FRAUNHOFER INSTITUTE FOR INDUSTRIAL ENGINEERING IAO

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LIGHTWEIGHT ROBOTS IN MANUAL ASSEMBLY – BEST TO START SIMPLY!

EXAMINING COMPANIES' INITIAL EXPERIENCES WITH LIGHTWEIGHT ROBOTS

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FOREWORD

Human-robot collaboration (HRC) is a permanent fixture in the media. But when we take a look along the production lines at German assembly companies, we see that – except in a few automotive plants – robots are virtually always fenced in and kept strictly separate from human workers. Even those who make and sell robots or handle system integration are not yet ready to report that we have entered the age of comprehensive cage-free robot installations on the assembly line

At the moment, robots are a less than common feature in the assembly halls of Germany's small and medium-sized enterprises (SMEs). This is because these companies' typically small batch sizes and large numbers of variants make automation more expensive and hence difficult to amortize in a reasonable time. Now this is set to change, thanks to what are known as lightweight robots (LWRs). Designed for cage-free work, the new robots do away with some of these constraints, and they are available at affordable prices.

This new technology opens up entirely new ways of working. In addition to helping make work more ergonomic, the arrival of LWRs means that we can completely reorganize how we work and offers us a myriad of new task options. Many companies – including SMEs –recognize these opportunities and are keen to learn from the first users' experiences. To help them, we have put together a brief study featuring 25 applications that explores the most important factors and conditions in play. Our aim is to give you, the reader, an overview of what is already possible now, so that you can judge for yourself where you might want to start.

And take a tip from us:
»Start simply«

Wilhelm Bauer

CONTENTS

1 OVERVIEW

1.1 BRIEF DESCRIPTION OF THE STUDY

In light of the significant recent media interest, numerous articles in newspapers and journals, and conference presentations, we decided to investigate the current status of cage-free – sometimes referred to as "inherently safe" – robot technology in German industry. The aim of our study was to find companies that are already using lightweight robots on their production lines and to learn about their experiences with implementing the robots, gaining acceptance from human coworkers and improving operational efficiency. Research carried out among our industry partners and in publications on cage-free robots in German industry yielded descriptions of approximately 50 applications, 25 of which we selected for our study. We used the following criteria to select the applications:

- The application is already or about to be up and running on a production line
- The robot is already being used by several companies.

Of the 25 applications we selected, we were able to document 18 of them by speaking directly to the users and 7 of them by consulting publications. An overview of our key findings is presented in section 1.5.

1.2 HUMAN-ROBOT COOPERATION: PLENTY OF HYPE AND HIGH EXPECTATIONS

In recent years, human-robot cooperation – also known as human-robot collaboration, or HRC – has taken center stage at trade fairs such as Hannover Messe and Motek. The term HRC applies to any situation where robots work directly alongside humans without safety barriers on the manufacturing floor.

Articles in newspapers and trade journals describe – sometimes euphorically – how robots will be our new workplace colleagues, working hand-in-hand with their human coworkers. Figure 1 shows a selection of articles that appeared during Hannover Messe 2015. An online survey conducted by www.produktion.de in September 2014 reported that 86% of respondents are keen to invest in lightweight robots (1).

This combination of extensive press coverage and prices for simple robots starting as low as 15,000 euros has prompted significant interest in this technology among corporate decision-makers and created a certain amount of hype. Even articles in trade journals sometimes give

Fig. 1:
Press reports during Hannover Messe 2015

the impression that these new robots are so "safe" that companies can simply install an application with virtually no trouble at all and get started right away. Small businesses in particular have high and occasionally exaggerated expectations of how easy it will be to implement robot technology, especially if they are making a shift from manual processes or have limited experience with automation.

Even companies which have considerable experience with automation and their own in-house industrial engineering departments occasionally told us their expectations had been unrealistic, with feedback such as: "When we began this process we couldn't have guessed what lay in store for us!"

1.3 IT WORKS!

One of the key pieces of feedback from our study is that the new technology works (!), a fact that was confirmed in all the one-to-one interviews we conducted. People also made a number of comments about problems they had experienced with programming and doubts as to how to properly implement occupational safety standards and provisions. Uncertainties also emerged in relation to the planning process, the choice of application and the best configuration of the human-robot interface. Yet there was no sense that the respondents were questioning the value of the new technology itself. Everyone we spoke to seemed confident that they would be pursuing follow-up projects and that they were very much on a learning curve. The most frequent comments we heard in our interviews were:

- We have learned a lot.
- It was harder than we thought it was going to be at the start.
- We'll tackle the next project differently.

1.4 WHAT IS COOPERATIVE/COLLABORATIVE ASSEMBLY?

The term human-robot cooperation generally refers to the use of robots without safety fencing, i.e. cage-free robots. In our study we broke down the levels of interaction between humans and robots to distinguish and classify the different types of interaction. The tasks carried out by human workers and robots are combined within a single working environment, eliminating the strict division between the workers' manual work and the robot's automated work. The robots' and workers' work zones overlap, creating a common workspace (Fig. 2).

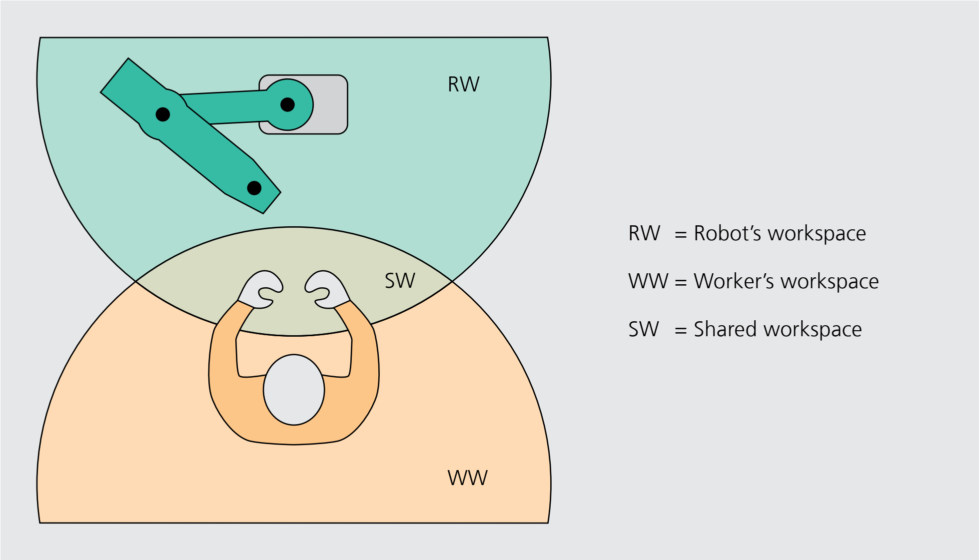


Fig. 2: Workers' and robots' workspaces (2)

On this basis, we defined the following types of interaction in the shared workspace, in all cases based on the task specified in the application:

- Cell – Not a genuine cooperation scenario since the robot is operated in a traditional cage.

- Coexistence – Human and cage-free robot work alongside each other but do not share a workspace.
- Synchronized – The design of the workflow means that the human worker and the robot share a workspace but that only one of the interaction partners is actually present in the workspace at any one time.
- Cooperation – Both interaction partners may have tasks to perform at the same time in the (shared) workspace, but they do not work simultaneously on the same product or component.
- Collaboration – Human worker and robot work simultaneously on the same product or component.

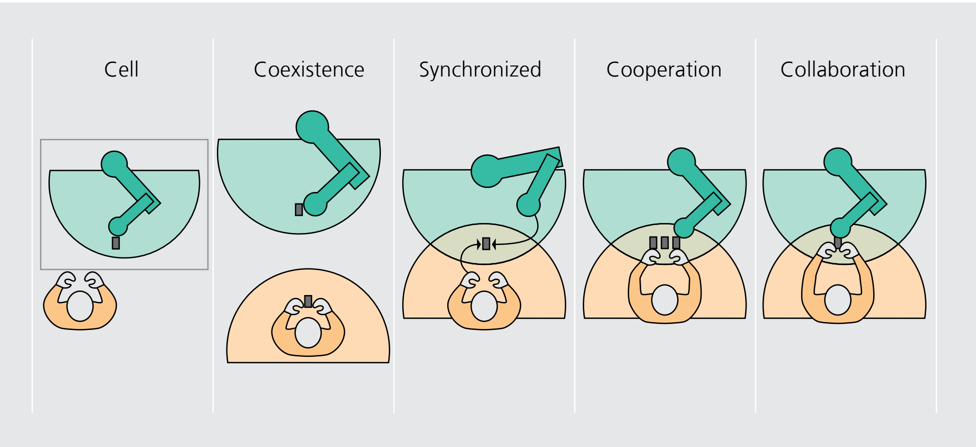


Fig. 3: The various levels of cooperation between a human worker and a robot

1.5 OVERVIEW OF KEY FINDINGS

This section lists the key findings that have not already been described above.

- Based on the distinctions made above, collaborative applications are virtually non-existent in production facilities at the present time.
- Human workers and robots primarily work alongside each other in a form of coexistence, an arrangement in which the new technology is very reliable.
- The key goal of using robots is to improve operational efficiency. Users also pursue additional goals such as improving ergonomics and trying out innovative technology (see reasons for choosing the application).
  - Typical ergonomic improvements include avoiding overhead work and reducing monotony.
  - Companies are perfectly willing to accept longer payback periods when it comes to improving ergonomics.

- These secondary goals mean that the payback periods of HRC systems are longer than those of "traditional automation." Users incur higher costs when it comes to safety issues, certification and the declaration of CE conformity, at least in the initial projects.
- The cost of cage-free robot operation is significantly higher than expected at the start of the planning process.
- Regulators are compiling new standards and guidelines for cage-free operation. Users still have little experience with these regulatory provisions, which they often find unsettling.
  - The safety issues of collaborative working have to be addressed not only by the systems integrator, but also by the user company itself.
- Most companies need new and additional support for their planning processes (tools, advice, resources, etc.) to enable them to implement cage-free robots on the assembly line.
- Experience suggests that an evolutionary process is the recommended option, in other words "starting simply," e.g. progressing from coexistence to collaboration.

In terms of the people working within the assembly system, our study produced the following findings:

- High acceptance of the new technology can be achieved among production workers and system supervisors only if they are integrated in the planning process, kept fully informed at all times, and properly trained.
- Upgrading the skills of production workers to enable them to perform new tasks related to robots opens up opportunities for new skills profiles and new ways of organizing work not currently used (e.g. training assembly workers to program robots). Upskilled machine operators and maintenance staff can also take responsibility for the support and maintenance of lightweight robots.
- Human factors research suggests that it is a good idea to include staff in the workplace design process – an approach that is already used for other work systems such as cardboard assembly, but not for robot systems. This would help improve acceptance.

1.6 BOTTOM LINE: DON'T LET OBSTACLES PUT YOU OFF – BEST TO START SIMPLY!

The technology certainly works, but it is not as widespread as you might think from the media hype. So what are the obstacles which are preventing the more generalized adoption of cage-free robots? Here are some of our suppositions based on the feedback we received:

- Uncertainties as to how standards should be implemented, e.g.:
  - How and where should we be measuring compliance with biomechanical limits? (ISO TS 15066)
  - What changes can the operator make to the approved application without infringing applicable standards and regulations (product, kinematics, environment)?
- Uncertainties about operational efficiency. The cited performance figures are typically based on everything running according to plan. In reality, however, workers may get close to a robot or collide with it, causing the robot to slow down or stop suddenly. This can reduce productivity and, in the worst-case scenario, have a negative impact on upstream and downstream workstations.
- Major uncertainty among management and works council members as to how this technology will affect jobs. Is the technology intended to support workers or take away their jobs?

We subsequently asked some users how they would approach a project to implement cage-free robots in the future based on their experiences and the knowledge they had gained. The response to this scenario was fairly unanimous: "choose an application that will work." In other words, implement an application that is not too complex, has simple requirements in regard to materials provisioning, doesn't involve sharp or pointed parts, and includes a reliable (assembly) process.

In terms of choosing the type of interaction, "coexistence" may well be the right way to start. It allows the company to show workers that they can approach and even touch a modern, properly implemented lightweight robot without any risk or danger.

"Best to start simply" is arguably the best tactic.

2 BACKGROUND

2.1 LIGHTWEIGHT ROBOTS OFFER NEW POTENTIAL IN THE REALM OF AUTOMATION

Compared to other countries, Germany has high wage costs. This exerts an enormous pressure on the cost of manual assembly systems, yet most assembly jobs in Germany are still manual. The reasons for this include more and more product variants (and even products specific to a single customer) that are generally not created until the assembly line stage, plus shrinking batch sizes and shorter product lifecycles. These reasons are well-known, and apply particularly to small and medium-sized enterprises (SMEs). Automation is not cost-effective in this situation, because small production runs do not lend themselves to reasonable payback periods and because high variance on the manufacturing floor makes automation more expensive.

