
# Human-Robot Collaboration

*Internal training presentation*

Product Management Gripping Systems | July 2017

Superior Clamping and Gripping

SCHUNK®

# Human-Robot Collaboration

*Internal training presentation*

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# Human-Robot Collaboration

## *Definition of Terms*

Source: SCHUNK GmbH & Co. KG

### What is HRC?

Abbreviation for the term “Human-Robot Collaboration”

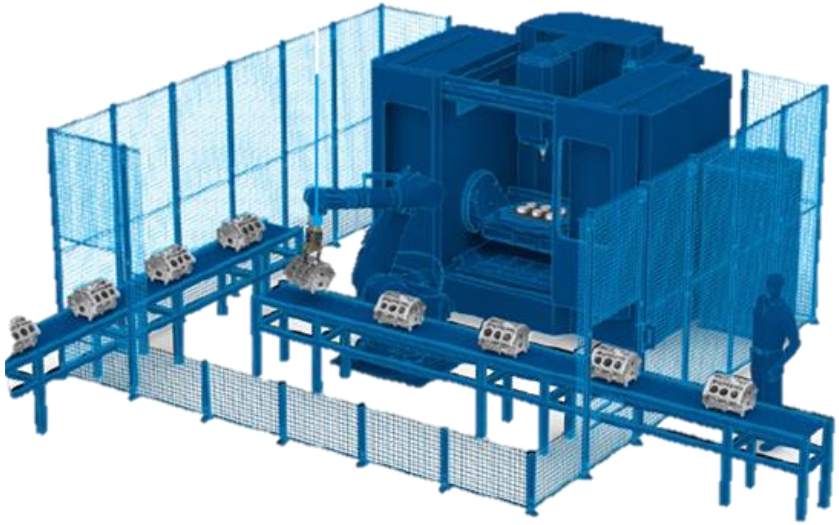
### Explanation:

Refers to the **interaction** between an **operator [human]** and a **robot** without guards.

Regardless of the **kind of collaboration**, protecting humans is always the primary focus. In order to ensure safety at all times, collaboration is partially regulated by **standards and certifications**.

However, **some points** often remain unclear, leading to uncertainty in the market.

# From full Automation to Human-Robot-Collaboration



## Definition

**Interaction between an operator [human] and a robot without guards in a shared working space**

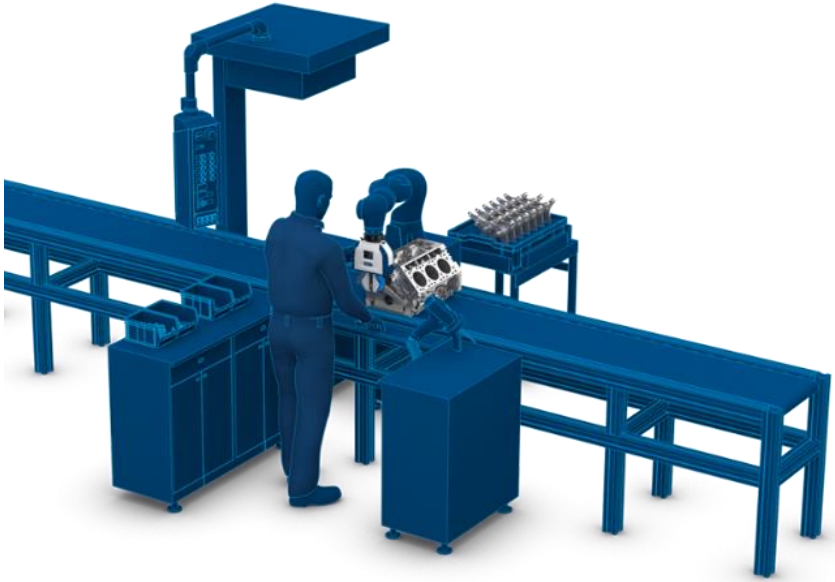


*Image Sources: SCHUNK GmbH & Co. KG*

## Advantages

- ✓ Ergonomic benefit for employees
- ✓ Flexibility of work processes
- ✓ Increased efficiency in robot applications
- ✓ Retrofitting and more flexible logistics, loading, assembly and handling

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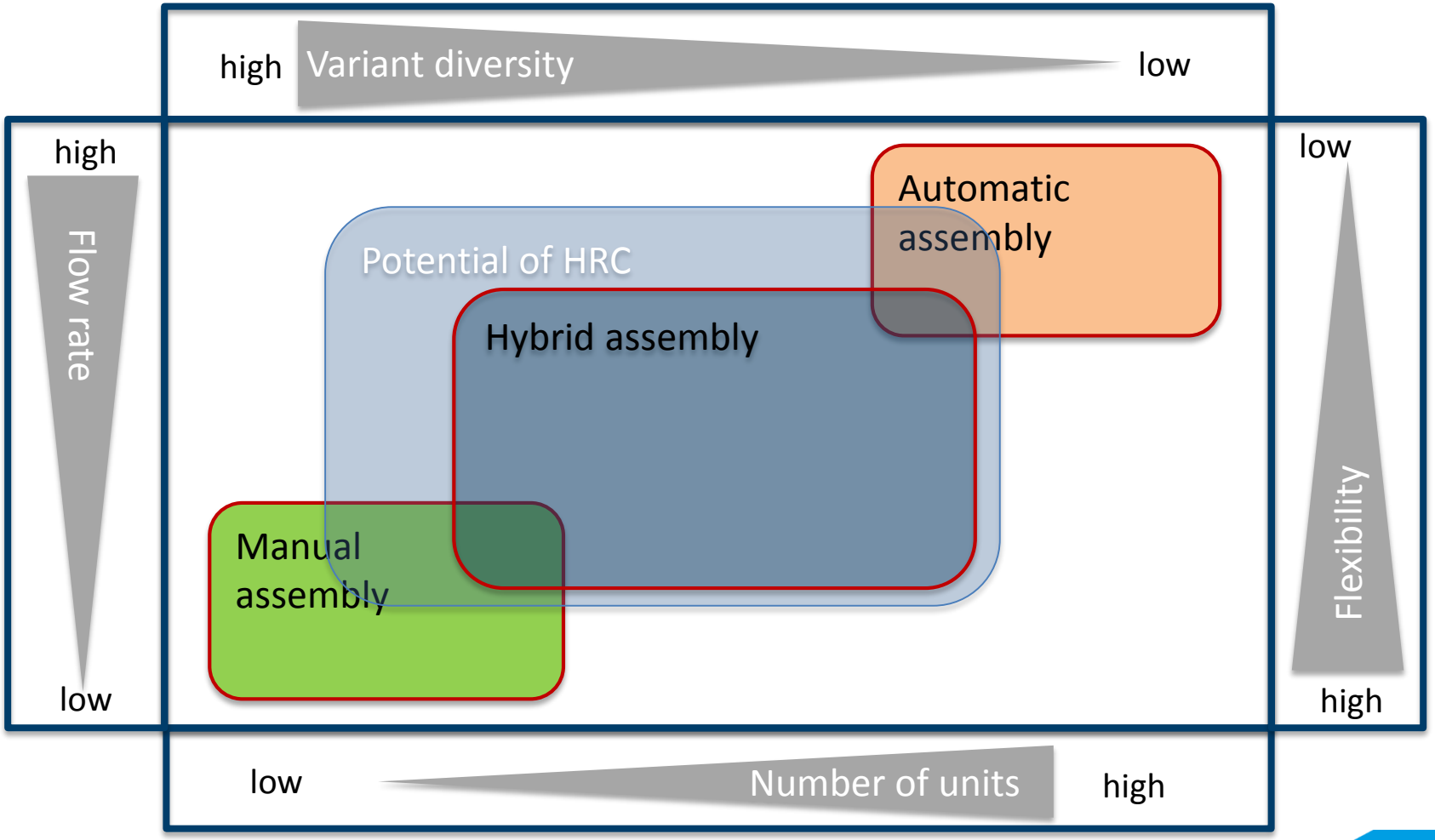
# Automation Potential

