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KUKA: Innovations in Industrial Robotics

Automation with Industrial Robots

The use of industrial robots has increased steadily in recent years. Automation is the decisive key to higher productivity and greater cost-effectiveness. It improves product quality, reduces cost-intensive use of materials and minimizes the consumption of dwindling energy resources. Robots replace the rigid and expensive special machines that were still customary fifteen years ago with highly flexible automation solutions.

In the past industrial robots were used almost exclusively in the automotive sector and in series production. Thanks to the systematic ongoing development of robot and control technology, industrial robots have now become established in many other sectors besides the automotive industry. The primary objective here is the development of applications in new markets – in the fields of plastics, metalworking, foundry, electronics, medical technology, but also in the creative industries, from entertainment to art and architecture.

New Robot Technologies

In 1996, KUKA presented the first PC-based robot controller, marking the dawn of a new era of "real" mechatronics, characterized by the precise interaction of software, controller and mechanical systems. Within the past two years, KUKA has introduced two completely new robot families, the KR QUANTEC series of high-payload robots, and the KR AGILUS, a small robot with extreme speed and high precision. Another recent development is the KUKA LWR (lightweight-robot), a small robot originating from the aerospace industry, whose seven axes allow extremely human-like motions. These advances in new hardware are supported by newly developed software and interfaces such as the KR C4 robot controller, the SafeOperation package for safe human-robot interaction, and the KUKA CNC package, which allows robot to be used as CNC machines, without requiring external software.

KUKA KR QUANTEC: Efficient High-Payload Robots

KUKA KR QUANTEC robots are characterised by their extremely high power density, offering up to 160 kg less weight and 25% less volume, compared to the Series 2000 robots, while keeping reach and payload unchanged. The KR QUANTEC robot family covers the entire high payload range from 90 to 300 kg, with reaches from 2,500 to 3,100 mm. As the most compact robots in

S. Brell-Çokcan et al. (eds.), *Rob | Arch 2012*

their class, the reduced space requirements open up new fields of potential applications for production in confined areas.

The series has been designed by implementing a concept based on shared parts with just four motor and gear unit variants. All models have the same hole pattern for the mounting base, the same as that for the previous series, and an identical tool flange on the wrist, making the KR QUANTEC series thus fully compatible with existing cell layouts based on the Series 2000. The design of the KR QUANTEC series is distinguished by minimized disruptive contours and a compact wrist for accessibility, even in confined spaces.

As such, the KR QUANTEC robots can be used in virtually all branches of industry: the palletizers in the logistics sector, the foundry variants in foundry settings, the shelf-mounted robots in the plastics industry and the press-linking robots in the metalworking industry.

KUKA KR AGILUS and LWR: Innovative Small Robots

The most recent developments by KUKA in the area of small robots are the KR AGILUS and the LWR robots. While the new KR AGILUS small robot is characterized by precision and speed, the 7-axis LWR, a sensitive lightweight robot with integrated sensors, opens up a large range-of new possibilities both for innovative research and industrial applications.

The KR AGILUS is characterized by its extreme speed, short cycle times and high level of precision and safety. For handling tasks, especially Pick&Place, it offers minimized cycle times while at the same time working with great precision, enabling manufacturing quality of the highest standard. Its speed and accuracy make the performance of the KR AGILUS unique in its payload category. The basic model, KR 6 R900 sixx, weighing 51 kg, can carry a maxi-

Figure 1 KUKA KR QUANTEC robot in a tooling application

mum payload of 6 kg. The energy supply system of the KR AGILUS is integrated into the robot to save space and includes a 100 Mbit Ethernet cable, three 5/2-way valves for compressed air, a direct air hose, six digital inputs and two digital outputs. The KR 6 R900 sixx can reach points both near the robot base and also in the overhead area, performing its tasks as a floor, ceiling or wall-mounted robot.

