to sense the force exerted on the robot tool. Force torque sensors at the robot wrist or at the robot actuator can be used to achieve these applications.

Speed and Separation Monitoring

This type of collaboration is achieved when different safety zones are delimited in the robot working space. Certain zones will allow maximum speed for the robot though some zones will require lower speeds, because of the potential proximity of the worker. Other zones will stop the robot altogether, usually because the worker is very close to the robot. The monitoring of the safety zone is done by different monitoring systems mostly using vision. The safety zone can be of any size and geometry, the user will set different zones and will associate different acceleration and speed settings to these zones to make sure the worker will not be harmed by the robot under any conditions. This might occur in cases where collaboration between the human and the robot is not constant and where the robot will work most of the time at full speed, alone. Doing it this way can speed up the process and still allow worker robot collaboration. For example, in the case of machine tending, where bins have to be filled by a worker while the robot is still operating another machine.

Power and Force Limiting

By inherent design and control the robot is able to feel an abnormal force being exerted on its body. So in the case of contact, the robot only imparts limited static and dynamics forces. In other words, once it hits something the actuators and brakes act to provide less energy (inertia) in the direction of the impact. Some robots will simply stop and others will respond by moving in the opposite direction from the impact. These robots are used for a wide range of applications. This is where the name "collaborative robot" or "lightweight robot" comes from.

Here is a short list of power and force limited robots:

- ABB YUMI
- Kuka LBR IIWA
- Rethink Robotics Baxter
- Universal Robots

2.5 Collaborative robot risk assessment details

ISO/TS 15066 raises collaborative robot or cobot, for short, safety standards by emphasizing four different aspects of human robot collaboration. The distance which the robot will travel before the **robot stops** (specially used in speed and separation mode), the **allowable speed** which directly translates into the **force** and **pressure** that can applied on a human before feeling pain and/or harm occurs to a worker.

Distance Before a Complete Stop

This parameter is being used in speed and stop monitoring, for collaborative mode. The TS provides a complete calculation of the distance (and time) required for a robot to stop. This parameter has to be set and approved to limit the speed of the robot if it is working alongside humans. The calculation will include the different speeds involved (robot and human) and the distance separating them, as well as a couple of other parameters that will allow you to calculate the stop time, distance and speed required for the application.

Speed Conditions

This part of the TS is generally used for safety monitored stops. In fact, this part of the risk assessment will list the different conditions under which you can run the robot and at what speeds, as well as when it should stop. So in certain types of conditions you will be able to run the robot full speed and in other enumerated situations, the robot should slow or stop completely (though it can still remain powered).

Force

Since human robot collaboration most probably will include human robot contact, it is important to have data on what is the limit a robot can reach without harming humans. The tech spec uses a study which analyzed human pain levels and uses the different data of this study to establish acceptable force thresholds that a human can endure without permanent harm. The chart that was created lists all body parts and gives precise force thresholds that should not be contravened at any time during the collaborative operation. Note that this data is only valuable in the use of power and force limited robots. In fact industrial robots even when they are used in a collaborative operation should **never** come in contact with humans at their normal running speeds.

Pressure

Pressure is the force applied divided by the surface area of the part applying the pressure. As the robot can create certain forces on the human worker (uniquely in force and power limited applications) the pressure area might need to be enhanced to make sure that the robot does not overshoot acceptable pressure levels. This means that the surface area might need to be enhance and perhaps cushioned or made compliant to make sure too large an amount of pressure isn't applied.

Transient and Quasi-Static Forces

The new technical specification lists maximum forces (thus pressure) that should not be breached in the use of robots. However, there is a slight difference between a static and dynamic force. In fact, an impact is calculated by the relative speed of each object. If you are moving in the same direction as the robot, the impact won't be as strong as if the robot is running straight into you while you are standing still or while you are moving towards it. So here's a short definition of each type of contact.

- **Quasi-Static Contact:** This type of impact includes clamping or crushing situations in which a part of the body is trapped between a moving part of the robot and a fixed or moving part of the robot cell. In this precise situation, the robot will apply a force/pressure on the trapped body for an extended amount of time until the robot is removed. This type of contact requires a smaller force to reach the pain threshold.

- **Transient Contact:** This type of impact is referred to as 'dynamic impact' and describes a situation where the moving robot hits a human body part with the possibility to retract or recoil without clamping or trapping between the robot and the human body part. This type of impact is considered as being of short duration. A transient contact depends on the inertia of the robot, the inertia of the body part and the relative speed between them.

2.6 Who Should Perform the Risk Assessment?

There is no absolute answer to this question. In fact, end users can perform risk assessments in their own plant. However, integrators are used to doing these evaluations and are usually faster than having to learn the whole process from scratch. Integrators will have templates and will know exactly what to do first to reduce a risk at the design stage. Doing it yourself is still doable, but will involve more time. On the plus side, you will gain in-house knowledge on how to perform a risk assessment. On the down side, you will keep all the liability in-house as well.