## *Influence of different areas of tension*




*Source: Fraunhofer IPA / 2017*

# Jobs that make sense for using direct interaction between humans and machines

## Jobs with quality issues

- Activities with a high demand for reproducibility, e.g. bonding processes
- Activities/jobs with an incidence of errors (e.g. forgotten parts)
- Activities requiring documentation (e.g. screwed connections)

## Jobs with ergonomic issues

- Component weights (4 kg to 12 kg) to be moved at a height or a high total load in one shift

  *Example: 500 g per minute is 240 kg per shift*

- Application of joining forces, especially with small surfaces
- Working in ergonomically awkward positions (for example, activities performed over the head, bending over far, stooped postures)

# Jobs that make sense for direct interaction between humans and machines

## Workplaces with an operator capacity of more than 100%

- Through automation, plant utilization can be reduced to less than 100%, or the operator can operate several machines

# But be careful!

Human-robot collaboration is currently a **trending topic**, a variety of applications are being referred to as “HRC applications”.

These applications are often **easier to realize** using existing standard methods.

The **topic of cycle time** in particular does not apply well in the field of HRC.

→ **An open review** of “HRC Applications” **including all advantages and disadvantages**!

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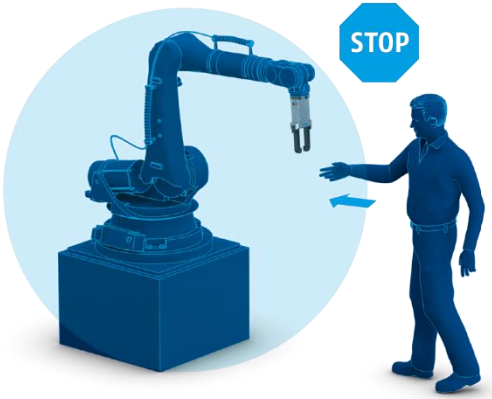
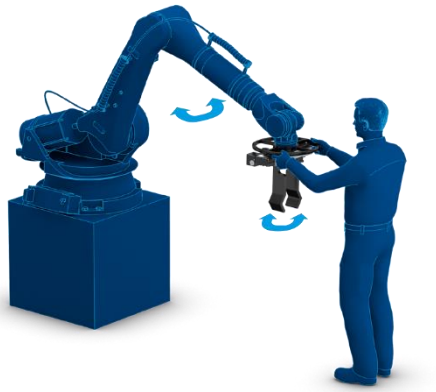
# Four Types of Human-robot collaboration

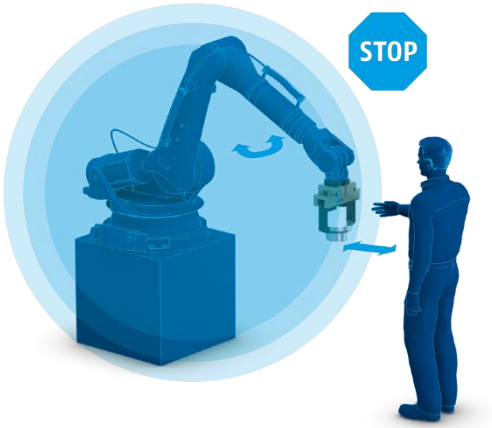
***Source: ISO/TS 15066:2016 Robots and robotic devices – Collaborative robots***




***Method 1*** *- Safety-rated monitored stop*



***Method 2*** *– Hand guiding*

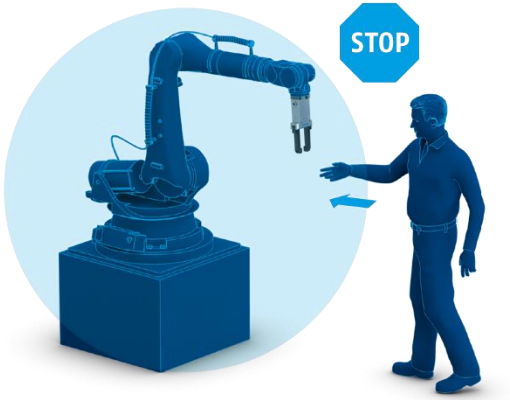



***Method 3*** *- Speed and separation monitoring*

***Method 4*** *– Power and force limiting*

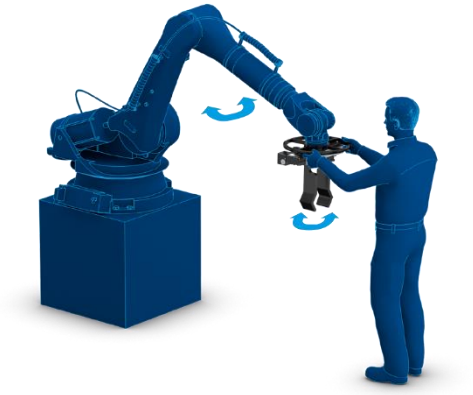
*Image Sources: SCHUNK GmbH & Co. KG*

# Normative classification of human-robot collaboration




## Method 1 – Safe Hold

The robot system works at normal speed, provided that there is free access in the machining area. When a human enters the area this is monitored i.e. by a laser scaner, and the robot system enters into a safety-monitored stop.

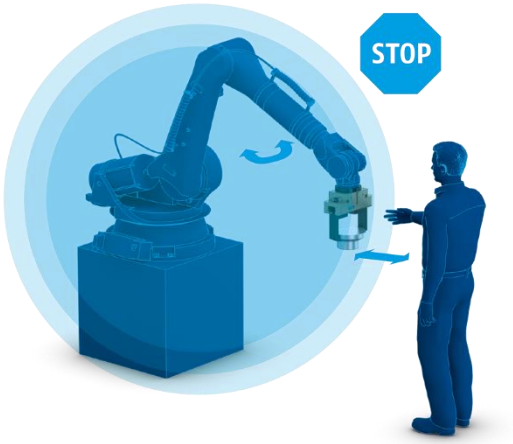


## Method 2 – Hand Guiding

The robot system is guided by a human.
In order to do so, the system must be able to detect the force of the human e.g. using a force/torque sensor. The robot system only moves when this movement is enabled by the human using a safety switch. Otherwise the robot system is in a safety-monitored stop.