Lightweight robots, or LWRs, can overcome some of these objections. They raise the hope of being able to support manual assembly tasks with reasonably priced technology, opening up automation potential that was previously inaccessible.

This brochure highlights some of the concepts and industrial applications of lightweight robots on assembly lines and in areas closely linked to assembly. In this context the term "lightweight robot" refers to any robot that can work together with a worker without safety fencing (cage-free), approximates the human arm in size, and can be moved easily. In general, people apply the term LWR to robots which weigh relatively little. However, some robots such as the Bosch APAS and the KUKA KR5 SI are heavy robots with a larger reach that can also be operated cage-free in collaborative workspaces. We have therefore also included these robots in our study.

2.2 THE IMPACT ON MANUAL ASSEMBLY

Cage-free robot operation particularly affects manual assembly since it opens up entirely new opportunities for supporting human workers without having to make the kind of major changes to work system layouts that would be required for a robot cell with safety barriers. With prices starting at approximately 15,000 euros (robot capital cost), it is possible to implement simple applications rapidly and cost-effectively without requiring major investments in material provisioning systems, additional safety installations, or expensive robot end effectors.

The increasing proximity of humans and robots prompts the consideration of new cooperation scenarios that could be applied to assist human workers, e.g.:

- Supporting humans by improving ergonomics, taking over monotonous tasks, or performing support tasks.
- Providing support in tasks that are difficult for human workers or that require high precision or repeatability.
- Providing support to overburdened workers in production processes that run very fast, for example by taking over some portion of the tasks involved.
- Providing support to address temporary or permanent shortfalls, such as a period following an accident, reintegration, and other performance-limiting incidents.

2.3 WHAT'S NEW ABOUT USING LIGHTWEIGHT ROBOTS?

The key advantages of the new LWRs are the low cost of acquisition and less inertia thanks to lower weight. This latter benefit has quickly prompted users to seek ways of using the robots as portable units in multiple locations, in some cases by equipping them with wheels. (3)

Anyone seeking to implement human-robot collaboration must adhere to the pertinent standards on automation, in particular EN ISO 10218 -1,-2 and ISO/TS 15066 (4).

All the robots in the applications we examined have capabilities that, in principle, allow them to operate cage-free. Since robots are considered to be an incomplete machine under the Machinery Directive, their safe use can only be assessed in the context of the intended application, including the workpiece, tool, work environment, etc. Depending on each individual application, additional protective measures may be required, for example a lower robot speed. One of the shortcomings of the new type of lightweight robot is their lower load capacity, though this is nevertheless sufficient for many applications.

2.4 SAFETY REQUIREMENTS FOR COLLABORATION

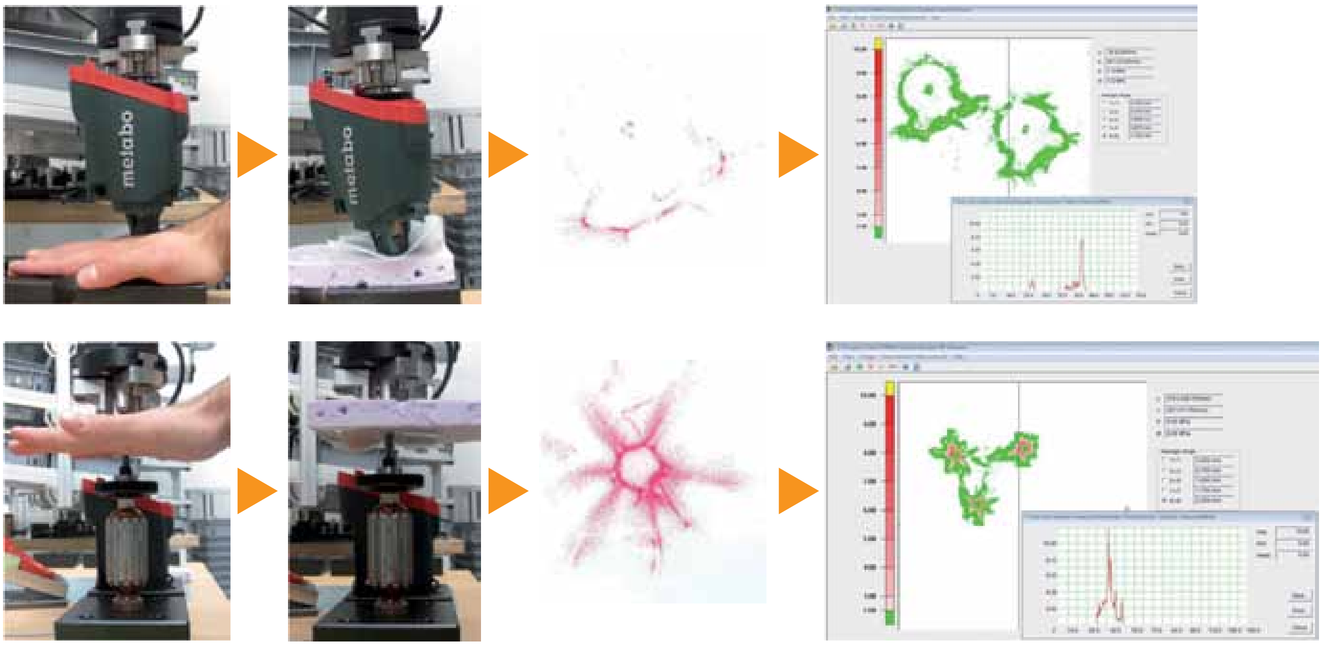
In terms of a certification of safety and conformity from the manufacturer, it is important to remember that a LWR cannot be CE marked and can only be provided with a Declaration of Incorporation. Without its associated application, sensors and end effectors, an LWR is considered to be an incomplete piece of machinery. Only after assembling individual machines and incomplete machines into a complex installation is it then possible to subject the complete system to a risk analysis (as per Machinery Directive 2006/42/EC) or risk assessment (as per the German law on safety and health at work, ArbSchG) in order to determine whether there is still a risk of collision.

All applicable safety and medical/biomechanical requirements must be taken into account in this process in order to keep any risk of injury to a low, acceptable level. Partial dynamic collision forces and pressures are transferred to the contact area between the human and the machine. These determine the risk of injury. The medical/biomechanical requirements set appropriate limit values for the injury criteria of "force" (clamping/squeezing force or impact force) and "pressure/surface pressing" (cf. BGIA 2011). Compliance with these limit values ensures that the load applied to the person by mechanical forces is kept low (cf. DIN EN ISO 10218 Parts 1 and 2).

Defined measurement principles and processes can be used to check the required safety limit values as part of a risk assessment. These provide a means of measuring the speeds, forces and pressures exerted in the application. Pressure-sensitive films are often used to measure pressure in this context. For example, Fig. 4 shows two possible ways in which a human hand could be squashed between the robot and the workpiece or between the workpiece and the workbench (left) in a drill assembly used in Fraunhofer IAO's model factory. The illustration in the middle of this figure shows the pressures exerted on a pressure-sensitive film (MOS FUJI pressure measurement film LW) in the event of a collision. On the right we can see the evaluation of these pressure measurements using the FDP-8010Win analysis software, with the critical points shown in red.

Results such as these were used as a basis for reducing the robot's speed on the one hand, and reducing the force required to trigger an emergency stop in order to reduce the critical pressure levels. When it comes to these kinds of measurements, we recommend using the services of institutions that have the necessary measuring tools (e.g. DGUV, BGHM).

Collision | Pressure measurements* | Result | Analysis software**



* MOS FUJI pressure measurement film LW

** FDP-8010Win software

Fig. 4: Pressure measurements in the event of a collision with a drill assembly

3 LWR DESIGN CRITERIA

In order for humans and robots to work together collaboratively, a series of design guidelines must be taken into account in order to obtain acceptable, successful solutions. These can be divided into the following five design criteria:

- operational efficiency,
- safety,
- ergonomics,
- development of the work content and work organization, and
- acceptance.

3.1 OPERATIONAL EFFICIENCY

Survey results

Increasing operational efficiency was cited as the most frequent reason for choosing an application (see Fig. 5) and a number of cost-effective applications are already up and running. This is remarkable for such a young technology at such an early stage of its implementation.

Yet, for most of the applications we examined, "different rules" apply to operational efficiency than those applicable to conventional automation. The length of time companies will typically accept to pay off an investment in conventional automation varies enormously depending on the company and industry involved. Automotive and electronics manufacturers often expect this to take one year or less (5). However, most companies make exceptions when it comes to human-robot collaboration, showing a willingness to "extend" the normal payback period. Even setting aside the cost of researching, testing and familiarizing themselves with the new technology, companies still need to accept that payback will take longer. Almost every application was chosen for at least some reasons that cannot be evaluated in monetary terms, the most important of which are:

- Improving ergonomics – taking the strain off employees in terms of both physical and mental workloads (monotony).
- Improving quality – customer requirements (e.g. clean adhesive bonds, sensitive surfaces, process reliability).
- Increasing flexibility in regard to batch sizes.

There is one key reason for choosing an application which is referred to in the literature (cf. (6)) but which was not cited by the respondents in this study, namely the flexible use of (mobile)

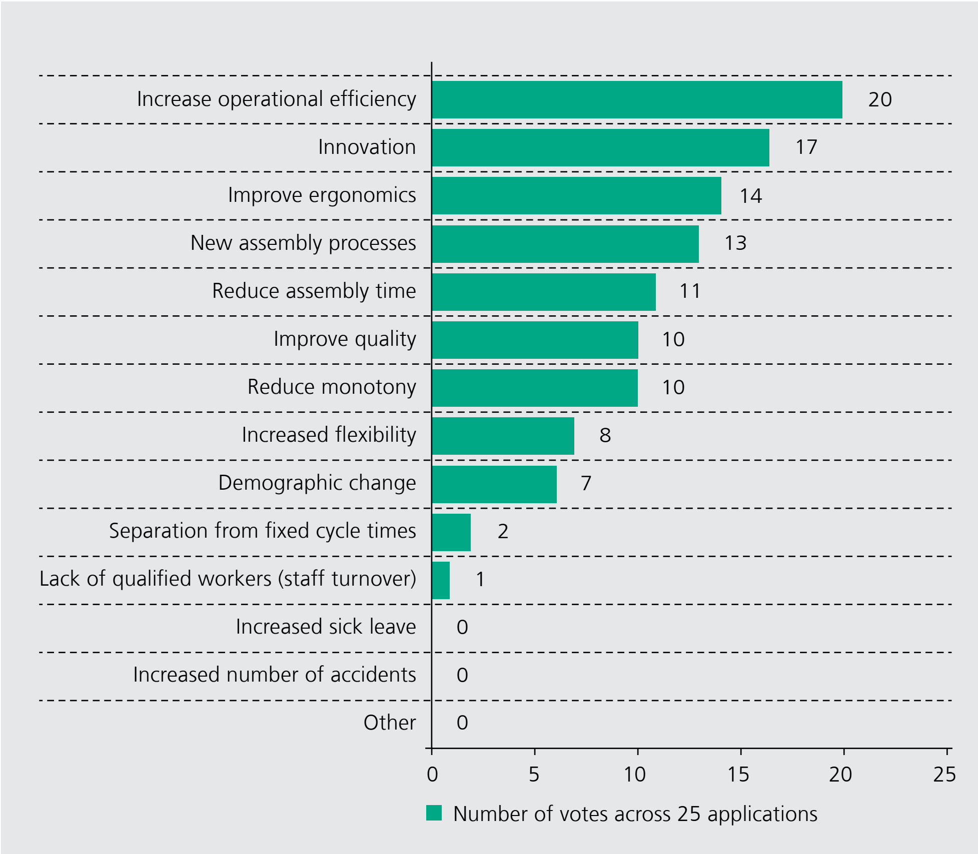


Fig. 5:
Reason for choosing application (more than one option may be chosen)

robots in various applications and/or in various assembly systems. This would allow the investment to be spread over multiple products. At the companies we visited, we encountered no sign of any mobile application for multiple products using lightweight robots that is anywhere close to production-ready. At present the companies are focused on building up some initial experience with stationary pilot applications. Improving operational efficiency by using a single robot for multiple systems is not currently required and would represent an additional degree of complexity.

Interpretation and recommendations

In conventional automation projects, the cost of the robot represents just one third of the total investment. All the other costs combined come to two thirds of the total project cost. It would appear that this rule of thumb is also applicable to lightweight robots. The key cost drivers behind the investment are provisioning the material in the manner required by the robot and providing the necessary guarantees, including certifying the safety of assembly workers. It is important not to underestimate the cost of supplying the materials required for assembly when you are switching from a purely manual system based on containers of unsorted parts to a system suitable for providing materials to a lightweight robot. Large parts can be made available in containers, clearly separated and arranged using inserts. Depending on the shape of the parts it may be necessary to use a camera or similar system to determine the exact position of each part. Smaller parts can be supplied to the assembly system using methods such as a spiral conveyor. The fundamental questions of whether part provisioning can be automated at all and how much this will cost must be investigated for each part separately.

