SAFE HRC SYSTEMS
HUMAN ROBOT INTERACTION FOR STARTERS

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Productmanagement „Industrial Safety & Motion Control Sensors“
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REMARKS TO THIS WEBINAR

- This webinar will be recorded!

- If you would like to receive the **presentation** and / or the **recording** afterwards, we ask for your **consent in accordance with the GDPR**!

https://s.sick.com/newsletter_registration_at-de
AGENDA / CONTENT

- Marketoverview Robotic
- Terminology
- Trends to HRC
- Standards
- Possible HRC Interactions
- Safety Distances
- Information to ISO/TS 15066
- Technical Execution
- Riskassessment
Market potential for collaborative Robots (global)

Productivity Growth by application of Robots

Manual: High flexibility with limited productivity (and quality)

Automated: High productivity and quality with limited flexibility

HRC: High flexibility and high productivity

Source: Daimler
Robot Market
Figures & Facts

High strategic importance

- Currently more than 2 million robots installed worldwide
- Expectations are more than 14% annual average growth from 2020 onwards, by 400,000 units

Industries

Main drivers:

- Automotive- und Electronicindustrie
  - Mainly handling and assembly
- Consumer Goods
  - Handling / Palletizing
- Machinebuilding
  - Handling and assembly

*IFR statistical department, world robotics 2018
Market potential for collaborative Robots (global)

Industries: Automotive, Machinebuilding, Electronic, Customer Goods and Logistic applications

Future collaborative Market (ABI Research)
Definition according to ISO 8373:

- Industry Robot = Manipulator
  - automatically controlled
  - programable
  - 3 or more axis
  - versatilely and universally applicable
  - stationary or mobile applications
  - designed, to be used in industrial automation applications
(Industrial) Robot-Systems consist of:

- Robot Systems consist of:
  - Robot Controller
  - Safety Equipment
  - Incomplete Machine
  - End-Effector (e.g., gripper), holder, tools, workpiece
TARGET

is, to combine the strengths of humans and robots together

**HUMAN ROBOT INTERACTION**

Detection of deviations from the working process

Sensitive recognition

Fine motor skills

Power of abstraction (reaction to unforeseeable circumstances)

Human – Robot – Collaboration

Speed

Force

Performance capabilities

Repeatability
What differentiates HRC applications from “classic” (standard) robot applications?

**HRC applications place new demands on security:**

**Essential Differentiations:**

- Collisions between robots and humans are allowed
- However, they must not lead to any injuries

**Preconditions therefore are:**

- The robots used must be enabled by suitable measures to either detect the collision beforehand or at the latest when it comes into contact with humans and to initiate safety measures.
OVERVIEW ON TODAY'S APPLICATION SCENARIOS

DIFFERENTIATION BY APPLICATION SCENARIOS

Realization with standard industrial robots, as well as with COBOTS

Realization only with COBOTS

COEXISTENCE

COOPERATION

COLLABORATION

w/o contact

with contact
WHICH ROBOTS ARE SUITABLE?
FUNCTIONAL SPECS FOR ROBOTS

**Industrial-Robots with safe rated kinematics**
- Safe rated position
- Safe rated stopp
- Safe rated speed
- Safe rated area

**Lightrobot - COBOTS**
- Safe rated kinematics
- Safe rated force and torques
- Capacitive / tactile skin for collision detection
WHICH ROBOTS ARE SUITABLE?
ROBOT-Types FOR COLLABORATION WITH HUMANS

COBOTS – SUITABLE ROBBOTS FOR DIRECT INTERACTION WITH HUMANS

LEICHTROBOTER MIT DREHMOMENT- / KRAFTBEGRENZUNG

- reduced payload → max. 35kg

Technical Restrictions
- Higher moving speeds are only applicable with additional safety sensors with a higher reach

ROBOTER MIT TAKTILEN ODER KAPAZITIVEN OBERFLÄCHEN
DIVERSITY BY APPLICATION SCENARIOS
OVERVIEW ON TODAY'S APPLICATION SCENARIOS