*Source: ISO/TS 15066:2016*

# Normative classification of human-robot collaboration




## Method 3 – Speed and Separation Monitoring

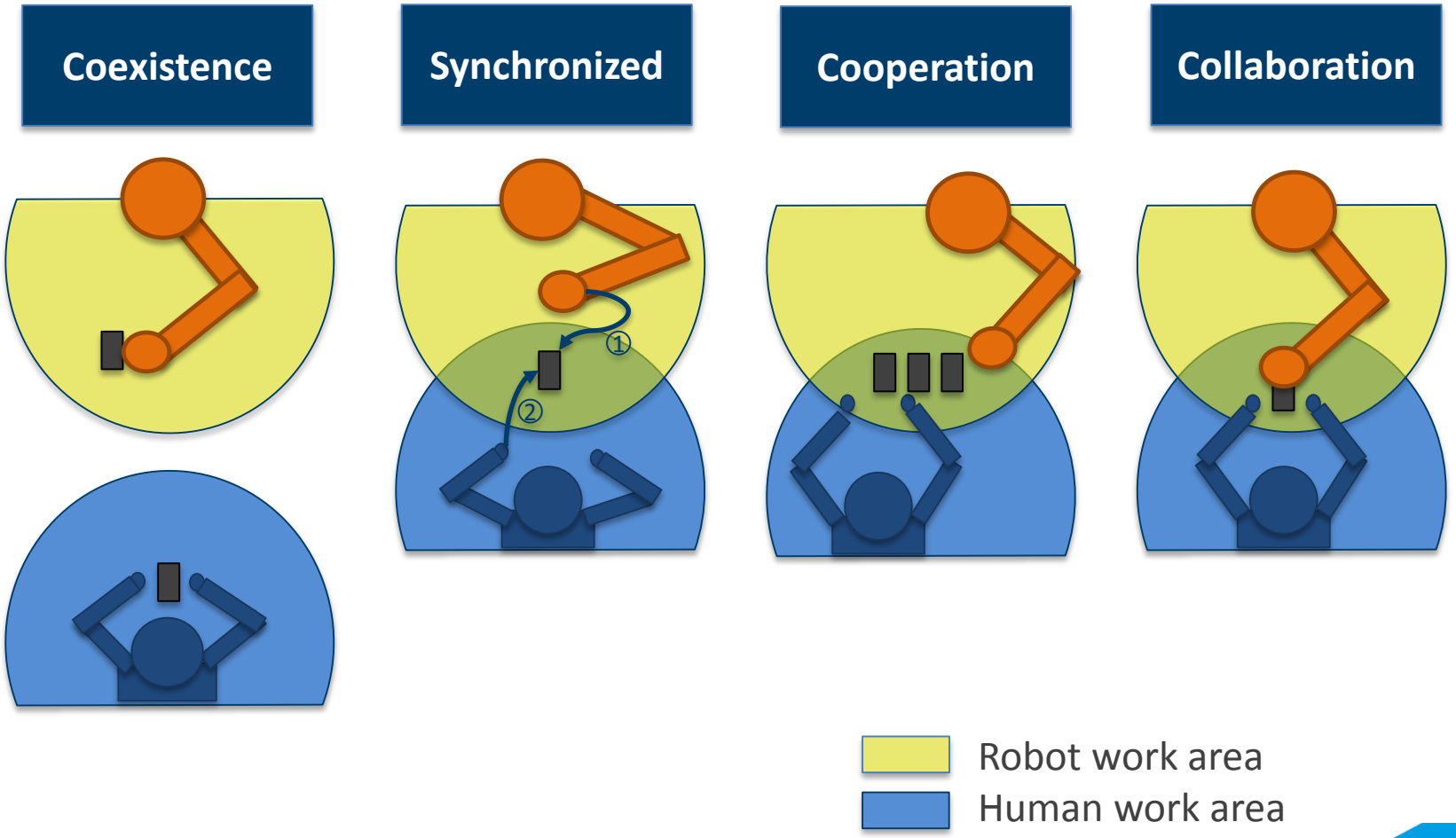
The machining area of the robot system is divided up into successive zones. If the entry of a human into one of the first zones is detected for instance by a laser scanner, the robot system goes into a lower speed. When the zone directly next to the robot is entered, the robot system goes into a safety-monitored stop.

## Method 4 – Power and Force Limiting

The robot system works with limited force and power when collaborating directly with humans. The maximum forces and pressures applied to humans may not exceed the values specified in the technical specifications. This is ensured by an inherently safe design or safety functions.