The systems integrator is responsible for verifying that the assembly workers can collaborate with the robot safely and for certifying this fact in the form of a CE declaration of conformity in line with the Machinery Directive. The operator must carry out a risk assessment before starting to work with the system. This must be re-checked and, where necessary, repeated every time that the application is changed (tool, parts, robot programming, etc.). There is currently insufficient real-life data to offer accurate figures for the cost and effort this involves. It also remains unclear whether it is better for the systems integrator or the operator themselves to perform these checks and re-approval procedures, especially in the case of small SMEs that do not have their own industrial engineering department.

In many cases, robots perform assembly tasks significantly slower than human workers because cage-free operation puts constraints on their maximum speeds. In addition, a robot can generally be equipped with only one tool or one specific gripper, which can often only be used to hold one specific part. That somewhat limits the tasks robots can take over from humans and that can be offset as potential savings.

It is therefore necessary to consider the robot's higher capacity for work. The savings that can be potentially achieved by a robot taking over from a human worker in an assembly process for a specified period of time are relatively low, hence the use of LWRs requires an alternative justification (e.g. ergonomics, see above) or longer running times (e.g. three-shift operation) in order to achieve adequate levels of operational efficiency in a traditional sense (7).

Operational efficiency was a major reason behind the choice of application in all the applications we examined, though none of the people we spoke to had carried out traditional analyses of efficiency and profitability at that point in time. Seen in this light, it would appear that investments in human-robot collaboration are currently in a transitional phase that can be attributed to the novelty of this technology. Once this transitional phase is over, companies will shift to viewing the calculation of whether HRC will be profitable in the same way they treat other investments – in other words it will become a prerequisite for making the investment in the first place. In the meantime, it is safe to assume that the price of robots will continue to fall.

3.2 SAFETY

Survey results

The safety of a lightweight robot is one of the essential prerequisites for using it on the factory floor, which is why the respondents in our study placed such an emphasis on issues of technical system safety and robot system certification. Our findings show that a safety strategy depends on the way in which the robot interacts with human coworkers. In most cases this is a form of coexistence in which humans only occasionally interact with the robot in a shared workspace (e.g. replacing a feeder tray).

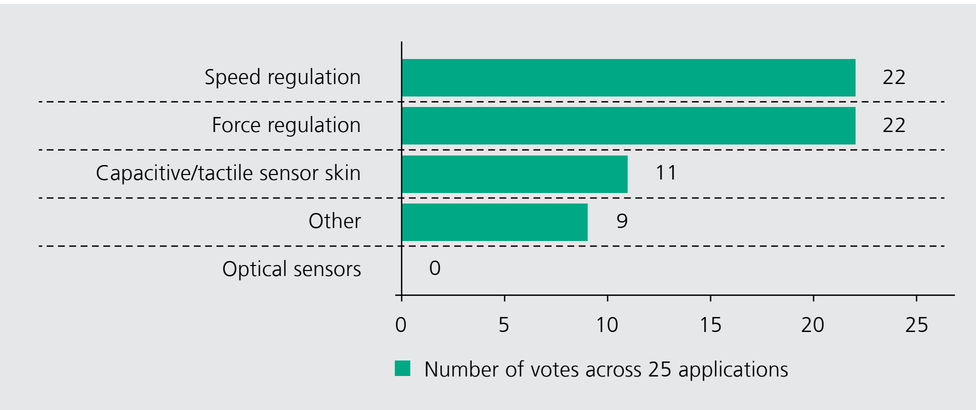


Fig. 6:

Robot safety features

Approximately three quarters of the applications do not feature any additional safety devices, leading to the assumption that the robot has the required safety features (see Fig. 6).

All the robots used in the applications include a means of regulating speed and force. In addition, the APAS and the KR 5 SI have capacitive and/or tactile sensors that reduce the robot's speed or bring it to a complete halt if someone approaches or touches the robot.
The robots also feature "safe grippers" that are provided by robot manufacturers or suppliers. A distinction is made between "optically and mechanically monitored grippers" (e.g. APAS) and "mechanically monitored grippers" (e.g. KR 5 SI).

A certificate of system safety is provided by means of certification or self-certification of the application, see e.g. (8). All but five of the applications are certified at the companies themselves (cf. Fig. 7). Certification normally comprises a system-related risk analysis by the systems integrator (i.e. the manufacturer of the application, generally an external partner in the case of SMEs) and an application-related risk assessment by the company operating the robot. Risks are generally assessed by the safety officer, in most cases supported by experts from the professional/trade association (e.g. force measurements). The declared goal of the collaboration between the safety officer and the systems integrator is to carry out certification independently in the future (i.e. self-certification).

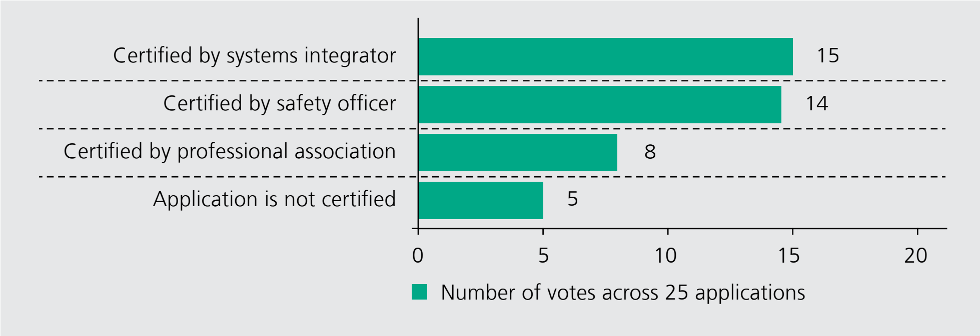


Fig. 7:
How the application is certified (more than one option may be chosen)

With their plentiful qualified staff, larger companies see little need to seek support in implementing and certifying lightweight robots. They often have their own in-house pre-development departments as well as safety officers with the requisite experience. In contrast, SMEs typically express a need for further support (cf. Fig. 12): this ranges from choosing the best application (taking into account safety, feasibility and operational efficiency) to selecting the best gripper and handling the certification process. Obviously the operational efficiency of the LWR application depends substantially on the company achieving an adequate level of safety.

Interpretation and recommendations

In practice, most lightweight robots currently work separately from human workers, either working in a shared space at different times or working in a completely separate space. Nevertheless, the industrial deployment of lightweight robots is already prompting the question of how to ensure the required level of safety in truly collaborative work environments in which workers and lightweight robots share the same space. In collaborative environments, undesired contact between humans and lightweight robots may occur not only during the actual assembly work, but also when setting up, maintaining and cleaning machines, etc. In all these situations, the priority is to guarantee worker safety while simultaneously avoiding intermittent disruption of the robot's work.

To minimize the risk of lightweight robots posing a hazard to humans, EN ISO 12100 "Safety of machinery – General principles for design – Risk assessment and risk reduction" defines a series of appropriate preventive measures. One of the key points made in this standard is that a collision between a human and a collaborative robot may not under any circumstances lead to any additional, non-mechanical, detrimental stresses or strains being placed on the person involved (e.g. through exposure to hazardous substances or electric shocks). The contact area of a collision between a human and a robot must be designed to reduce the risk of injury (e.g. avoiding sharp edges or small surfaces, rounding off corners, attaching padding, etc.).

3.3 ERGONOMICS

Survey results

One of the goals of using lightweight robots in industry is to unlock ergonomic benefits and minimize existing deficiencies. This primarily concerns the following areas:

- Providing support in situations where workers have to maintain a certain posture or hold themselves in an awkward position, e.g. unnatural postures, overhead work, static positions, uncomfortable reaching distances.
- Take the strain off workers in tough physical/chemical work environments (e.g. noise, light, climate, contaminants).
- Provide power assistance to employees whose performance has become diminished or limited in some way, especially against the current backdrop of demographic change.
- Releasing people from highly repetitive tasks (such as attaching clips) or tasks that require a level of precision which is beyond the capabilities of a human worker.

According to the respondents in this study, these kinds of ergonomic improvements are a key reason for deploying lightweight robots (cf. Fig. 5, ergonomics ranked third).

These expectations of ergonomic improvements largely seem to have been met, with the companies surveyed confirming that the strain on workers has been reduced in 17 applications (cf. Fig. 8).

Satisfaction with the optimized ergonomics of human-robot systems does not however manifest itself in financial performance indicators – at least not as things currently stand. The fact is that companies do not yet have the appropriate data or methods of calculation to measure this in financial terms, and it is not possible to establish plausible causal links between situations where people are working under strain, individual performance capabilities, and productivity. Automakers, in particular, view the ergonomic optimization of their assembly workstations as part of their social policy, which cannot be measured on the basis of strict criteria for operational efficiency or profitability. They therefore tend to show greater flexibility when it comes to ergonomic investments, for example by accepting a longer payback period (e.g. 4 to 6 years instead of 2 years).

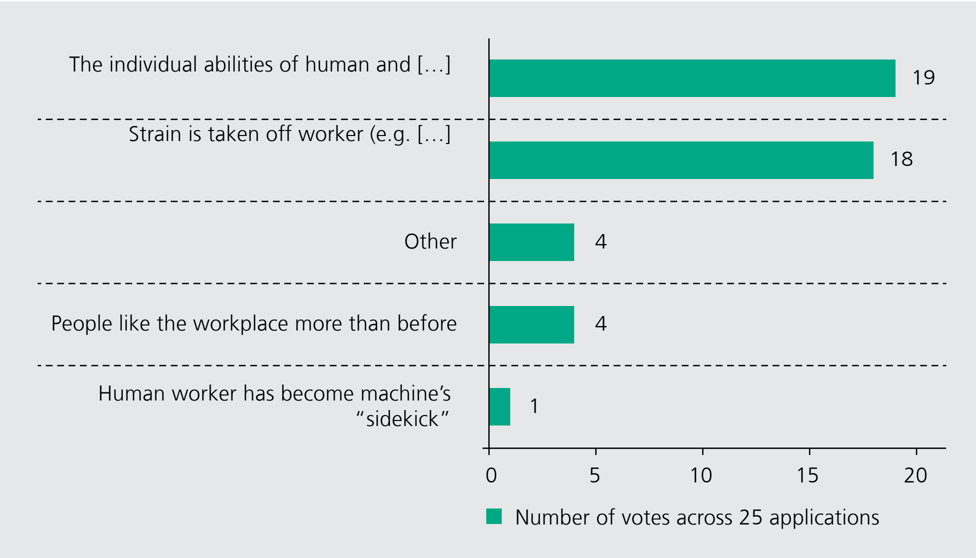


Fig. 8:
Effects on people and/or the work environment

Interpretation and recommendations

Ergonomics stems from a broader understanding of the need to create reasonable working conditions that are as comfortable as possible for workers. It therefore addresses not only physical factors, but also issues such as reasonable work content, giving employees leeway to schedule and define their own activities, finding the best ways for people to learn tasks, and the importance of gaining acceptance from employees. Experience has shown that these "soft" factors have a significant influence on the productivity of human-robot systems (9). Relevant design principles are documented in DIN EN ISO 26800 "Ergonomics – General approach, principles and concepts," DIN EN ISO 6385 "Ergonomic principles in the design of work systems" and DIN EN ISO 10075 "Ergonomic principles related to mental workload. General terms and definitions."

A thorough, systematic analysis and design of a human-robot system should look at human performance prerequisites/capabilities on the one hand and task-specific requirements on the other and then use the adaptability of modern robot technology to neatly dovetail these two points. The goal is to allow humans and robots to make the most of their respective strengths in the assembly process (cf. in Fig. 9).

	Human	**Robot**
Pros	▪ Assimilates (new) tasks rapidly and can make judgments ▪ Able to move freely and apply tolerance compensation ▪ Able to sense and locate things ▪ Flexible availability ▪ Can handle complex parts ▪ Able to innovate	▪ Consistent quality thanks to integrated process control ▪ Endurance ▪ Able to take on unreasonable and monotonous tasks ▪ Can handle heavy, hazardous parts
Cons	▪ Limited quality and process control ▪ Physical and mental performance limits, fatigue ▪ High cost of training ▪ Requires a jig to position parts accurately	▪ Limited movement ▪ Requires a defined deployment ▪ High cost of implementation, programming and certification ▪ Function-oriented rather than goal-oriented ▪ Fixed costs even if the workload fluctuates

Fig. 9:
Pros and cons of humans and robots in relation to LWR deployment

Qualified ergonomic analysis and design is a prerequisite for optimizing the interaction between humans and machines in assembly processes covering the whole spectrum from coexistence to collaboration. It also contributes to the sustainable operational efficiency of HRC systems.

