VDMA-Position Paper

“Safety in Human-Robot Collaboration”
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1 Introduction

Possible collaboration of humans and robots in shared workplaces without perimeter guarding opens up new possibilities and concepts in industry and production. The standardisation and legal situation allows for human-robot collaboration (HRC) within defined limits.

This document provides guidance for manufacturers, distributors and integrators and explains relevant rules and standards. This document and the standards mentioned therein serve to provide information for end customers (operators). The papers focuses on the last of the collaboration types described in the related standards (safety-rated monitored stop, hand guiding, speed and separation monitoring, power and force limiting).

To implement such workplaces it is necessary to study the Machine Directive (law) and standards thoroughly. A risk assessment must be done for each individual application. This position paper was elaborated by member companies of the VDMA Robotics group in cooperation with the Scientific Society for Assembly, Handling and Industrial Robotics (MHI e.V.).

2 Basics of Human-Robot Collaboration (HRC)

In robotics, the term "collaboration" (lat. con- = "with", laborare = "work") refers to cooperation between humans and robots. This cooperation is limited to a precisely defined collaborative workspace.

Hereinafter, the four different basic safety principles applicable in HRC are explained:

1. Safety-rated monitored stop
   Robot stops when operator enters the collaborative workspace and continues when the operator has left the collaborative workspace.

2. Hand guiding
   Robot movements are controlled by the operator.

3. Speed and separation monitoring
   Contact between operator and moving robot is prevented by the robot.

4. Power and force limiting
   Contact forces between operator and robot are technically limited to a safe level.

These four basic principles of protection in HRC are described in detail in the standard EN ISO 10218 "Robots and robotic devices - Safety requirements for industrial robots", Parts 1 [1] and 2 [2].

Legal note

The position paper serves as a guideline and provides an overview of relevant standards, laws and requirements regarding the safety in the collaboration between humans and industrial robots to the manufacturers of robot systems.

It does not claim completeness or provide an exact interpretation of the existing statutory provisions.

Other constellations are conceivable.

Neither does it replace the study of relevant guidelines, laws and regulations. In addition, the specifics of the respective products and their different fields of application have to be considered.
In all cases involving HRC, protection of the human must be ensured by safety measures. The technology used must meet certain safety requirements. According to the risk assessment the essential safety and health requirements are determined and corresponding measures are taken.

3 Machinery Directive

The Machinery Directive (2006/42/EG) [3] issued by the European Parliament provides for a uniform protection level of safety and health protection for machines which are brought into circulation within the European Economic Area (EEA). Each EU member must transpose the Machine Directive into national law. In Germany, this is done by the “Produktsicherheitsgesetz” (“product safety law”).

By the EC-Declaration of Conformity, manufacturers or EU importers (normally the system integrator) declare that the product meets the requirements as defined in Community harmonisation legislation. Then, a CE mark is issued.

One of the most important prerequisites for CE marking of a (complete) machine, i.e. of the robot application as a whole, is a risk assessment and the implementation of the resulting safety measures. These steps are described in [2]. Underlying fundamentals are detailed in [4]. If risk-reduction is done by control system, the requirements described in [2] and [5] must be met. In the sense of the Machinery Directive, industrial robots are so-called “partly completed machinery” and do not obtain CE marking; they must be supplied with a so-called “Declaration of Incorporation”.

4 Risk Assessment

The first step is always to precisely specify the application including all boundary conditions and components. Risk assessment must then define the necessary technical safety requirements. It determines whether a risk minimisation is required and whether hazards must be eliminated or reduced by protective measures. An example for such a measure in the context of a robot system would be safe reduced speed in combination with a safe collision detection. Only if the final risk assessment confirms that an acceptable safety level has been reached a CE mark can be issued.

Risk assessment must take into account the various aspects regarding the HRC. This must include the so-called “intended use” as well as “foreseeable misuse” by persons within reach of collaborative robots.

The procedure of assessing the application as well as the description of safety related requirements are described in detail in the standard EN ISO 10218 parts 1 and 2 [1][2]. The missing threshold values for contacts between humans and robots are currently being drawn up in ISO/TS 15066 (expected completion: end of 2014). At present the BG/BGIA recommendation for risk assessment according to the Machinery Directive [6] is a suitable guideline.
The main risk situations to be considered and relating prevention of hazards to humans caused by robots:

Contacts between robots and humans

**Transient contact**
- Free, non-clamping contact possibly at higher speeds
- Limited speed depending on body region, mass and shape of robot, tool and workpiece
- Fast, reliable collision recognition to avoid “post pushing”

**Quasi-static contact**
- Low speeds in areas where clamping is possible
- Limited contact force depending on body region and shape of robot, tool and workpiece
- Force limits must not be exceeded

Speed and force limiting must be implemented in safe technology

**Conclusion**
- Without risk assessment human-robot collaboration cannot take place.
- The overall application must always be considered (process, fixtures, gripper technology, robot), i.e. not only the robot.
- Safety functions must be implemented using suitable components in accordance to determined requirements.

5 How do standards help?

In order to meet the Machinery Directive, manufacturers, distributors, integrators and end users can apply the relevant harmonised European standards [1][2][4][5].

Observing the standards leads to the so-called “presumption of conformity” this means, if the standard is fulfilled, compliance with the Machinery Directive can be “presumed” and does not have to be verified individually. Not using the normative technical safety requirements result in the obligation to provide evidence that the complete system achieves an equivalent or higher safety level.

Standards must be applied in their current versions. Thus, for example, a maximum power of 80W or a contact force of 150N stated in EN ISO 10218-1:2006 are no longer valid.

As harmonised European standards are frequently based on the international standards of ISO or IEC or are direct adaptations of these, the advantage of compliance to these standards when constructing robots or designing applications is that conforming solutions can also be offered beyond European borders.
6 Technical Safety Requirements

To avoid hazards to humans also in case of a system fault, control-relevant measures for maintaining limit values are required to be implemented safety-rated. The term “safety-rated” is described in ISO 13849-1 [5] by means of categories and performance levels and must be applied to all safety-relevant components.

In the robot safety standard ISO 10218-1 [1], the safety functions of the robot controller are defined as category “3” and the performance level as “d” unless risk assessment requests a higher or lower level.

Category 3 means a cross monitoring, dual-channel system. It is not sufficient, however, e.g. to use two identical components. The performance level (PL) determines, besides others, the required failure probability / reliability.

Risk assessment of a specific complete application results in the required performance level. The system integrator is responsible that all applied safety functions (e.g. monitoring of the robot speed and contact force) meet this required performance level, before the application is put into operation. When selecting the robot and other components, it must be confirmed that the required safety functions are provided with the required performance level.

It should be explicitly noted that the manufacturer of a particular system or application is responsible for compliance to safety requirements (self-certification). He can be consulted and supported from external experts. This applies also for robots and their manufacturers – self-certification for the implemented safety functions is to be done.

7 References