- **COEXISTENCE**: 97% of all applications
- **COOPERATION**: w/o contact
- **COLLABORATION**: with contact

3% of all applications
Standards for HRC applications

Safe setup
Risk assessment and risk reduction
EN ISO 12100

Equipment of machines
- Electrical: EN 60204 = IEC
- Hydraulic: EN ISO 4413
- Pneumatic: EN ISO 4414

Guards
EN 953 ▶ ISO 14120

Safety distances
- EN ISO 13857
- Avoidance of crushing: EN 349 ▶ ISO 13854
- Avoidance of unexpected starting: EN 1037 ▶ ISO 14118

Protective devices
- Minimum distances: EN ISO 13855
- Safety controller: EN ISO 13849-1/-2

Fixed
- Fences, barriers to be removed only with tool
- Interlocks: EN 1088 ▶ ISO 14119

Movable
- Doors, gates, flaps, and barriers which are actuated
- Pressure sensitive (PSPE): EN 1760-x ▶ ISO 13856-x

Tripping function
- Electrosensitive (ESPE) EN 61496-1 ▶ IEC
- Two-hand control: EN 574 ▶ ISO 13851

Position fixing
- Emergency stop
  -1) Enabling device
  -2) AOPD

Movable
- Edges & Bars
- Bumpers & Plates
- VBPD

Type A standards
Type B standards
Type C standards

MACHINE-SPECIFIC C-TYPE STANDARD, e.g., EN ISO 10218-2 robot systems
Standards for HRC applications
Overview

- DIN EN ISO 10218 Industry Robots part 1 und 2
  - DIN EN ISO 10218-1:2012-01
    Industry Robots- Safety requirements- Part 1: Robot
  - DIN EN ISO 10218-2:2012-06
    Industry Robots- Safety Requirements- Part 2: Robotsystems and Integration

- DIN ISO/TS 15066 Robots und Robotic Devices - Collaborative Robots
  - Actual limits are conservatively determined (= safety equipment is required in most of the cases)
    Robots and Robotic Devices - Collaborative Robots

TS 15066 is a completion to EN ISO 10218-2:
- As a guide for the implementation of collaborative robot applications
- Especially when humans and robots share a workspace at the same time
Overview

Other important content and information

- **Collaboration**
  - only for predefined tasks
  - only permitted if necessary protective measures are active
  - only for robots that are specially designed for collaborative operation and conform to ISO 10218-1. This does not necessarily have to be a real COBOT, some manufacturers then modify standard robots in terms of safety, for example by covering them with padding or tactile skin.

**Integrator Responsibility:**
- specify in the user information the protective devices and the operating mode selection, which are required for the collaborative operation.
- Perform a risk assessment that takes into account the entire task to be performed together and the shared workspace.

**COMMENT:** Refer to Attachment E of EN ISO 10218-2 for examples
Robots that are integrated into a collaborative workspace must meet the requirements of ISO 10218-1;

Non-separating protective devices required for presence detection must meet the requirements of 5.2.2;

Additional non-separating protective devices in a Collaborative workspace must meet the requirements of 5.2

The technical protective measures must be designed so that they prevent or recognize a progressive approach of a person into a protected area beyond the collaborative workspace. The intrusion into the protected area beyond the collaborative workspace has to result in a robot to stop and all dangerous machine functions have to be terminated.
5.2.2 Performance requirement