3.4 WORK CONTENT DEVELOPMENT AND WORK ORGANIZATION

Survey results

One aspect of developing work content is to determine how tasks will be divided between humans and robots. The tasks should be configured in such a way that the assembly workers' situation does not deteriorate, but ideally improves. All the applications examined in this study are HRC applications that have been integrated – or are in the process of being integrated – in existing assembly lines. In other words the companies looked at an existing assembly system and then selected a suitable application for human-robot collaboration.

The process of work organization takes into account how all the tasks are divided up in a work system. These tasks stem from cooperation and interaction with other groups, people, pieces of equipment, information sources and other resources and include higher-level design and development tasks as well as the places, times and personnel to which these tasks are assigned. We limited the focus of our survey to the direct assembly tasks and the new tasks that emerge as a result of the HRC application. These new tasks are (6):

- direct assembly tasks (in tiered HRC scenarios, Fig. 3),
- installing and setting up robots and rectifying (minor) faults,
- training and teaching robots,
- planning and organizing the HRC deployment in regard to material planning and scheduling,
- programming and maintaining robots,
- planning and evaluating new HRC applications, and
- implementing HRC applications.

In terms of assembly systems, the companies surveyed mostly make a distinction between assembly tasks and robot supervision/support tasks, something that is reflected in the qualifications required for these different sets of tasks (Fig. 10).

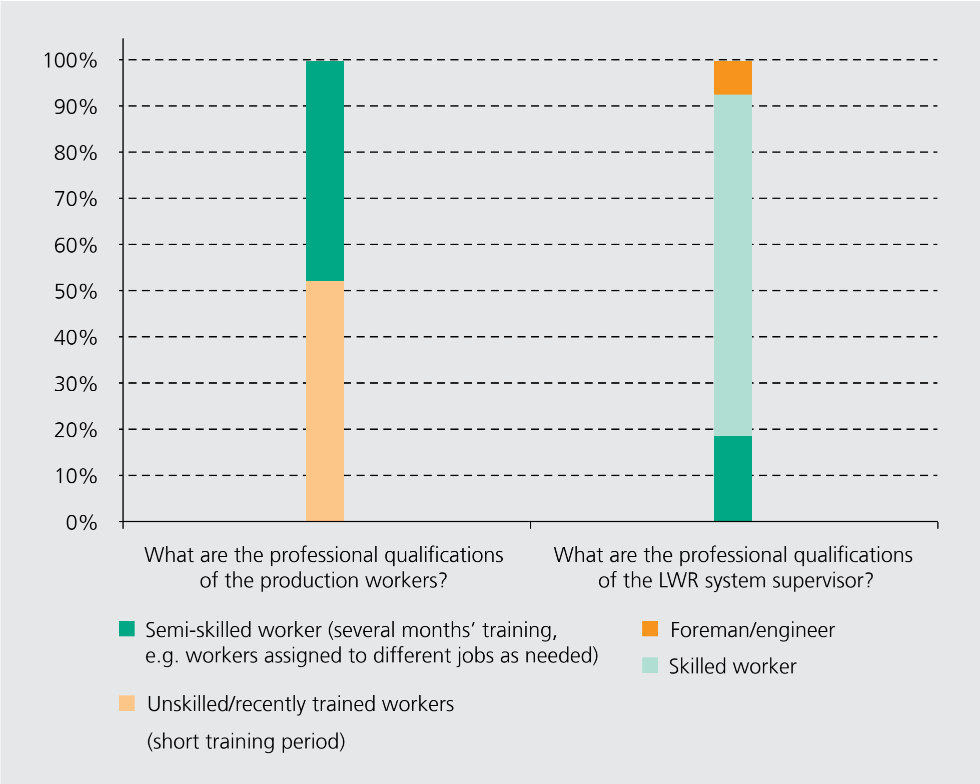


Fig. 10:
Professional qualifications

When it comes to the robot supervision/support tasks, a distinction is made between rectifying minor incidents (e.g. restarting after an emergency stop, sorting out jammed parts, etc.) and major changes to the application such as reprogramming. The way these tasks are currently divided up at the companies is shown in Fig. 11, and no changes are currently envisaged.

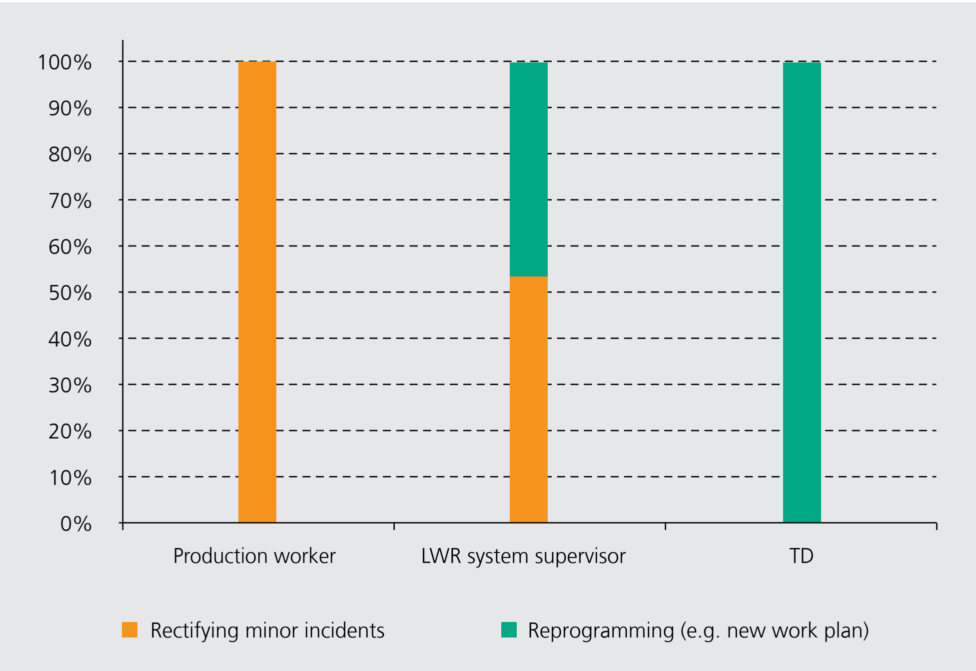


Fig. 11:
Division of tasks in the assembly system

Interpretation and recommendations

The human-robot interface must be oriented to the respective capabilities of humans and robots. However, the humans involved should not be left with any residual monotonous tasks, but rather tasks that challenge them to the correct degree. No tool is currently available to help efficiently support the design of this interface. Innovative new ideas for dividing up labor – such as varying the tasks performed by a robot in order to support the differing abilities of different human co-workers – are currently being studied by researchers (6) but are still a long way from being incorporated in real-life production environments.

Human-robot collaboration offers significant potential for improving how work is organized (see the range of tasks covered in the work content) – the key is to exploit this potential. The new range of tasks and requirements offers plenty of scope to configure how work is organized and to incorporate work that challenges people to the correct degree while enhancing their qualifications and enriching their life on a personal level. Some possible ways of modifying the design of work content and how work is organized include (10):

- guaranteeing a diversity of challenges in work tasks,
- completeness of the task,
- rotating people through tasks that present them with various different challenges,
- skills and qualifications as a prerequisite for rotation, and
- allowing employees to participate in configuring their own working conditions (see acceptance).

This represents an opportunity to redesign the kind of manual assembly work that has previously tended to feature monotony and repetitive physical labor with limited variations. The wide range of new tasks provides an excellent chance to offer tiered skills profiles and development opportunities to workers. As yet, companies are not exploiting this potential.

3.5 ACCEPTANCE

Survey results

Acceptance is a key prerequisite for running an HRC application productively (9). One respondent said that “when people start giving the robots pet names then you know they’ve accepted the technology.” In the applications examined in this study, acceptance has been achieved by providing comprehensive information on the project to everyone involved. Clarification as to how jobs will be retained is important both to the workers and the works council.

In manual assembly systems it has become customary to involve workers in certain phases of planning how their work will be structured (e.g. with workshops or cardboard engineering) (11) in order to reap benefits such as increasing their acceptance of the new system. But in the realm of human-robot collaboration, there is a lack of corresponding standardized approaches that would give workers a voice in designing aspects such as intervals and tasks. The applications we examined in this study do not feature any participative approaches of this kind.

Interpretation and recommendations

There are many possible ways of increasing workers' acceptance of human-robot collaboration. There is no doubt that one of the most important is clarifying exactly how the HRC will actually work. Clarification begins with people's concerns about their own jobs, though demographic change means this issue is not actually as pressing as one might assume (7).

If the design principles outlined in section 3 are properly addressed, this creates the prerequisites for a good, worker-oriented HRC workplace. Actually achieving the necessary acceptance of the new technology among workers – or better still their trust and confidence – requires that the planning and implementation process should have a cooperative slant. Cooperative design means getting all the relevant participants involved and contains the following components:

- **Participation**
  Detailed planning of how to implement the HRC solution is carried out on a decentralized basis with the workers involved. Responsibility is task-focused and delegated down to the shop floor level. If the company has a works council, this should also be incorporated in the process and kept informed from an early stage
- **Constant flow of information**
  Keep people informed from an early stage and update them regularly on how the process is unfolding. Ensure the goals of the HRC are transparent and clearly link them to the company's overall objectives.
- **HR development**
  Start providing workers with the basic skills they will need and make sure they obtain more specific skills in plenty of time (see Fig. 11). Skills training must be provided to managers, too, as well as tools for dealing with any conflicts that may arise.
- **Create a climate of trust**
  Communicate openly and honestly with each other. Gain the employees' trust.

4 HOW FRAUNHOFER IAO CAN HELP

4.1 QUICK CHECK OF LWR POTENTIAL

Many companies – especially SMEs – recognize that they need some form of support. This ranges from choosing the best application (taking into account operational efficiency, safety, feasibility, and collaboration) to selecting a process tool (such as a gripper) and working through the entire planning and certification process.

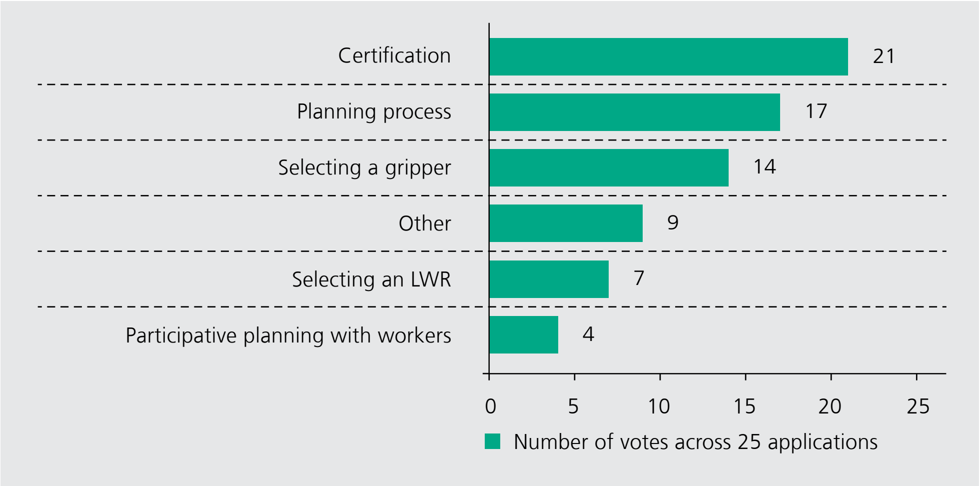


Fig. 12:
Areas in which companies seek support (more than one option may be chosen)

Selecting the application or task to be performed by the lightweight robot is particularly important in this context. There are a number of issues that arise here, and we can support you by offering a quick check or some other form of assistance in the following areas:

- Identifying high-potential tasks (LWR potential).
- Making an initial appraisal of the tasks to determine how feasible it is to automate them in terms of providing adequate levels of safety, and how easy this is likely to be.
- Estimating the operational efficiency of the tasks to be automated.
- Providing an initial recommendation of which robot would be most suitable for the specific application.

4.2 RESEARCH GROUPS

Whether you are an experienced user or taking your first steps in this field, Fraunhofer IAO's research groups can support you in introducing and designing cost-effective LWR applications that are accepted by the workforce.

Research group for newcomers to the field of LWRs

The participants meet up at regular intervals, holding a one-day workshop approximately once every 2 to 3 months. A total of 5 workshops are held each year, designed for 15 to 20 participants. Fraunhofer IAO plans, organizes and facilitates the one-day workshops. Key players and protagonists in the realm of human-robot collaboration offer ideas on how to design and implement LWRs.

Research group for LWR users

The second research group offers eight participating companies the opportunity to gain in-depth knowledge of the design criteria for collaborative assembly processes using lightweight robots and to examine methods of introducing LWRs. In each case, the host company showcases the current status of its LWR applications and the participants then discuss possible improvements. With the guidance of Fraunhofer IAO experts, the participants work together to develop ideas and methods tailored to their own business.

