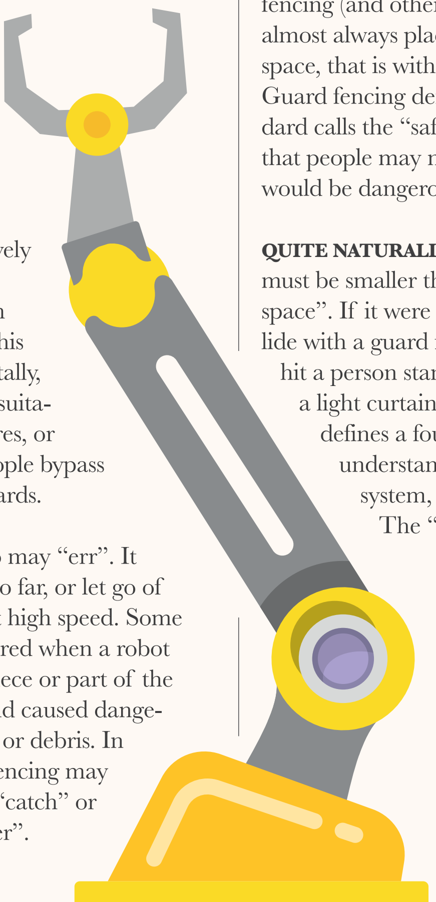
KEEPING PEOPLE OUT OR ROBOTS IN?

"Are your fences robot-proof?" Many have asked that question during the last three to five years. A little daringly the answer could be a counterquestion, "Do they have to be?" Almost everyone appears to think so; but as is so often the case, the answer should depend on the circumstances.

Three aspects should be considered:
- Will the guard fencing, housings and other objects be placed within the robot's reach?
- How big and fast is the robot?
- Does the robot feature a safe robot control system or other motion range limiting devices?

And a fourth question may also be asked, although it is a little bit of a hubris:
- What bearing does the robot accident history have on the issue?

LET'S ADDRESS THAT question first. In the relatively short history of industrial robots, guard fencing was primarily – if not exclusively – considered a means to keep people out of the hazard zone. And rightly so. The accident history of robots shows that people are hit or otherwise injured by robots almost exclusively when they enter the hazard zone, in which the robot operates. This occurs either accidentally, because there are no suitable protection measures, or deliberately when people bypass or manipulate safeguards.



BUT THE ROBOT also may "err". It may move too fast, too far, or let go of a workpiece or tool at high speed. Some robot accidents occurred when a robot crashed into a workpiece or part of the machinery around and caused dangerous ejection of parts or debris. In all such cases guard fencing may theoretically act as a "catch" or even as a "robot tamer".

WHAT DO STANDARDS SAY?

Already the first European robot safety standard EN 775, published in 1992, mentioned the need to limit the motion range of robots. However, it did not contain clear information on how to achieve that. The same is true of the American robot safety standard, ANSI RIA 15.06. Then, in 2006, an international standard on robot safety was first published, ISO 10218-1. The current version is from 2011 and a part 2 for integration of robots into manufacturing systems was added in the same year (ISO 10218-2).

Chapter 5.4 of ISO 10218-2 makes a difference between the so called "maximum space", that is the motion range of the robot, and its "operating space", that is the space actually used by the robot when operating. Often the "maximum space" is much bigger than needed for the application. A system designer, however, wants to use as little floor space as possible for his application. Consequently, guard fencing (and other safety equipment) is almost always placed inside the maximum space, that is within the reach of the robot. Guard fencing demarcates what the standard calls the "safeguarded space", an area that people may not enter, because that would be dangerous.

QUITE NATURALLY, the "operating space" must be smaller than the "safeguarded space". If it were not, the robot could collide with a guard fence during operation or hit a person standing directly in front of a light curtain. Therefore, the standard defines a fourth term one needs to understand to design a safe robot system, the "restricted space". The "restricted space" is larger than the "operating space" and smaller than the "safeguarded space". It serves to ensure that a safety distance will always remain between the safeguard and the operating space. Why is that needed? For two reasons: (1) the robot needs time to slow down and come to a standstill when a person entering the protected space is detected (by a light-barrier, scanner, camera, or door switch). (2) When the "safeguarded space" is formed by fencing, which is still the most frequent safety measure, a person can stick his fingers through the wire-mesh and could get hurt if the robot would come very close to the fence. Depending on the mesh pitch a distance of 120 to 200 mm is required to prevent injury to fingers (see ISO 13857, Table 4). Did you get lost between all the "spaces" mentioned? Then see the box and illustration below for clarification.

> Safety is more important than efficiency!