Safety related parts of a control shall be designed so that they comply with PL =d with category 3 as described in ISO 13849-1:2006 or so that they comply with SIL2 as described in IEC 62061.
The following 4 methods / measures are described in detail in ISO 10218 and ISO / TS 15066.
<table>
<thead>
<tr>
<th>Method</th>
<th>Safety Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand guiding</td>
<td>Humans may only approach the robot when it is at a standstill. Manual guidance of the robot using a guidance device and an enabling button at a safe speed. Level of speed depends on the risk assessment. A clear, unobstructed view of the entire collaboration space is required. When the enabling button is released, a safety rated monitored stop takes place.</td>
</tr>
<tr>
<td>Speed and distance control</td>
<td>Use of non-separating protective device to implement a safe Distance control, e.g. with a safety laser scanner or 3D safety camera. Speed is dynamically adjusted depending on the distance. Level of the speed and the required safety distance following the risk assessment.</td>
</tr>
<tr>
<td>Safety rated monitored stop</td>
<td>When a person enters the collaborative workspace, a safety rated monitored stop is triggered. When leaving the collaborative workspace, Robot can resume its operation. The need for a manual reset of protective device or automatic restart of the robot, as well as the level of the speed results from the risk assessment.</td>
</tr>
<tr>
<td>Power and force limitation</td>
<td>Human and robot are sharing collaborative workspace at the same time. Collision between humans and robots in compliance with the biomechanical limit values according to TS 15066 is permitted. Force and torque monitoring through tactile protection devices, torque sensors. Adherence to safe rated monitored speed.</td>
</tr>
</tbody>
</table>

*1 Robots have to be used which comply to ISO 10218-1
HUMAN ROBOT COLLABORATION
Possible combinations of methods for collaborative interaction

Non collaborative workspace

Collaborative workspace

Position des Arbeiters

V_0
V_1
V_2
V_3
V_{Max}

*) ISO 10218-2/TS 15066
SAFETY DISTANCE
EN ISO 13855: Safety Distance

„SAFETY DISTANCE“

for

Physical guards, fences & barriers

Contactless sensing

AOPD

Pressure Sensitive Devices

AOPDDR
Definition of the standard

\[ S = (K \times T) + C \]

with

- **S**: minimum distance [mm]
- **T**: stopping / run down time of the overall system [s]
- **C**: is the additional distance that represents the intrusion into the hazard zone [mm]
- **K**: Parameter for the approach speed [mm/s]

SAFETY DISTANCE EN ISO 13855

Basic Formula

A C-Standard exists and determines the safety distance for a specific application

S\(_{\text{min}}\) = 100mm

HINT: Further detailed information refer to our guideline „Six Steps to a Safe Machine“
5.5.4.2.1 General

If the separation distance between a hazardous part of the robot system and any operator falls below the protective separation distance, then the robot system shall:

a) initiate a protective stop;
b) initiate safety-related functions connected to the robot system in accordance with ISO 10218-2:2011,
The possibilities with which the control system of the robot can avoid violation of the safety distance include amongst others:
• **speed reduction**, possibly followed by a transition to a safe rated monitored stop (refer to 5.4.1)
• Following an **alternative path**, where the safety distance is not violated thereby continuing with active speed and distance control
• If the actual distance corresponds to the safety distance or exceeds it again, the robot movement may be resumed.
EMERGE OF ISO/TS 15066
INFORMATION TO ISO/TS 15066

- Collision risks had to be determine
- Biomechanical stress effects due to collision had to be limited

- What are tolerable stress effects?
  - Pain threshold
  - Entry of injury
    -body stress
- First thresholds for stress effects as an orientation:
  - Clamping / Squeezing force
  - Push force
  - Pressure / surface pressure
- Power threshold per body regions
EMERGE OF ISO/TS 15066

- Measuring the transition from an increasing feeling of pressure into an initial feeling of pain.
- Research project of the Gutenberg University Mainz in cooperation with the IFA
- Cadastral creation based on a body model with 15 individual body areas
- Examination of 29 body points
- Development of an automatic pressure algometer, when the pain threshold was reached the people showed through pressing a push button.
- By a number of subjects of around 100 people about 9000 usable pain threshold measurements were taken

Quelle: ifa
The skull, the forehead, the face are critical areas !!!