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6 APPENDIX

Appendix A1 contains a table showing key information on each application to enable readers to quickly choose an application that interests them.

Appendix A2 contains a detailed description of the individual applications.

Fig. 13:

Overview of all applications

6.1 A1: OVERVIEW OF ALL APPLICATIONS

Application number	1	4	5	6	7	7_1	7_3	8	9	12	13	20	21	22	25	26	27	28	42	43	44
1 Sector																					
Mechanical and plant engineering		●								●											
Automotive					●	●	●	●							●	●	●	●	●	●	●
Electrical engineering	●										●	●	●				●	●	●		●
Consumer goods			●	●																	
Other									●					●							
2 Shape of parts																					
Small (100 x 100 mm)				●			●		●		●	●	●		●	●	●	●		●	●
Large (> 100 x 100mm)	●	●	●		●	●		●		●				●					●		
3 Weight of parts																					
< 200 g				●			●				●	●	●		●		●	●			
200 - 4000 g	●		●					●	●	●				●		●			●	●	●
4000 - 9000 g																					
> 9000 g		●			●																
4 Cycle time																					
< 15 sec											●		●		●	●	●	●	●		
15 - 60 sec	●		●	●	●					●		●		●							
> 60 sec						●	●	●													
5 Application maturity																					
Demonstrator	●													●			●		●		●
Test under real production conditions						●	●														
In ongoing production		●	●	●	●			●	●	●	●	●	●		●	●		●		●	
6 Application area:																					
Assembly	●	●		●	●	●	●	●	●	●	●	●	●	●	●					●	●
Logistics																	●				
Part manufacturing			●													●		●	●		

Application number	1	4	5	6	7	7_1	7_3	8	9	12	13	20	21	22	25	26	27	28	42	43	44
7 Reason for choice																					
Reduction in assembly time	●	●						●	●	●	●	●	●								●
Reduction in monotony											●				●	●	●	●	●	●	
Increase in batch size flexibility			●							●					●	●	●	●	●		●
Ergonomic enhancement	●	●	●	●	●	●	●	●		●						●	●	●	●	●	
Increase in quality		●					●	●		●	●							●	●	●	●
Economic advantage	●				●	●	●	●	●	●	●		●		●	●	●	●	●	●	●
Innovation		●			●		●	●	●		●	●	●	●	●	●	●	●		●	
New assembly processes		●			●		●	●	●	●			●	●		●	●	●	●		
8 Application classification																					
Mount and join	●		●	●	●		●		●		●			●							
Quality control		●	●		●		●	●											●		●
Tool insert		●		●		●				●				●							●
Load a machine			●						●		●	●		●					●	●	
Glue or weld										●											
Pick & place	●		●									●			●	●	●	●	●	●	
Pack & palletize			●	●								●			●	●	●	●	●		
Grip a part							●	●	●						●	●	●	●		●	
Grip multiple parts	●				●						●		●	●							●
Provide a part						●		●													●
9 Robots used																					
KUKA iiwa		●	●	●	●	●	●														
APAS															●	●	●	●	●	●	●
KR 5 SI								●	●												
YuMi											●										
UR5 or UR10	●									●		●	●	●							
10 Reason for choice																					
Simple certification								●	●		●				●	●	●	●	●	●	●
Low investment	●									●		●	●	●							
Sensitivity		●	●	●	●	●	●														
11 Certification																					
Application is not certified	●													●			●		●		
By trade organization		●			●	●	●	●	●											●	
By systems integrator		●	●	●	●			●	●	●	●				●	●		●		●	●
By safety officer						●	●		●		●	●	●		●	●		●		●	
Other																					
12 Degree of collaboration																					
Cell																					
Coexistence			●	●			●		●		●		●		●	●	●	●	●	●	
Synchronization		●								●		●		●							
Cooperation	●				●																●
Collaboration						●		●													

The diagrams below summarize some of the key data relating to all 25 applications, for example the different makes of robot used, the degree of collaboration involved, and the applications' level of maturity.

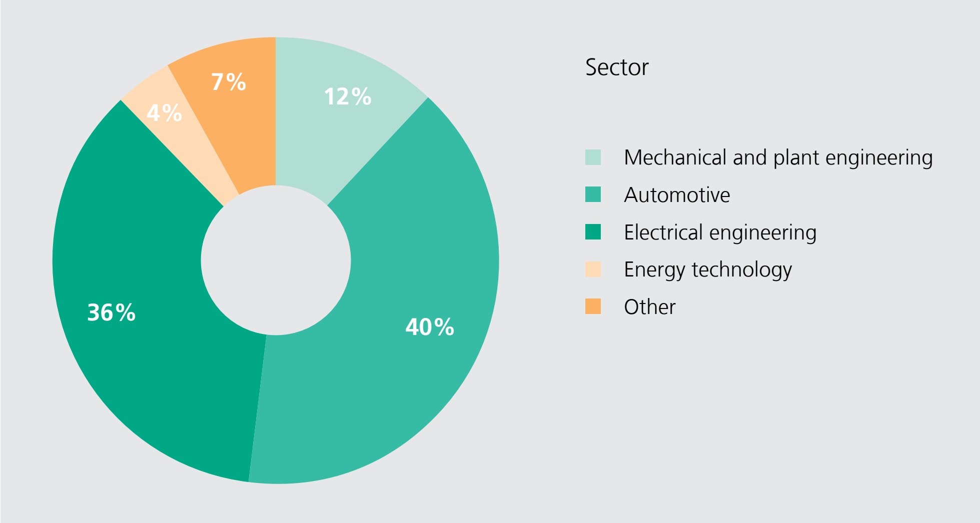

Fig. 14:
Applications grouped by sector

It is noteworthy that three quarters of the applications fall within the electrical engineering and the automotive sectors.

Relatively few robots – just 12 percent – are currently deployed in the mechanical and plant engineering sectors.

Over 80 percent of the applications are already up and running on the factory floor. The demonstrators and robots that are still undergoing testing under real-life production conditions are all close to being deployed on the assembly line. All the applications are running satisfactorily.

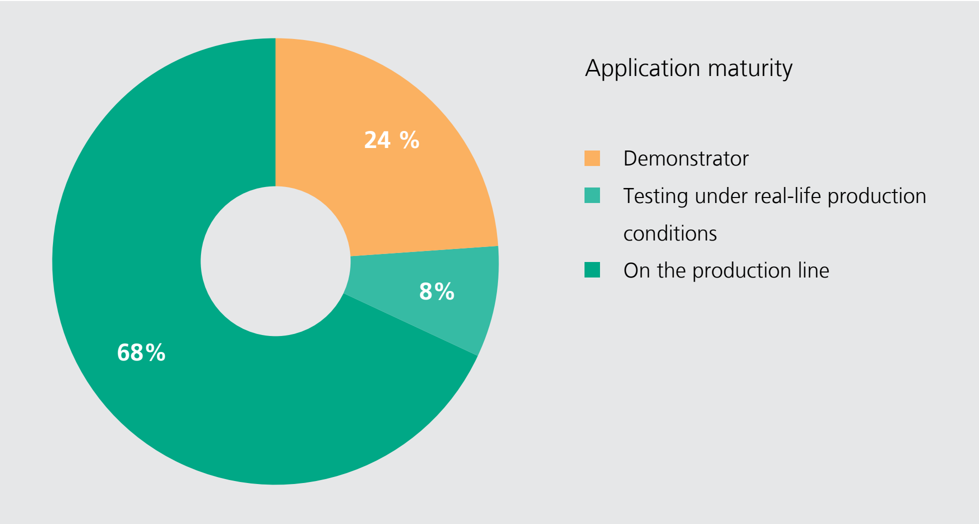

Fig. 15:
Level of maturity of the applications

Over 70 percent of the applications are in the assembly area.

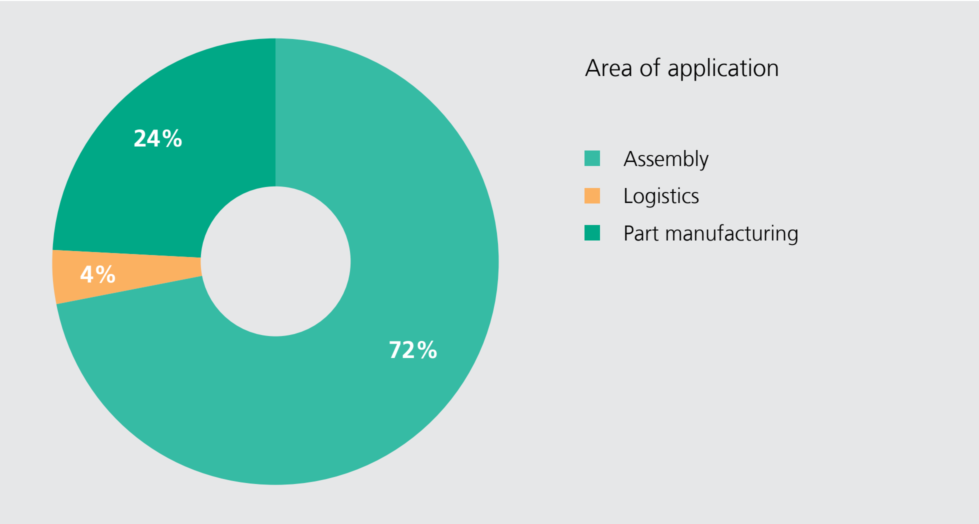

Fig. 16:
Area of application

This diagram highlights the many different uses of lightweight robots.

The applications can essentially be divided into three main groups. The first group involves "gripping" one or more parts and "joining" them. The second group comprises "pick & place" applications, "machine loading" and "packing & palletizing" – basically simple processes for transferring parts or products from one place to another. The last group features processes in which the lightweight robot is equipped with a tool, for example "screw tightening," "gluing" and "welding." Quality control is an add-on in all the groups.

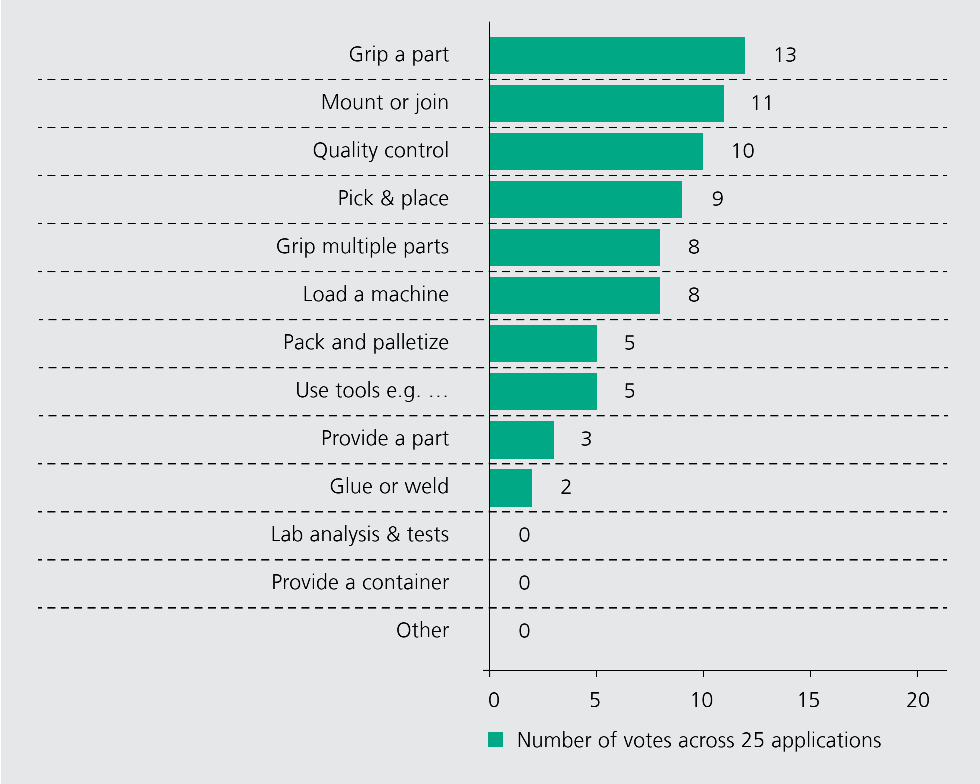

Fig. 17:
Classification of applications (more than one option may be chosen)

The diagram shows how frequently each make of robot appears in the study. In selecting the applications we attempted to maintain a more or less even distribution of the robot types, though it is important to note that these robots exhibit some fundamental differences.

