**Timo Malm*, Timo Salmi, Ilari Marstio, Iina Aaltonen**

# Are collaborative robots safe?

**Keywords:** functional safety, collaborative robots, safety requirements, levels of collaboration

***Corresponding Author: Timo Malm:** VTT,
P.O. Box 1300, FI-33101 Tampere, Finland
E-mail: timo.malm@vtt.fi

**Timo Salmi**, VTT
E-mail: timo.salmi@vtt.fi

**Ilari Marstio**, VTT
E-mail: ilari.marstio@vtt.fi

**Iina Aaltonen**, VTT
E-mail: iina.aaltonen@vtt.fi

**Extended abstract:**

Collaborative robots (cobots) have been under discussion for some years. They have properties, which make it possible for humans to work safely beside them. Cobots are expected to open up new possibilities for flexibility, productivity and user friendliness. Also, fenceless production cells are often mentioned. Collaborative robots are typically small and their reach is usually below 1.3 m and due to the size, their applications are often related to handling of small size objects. However, new applications are expected to appear.

The text shows safety design process for collaborative robots, which helps to find safety limits for the collaborative application.

One advantage of the collaborative robots is that, usually, they are easier to program and the robot workspace does not have as many objects as the workspace of an industrial robot. On the other hand, collaborative robots are used in applications, which change more often than industrial robot applications. Continuous changes make it challenging to maintain adequate level of safety. Quite often people feel that risk assessment is more difficult to make for cobots than for industrial robots, since cobots can be working beside persons.

Most of the collaborative robots are designed according to inherently safe principles i.e. they are small and power is limited. The collaborative robots are controlled and monitored so that they should not exceed the defined force, speed and area limits. The collaborative operations must apply at least one of the means: safety-rated monitored stop, hand-guiding, speed and separation monitoring or power and force limiting by inherent design or control. In old robot safety standard (ISO 10218-1:2006) there has been a general force limit (150 N), but now the limit is specific for each body part of the human according to ISO TS 15066. The power and force limiting, brings new kind of thinking, since the contact is now a designed feature and not just a rare mishap. The designer needs to estimate, which body parts can be exposed to an impact of the robot and then limit forces accordingly. One special problem with robots is that the impact (clamping) phenomenon is complex to estimate due to typically six different actuators and brakes, multitude of possible directions and locations to contact, variant loads, various speeds and multitude of cobot control parameters. Measurements at VTT with three different cobots showed that the impact forces are difficult to predict without measurements.

*Figure. An example of safety measures.*

One issue is that according to ISO 10218-2 section 5.2.2 safety related parts of the robots must comply with PL d and Cat 3 requirements of ISO 13849-1. This is related, among others, to stop, speed, area, power and

force limiting and control. Many of the current robots do not comply with the requirements and therefore one have to consider, can e.g. a speed limit be applied to guarantee safety.

One obvious issue are the applied tools. Sharp tool is usually dangerous and the robot work area may have corners or other machines, which cause potential hazard if human body part is crushed against it. In addition, grippers may be hazardous, but there are also models, which take into account the human presence.

In addition, the level of collaboration affect the risks that the worker is exposed. The levels of collaboration can be defined as follows: no coexistence, coexistence, cooperation and collaboration. The level of risk depends on the level of collaboration, due to the exposure time and separation distance. If humans and the robot are usually not at the work area at the same time (no coexistence or coexistence), the risk for a person is not so high since the person is not exposed to danger. Typically, the risk is higher when collaboration level is high and due to collaboration, the person is working at the robot.

VTT is developing in the Business Finland funded NxtGenRob project the optimum ways to utilize next generation robotics in Finnish industry by developing solution models, design practices and (by evaluating) demonstrations from different perspectives.