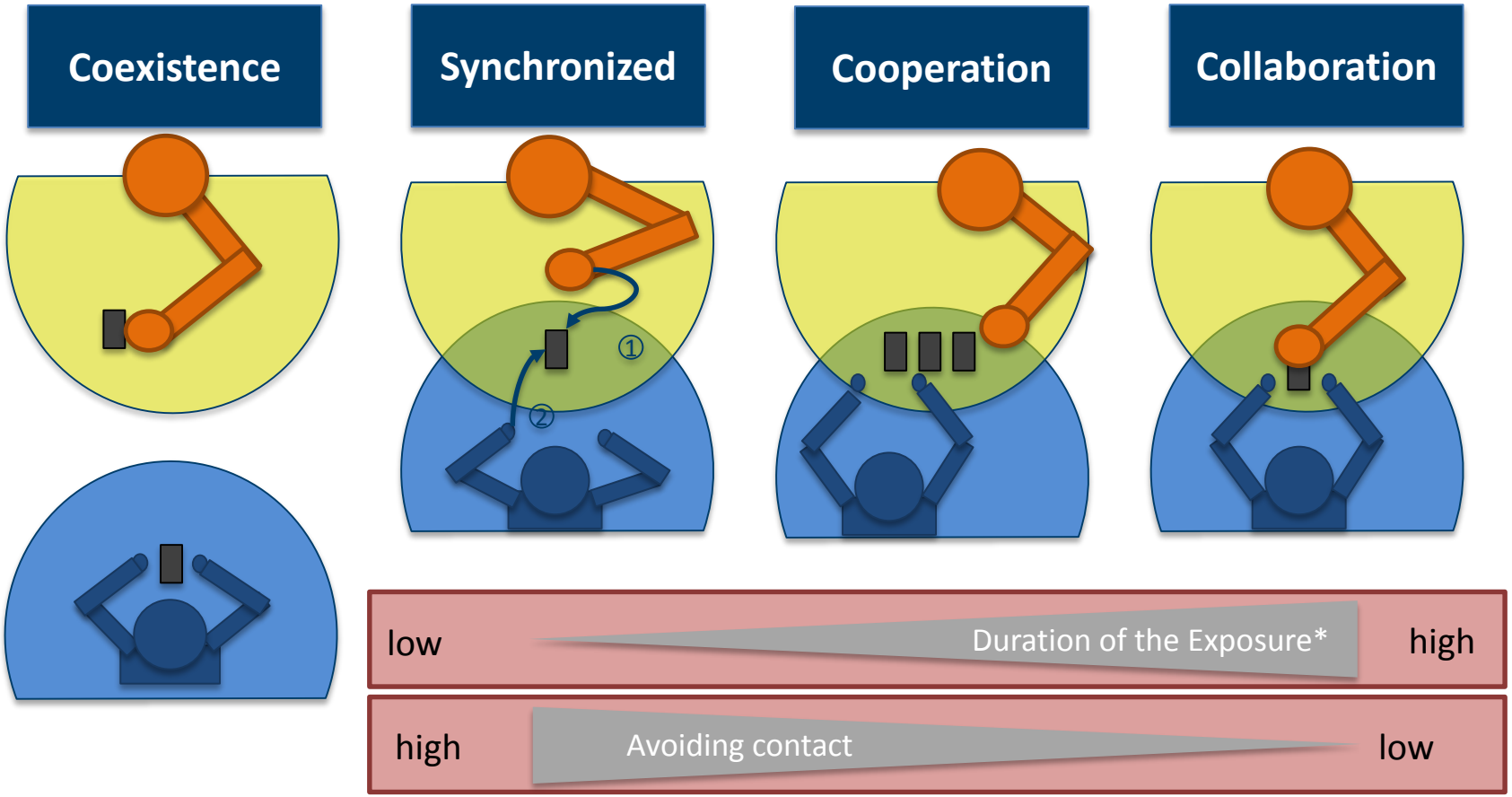
*Source: ISO/TS 15066:2016*

# Classification in the collaboration between human and robot




*Source: Fraunhofer IAO, 2016*

# Classification in the collaboration between human and robot




Source: Fraunhofer IAO, 2016

** Def. Duration of the Exposure: Length of time that the human is exposed to a hazard.*

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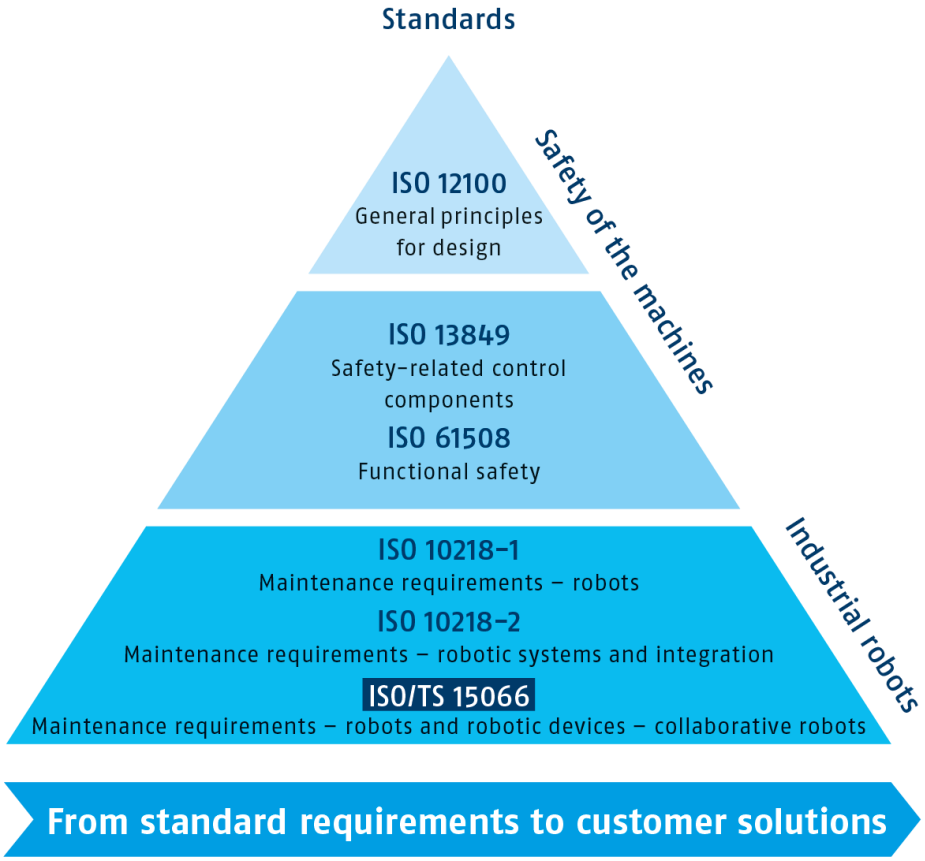
# Standards and guidelines

## *In the context of human-robot collaboration*




The listed standards and guidelines are not exhaustive. For every application the applicability of further standards or guidelines have to be determined.

*Source: SCHUNK GmbH & Co. KG*

# Recommendation for the implementation of HRC

## *True to the motto “step-by-step”*

Human-Robot Collaboration (HRC) is far more than merely the acquisition and installation of a safe robot:

- **Step 1:** Safety assessment of all the requirements, starting with the robot **and** the gripper/tool **and** the workpiece!
- **Step 2:** Clarifying the legal framework for work safety.
- **Step 3:** Introduction of new robot and gripper generation, an innovative project **not** to be underestimated!
    - Humans set the pace!
    - Use HRC thoughtfully and with care.
    - Take a holistic approach, acting within standards.

# Conducting a risk assessment

## *Specific to applications in the HRC environment*

1. Consideration/determination of risk factors (risk analysis)
2. Identification of hazards
3. Elaboration of a comprehensive safety concept (for example, safe work rooms etc.)
4. Parameterization of the safety functions
5. Programming the safety features
6. Validate and document all safety functions
7. Verification of adherence to the biomechanical limit values set forth in ISO/TS 15066
8. Completion of risk assessment and documentation

**NOTE:** The acting company (mechanical engineer or authorized representative) is responsible for these points.

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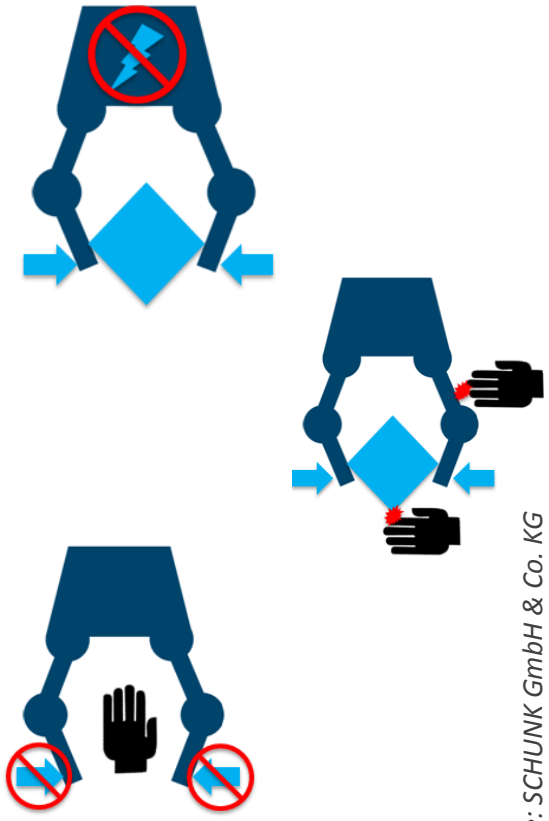
# Gripper safety principles for collaborative applications

## Derivation of the requirements from the standards:

1. **Gripper never loses a workpiece**
   - Gripping force retention even in the case of energy loss or an emergency stop
2. **Gripper always detects human contact**
   - Covering the gripper and gripper fingers, e.g. with capacitive sensors
   - Recognition of the workpiece using prior programming
3. **Gripper never cause injuries when gripping**
   - Limitation of the gripping force in the collaborative operation to uncritical value