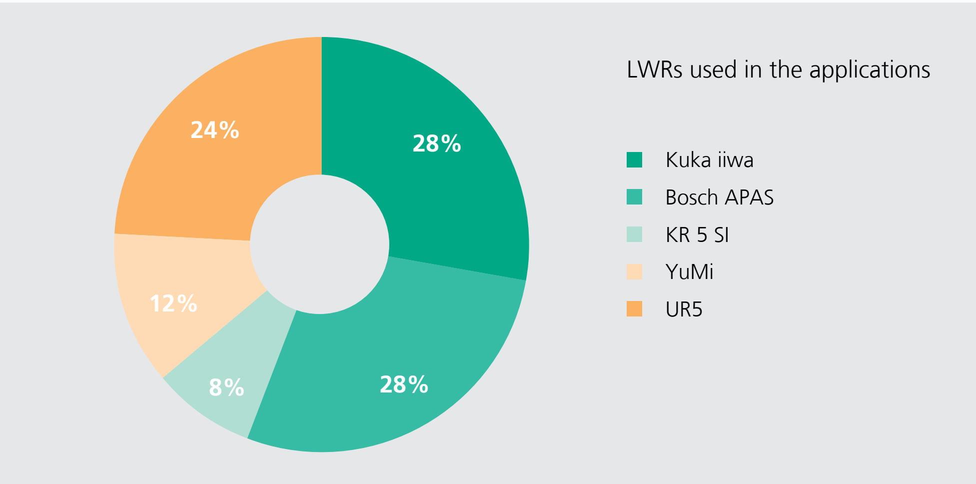

Fig. 18:
Robots used in the applications

There was only one application where a worker genuinely collaborates with the robot. In the majority of cases the applications involve a form of coexistence in which the humans and robots only occasionally share the same workspace (e.g. replacing a feeder tray).

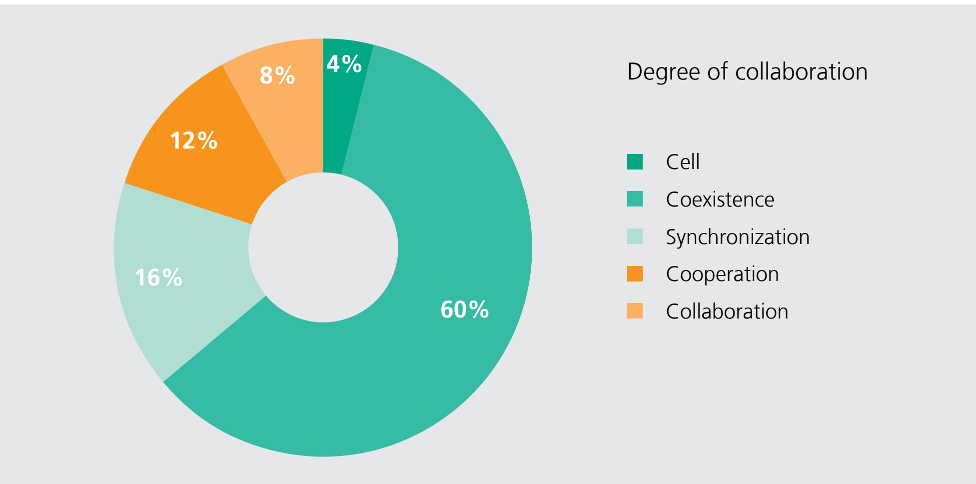

Fig. 19:
Field of application

6.2 A2: DETAILED CHARACTERIZATION OF INDIVIDUAL APPLICATIONS

This section provides an anonymized, detailed description of all 25 applications in tabular form. In cases where the company granted its approval, we have included a photo of the respective application – otherwise only the lightweight robot arm is shown.

1

Anwendungsfall

Bohrmaschinenmontage

Wesentliche Informationen	LBR: UR5 Kollaborationsgrad: Kooperation	Applikationsreife: Demonstrator Applikationsort: Montage Branche: Elektrotechnik

Applikationsbeschreibung

- Ausgangszustand: manuelle Montage an Sitz-/Steh-AP mit Flansch auf vormontiertes Motorgehäuse fügen, vormontierten Anker einpressen und Baugruppe in Magazin abstapeln
- Neuzustand: alle Montage-/Fügetätigkeiten übernimmt Roboter, Mitarbeiter macht Motorgehäuse- sowie Ankervormontage und übernimmt die komplette Teilebereitstellung

Produktbeschreibung

- Produkt: Schlagbohrmaschine
- Größe: 350 x 200 x 120 mm
- Gewicht: 3,5 kg

Zahlen, Daten, Fakten

- Vorgabezeit: ca. 6 min
- Taktzeit: ca. 30 sec
- Anzahl Schichten: 1

Fragen zur Applikation

Auswahlgrund: verbaute Einzelteile scheinen applikationsgerecht (keine scharfen Kanten oder Spitzen), Taktzeit wird an dieser Station im Ausgangszustand überschritten (Engpass), manuelles Eindrücken des Ankers ist sehr belastend

Klassifikation der Applikation:

- Montieren bzw. Fügen
- Mehrere Teile greifen
- Pick & Place (Produkt umsetzen)

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
- Greifer:
  - keine Sicherheitsvorrichtugen

Zertifizierung:

- Applikation ist nicht zertifiziert

Auswirkungen auf die Mitarbeiter

- Arbeitsplatz ist beliebter als vorher
- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährlichen Teilen usw.)

4

Anwendungsfall

Getriebegehäuse-Verschraubung

Wesentliche Informationen

LBR:iiwa
Kollaborationsgrad: Synchronisation

Applikationsreife: in laufender Produktion
Applikationsort: Montage
Branche: Maschinen- und Anlagenbau

Applikationsbeschreibung

- Ausgangszustand: manuelles Verschrauben von 30-36 Schrauben mit 104 Nm an ergonomisch ungünstigem Handarbeitsplatz
- Neuzustand: aut. Einmessen, iiwa startet bei Berührung, dann automatisierter Schraubprozess, nach Verschraubung geht iiwa in Ruheposition, Mitarbeiter bestückt parallel 2. Ablagetisch und steckt Schrauben vor

Produktbeschreibung

- Produkt: Getriebegehäuse in 4 Varianten
- Größe: ca. 1500 x 450 x 350 mm (komplettes Getriebe)
- Gewicht: ca. 150 kg (komplettes Getriebe)

Zahlen, Daten, Fakten

- Vorgabezeit: 9 bis 10 min
- Taktzeit: ca. 20 sec
- Anzahl Schichten: 1 bis 2

Fragen zur Applikation

Auswahlgrund: Steigerung der Produktivität an ergonomisch ungünstigem Arbeitsplatz (hohes Anzugsdrehmoment), Montage von 30-36 identischen Schrauben

Klassifikation der Applikation:

- Werkzeugeinsatz z. B. Schrauben
- Qualitätskontrolle

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
- Greifer:
  - keine Sicherheitsvorrichtugen

Zertifizierung:

- zertifiziert durch Berufsgenossenschaft (DGUV)
- zertifiziert durch Systemintegrato

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

5
Anwendungsfall
Autarke Drehzelle

Wesentliche Informationen	LBR:iiwa Kollaborationsgrad: Koexistenz	Applikationsreife: in laufender Produktion Applikationsort: Teilefertigung Branche: Elektrotechnik

Applikationsbeschreibung

- Ausgangszustand: manuelles Handling (Greifen, Spänebeseitigung, Ablage & Greifen in/aus Messvorrichtung, Ablage in IO- und NIO-KLT) zum Beladen eines Umlaufbandes einer CNC-Drehmaschine
- Neuzustand: automatisiertes Handling & Bauteileidentifikation aller 29 Gehäusevarianten, Handling KLT auf Rollenband und aut. Einmessen durch Roboter, Roboter = flexibler Springer, Werker kann aber jederzeit eingreifen

Produktbeschreibung

- Produkt: Stator
- Größe: 120 mm Länge, 100 mm Durchmesser
- Gewicht: ca. 500 g

Zahlen, Daten, Fakten

- Vorgabezeit: nicht bekannt
- Taktzeit: < 60 sec
- Anzahl Schichten: 2

Fragen zur Applikation

Auswahlgrund: Entlastung der Mitarbeiter, höhere Flexibilität, Springerkonzept damit jederzeit Werker eingreifen und den Roboter je nach Situation ablösen können.

Klassifikation der Applikation:

- Montieren bzw. Fügen
- Maschinenbestückung
- Qualitätskontrolle
- Pick & Place (Produkt umsetzen
- Werkzeugeinsatz z. B. Schrauben

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheits-vorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeits-regulierung
- Greifer:
  - keine Sicherheits-vorrichtugen

Zertifizierung:

- zertifiziert durch Systemintegrator

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

6

Anwendungsfall

Autarke Drehzelle

Wesentliche Informationen

LBR: iiwa
Kollaborationsgrad: Koexistenz

Applikationsreife: in laufender Produktion
Applikationsort: Teilefertigung
Branche: Weiße Ware

Applikationsbeschreibung

- Ausgangszustand: manuelles Einbringen und 4x Verschrauben in Fliesslinie in ungünstiger Körperhaltung
- Neuzustand: Bereitstellen der Schrauben durch externe Zuschießeinheit, Ausgleichen von Positionstoleranzen (1-2 mm), automatisches Verschrauben und Drehmomentüberwachung mit angedocktem iiwa im Fliessband (= ortsflexibles hybrides Montagesystem

Produktbeschreibung

- Produkt: Schraube für Pumpentopf
- Größe: ca. 30 mm, ca. 6 mm Durchmesser
- Gewicht: < 25 g

Zahlen, Daten, Fakten

- Vorgabezeit: nicht bekannt
- Taktzeit: ca. 20 sec
- Anzahl Schichten: 2

Fragen zur Applikation

Auswahlgrund: Automatisierung eines ergonomisch ungünstigen Arbeitsplatzes

Klassifikation der Applikation:

- Montieren bzw. Fügen
- Werkzeugeinsatz z. B. Schrauben
- Ein Teil greifen

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - Fußmatte vorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeits- regulierung
- Greifer:
  - keine Sicherheits- vorrichtugen

Zertifizierung:

- zertifiziert durch Systemintegrator

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)

7

Anwendungsfall

Montage Doppel-Kupplungsgetriebe

Wesentliche Informationen

LBR: iiwa
Kollaborationsgrad: Kooperation

Applikationsreife: in laufender Produktion
Applikationsort: Montage
Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuelles Handhaben (12 kg), Fügen und Reparieren des Getriebes
- Neuzustand: mobiler LBR, der den MA unterstützt (kann dann mehrere Stationen betreuen) -> Produktionskonzept »Robot Farming«

Produktbeschreibung

- Produkt: Doppel-Kupplungsgetriebe
- Größe: 250 mm Durchmesser ca. 6 mm Durchmesser
- Gewicht: 12 kg

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: ca. 45 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Ergonomie; Wirtschaftlichkeit; bei neuen Teilen, falls noch kein Roboterprogramm vorhanden ist, kann Mitarbeiter Montage übernehmen; definierte Teile-Lage war bereits vorhanden

Klassifikation der Applikation:

- Montieren bzw. Fügen
- Mehrere Teile greifen (Lager und Kupplung)
- Qualitätskontrolle (korrekter Sitz des Dichtrings)

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheits-vorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeits-regulierung
- Greifer:
  - keine Sicherheits-vorrichtugen

Zertifizierung:

- zertifiziert durch Berufsgenossenschaft
- zertifiziert durch Systemintegrator (KUKA)

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

7_1
Anwendungsfall
Motoraufrüstung mit Getriebe

Wesentliche Informationen

LBR: iiwa
Kollaborationsgrad: Kollaboration

Applikationsreife: Test in realer Produktion
Applikationsort: Montage
Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuell durch 2 Mitarbeiter mit Manipulator im Fliessbetrieb, Getriebe wird mit hängendem Motor verschraubt (1. MA bringt Getriebe mit Manipulator, 2. MA hält Motor dagegen und dreht zum Einfädeln an Motorwelle)
- Neuzustand: LBR im MRK-Betrieb, 2. MA wird durch Roboter ersetzt (hält Motor dagegen und dreht zum Einfädeln an Welle)

Produktbeschreibung

- Produkt: Motor mit Getriebe
- Größe: PKW-Getriebe
- Gewicht: ca. 150 kg

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: ca. 80 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: schlechte Auslastung von 2 Mitarbeitern, schlechte Ergonomie, Wirtschaftlichkeit (Einsparung von einem Mitarbeiter)

Klassifikation der Applikation:

- Montieren bzw. Fügen
- Teil andienen (Motor gegenhalten)

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheits-vorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeits-regulierung
- Greifer:
  - keine Sicherheits-vorrichtugen

Zertifizierung:

- zertifiziert durch Berufsgenossenschaft
- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

7_3
Anwendungsfall
Stopfen-Montage

Wesentliche Informationen

LBR: iiwa
Kollaborationsgrad: Koexistenz

Applikationsreife: Test in realer Produktion
Applikationsort: Montage
Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuell, Über-Kopf-Arbeit, Produkt und Roboter stehen, Fahrzeug wird im Takt weitertransportiert (Taktbetrieb)
- Neuzustand: LBR im MRK-Betrieb, Taktbetrieb wie im Ausgangszustand