3 MANUFACTURER CERTIFICATION

A risk assessment is required for the entire robotic cell. In this environment, the robot will be playing a major role, but all other devices will also be involved in the risk calculation. This is the reason why each manufacturer should provide a minimum certification for their product, so the end user does not have to repeat the entire risk assessment ad nauseam.

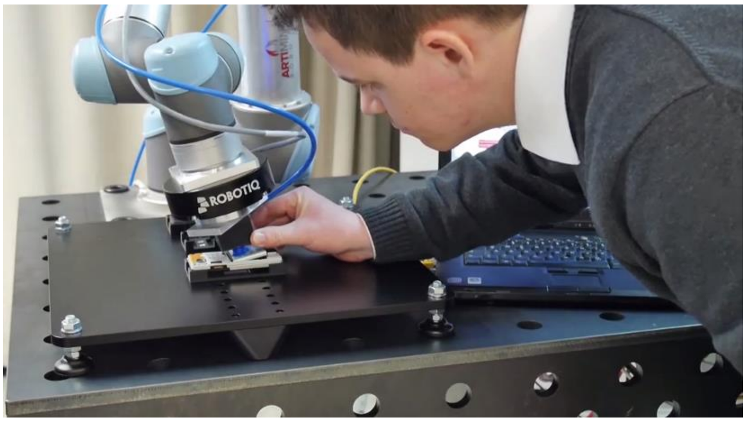


Photo Source [Artiminds]

Take the example of a toaster. It can be a slightly dangerous tool if not used in the right way. The toaster manufacturer needs to do the initial risk assessment to see what the potential dangers are relative to the use of the toaster. This is one of the reasons why the toaster comes with a bunch of caution messages such as: "Do not operate the toaster in a heated oven or microwave". It sounds quite intuitive, but the manufacturer has identified this as a potential danger while doing its risk assessment and thus gives a general warning to the user so s/he is aware of this potential danger.

Manufacturers selling in European countries will have to respect the CE requirements. These requirements are certified by the manufacturer itself and not by a third party. These standards are the minimum to be used in European countries. However, if you want your product to respect a given standard you may want to use a third party to approve your product.

The case of Bosch's collaborative robot, APAS is a great example of third party accreditation. In fact, before its release the robot was certified by the German Employers' Liability Insurance Association as being "inherently safe" for use in human robot collaboration. Since this organization probably applied the most severe standards in terms of safety, Bosch ensured it would have top level and credible safety certification for its robot. It can then be used in different countries, though it must still be approved by the local norms, which it will no doubt meet. In other words the manufacturer made sure its robot was certified by the toughest certification on the market to make sure it can be approved as "safe" everywhere else.

3.1 Performance Requirements

If we go into deeper detail on what is considered as acceptably safe in a robotic cell, we have to refer to section *5.4.2 Performance requirement* of *ISO 10218-1:2011* which states:

Safety related parts of control systems shall be designed so that they comply with PL ''d'' with structure category 3 as described in ISO 13849-1:2006 (Safety of machinery) ...

This means in particular:

a) A single fault in any of these parts does not lead to the loss of the safety function;
b) Whenever reasonably practicable, the single fault shall be detected at or before the next demand upon the safety function;
c) When the single fault occurs, the safety function is always performed and a safe state shall

be maintained until the detected fault is corrected; and

d) All reasonably foreseeable faults shall be detected.

So, what does this really mean? Well, in order to respect the ISO standards, all equipment or machinery must respect a certain level of safety. This level, the Performance Level, is set with regards to the probability of failure for the equipment being tested. Table 2 describes the different performance levels set out in *ISO 13849-1.*

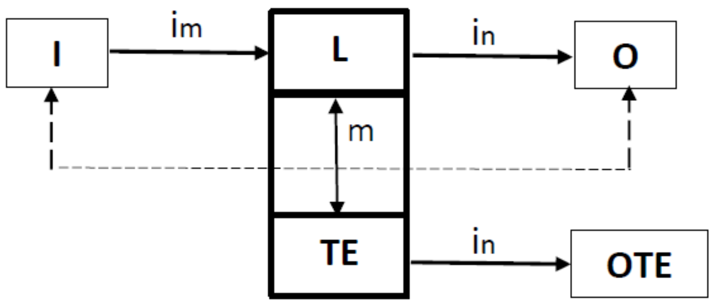
Table 2: Performance Level (PL)

PL	Mean Time to Dangerous Failure per hour 1/h
a	$\geq 10^{-5}\ to\ < 10^{-4}$
b	$\geq 3x10^{-6}\ to\ < 10^{-5}$
c	$\geq 10^{-6}\ to\ < 3x10^{-6}$
d	$\geq 10^{-7}\ to < 10^{-6}$
e	$\geq 10^{-8}\ to\ < 10^{-7}$