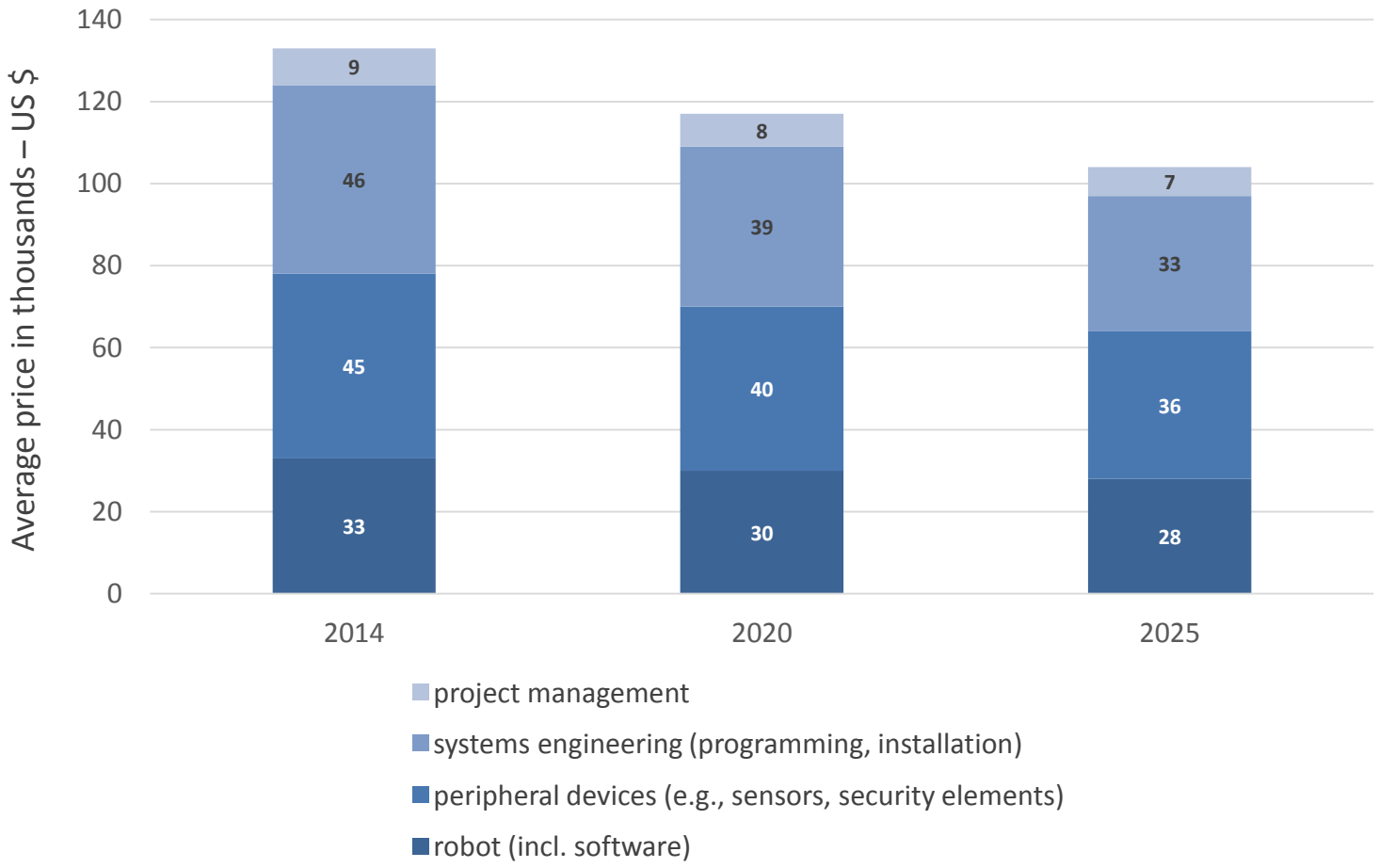


*Source: SCHUNK GmbH & Co. KG*

**NOTE:** A gripper for collaborative applications should have these safety functions implemented, but it is not a must.

# Costs of robot applications

## *Percentage of components/services*




*Source: Fraunhofer IPA / 2017*

# Supported by SCHUNK

## *HRC application with gripper application*


**Selection of the right gripper for the application**

- Co-act team for the design of the appropriate gripper for your application

**Operating instructions with comprehensive information**

- SAC (Safety Application Conditions) → Notes on the risk assessment, implementation of the gripper and part of the overall documentation

**Support from SCHUNK Service**

- Support for the implementation of the product in the robot control and commissioning of the product

Assistance with general **application advice** or with **product acceptance/ safety verification** is carried out by service providers.

*Image Source: SCHUNK GmbH & Co. KG*

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# Cobots - Collaborative robots

## *Basis for end-of-arm-tooling*

Robots are the **foundational system** of an HRC application.

**Here, it is important** to consider:

- Safety functions
- Safety level (PL/SIL)
- Controls, incl. connection options
- Connection options on the front axles or on the flange


*Source: own images, Universal Robots, Fanuc, Rethink Robotics, KUKA, ABB, Stäubli, Yaskawa, Kawasaki*

# Product selection

*Gripper for collaborative applications*

**Step 1: Task description and feasibility study**

→ Are my application/task position and the workpiece suitable for an HRC application?

**Step 2: Selection of the robot or cobots**

→ Definition of the basic system with mechanical and electrical connection of the peripheral devices.

**Step 3: Selection of the gripper**

→ Selection of the gripper together with the co-act-team:

- Gripping position (at the workpiece and at the receiving and storage location), necessary gripping force, necessary stroke
- Covering the gripper and the moving parts, avoiding clamping or shearing

# Product selection

*Gripper for collaborative applications*

**Delivery status scope of delivery**

- Grippers and gripping systems are considered to be incomplete machines according to the Machine Directive
- Construction of the collision protection sleeve is carried out according to BG/BGIA

**Indication of the gripping force**

- Observe the technical data with regard to max./min. gripping forces
- View of the impulse forces during gripping movements (4 times for approx. 50 ms)
- Gripping forces apply at operating pressure and nominal voltage → safe limitation required!
- Considering workpiece loss through loss of the gripping force in the risk assessment

**Actuation**

- Ensuring a defined control (valves or grippers)

# Product selection

*Gripper for collaborative applications*

## Finger design

- Top jaws must be provided with radi, also in the Z direction
- Please note the outer contour as well as the contour direction of the workpiece

→ The top jaws have a great influence on suitability for HRC!

→ The top jaws must also be assessed and observed in the risk assessment and the force/pressure measurement!

*Image Source: SCHUNK GmbH & Co. KG*

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# Technology Carrier Co-act JL1 gripper

## Improvements 2017
- Slim housing
- Larger display
- Improved tactile electronics

## Touchscreen
Enables communication with the gripper as well as teaching or switching to various operating modes

## Capacitive Sensors
For the prevention of collisions


## Parallel and Angular Grips
Two types of gripping for gripping any geometries

## Camera
Mounted between the fingers for detecting the surroundings, differentiating and searching for objects

## Optical Feedback
Through the use of LED lights, the JL1 Co-act gripper provides information to the operator about the status of the gripper and identification of the workpieces

## Tactile Sensors
For in time detection and differentiation of workpieces and humans

**No sale / No sample delivery!**

*Source: SCHUNK GmbH & Co. KG*

# SCHUNK 5 Finger Hand SVH

## *DGUV certified for safe, collaborative operation*

Gripping hand

Key grip

precision grip

Power grip

As the world's first robot gripper, the SCHUNK 5-finger-hand SVH has been certified and approved by the German Statutory Accident Insurance Association (DGUV) for collaborative operation.

*SCHUNK Press release from 25 January 2017*

**Product features**

- Available in left- or right-hand versions
- Low energy consumption at 24 V DC
- Complete integration of control- and power electronics in wrist

*Image Sources: SCHUNK GmbH & Co. KG*

# State of the art
# - gripper for collaborative use

**Basic requirement:** Customer (mechanical engineer, system integrator or end customer) is responsible for the safety of the complete machine and thus also responsible for assessment/certification of the same.

**Current approach:**

- Customer receives a SCHUNK gripper incl. cover on request
- Customer is responsible for the certification or assessment of the gripper

**Objective with co-act standard portfolio:**

- Customer receives a gripper from our standard portfolio for collaborative operations
- Customer can use a BG certificate for the gripper in the safety assessment

# Co-act customer-specific gripper solutions

## *… suitable for your application*

Various grippers have already been implemented for collaborative applications and for various types of robots.