Produktbeschreibung

- Produkt: Gummi-Stopfen
- Größe: 28 mm Durchmesser
- Gewicht: 10 g

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: ca. 1,5 min
- Anzahl Schichten: 2 bis 3

Fragen zur Applikation

Auswahlgrund: Qualität (fehlende Stopfen)

Klassifikation der Applikation:
- Montieren bzw. Fügen
- Ein Teil greifen
- Qualitätskontrolle

Sicherheitsvorrichtungen:
- Arbeitsraum:
  - keine Sicherheits-vorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeits-regulierung
- Greifer:
  - keine Sicherheits-vorrichtugen

Zertifizierung:
- zertifiziert durch Berufsgenossenschaft
- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)

8

Anwendungsfall

Anreichen Kühlmittelausgleichsbehälter

Wesentliche Informationen	LBR: KR 5 SI Kollaborationsgrad: Kollaboration	Applikationsreife: in laufender Produktion Applikationsort: Montage Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: ungeordnete Bereitstellung der Behälter in Großladungsträger (GLT), MA holt Behälter aus GLT komplettiert und verbaut ihn in der Endmontagelinie
- Neuzustand: Roboter übernmmt Griff in den GLT und dient MA den richtigen Behälter, zur richtigen Zeit. ergonomisch korrekt an

Produktbeschreibung

- Produkt: Kühlmittelausgleichsbehälter
- Größe: ca. 300 x 200 x 100 mm
- Gewicht: < 1 kg

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: ca. 80 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Ergonomie verbesserungswürdig, Verwechslungsgefahr durch Behältervarianten

Klassifikation der Applikation:

- Ein Teil greifen
- Teil andienen
- Qualitätskontrolle (richtige Variante)

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
  - kapazitive bzw. taktile Sensorhaut
- Greifer:
  - mechanische Überwachung
  - taktile Überwachung

Zertifizierung:

- zertifiziert durch Berufsgenossenschaft
- zertifiziert durch Systemintegrator

Auswirkungen auf die Mitarbeiter

- Arbeitsplatz ist beliebter als vorher.
- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

9
Anwendungsfall
Ventilvormontage

Wesentliche Informationen	LBR: KR 5 SI Kollaborationsgrad: Koexistenz	Applikationsreife: in laufender Produktion Applikationsort: Montage Branche: Pneumat. & elektromech. Antr.technik

Applikationsbeschreibung

- Ausgangszustand: manuelle Montage an 2 hybriden Montagearbeitsplätzen, MA 1 führt eine Montage- & Verpreßtätigkeit am Ventilgrundkörper durch & legt Produkt in Puffer ab, MA 2 macht restl. Montage und Verpackung
- Neuzustand: Tätigkeit von MA 1 übernimmt Roboter und legt Produkt in Puffer ab (ist etwas schneller wie MA2), MA 2 siehe Ausgangszustand

Produktbeschreibung	Produkt: Ventil	Größe: ca. 120 x 50 x 30 mm	Gewicht: < 250 g
Zahlen, Daten, Fakten	Vorgabezeit: ca. 1 min	Taktzeit: ca. 30 sec	Anzahl Schichten: 1 bis 2

Fragen zur Applikation

Auswahlgrund:	Beispiel zum Know-How-Aufbau, Lernen und Erfahrungen sammeln		
Klassifikation der Applikation:	Montieren bzw. Fügen	Ein Teil greifen	Maschinenbestückung (Ventil in Preßvorrichtung)
Sicherheitsvorrichtungen:	Arbeitsraum: - keine Sicherheitsvorrichtungen	Roboter: - Kraftregulierung - Geschwindigkeitsregulierung - kapazitive bzw. taktile Sensorhaut	Greifer: - mechanische Überwachung - taktile Überwachung
Zertifizierung:	zertifiziert durch Berufsgenossenschaft	zertifiziert durch Sicherheitsfachkraft	

Auswirkungen auf die Mitarbeiter

- Mensch ist zum »Handlanger der Maschine« geworden (Roboter treibt Mensch an)

12

Anwendungsfall

Montage Saugrohr

Wesentliche Informationen

LBR: UR5
Kollaborationsgrad: Synchronisation

Applikationsreife: in laufender Produktion
Applikationsort: Montage
Branche: Maschinen- und Anlagenbau

Applikationsbeschreibung

- Ausgangszustand: manueller Sitz-/Steh-AP, manuelles Verclipsen von 3-7 »Kunststoff-Verschleißteilen«
- Neuzustand: teilautomatisierter Steh-AP mit verkleben der »Keramik-Verschleißteile«, Roboter übernimmt Kleber dosieren und Kleber spenden (2 Klebepunkte pro Verschleißteil)

Produktbeschreibung

- Produkt: Saugrohr
- Größe: Länge: 200-700 mm, Durchm.: 30-40 mm
- Gewicht: < 250 g

Zahlen, Daten, Fakten

- Vorgabezeit: ca. 60 sec
- Taktzeit: ca. 20 sec
- Anzahl Schichten: 2

Fragen zur Applikation

Auswahlgrund: Höhere Flexibilität und niedrigere Kosten als ein Linearsystem statt LBR, Wirtschaftlichkeit, Arbeiterleichterung für MA (kein manuelles Dosieren, weniger Kleberdämpfe)

Klassifikation der Applikation:

- Werkzeugeinsatz z. B. Schrauben (Dosiersystem)
- Kleben bzw. Schweißen

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - Umhausung
  - dyn. Arbeitsraum-überwachung
- Roboter:
  - Kraftregulierung
  - Geschwindigkeits-regulierung
- Greifer:
  - keine Sicherheits-vorrichtungen

Zertifizierung:

- zertifiziert durch Systemintegrator

Auswirkungen auf die Mitarbeiter

- Arbeitsplatz ist beliebter als vorher.
- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

13
Anwendungsfall
Umhausungsfreie Kleinteilmontage

Wesentliche Informationen	BR: YuMi Kollaborationsgrad: Koexistenz	Applikationsreife: in laufender Produktion Applikationsort: Montage Branche: Elektrotechnik

Applikationsbeschreibung

- Ausgangszustand: manueller, höhenverstellbarer Sitz-/Steh-AP mit Kniehebelpressen
- Neuzustand: vollautomatische Montage mit YuMi

Produktbeschreibung

- Produkt: Schaltereinsatz
- Größe: ca. 40 x 40 x 20 mm
- Gewicht: < 30 g

Zahlen, Daten, Fakten

- Vorgabezeit: 6 sec
- Taktzeit: 6 sec
- Anzahl Schichten: 2

Fragen zur Applikation

Auswahlgrund: Wirtschaftlichkeit, einfacher Anwendungsfall um neue Technologie kennenzulernen und Akzeptanz der MA zu erreichen

Klassifikation der Applikation:
- Montieren bzw. Fügen
- Mehrere Teile greifen
- Maschinenbestückung

Sicherheitsvorrichtungen:
- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - inhärente Sicherheit
  - Motorstrommessung
- Greifer:
  - keine Sicherheitsvorrichtungen

Zertifizierung:
- zertifiziert durch Systemintegrator (BM-Bau)
- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (Monotonie)

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Anwendungsfall

UR-Einsatz in der Endmontage

Wesentliche Informationen	LBR: UR5 Kollaborationsgrad: Synchronisation	Applikationsreife: in laufender Produktion Applikationsort: Montage Branche: Elektrotechnik

Applikationsbeschreibung

- Ausgangszustand: komplett manuell an Geh-/Steh-AP mit 2 MA, manuelles Beschicken Laserstation (manuelles Einlegen, Drehen und Entnehmen von Produkt in Laserstation) (2 Produkte im Laser, lasern auf 2 Seiten, zwischendrin Produkt drehen) (incl. Auf- & Zuklappen)
- Neuzustand: manuelle Tätigkeiten 1 (bis Ablage Produkt in Vorrichtung 1 & Auslösung Start für Robbi), automatisierte Laserbeschickung (Produkt aus Ablage 1 holen und nach Bearbeitung wieder in Ablage 2 ablegen; manuelle Tätigkeiten 2 (Produkt aus Ablage 2 holen & Verpacken) mit 1 MA an Steh-/Geh-AP

Produktbeschreibung

- Produkt: Elektronikkomponente
- Größe: ca. 80 x 80 x 50 mm
- Gewicht: ca. 150 g

Zahlen, Daten, Fakten

- Vorgabezeit: 120 sec für Mitarbeiter
- Taktzeit: 30 sec Robbi (incl. Wartezeiten)
- Anzahl Schichten: 2

Fragen zur Applikation

Auswahlgrund: Beherrschbarer Anwendungsfall für Forschungsprojekt sowie sinnvoller Einsatz gesucht, Pilotprojekt (gestartet in 2012)

Klassifikation der Applikation:

- Ein Teil greifen
- Maschinenbestückung
- Pick & Place (Produkt umsetzen)

Sicherheitsvorrichtungen:

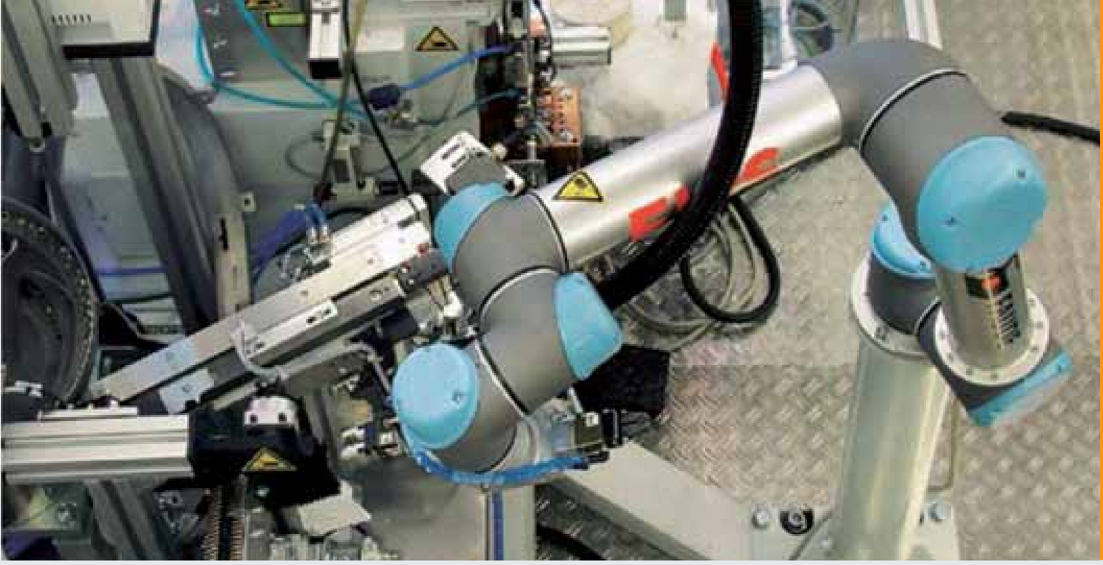
- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
- Greifer:
  - keine Sicherheitsvorrichtungen

Zertifizierung:

- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.



