Robots working together with machine tools.
Maximum productivity through intelligent automation with robots.
Abstract

Making production faster, safer and more cost-effective with automated machine tools. With ever shorter delivery times, production has to meet ever increasing demands with regard to quality and precision. At the same time, the risk of errors in production of the parts increases. Smaller batch sizes increase the cost of retooling the machines. And unit labor costs are rising.

In view of this situation, how can production be made as efficient and cost-effective as possible? Outsourcing to countries with a lower wage level has its limits, as companies need short supply chains, their own specialist personnel with a high degree of loyalty, and geographic proximity for reliable quality control.

Many machining companies would be significantly more competitive with robots.

Studies show that the efficiency and cost-effectiveness of production would be significantly improved by robotic automation for 20 percent of all machine tools. However, only a fraction of this 20 percent is currently automated. This is because many reservations about robots still hold sway, even though technical developments have long since moved on.

Today, robots are safer, simpler and more cost-effective than is generally known in the industry. On average, they pay for themselves in under two years in the machine tool and mechanical engineering sector. For years now, robots have been used in direct contact with humans in areas with stringent safety requirements, such as medical technology. And they have become easy to program and to operate. The use of robots makes work more cost-effective, thus increasing job security.

Quick-Check. Machining companies and machine tool users ask us: will the use of robots pay in my specific application? The decisive factors here are quality requirements, productivity, unit labor costs, speed of delivery and safeguarding the viability of the manufacturing location. A preliminary answer can be given in our Quick Check.
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One of the world’s leading suppliers of industrial robots.
Increasing quality requirements, shorter delivery times, falling prices, growing pressure from competition: these are the challenges faced by companies in the machine tool and mechanical engineering sector. Is there a solution that can meet all these challenges?

In many cases, automation with robots is the right answer: robots work with a very high degree of precision. Even with complex and heavy components, the reject rate is practically zero. They can work around the clock, and their performance is just as good after 24 hours as in the first minutes. In lightly-manned and fully automated production shifts, they improve the capacity utilization of the machines and reduce the unit labor costs. Robots therefore offer enormous potential. This potential is still used too little in the industry. But things are beginning to change.

The nine greatest challenges for machine tool users

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing quality requirements regarding the parts to be machined</td>
<td>92%</td>
</tr>
<tr>
<td>Increasing importance of quality vs. price</td>
<td>60%</td>
</tr>
<tr>
<td>Increasing complexity of the parts to be machined</td>
<td>85%</td>
</tr>
<tr>
<td>Increasing importance of schedule keeping vs. price</td>
<td>58%</td>
</tr>
<tr>
<td>Increasing pressure from domestic competition</td>
<td>43%</td>
</tr>
<tr>
<td>Falling prices for the same products/services</td>
<td>65%</td>
</tr>
<tr>
<td>Increased importance of additional work (e.g. assembly)</td>
<td>56%</td>
</tr>
<tr>
<td>Increasing demands for ever-shorter delivery times</td>
<td>88%</td>
</tr>
<tr>
<td>Shrinking order volume for machining work</td>
<td>18%</td>
</tr>
</tbody>
</table>

Industry study 2011: The Future of Machining in Germany. (Number of respondents: 90)

Robots have become simpler, more profitable and more powerful. Independent studies have shown: substantial potential for improvement often remains unused. That’s because 20 percent of all machine tools could be operated more efficiently in conjunction with robots. Despite this, the automation rate is only 1.5 percent. What is the reason for this reluctance? Robots are still subject to widespread reservations in the industry, even though technical developments have long since moved on.

1 IFR. World Robotics Report 2012
The most frequent objections to the use of robots with machine tools:
- **Too expensive** – In fact, robots usually pay for themselves within a period of two years.
- **Too dangerous** – In fact, robots have been used successfully for years, even in areas with stringent safety requirements.
- **Too complicated** – In fact, robots can now be programmed and operated in a very user-friendly manner.

The following pages provide current information about cost-effectiveness, safety and ease of use. In addition, the effects of automation on jobs is examined.

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### 02 Robots today

**Robots are cost-effective** – **The payback period is short, productivity high.** It is their constant high performance that makes robots cost-effective: human operators still work faster and more precisely than a robot – but only during the first 20 minutes; after that, their attention declines. A robot, on the other hand, can work for 24 hours at the same high quality – without a break. Without robots, machine tools achieve a utilization capacity of about 70 percent; with robots, nearly 100 percent is possible. Because robots don’t need to rest.