**SCHUNK Grippers**

JGP, PGN-plus, EGA, WSG, MPG-plus

… suitable for **your particular robot type** (incl. KUKA, UR, Fanuc, ABB)!

*ImageSsources: SCHUNK GmbH & Co. KG*

# Co-act customer-specific gripper solutions

## *Task: welding - chamfering of workpieces*


**Function manual:**

Gripping movement is carried out only upon approval by the user

**Objective:**

Improved ergonomics

*Image Sources: SCHUNK GmbH & Co. KG*

# Co-act customer-specific gripper solutions

## *Task: Assembly - electronics*

**Products used:**

- Pneumatic grippers with integrated microvalves
- Electric grippers with digital control
- Integrated sensors (magnetic or inductive)

**Application:**

Gripping small workpieces

**Advantages:**

Easy integration into the electrical and mechanical interface of the robot



*Image Sources: SCHUNK GmbH & Co. KG*

# Co-act customer-specific gripper solutions

## *Task: Assembly/handling*

**Products used:**

- Intelligent electric SCHUNK gripper
- Distance and color sensors

**Application:**

Gripping for larger workpieces with a low weight or high part variance

**Advantages:**

Simple mechanical integration with the robot, a compact unit consisting of sensors and grippers

*Image Sources: SCHUNK GmbH & Co. KG*

# Planning Co-act product portfolio
## *Overview*

**Low workpiece weight (< 1.5 kg)**

- Co-act EGP
- Co-act MPG-plus
- Co-act KGG

**High workpiece weight (< 10 kg)**

- MRK-G (working title)

**Plug & play on Cobot:**

- Gripping system for Universal Robots (based on EGP)

→ Without approval for the collaborative operation

# Co-act gripper modular systems

## *Certified grippers for collaborative operation - in planning*

### Gripper modular systems

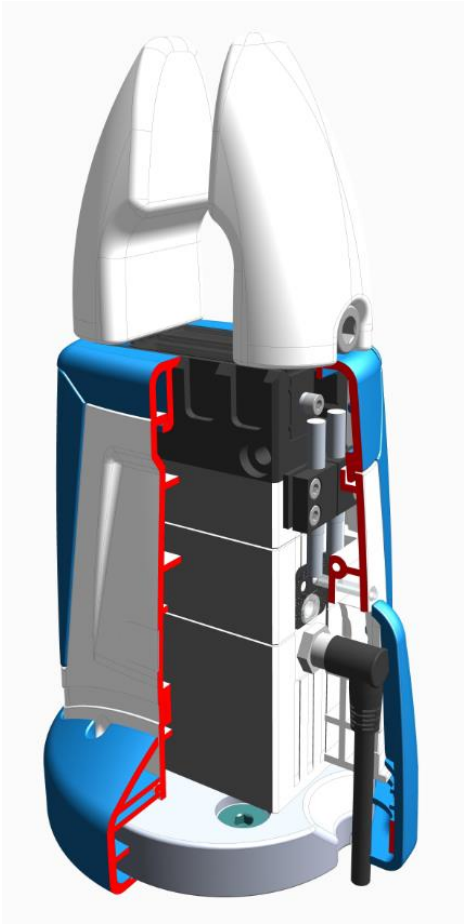
Extensive modular systems are based on three standard grippers (EGP, MPG-plus and KGG) for the greatest possible coverage of applications

### Plug & play on various robots

Prepared for direct mechanical and electrical adaptation, long-term including program blocks for simple control

### Certified for collaborative operations

For easy assessment in risk analysis



*Source: SCHUNK GmbH & Co. KG*

# Co-act gripper modules

## *Certified grippers for collaborative operation - in planning*

**Status:** in development

**Planned grippers:**

- EGP 25,40,50,64
- KGG 60-20,80-30
- MPG+ 25,32,40,50,64

**Features:**

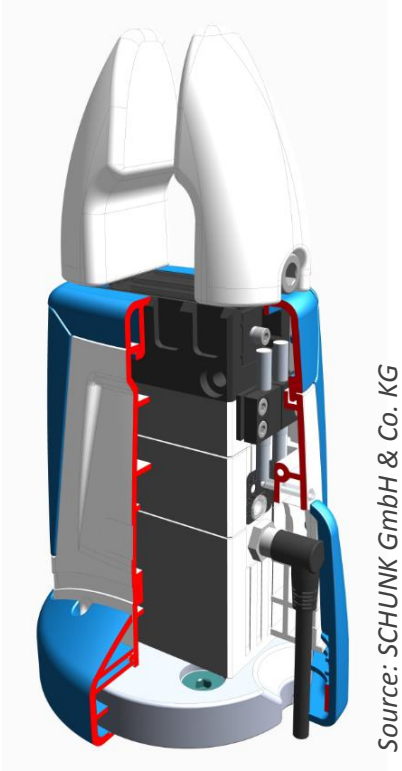
- Certification of BG
- Integrated sensors
- Standard finger optional
- Lighting optional

**Compatible with:**

- UR 3,5,10
- KUKA 7, 14
- Fanuc
- ABB
- … and many more!

**Schedule:**

Completion in 2017 (Co-act EGP)



*Source: SCHUNK GmbH & Co. KG*

# Gripper for collaborative operations < 10 kg

## *MRK-G development project*

**Status:**

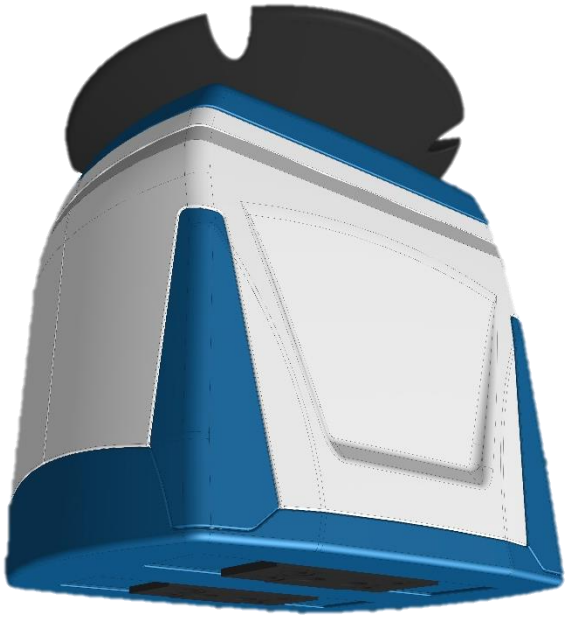
Development project – do not communicate

**Aim:**

- Electric gripper for collaborative operations
- Up to 10 kg workpiece weight (force-fit gripping)
- Integrated sensor system (stroke measuring system)
- Integrated safety features

**Sales release:**

End 2018



Source: SCHUNK GmbH & Co. KG

# Gripping system for universal robots

## *EGP with anti-collision device*

**Status:**

Completed - available as a semi-standard product

**Information:**

- EGP with collision protection sleeve and integrated inductive sensors
- Suitable for robot types UR 3, UR 5 and UR 10
- Plug & play mechanical and electric with UR robots
- Internet presence on UR+
  *https://www.universal-robots.com/plus/*
- Optional with gripper finger