ISO 10218-2 CLEARLY requires limiting the motion range of a robot for safety. How? By any of the following measures:
- Space limiting or hard stops (stopper blocks and pins)
- External limiting devices (mechanical or proximity switches)
- Safety-related software control of the motion (meeting at least PL = d to ISO 13849-1)

Interestingly, the standard rules out using fence to define the "restricted space". ISO 10218-2 says: "Using a perimeter guard as a limiting device is normally practicable only when robots cannot cause hazardous deformation of the guard" (quote of Note 4 in section 5.4.4). However, a robot colliding with the fence at high speed and force will cause at least *some* deformation, even to a strong fence. This might be hazardous. Also, as noted above, people can stick their fingers through fences. Another note in the standard has a bearing on this. It reads: "The restricted space is defined where the robot motion actually stops, not by where a stop is initiated" (quoted from Note 2 in section 5.4.4). Thus, a robot application allowing the robot to theoretically hit the fence is not allowed. A stop command to the robot would have to be issued early enough to prevent the robot from colliding with the guard. "Robot-proof" fencing thus is both an illusion and a misconception at the same time.

EXCEPTIONS TO THE RULE

There are "BUTs", however:

- But what if space is very scarce and the robot must move fast to meet tight cycling times? Then it might not be possible to limit its motion so it stops before hitting the fence. At least it might not stop 120 to 200 mm before crashing into the fence. What to do?
- But what if the robot could simply let go of a workpiece or tool at high speed? Would not the guard fence need to hold back the stray part?
- But what if the robot and control system are rather old and do not offer safe robot motion control?

All these cases may require using guard fencing that is strong enough to hold back the robot or a stray part. In many cases additional safety measures will be needed, such as:

- Reinforcing the fence with additional parts
- Metal or polycarbonate panelling holding back objects that could pass a wire mesh
- Light curtains, laser scanners or other sensing equipment inside the "safeguarded space" detecting a robot coming to close to the fence (usually this will only be needed to retrofit older robot installations that do not feature a safety-related robot control system)

HOWEVER, THE SITUATION and its specific hazards should be studied in a risk assessment. This would include calculating the expected impact energy from the mass moving multiplied by the square of the speed, devided by two [(m x v^2)/2]. Based on the results of the risk assessment and impact energy calculations one should then select the required additional measures. In most cases today, it will be possible to limit robot motion safely by means of a two-channel (redundant) motion control system. Loss of workpieces and tools can be prevented by grippers that positively lock the part handled instead of relying on friction or clamping force only. In some cases, there may be no other choice than to reduce the motion speed of the robot and live with a longer cycling time. Remember: Safety is more important than efficiency!

WHAT FENCES CAN'T DO

Some manufacturers may claim that their fences are "robot proof". This is easy to understand, because customers may ask for just that. However, such claims may rightfully be doubted. Since no two robot applications are the same, it is not likely that one specific guard fencing product can meet the requirements in each case. With a very big and fast robot, the impact energy may well rise beyond 5000 Joules. That is equivalent to a Volkswagen Golf hitting a fence at about 20 km/h. A standardised fencing product will hardly be able to withstand such impact.

AXELENT, THEREFORE, DOES not claim that our products withstand any and all types of impact. Our tests prove our products to be safe and reliable in the field of small to medium sized or relatively "normal" robot applications with maximum impact energies of about 1200 to 1600 Joules. Where that is not enough, the stronger 70x70 mm posts and special reinforcement fixings for the panels can be used to increase the impact resistance to 2000 Joules or more.

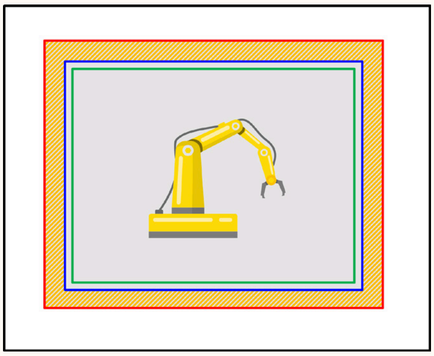
Selecting the right guard fencing solution should begin with a careful risk analysis. What type of hazards must realistically be expected? Can workpieces get lost? If so, will they just drop to the floor inside the hazard zone or might they be "ejected"? How big and heavy will such ejected objects be? Where might they be expelled and where would they hit parts of the system or the guard fencing? The answers to these questions will help look for measures preventing the ejection itself.

Where such measures are not feasible, "flying objects" may have to be held back. But that, too, may not be needed around the entire hazard zone or in the entire system, but just in particular spots. Probing deeper and answering the above questions carefully, will help find the right solution and save money, too.

However, one should understand, that principally guard fencing is not meant to hold back stray robots. ISO 10218-2 clearly shows that other measures shall be taken to restrict robot motion. Machinery and system design that relies on guard fencing as a "catch all" is faulty design.

THE FASTER AND stronger the robot, the less you should rely on guard fencing to keep it in check. It simply is a faulty approach to robot safety, no matter how strong the fence is. Guard fencing is primarily meant to keep people **out**, not the robot **in**.

** The translation of quotations is ours and may slightly differ from the original text in the respective language.*



- **Maximum space****
Entire space a robot can access while moving (motion range)
- **Safeguarded space***
Space defined by the perimeter safeguarding (that is "guard fencing" and other devices for protection)
- **Safety distance**
- **Restricted space***
Portion of the maximum space restricted by limiting devices that establish limits which will not be exceeded
- **Operating space***
Portion of the restricted space that is actually used while performing all motions commanded by the task programme

**Source: ISO 10218-2*
***Not defined in the standard, definition ours*

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