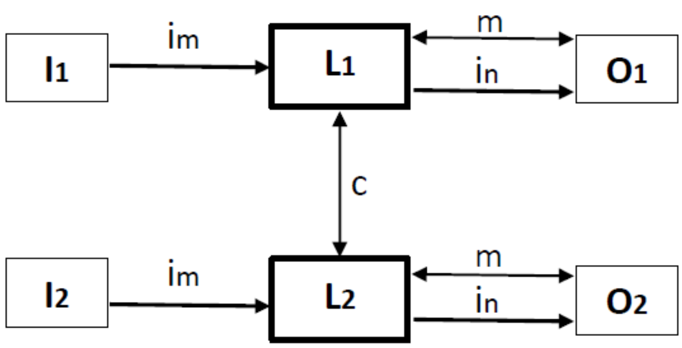
The structural category depends on the amount of redundancy that your device uses. To put this another way, if you have a single channel hardware (encoder, for example) you will have a lower level of redundancy than a system that is using double encoders that double check each other to ensure the position of the robot is right where it should be. The following diagram demonstrates the different category levels.

Category 1

Category 2



Category 3-4



Without going into complete detail regarding the diagram, Category 1 would include a simple single channel safety hardware. So for example, a switch (input or **I**) that is turned off will be treated by the Logical device (**L**) and will result in a stop (output or **O**).

A Category 2 device will include a second device (TE or Test Equipment) that will always verify the validity of the input and output (OTE Test Equipment Output) for the main system and will react when a failure occurs. Let’s say, a device with an emergency stop can be considered as a Category 2 safety device.

A Category 3 or 4 device incorporates two parallel devices that will act independently, but will always double check each other to make sure they have the same signal. This way, a single fault can occur and the second channel will still be able to see that there is a fault. This ensures that the system can still read a defect if a channel has failed.

So as you may have seen the different nomenclature elsewhere, PL=d category 3; you now know what it all means. Most safety devices (Safety relays, key switches, estops, etc.) will be rated in this nomenclature. As mentioned before, all devices that will be involved in the collaborative robot cell must be rated at least PL=d category 3 to respect the ISO standards.

CONCLUSION

The risk assessment process is designed to protect workers who are using industrial machinery. In the case of robotics, it is implemented to make sure robotic cell users are safe while performing an operation with the robot and its accessories. Risk assessments are also implemented to standardize robot integration and to make sure a certain level of safety is reached by the robotic cell. But the risk assessment process should also be done in accordance with the laws and legislation applicable where the cell is integrated.

Even if the robot and robotic device manufacturers have established safety requirements (*PL=d category 3*) for their devices, **there is still a big part of the risk assessment process that has to be done by considering the application and the environment itself**. Collaborative applications have to be taken very seriously since direct or close contact occurs between robots and humans.

Finally, remember that we are not a risk assessment firm and that this information is provided as a guide and to initiate discussion. For more relevant information specific to your particular situation you should contact your local robot integrator who can point you in the right direction.

RESOURCE CENTER

Here are some of the links and references that have been used in this document, as some information in this eBook has been taken from various standards and private documents, only the public references are listed below.

- **Industrial Safety Requirement for Collaborative Robots and Application, ABB, Consulted August 2015**
- **ISO website, Consulted August 2015**
- **Robotic Industries Association website, Consulted August 2015**
- **Universal Robots Safety Guide, Zacobria, Consulted August 2015**
- **Universal Robots Zarcobia Risk Assesment, Zacobria, Consulted August 2015**

ABOUT ROBOTIQ

Robotiq exists to free human hands from tedious jobs. The fast-growing company designs and manufactures advanced robot grippers and a force torque sensor. Robotiq is based in Quebec City, Canada. It works with a global network of highly capable local partners to solve flexible automation challenges in more than 30 countries.

LET'S KEEP IN TOUCH

For any questions concerning robotic and automated handling or if you want to learn more about the advantages of using flexible electric handling tools, contact us.

Robotiq's Blog

Robotiq's Facebook page

LinkedIn Page

Robotiq TV

Robotiq's Google+ Page

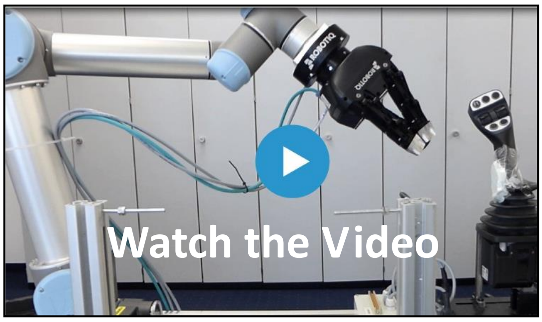
Robotiq's Twitter Account

Popular Applications

Machine Tending

Use a **single, programmable,** [flexible robot gripper] to handle a wide variety of parts in your machine tending applications. **Reduce your tooling cost** and **eliminate changeovers** by using a single Gripper.

Product Testing



Implement a **flexible** production line testing application that uses an easy to integrate [Adaptive Gripper] designed to control grip force and be able to adapt to various geometries.

Other Interesting eBooks

[Getting Started with Collaborative Robots]

[Collaborative robots in global companies]