*Image Sources: SCHUNK GmbH & Co. KG*

# Planning Co-act product portfolio

## *Overview with schedule*

**Low workpiece weight (< 1.5 kg)**

- Co-act EGP
- Co-act MPG-plus
- Co-act KGG

Co-act EGP until the end of 2017

**High workpiece weight (< 10 kg)**

- MRK-G (working title)

Until the end of 2018

**Plug & play on Cobot:**

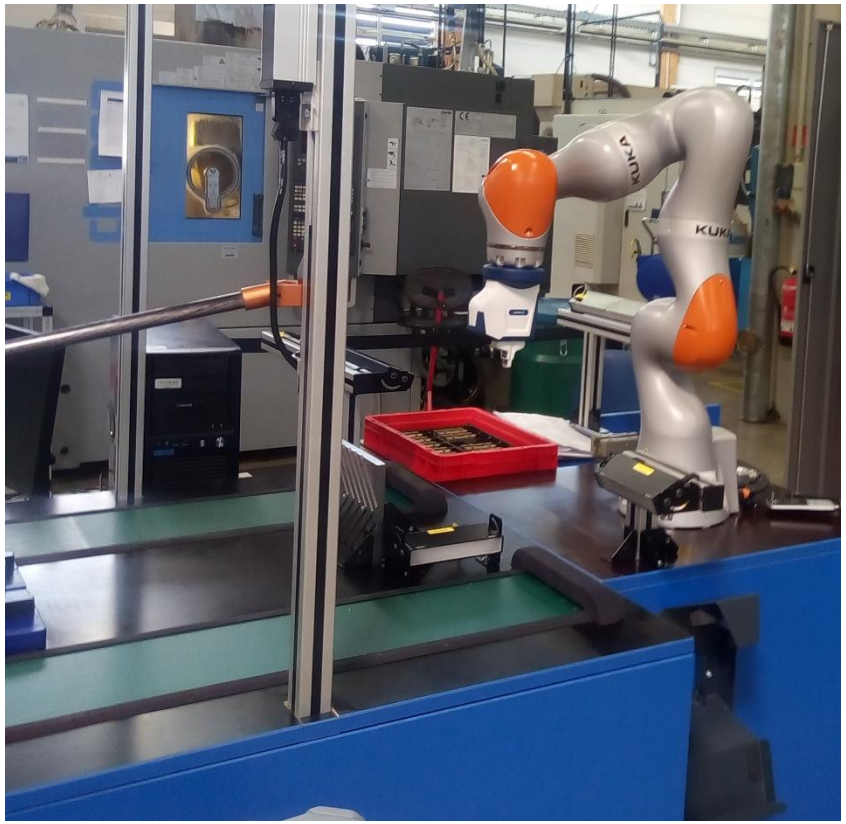
- Gripping system for universal robots (based on EGP)

→ Without approval for the collaborative operation

Starting now → PAC Mechatronics

# Co-act customer-specific gripper solutions

## *Human-robot collaboration in SCHUNK Production*



*Source: SCHUNK GmbH & Co. KG*

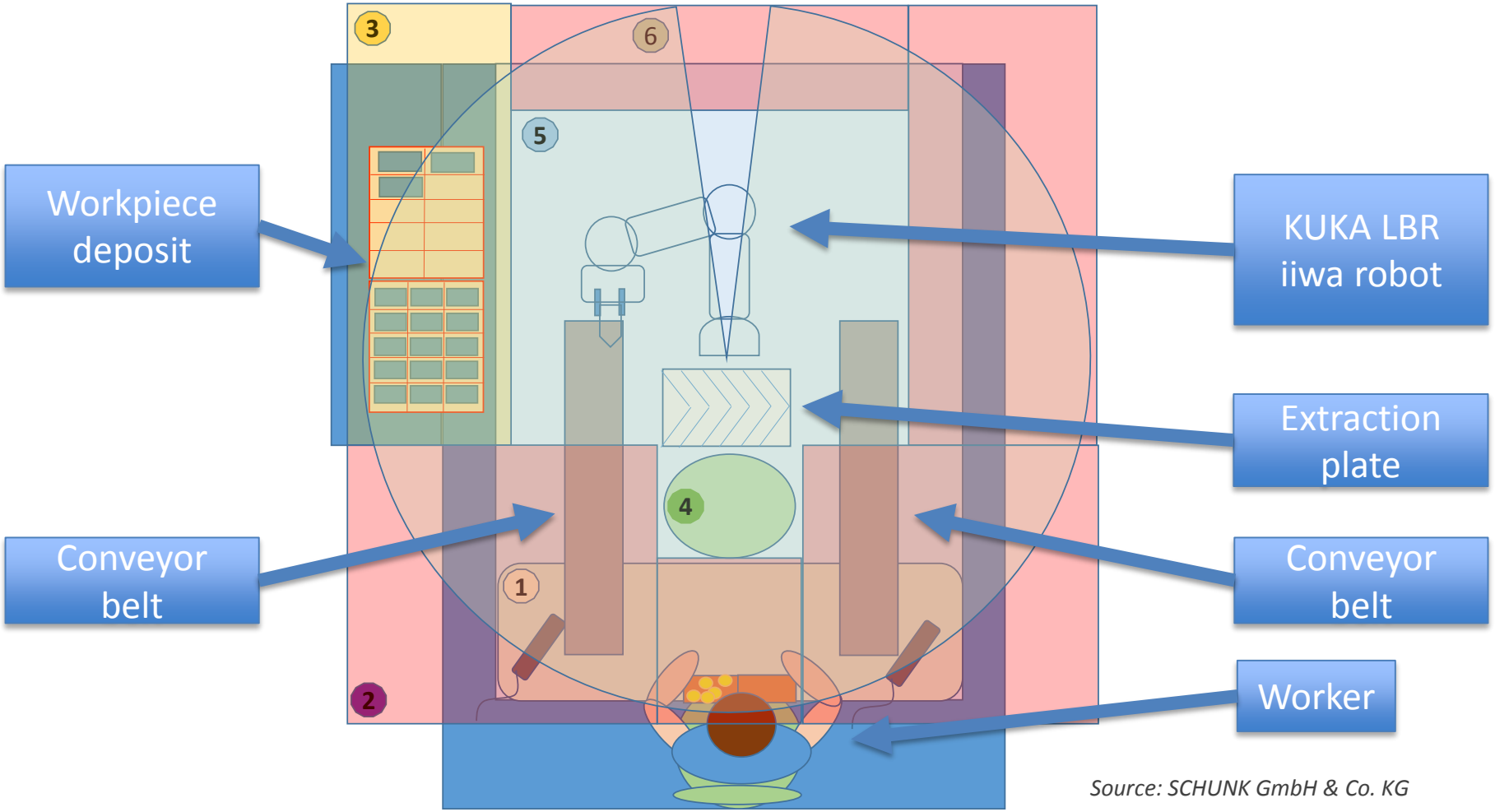
**Aim of the application:**
Partial automation of a process that is currently purely manual, improved ergonomics for the operator

**Current process:**
Sealing air connections on the gripper PGN-plus by means of threaded pins and subsequently removing other screw adhesives

**Topics covered:**
- Human-Robot Collaboration
- Plug & play with the robot control system
- Image processing

# Co-act customer-specific gripper solutions

## *Human-robot collaboration in SCHUNK Production*




*Source: SCHUNK GmbH & Co. KG*

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# Co-act Gripper

## *Info in STB*

### Co-act Greifer


Sizes | Weight | Gripping force | Stroke per jaw | Workpiece weight

**Description**

The NEW Collaborative SCHUNK Gripper

**Application area**

With its Co-act gripper, SCHUNK is capturing a trend and focusing on carrier technology in the development of HRC-ready actuators. The aim is for SCHUNK Co-act grippers to directly interact with humans and to communicate in accordance with regulatory requirements.