**Robots will never replace humans.** But by compensating for humans’ limitations, robots safeguard the economic efficiency of production – and thus also protect jobs. Relocating production to low-wage countries is no longer an issue with robots, because robotic automation is a considerably more efficient, cost-effective and reliable option.

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2 GEO / Factory of the Year 2010 (productivity of German machine operators during hours of attendance)

3 DAK Health Report 2011 (average periods of absence due to sickness)

4 Evaluation of a major German automotive manufacturer for several 100 robots (the robot is “absent” only once every 40,000 hours, and only for an average of two hours)
It is true that a robot cell can double the investment costs for a machine tool. What counts, however, is the payback period. And this is often under two years – even with an extensive range of parts.

**What robots are capable of today.** Robots load machine tools quickly and precisely with blanks and then remove the machined parts. But what do they do while the machine tool carries out the machining process? The longer these intermediate times, the greater the importance of additional tasks such as:

- deburring
- loading and unloading
- tool change
- labeling
- cleaning
- sorting

Robots are safe – they are used in areas with stringent safety requirements. Safety concerns about the use of robots have been dispelled for many years now. This has long been a recognized fact in many areas with high safety requirements.

For example, KUKA robots are today used quite routinely for transporting patients in operating rooms. And the KUKA Robocoaster is the world’s first robot to be licensed to carry passengers, being certified by the German technical inspectorate TÜV as conforming to EN 13814 (DIN 4112). Its structural components and gear units are 100 percent certified.

**Safety functions for industry.** Special safety functions have been created for the use of robots in industry. KUKA.SafeOperation, for example, ensures the limitation and monitoring of workspaces and protected spaces. And the safe operational stop enables safe, smooth cooperation between humans and machines.

**Monitored protected spaces with KUKA.SafeOperation**
Approved to ISO 13849-1 (Performance-Level d – Kategorie 3)

KUKA.SafeOperation creates workspaces and protected spaces for safe use of robots. The software and hardware package supports safe cooperation between humans and machines. Thanks to the monitoring functions, no mechanical axis range monitoring is required on the robot. All the functions can be configured quickly and easily.

- **Workspace-based and workspace-independent velocity and acceleration monitoring**
- **Reporting of the current robot position**
- **Cell configuration**
- **Set-up of monitoring spaces, safety fences and signal outputs**
- **Reduced space requirements**
- **Safe operational stop**
Robots are simple. For configuration, programming and control, unnecessary work can now be avoided.

The following four options show how you can arrive at a solution that can be simply configured, programmed and controlled.

**How easy is the robot programming language to learn?**
Every manufacturer programs its robots in its own language. The easier this language is to learn, the less training is required for the customer. The programming language for KUKA robots – the KUKA Robot Language KRL – can be learned in just a few days. This can be done at one of 30 training centers around the world. Alternatively, KUKA offers solutions for which knowledge of a specific robot language is no longer necessary.

**How far advanced is the integration of robots and machines?**
KUKA and Siemens offer a unified user interface for robots and machine tools. For this, the CNC user interface can be switched freely between the robot controller and the machine controller. This allows the entire system to be controlled entirely from the machine tool’s operator panel – using the same language for both the machine and the robot. Both components are thus growing ever closer to serve as a machining center.

Convenient control of the robot and the machine tool is today possible via a shared user interface on an end device.

**One world for both integrator and end user:** With mxAutomation, machine tools and robots can be programmed and operated using the same software tools. The motion sequence of the robot can be programmed entirely in the Sinumerik controller; configuration takes place in the Siemens S7 world. Special knowledge of robot programming and operation is no longer necessary. The difference between the underlying machine and robot controllers is barely noticeable for the operator.

- For customers with expertise in configuring and programming PLCs.
- For configuration, basic knowledge of robot technology is sufficient.
- Module library for planning robot motions and sequences, including the control of components such as grippers and safety gates.
- Simple control via the Siemens 840D sl operator panel.
How consistent is the development environment?
The programming work required for the robot cell can be considerably reduced thanks to a development environment with a consistent database and standardized operator guidance throughout the software life cycle. KUKA.WorkVisual is one such environment.

- 3D cell layout and 3D programming
- Simple handling using Copy & Paste or Drag & Drop
- Logic check
- Comparison of the online and offline worlds

How powerful and user-friendly is the software?
The choice of software has an influence on how simple or complicated it is to program and control the robot and the machine tool. To date, only KUKA offers software packages that enable integrated programming and control of a robot and a machine tool: KUKA.CNC and mxAutomation.