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Anwendungsfall

UR-Einsatz: Kommissionieren

Wesentliche Informationen	LBR: UR5 Kollaborationsgrad: Koexistenz	Applikationsreife: in laufender Produktion Applikationsort: Montage Branche: Elektrotechnik

Applikationsbeschreibung

- Ausgangszustand: Handarbeitsplatz an Verpackungsmaschine durch 1 MA (1 MA vorne und 1 MA hinten an Maschine)
- Neuzustand: vollautomatische Verpackung: UR greift Bedienungsanleitung & Kunststoffteil, Abwurf in Schacht in Beutel, Verpackungsmaschine erstellt Beutel und verschweißt ihn abschließend

Produktbeschreibung

- Produkt: Bedienungsanleitung & Kunststoffteil
- Größe: ca. 80 x 80 x 25 mm
- Gewicht: ca. 50 g

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: 10 sec
- Anzahl Schichten: 2

Fragen zur Applikation

Auswahlgrund: Rationalisierungmaßnahme (Einsparung von 1-2 MA)

Klassifikation der Applikation:

- Mehrere Teile greifen bzw. ansaugen

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
- Greifer:
  - keine Sicherheitsvorrichtungen

Zertifizierung:

- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Mitarbeiterkapazitäten können anderweilig eingesetzt werden (keine Entlassungen, ev. keine Einstellung von befristetem Personal)

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Anwendungsfall
Sicherheitsventil-montage

Wesentliche Informationen

LBR: UR10
Kollaborationsgrad: Synchronisation
Applikationsreife: Demonstrator
Applikationsort: Montage
Branche: Energietechnik

Applikationsbeschreibung

- Ausgangszustand: manuelle Montage von 3 Baugruppen und manueller Zusammenbau (Prüfung automatisiert) sowie Verpackung
- Neuzustand: automatisierter Zusammenbau des Grundkörpers und der 3 Baugruppen

Produktbeschreibung

- Produkt: Sicherheitsventil
- Größe: ca. 150 x 150 mm
- Gewicht: ca. 1 kg

Zahlen, Daten, Fakten

- Vorgabezeit: ca. 3 min
- Taktzeit: ca. 90 sec
- Anzahl Schichten: 1

Fragen zur Applikation

Auswahlgrund: Ausscheidende Mitarbeiter, höherer Automatisierung bei einfachen Tätigkeiten angestrebt (Arbeitsplatzsicherung im Hochlohnland D)

Klassifikation der Applikation:
- Montieren bzw. Fügen
- Werkzeugeinsatz z. B. Schrauben
- Mehrere Teile greifen
- Maschinenbestückung

Sicherheitsvorrichtungen:
- Arbeitsraum:
  - keine Sicherheits-vorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeits-regulierung
- Greifer:
  - keine Sicherheits-vorrichtungen

Zertifizierung:
- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

25
Anwendungsfall
Piezo-Elemente abstapeln

Wesentliche Informationen	LBR: APAS assistant Kollaborationsgrad: Koexistenz	Applikationsreife: in laufender Produktion Applikationsort: Teilefertigung Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuelle Beidhandarbeit im Stehen mit monotonem Arbeitsablauf, Behälter- bzw. Blisterwechsel alle 20-30 min durch Mitarbeiter
- Neuzustand: Roboter arbeitet autark, Materialversorgung über Blister auf Röllchenbahnen und Entsorgung über Kisten-/Magazin-Hubgerät, alle 20-30 min Blister-/Magazinwechsel durch Mitarbeiter (Zeitbedarf ca. 5 min)

Produktbeschreibung	■ Produkt: Piezo-Element	■ Größe: ca. 15 x 5 x 4 mm	■ Gewicht: < 10 g
Zahlen, Daten, Fakten	■ Vorgabezeit: keine Angabe	■ Taktzeit: 6 sec	■ Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Monotone Arbeit mit empfindlichen und bleihaltigem Produkt, Mitarbeiter kann im Neuzustand Mehrmaschinenbedienung durchführen

Klassifikation der Applikation:	■ Ein Teil greifen	■ Pick & Place (Produkt umsetzen)	■ Verpacken & Palettieren
Sicherheitsvorrichtungen:	■ Arbeitsraum: - keine Sicherheits-vorrichtungen	■ Roboter: - Kraftregulierung - Geschwindigkeits-regulierung - kapazitive bzw. taktile Sensorhaut	■ Greifer: - mechanische Überwachung - optische Überwachung
Zertifizierung:	■ zertifiziert durch Systemintegrator (ATMO)	■ zertifiziert durch Sicherheitsfachkraft	

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

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Anwendungsfall
Umstapeln Benzinpumpen

Wesentliche Informationen	LBR: APAS assistant Kollaborationsgrad: Koexistenz	Applikationsreife: in laufender Produktion Applikationsort: Teilefertigung Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuelle Arbeit (ev. beidhändig) an Sitz-Arbeitsplatz mit schlechter Ergonomie (Körperdrehung alle 15 sec), Behälter- bzw. Magazinwechsel alle 20-30 min durch Mitarbeiter
- Neuzustand: Roboter arbeitet autark, Materialversorgung über Magazine auf Röllchenbahnen und Entsorgung über Kisten-/Magazin-Hubgerät, alle 20-30 min Kisten-/Magazinwechsel durch Mitarbeiter (Zeitbedarf ca. 5 min)

Produktbeschreibung

- Produkt: Benzinpumpen
- Größe: ca. 70 mm lang, 40 mm Durchmesser
- Gewicht: ca. 500 g

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: < 15 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Monotone Arbeit mit Benzin-/Öl-Geruchsbelästigung und schlechter Ergonomie, Mitarbeiter kann im Neuzustand Mehrplatzbedienung durchführen

Klassifikation der Applikation:

- Ein Teil greifen
- Pick & Place (Produkt umsetzen)
- Verpacken & Palettieren

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
  - kapazitive bzw. taktile Sensorhaut
- Greifer:
  - mechanische Überwachung
  - optische Überwachung

Zertifizierung:

- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

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Anwendungsfall

Steckerleisten umstapeln

Wesentliche Informationen	LBR: APAS assistant Kollaborationsgrad: Koexistenz	Applikationsreife: in laufender Produktion Applikationsort: Teilefertigung Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuelle Arbeit (ev. beidhändig) an Sitz-Arbeitsplatz mit schlechter Ergonomie (Körperdrehung alle 15 sec), Behälter- bzw. Magazinwechsel alle 20-30 min durch Mitarbeiter
- Neuzustand: Roboter arbeitet autark, Materialversorgung über Magazine auf Röllchenbahnen und Entsorgung über Kisten-/Magazin-Hubgerät, alle 20-30 min Kisten-/Magazinwechsel durch Mitarbeiter (Zeitbedarf ca. 5 min)

Produktbeschreibung

- Produkt: Steckerleisten
- Größe: ca. 100 x 25 x 10 mm
- Gewicht: ca. 100 g

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: < 15 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Monotone Arbeit und schlechte Ergonomie, Mitarbeiter kann im Neuzustand Mehrplatzbedienung durchführen

Klassifikation der Applikation:

- Ein Teil greifen
- Pick & Place (Produkt umsetzen)
- Verpacken & Palettieren

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
  - kapazitive bzw. taktile Sensorhaut
- Greifer:
  - mechanische Überwachung
  - optische Überwachung

Zertifizierung:

- zertifiziert durch Systemintegrator (ATMO)
- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

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Anwendungsfall

Palettierung von Ventilhaltekörpern

Wesentliche Informationen

LBR: APAS assistant
Kollaborationsgrad: Koexistenz

Applikationsreife: in laufender Produktion
Applikationsort: Teilefertigung
Branche: Elektrotechnik

Applikationsbeschreibung

- Ausgangszustand: manuelle Arbeit (ev. beidhändig) an Sitz-Arbeitsplatz mit schlechter Ergonomie (Körperdrehung alle 15 sec), Behälter- bzw. Magazinwechsel alle 20-30 min durch Mitarbeiter
- Neuzustand: Roboter arbeitet autark, Materialversorgung über Magazine auf Röllchenbahnen und Entsorgung über Kisten-/Magazin-Hubgerät, alle 20-30 min Kisten-/Magazinwechsel durch Mitarbeiter (Zeitbedarf ca. 5 min)

Produktbeschreibung

- Produkt: Ventilhaltekörper
- Größe: ca. 80 mm lang, 5 mm Durchmesser
- Gewicht: ca. 100 g

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: < 15 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Monotone Arbeit mit Benzin-/Öl-Geruchsbelästigung und schlechter Ergonomie, Mitarbeiter kann im Neuzustand Mehrplatzbedienung durchführen

Klassifikation der Applikation:

- Ein Teil greifen
- Pick & Place (Produkt umsetzen)
- Verpacken & Palettieren

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
  - kapazitive bzw. taktile Sensorhaut
- Greifer:
  - mechanische Überwachung
  - optische Überwachung

Zertifizierung:

- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

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Anwendungsfall

Handling bei Statorprüfung und Abstapeln

Wesentliche Informationen

LBR: APAS assistant
Kollaborationsgrad: Koexistenz

Applikationsreife: Demonstrator
Applikationsort: Teilefertigung
Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuelle Arbeit (ev. beidhändig) an Sitz-Arbeitsplatz mit schlechter Ergonomie (Körperdrehung alle 15 sec), Behälter- bzw. Magazinwechsel alle 20-30 min durch Mitarbeiter
- Neuzustand: Roboter arbeitet autark, Materialversorgung über Magazine auf Röllchenbahnen und Entsorgung über Kisten-/Magazin-Hubgerät, alle 20-30 min Kisten-/Magazinwechsel durch Mitarbeiter (Zeitbedarf ca. 5 min)

Produktbeschreibung

- Produkt: Stator
- Größe: ca. 120 mm Länge, 100 mm Durchmesser
- Gewicht: ca. 500 g

Zahlen, Daten, Fakten

- Vorgabezeit: keine Angabe
- Taktzeit: < 15 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Monotone Arbeit mit schlechter Ergonomie, Mitarbeiter kann im Neuzustand Mehrplatzbedienung durchführen

Klassifikation der Applikation:

- Ein Teil greifen
- Pick & Place (Produkt umsetzen)
- Qualitätskontrolle
- Maschinenbestückung

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
  - kapazitive bzw. taktile Sensorhaut
- Greifer:
  - mechanische Überwachung
  - optische Überwachung

Zertifizierung:

- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

43
Anwendungsfall
Prüfung elektronisches Steuergerät

Wesentliche Informationen

LBR: APAS assistant	Applikationsreife: in laufender Produktion
Kollaborationsgrad: Koexistenz	Applikationsort: Montage
	Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: manuelle U-Linie mit 6 Prüfstationen, besetzt mit 2 MA
- Neuzustand: hybride U-Linie mit 6 Prüfstationen, besetzt mit 2 APAS und 1 MA oder vollautomatische U-Linie mit 6 Prüfstationen, besetzt mit 4 APAS
  (APAS übernehmen die Handlingprozesse für das Be- und Entladen der Prüfstationen)

Produktbeschreibung

- Produkt: elektronisches Steuergerät
- Größe: ca. 100 x 100 x 80 mm
- Gewicht: ca. 500 g

Zahlen, Daten, Fakten

- Vorgabezeit: ca. 80 sec
- Taktzeit: ca. 20 sec
- Anzahl Schichten: 3

Fragen zur Applikation

Auswahlgrund: Schaffung einer Standard U-Linie, die von manuellem bis vollautomatischem Betrieb skalierbar ist und somit den unterschiedlichen Gegebenheiten in Hoch- bzw. Niedriglohnländern ohne Änderung von Grundlayout und Prüftechnik angepasst werden kann (APAS übernimmt keine Montage- sondern nur Handlingtätigkeiten, Steuergerät ist z.T. 115 Grad Celsius heiß)

Klassifikation der Applikation:
- Ein Teil greifen
- Maschinenbestückung
- Pick & Place (Produkt umsetzen)

Sicherheitsvorrichtungen:
- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
  - kapazitive bzw. taktile Sensorhaut
- Greifer:
  - optische Überwachung bzw. Referenzieren

Zertifizierung:
- zertifiziert durch Sicherheitsfachkraft

Auswirkungen auf die Mitarbeiter

- Belastungen wurden vom Mitarbeiter verlagert (z. B. Lastenhandhabung, arbeiten mit gefährl. Teilen usw.)
- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.

44
Anwendungsfall
Ventilmontage

Wesentliche Informationen	LBR: APAS assistant Kollaborationsgrad: Kooperation	Applikationsreife: Demonstrator Applikationsort: Montage Branche: Automobilindustrie

Applikationsbeschreibung

- Ausgangszustand: Montage an manuellem Sitzarbeitsplatz in Fliesslinie (Engpassarbeitsplatz): Zusammenstecken Ober- und Zwischenteil, Fügen Oberteil und manuelles Verschrauben, Teilebereitstellung in Magazinen auf Rollenbahnen, Behälter- bzw. Magazinwechsel alle 20-30 min durch Mitarbeiter
- Neuzustand: Roboter fügt Zwischenteil auf Unterteil in WST, legt Baugruppe in Vorrichtung ab und fügt Oberteil. Mitarbeiter holt Baugruppe in seine (2.) Vorrichtung und verschraubt die 3 Teile, führt alle Magazinwechsel wie im IST durch

Produktbeschreibung

- Produkt: Ventilmodul in vielen Varianten
- Größe: ca. 50 mm Durchmesser, 100 mm lang
- Gewicht: < 250

Zahlen, Daten, Fakten

- Vorgabezeit: ca. 60 sec
- Taktzeit: ca. 30 sec
- Anzahl Schichten: 2 bis 3

Fragen zur Applikation

Auswahlgrund: Arbeitsplatz mit einem Mitarbeiter ist Engpass für die gesamte Linie (2. Mitarbeiter nicht ausgelastet), Qualitätserhöhung durch Reduzierung Teileverwechslung (Teileüberprüfung durch Kamera), Vollautomatisierung zu teuer und aut. Schraubvorgang sehr störanfällig

Klassifikation der Applikation:

- Montieren bzw. Fügen
- Qualitätskontrolle
- Mehrere Teile greifen
- Teil andienen

Sicherheitsvorrichtungen:

- Arbeitsraum:
  - keine Sicherheitsvorrichtungen
- Roboter:
  - Kraftregulierung
  - Geschwindigkeitsregulierung
  - kapazitive bzw. taktile Sensorhaut
- Greifer:
  - mechanische Überwachung
  - optische Überwachung

Zertifizierung:

- zertifiziert durch Systemintegrator

Auswirkungen auf die Mitarbeiter

- Die individuellen Fähigkeiten von Mensch und Maschine werden gut eingesetzt.
- Geringerer Taktdruck für den Mitarbeiter

Imprint

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