Accessories | Seal Kits | Shock absorber

| Title | Date (M/D/Y) |
|---|---|
| MRK training presentations 2017 are available in STB | 07/24/2017 |

**Series specific information**

Advantage | Operation | Application | Accessory | Document | Multimedia | Service | FAQs | News

**Misc**

| | |
|---|---|
| Co-act Gripper checklist | DE US |

**Internal documents**

| | |
|---|---|
| Availability of New Products Gripping Systems DE/EN | DE US |
| Co-act Gripper Applikationsbeschreibung Maschinenbeladung mit EGP | DE |
| Co-act Gripper Applikationsbeschreibung Medizintechnik | DE |
| Co-act Gripper assembly description curcuit boardhandling | DE US |
| Co-act Gripper assembly description curcuit braker handling | DE US |
| Co-act Gripper assembly description engine block assembly | DE US |
| Co-act Gripper assembly description machine loading with WSG | DE US |
| Co-act Gripper assembly description metal casting sector | DE US |
| Co-act Gripper assembly description tire handling | DE US |
| Co-act gripper - standards text for offers | DE US |
| Data sheet Co-act EGP for UR | DE US |
| MRK Grundlagenschulung 2017 | DE |
| MRK Info presentation Internal | DE US |
| MRK Schulung HMI 2017 | DE US |
| Marktbeobachtung Cobots | DE |
| Realisierte Co-act Greifsysteme | DE |
| Wettbewerbsbeobachtung MRK Greifer | DE |

Check-list

Text for the offer

Description of application

Cobot mark observation

Realized applications

Monitoring the competition

# Check-list for Co-act Gripper

## Checklist for Co-act Gripper

To determine the optimum SCHUNK Co-act Gripper, we recommend completing the following checklist and sending it to the SCHUNK Co-act team. This checklist is also available online at: **schunk.com/checklist-co-act**

### Contact data

| Company | Name | Department |
|---|---|---|
| Street | ZIP code | City and country |
| Phone | Fax | Email |
| Date | Consultant | |
| Order number | Offer number | |

### Application

**Field of application of the Co-act Gripper:**

☐ Assembly ☐ Handling ☐ Quality check ☐ Other

### Short description of the application

☐ Integration into existing system ☐ New workstation ☐ Replaces previous workstation

### Robot type

☐ Specified by the customer ☐ Suggestion desired ☐ Industrial robot, type

| | | | | |
|---|---|---|---|---|
| ☐ FANUC CR 35iA | ☐ KUKA Iiwa 7 | ☐ COMAU Racer5 Collabor | ☐ UR 3 | ☐ Rethink Robotics Sawyer |
| ☐ FANUC CR 7iA | ☐ KUKA Iiwa 14 | ☐ COMAU AURA 110 | ☐ UR 5 | ☐ BOSCH APAS Assistant |
| | ☐ ABB YuMi | ☐ COMAU AURA 60 | ☐ UR 10 | ☐ Other |

Portable robot version ☐ Yes ☐ No

### HRC type of collaboration

☐ Safe hold ☐ Hand guiding ☐ Speed and separation monitoring ☐ Force and power limiting

### Required gripping force

Note: For collisions with a hand, exact limits of 140 N of applied force and ~200 N/cm² pressure are valid; other safety aspects are to be observed for higher forces (e.g. sensor system in gripper fingers, actuation of grippers in a separate area).

Type of gripping: ☐ Form-fit gripping ☐ Friction ☐ 2 fingers ☐ 3 fingers ☐ Parallel

# Ideal sequence – Co-act inquiry to SCHUNK

| Sequence - Tasks | Competence | |
|---|---|---|
| 1. Customer request | AD | |
| 2. Customer visit | AD | |
| 3. Application documentation (images) | AD | |
| 4. Complete check-lists | AD | |
| 5. Resolve any open questions | AD | ID |
| 6. Technical clarification | | ID |
| 7. Preparation of the offer | | ID |

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# Experts are centralized in one Team

Your direct link to expert knowledge and experience in the field of “collaborative gripping”.

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For further information, please contact your local sales representative.

# The Co-act-Team

## *Your contact person*

| Co-act Team | |
|---|---|
| Team leader | Mike Mayer |
| Product management | Anna Jung<br>Benedikt Janßen |
| PAC Gripping/Turning | Holger Roth<br>Simon Achauer |
| PAC robot accessories | Felix Eißele |
| PAC Mechatronics | Jochen Krieger<br>Benjamin Schell<br>Oliver Herbrik<br>Martin Kunz |

# Summary - conclusion

**HRC offers advantages, but it is a not to be underestimated, time-intensive change process!**

- Integration of operational and working safety, standard-setting operation (integration of external partners (for example, BG)
- Change of working methods and process landscapes
- Basic acceptance by people

**First impressions count!**

- Appearance (visual field), motion sequences (speed, clipping), noise
- Mastery of the work processes and intuitive machine operation → Transparency

**Humans determine the cycle time now and in the future!**


*Source SCHUNK GmbH & Co. KG*

Superior Clamping and Gripping

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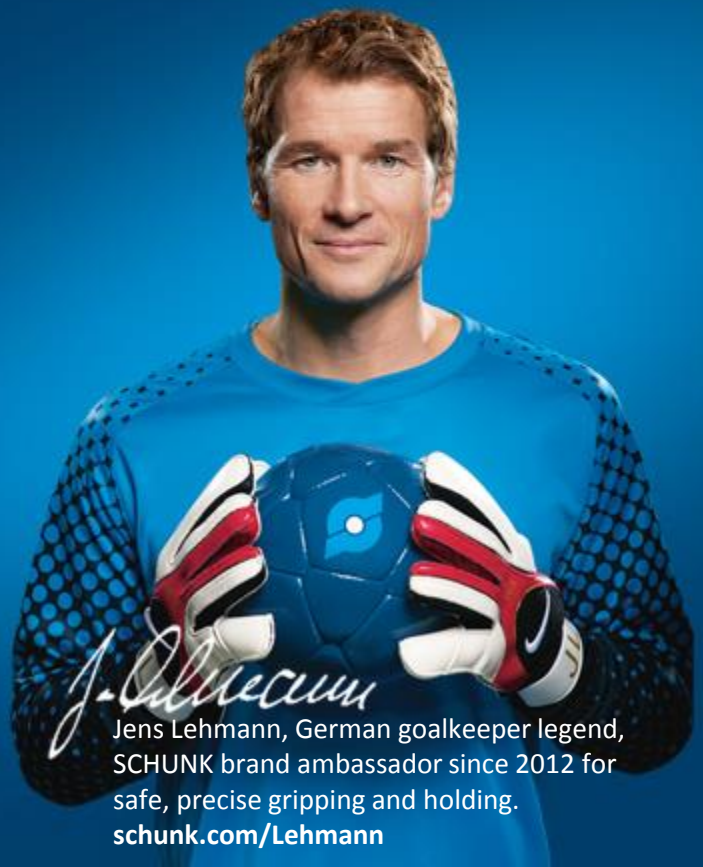

Jens Lehmann, German goalkeeper legend,
SCHUNK brand ambassador since 2012 for
safe, precise gripping and holding.
**schunk.com/Lehmann**