With KUKA.CNC and mxAutomation, knowledge of a specific robot language is no longer necessary.

**KUKA.CNC.** KUKA.CNC makes CNC programs accessible to the robot controller. The robot is programmed directly via a CAD/CAM chain.

- Robots can be programmed entirely in G-code.
- Programs can be created and modified directly on the controller in ISO code.
- In addition to loading and unloading, tasks such as deburring, drilling and milling can also be programmed.
- The robot is operated using screens that will be immediately familiar to any CNC machine operator.
- Simple toggling between the robot controller and the CNC machining process.

03 Robots protect jobs

**Increasing productivity – safeguarding jobs.** Do robots endanger jobs? At first glance, this would seem to be the case. It is indeed a fact that robots relieve humans of many tasks. But a closer look reveals that, by increasing the economic efficiency of production, robots make a decisive contribution to job security.

**Robots relieve humans of monotonous, strenuous and dirty work.** Robots take over work, which humans would otherwise have to carry out. Furthermore, this is work for which employers are often unable to find personnel. Because no-one is eager to carry out monotonous, physically strenuous or dirty work.
Robots ensure that production locations with high wage levels remain competitive.

Yes, robots can endanger jobs – but only if employers would have to relocate production to low-wage countries if no robots are implemented. Many orders can only be executed cost-effectively if the unit labor costs are kept low. This leaves only three options: firstly, not to accept such orders. This would not gain anything for the employees – they would be without work. Secondly, to relocate production to a country with low wage costs. Here too, the employees at the main plant would be the losers. Thirdly, to execute the orders with robots and humans working together as a team. In this case, the company makes a profit, and the jobs at the main plant are retained.

Why is relocating production not a good alternative, even from an economic standpoint?

Relocating production abroad in order to save on wage costs is a questionable decision, not only from the point of view of the employees and customers. For the company, too, the drawbacks are enormous: long logistics chains lead to delivery difficulties. Quality can only be monitored with considerable difficulties or at great expense, and time-consuming and costly travel is required on a regular basis. In addition, the loyalty of the distant colleagues is uncertain, and the risk of industrial espionage is high. In the end, it often becomes apparent that the cost of relocating production more than eats up the potential savings involved.

The alternative to relocations, redundancies and plant closures. Robots protect jobs where most machining companies and machine tool users would prefer to have their employees: at their easily accessible main plant.

Human operators are also needed for automated machining centers. However, the nature of their work changes: it becomes more interesting and lucrative.

In cooperation with robots, human workers can deal with considerably more orders. And the orders are there: worldwide, the volume of work is growing. Many orders are unprofitable, however – unless they can be automated using a robot. The robot carries out the work at night during the lightly manned shift. The next day, the finished products are packaged and shipped by the employees. After that, there is enough time left to gain qualifications in operating robots. That is certainly a lot more exciting than operating the same lever 320 times a day.

Cost-effective insourcing thanks to automation

<table>
<thead>
<tr>
<th>Advantages for the company</th>
<th>Advantages for the employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short logistics chain</td>
<td>Elimination of monotonous, strenuous and dirty tasks</td>
</tr>
<tr>
<td>Production close to the customer</td>
<td>Further qualifications</td>
</tr>
<tr>
<td>Less travel required</td>
<td>Job security</td>
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<tr>
<td>Simple, economical quality control</td>
<td></td>
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<tr>
<td>that can be reliably performed</td>
<td></td>
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<tr>
<td>High level of loyalty and productivity of the workforce</td>
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</table>
04 Case study: Low-manpower production of KR QUANTEC components

KUKA has automated the production of components for robots of the compact KR QUANTEC series. Productivity rose by ten percent, and the investment will have paid for itself within 2.6 years – or even sooner.

KUKA itself uses robots in the manufacture of industrial robots. In April 2012, a Burkhardt & Weber machining center went into operation in Augsburg. This is used to machine components for the KR QUANTEC robot series.

The robot alternately works on the link arm and rotating column of two different variants in the compact KUKA KR QUANTEC series. It loads and unloads the machine tool with the components, which measure up to 1.5 meters long. During the non-productive times, it carries out downstream processing tasks.

**Machine tool.** MCX 900 from Reutlingen-based Burkhardt & Weber Fertigungssysteme GmbH – equipped with a double pallet changer. One pallet is fitted with clamping fixtures for the link arm, while the other pallet has corresponding fixtures for the rotating column.

**Robot.** KUKA KR 500 L480-3 MT robot. With its large work envelope and arm extension, the robot can effortlessly reach the material magazine and the gripper rack.