<table>
<thead>
<tr>
<th>Körperfrontseite</th>
<th>Spezifische Lokalisation</th>
<th>Körperregion</th>
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<tbody>
<tr>
<td>1</td>
<td>Stirnseite</td>
<td>Schädel/Oben</td>
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<td>2</td>
<td>Schläfe</td>
<td>Schädel/Oben</td>
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<td>3</td>
<td>Keumuskul</td>
<td>Gesicht</td>
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<td>Schultergelenk</td>
<td>Rücken/Oben</td>
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<td>6</td>
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<td>Unterschenkel</td>
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<td>Hals (Säbel/Oben)</td>
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Body Map of DGUV-Information, FB HM-080 Entwurf 04/2017
## ISO/TS 15066
DEVELOPING A BODY MAP

<table>
<thead>
<tr>
<th>Körperlokalisation</th>
<th>Quasi statischer Kontakt (Klemmen)</th>
<th>Transienter Kontakt (Freier Stoß)</th>
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<tr>
<td>29. Wadenmuskulatur</td>
<td>Unterschenkel</td>
<td>210</td>
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</tbody>
</table>
What needs to be considered when planning the HRC application:

Select a suitable robot for HRC
- Safety functions (position, speed, force, moment, etc ... ...)
- Operation mode selection with enabling switch for operating mode manual guidance
- Control with PLd categorie 3

Design measures:
- Limitation of the range of motion
- Exclusion of large, heavy and angular workpieces
- Prevent contact with the head / neck area
- Flat contours, no shear points or edges or tips
- Cushionings
What needs to be considered when planning the HRC application:

- Consideration of interaction with humans
  - conscious / unconscious reach into the working area
  - Process monitoring (zB bending over)
  - Picking up parts that fall out during the process
  - Bumping on the robot, tool and workpiece

- Suitable workplace design:
  - Workplace lightning
  - Stability (prevention of slipping, stumbling, etc ...)
  - Instructed staff
  - Taking into account the presence of third parties
In consultation with the operator, the integrator should identify and document the specific collaborative tasks which should be carried out with the integrated system.

- Collaborative tasks are characterized by:

  Frequency and duration of operator presence in the collaborative workspace with a moving part of the robot system.

  Transition between collaborative and non-collaborative operations.

  Automatic resumption of robot movement after the minimum distance is reached again.

  Tasks that require more than one operator.
Because a robot system is always integrated into a particular application, the integrator shall perform a risk assessment to determine the risk reduction measures required to adequately reduce the risks presented by the integrated application. Particular attention should be paid to instances where safeguards are removed from individual machines in order to achieve the integrated application.

Risk assessment enables the systematic analysis and evaluation of the risks associated with the robot system over its whole lifecycle (i.e. commissioning, set-up, production, maintenance, repair, decommissioning).

Risk assessment is followed, whenever necessary, by risk reduction. When this process is repeated, it gives the iterative process for eliminating hazards as far as practicable and for reducing risks by implementing protective measures.
EXECUTION - RISIKASSESSMENT

Risk assessment according to EN-ISO 12100

1. Safe Design
2. Technical protective measures
3. Administrative measures
HUMAN ROBOT COLLABORATION

Significant Hazards

- Squeezing between gripper and static parts of environment
- Squeezing between workpiece and static parts of environment
- Catching, squeezing at robot arm
- Catching, squeezing at robot gripper or openings in the workpiece
HUMAN ROBOT COLLABORATION
SignificantHazards

- Squeezing between robot joints and static parts of the environment

- Squeezing between robot arm and static parts of environment

- Pinching of fingers at the robot gripper or openings in the workpiece
### Risk Assessment for HRC Applications

**Overview of Relevant Subjects for Risk Reduction**

Every application is unique and requires a separate risk assessment!

#### 4 Methods

- **Hand Guiding**
- **Safety Rated Monitored Stop**
- **Speed- and Distance Control**
- **Power- and Force Limitation by inherent design of Robot and its controls**

#### ROBOT Application

- ROBOTER Incomplete machine
- Safety Equipment
- Robotcontroller
- End-Effector (z.B. Gripper), Tools, Workpiece
Werner Zipperer
Produktmanagement „Industrial Safety & Motion Control Sensors“

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