**Robot controller.** The robot is set up, programmed and controlled with the KUKA.CNC software. This allows the robot motion to be programmed entirely in G-code. Translation of machine programs into the robot language is not necessary. The operators control the robot on the same user interface that is familiar to them from the machine tool.
The two material feeders are designed as two-axis positioners and can each carry eight parts. The WWR1200 tool changing system from the Ettlingen-based company sommer-automatic is equipped with two grippers and a machining spindle from the KUKA.Milling package.

**The robot performs loading and carries out five downstream tasks – with an option for more.** While one workpiece is being machined, the other pallet moves right out of the machine and can be loaded with a new workpiece. During loading and unloading, the robot is fitted with a handling gripper. For the machining mode, it exchanges the gripper for the machining spindle. With this, it fetches the required tool from the tool magazine. Five different brushes and deburring tools are available. The tool rack has space for five more tools, allowing scope for additional tasks.

<table>
<thead>
<tr>
<th>The physical exertion involved in precisely aligning the workpiece is no longer necessary.</th>
<th>01</th>
<th>Operation is largely unmanned; the night shifts are completely automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>The expensive clamping equipment is no longer at risk of being damaged by the crane during loading and unloading.</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>300 more components can be machined every year.</td>
<td></td>
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<tr>
<td>04</td>
<td>Clamping in two minutes instead of up to 15. Previously, the operator had to load the heavy components onto the clamping table manually with the aid of a crane and laboriously insert them directly into the machine fixture. Today, it is only necessary to place the parts on the simply-designed locations of the material feeder on the robot. This considerably reduces the time required for clamping a workpiece: where the operator used to take 15 minutes, the robot now only takes two minutes.</td>
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</table>

The investment will pay for itself within 2.6 years. Or even much sooner. For it is planned to make even greater use of non-productive times by transferring further tasks from the machine tool to the robot. Examples include the drilling of holes on the link arm and rotating column. This will make the robot even more cost-effective.
05 Quick-Check: Could your production benefit from the use of robots?

The automation level of machine tools is set to increase. There is still too little awareness in the industry of how rapidly robots pay for themselves in the machine tool and mechanical engineering sector, how reliably robots work and how simple they are to program and control. But wherever the advantages of automation are presented, the response is always extremely positive.

Decision criteria. 20 percent of all machine tools would benefit from robotic automation. Does this apply to the machine tools in your machining operation? The following criteria give an initial indication.

<table>
<thead>
<tr>
<th>Question</th>
<th>Applies</th>
<th>Applies to some extent</th>
<th>Does not apply</th>
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</thead>
<tbody>
<tr>
<td>Are you under pressure to increase your productivity?</td>
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<tr>
<td>Do your customers expect high quality and precision in machining?</td>
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<tr>
<td>Are the parts you machine highly complex?</td>
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<tr>
<td>Is it important for your company to shorten your delivery times?</td>
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<tr>
<td>Do you consider your unit labor costs to be rather high?</td>
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<tr>
<td>Would you like to relieve your operating personnel of unpleasant tasks?</td>
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<tr>
<td>Do you want to increase the spindle running time?</td>
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<td></td>
<td></td>
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<tr>
<td>Is your reject rate fairly high?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Would you like to increase the error-free handling of work pieces and reduce the reject rate?</td>
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<td></td>
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<tr>
<td>Do you want to introduce additional shifts without additional personnel costs?</td>
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<td></td>
<td></td>
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<tr>
<td>Are your parts buffers between work steps too large / too expensive?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you want to make your employees’ jobs more attractive?</td>
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</table>

Have you answered half of these questions with “Applies” or “Applies to some extent”? Then we recommend taking a closer look at the costs and benefits of robotic automation – even for small batch sizes. A KUKA specialist will be happy to explain all that you need to take into account in your specific situation in an individual consultation.
Robot systems for machining companies and machine tool users. KUKA offers all the essential components for the automation of machine tools from a single source – from robots and controllers to function and technology packages.

KUKA Roboter GmbH with its headquarters in Augsburg, is a KUKA Aktiengesellschaft company and ranks among the world’s leading suppliers of industrial robots. Core competencies are the development, production and sale of industrial robots, controllers and software. The company is the market leader in Germany and Europe, and the number two in the world. KUKA Roboter GmbH employs about 3,464 people worldwide. In 2013, sales totaled 754.1 million euro. 26 subsidiaries provide a presence in the major markets of Europe, the Americas and Asia.

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