The KR AGILUS is especially suited for operation in general industry, wherever automation with low payloads is required. In the context of universities or even architectural offices, robots such as the KR AGILUS can be used to quickly prototype robotic tasks, before moving on to a heavy-payload robot. KUKA SafeOperation makes the KR AGILUS especially suitable for such environments, as it greatly simplifies safe human-robot interaction. The software and hardware components of KUKA.SafeOperation monitor velocities and workspaces of both robot and external axes. This dispenses with the need for mechanical axis range monitoring systems and opens up new, cost-effective options for cell configuration and human-robot interaction. Similarly, the LWR has been specifically designed to share its workspace with the human operator in the future. A sensitive, lightweight robot, the LWR comes very close to the motion sequences of the human arm. The operator can manually guide the robot to different positions in the workspace and control and teach it using the very simple user interface. The LWR is able to perform demanding tasks that require high precision and a sensitive but powerful touch. With its in-built sensitivity, achieved by means of the integrated sensors, it is ideally suited to handling and assembly tasks. Its low weight of just 16 kg makes the robot energy-efficient and portable.

New Robotic Software and Interfaces

The robot control unit is the brain of every

Figure 2 KUKA LWR light weight robot

robotic arm. In addition to robot, motion, sequence and process control, safety control has also been seamlessly integrated into the new KR C4 control system. The KR C4 thus not only ensures the simple implementation of dedicated monitoring functions, but even more importantly the control technology ensures that the motion and velocity of the robot can be influenced safely.

By replacing limiting hardware with commonly-used, open industry standards, such as multi-core and Ethernet technology, the KR C4 offers a large performance and development potential. Based on these technologies Ethernet-based field bus systems, such as ProfiNet or Ethernet/IP, can be simply integrated as software functions. In this way the KR C4 concept will automatically benefit from future leaps in development and performance increases.

Figure 3 KUKA KR AGILUS robot

Furthermore, expanded software packages for a wide range of applications can be implemented at the controller. Especially interesting in the context of architectural fabrication is the KUKA CNC application, which enables the robot and machine tool to work together more efficiently as a system and simplifies production.

The smartPAD controller acts as the interface between user and robot control unit. Weighing only about 1,000 grams, the KUKA smartPAD offers a wide range of new user-friendly features, such as a USB port for convenient saving and loading of data directly on the control panel. It is operated using a large, high-resolution, 8.4" antireflection touch screen and a small number of keys, making it possible to control eight axes switching. When working with the KUKA smartPAD, the user is always offered precisely the operator control elements that are actually needed at any given moment.

Advances in Safe Human-Robot Cooperation

According to the International Federation of Robotics (IFR), there are around 234 industrial robots in Germany for every 10,000 employees in the manufacturing industries. As the number of robots increases, so, too, does their proximity to humans with the associated potential hazards. The objective is cooperation between the robot and the human, without endangering the latter.

Protection against injury takes the highest priority. Since it is impossible to preclude entirely the possibility of collisions between robots and humans in collaboration spaces, the minimum objective is to

reduce the risk of injury to a tolerable level. International norms and standards help manufacturers and integrators to implement safe systems.

Where humans and machines work together in close proximity and physical safeguards impede work sequences, other measures must be taken to ensure the safety and protection of the human workers. What is required is a safe, "intelligent" robot that reacts immediately in the event of danger.

With the integration of Safe Technology into the KR C4 controller software, KUKA has taken a step towards the concept of a safe and intelligent robot for which there is increasing need in order to perform collaborative tasks. Such a robot must be equipped with safety controllers, permanently sense the motions of the human worker, determine the risk of collision and adapt its own Cartesian motions.

Research towards Green Robotics

KUKA is committed to conserving environmental resources and developing robots that offer maximum energy efficiency. The specifications regarding energy savings and increased energy efficiency must therefore be taken into consideration early in the process. Drives and components are optimally rated, for example, in order to avoid overdimensioning the robot. Furthermore, research by KUKA has recognized that programming and control are increasingly relevant in terms of energy-efficient robot operation. The latest studies show that there is significant potential for savings in path programming. In the past, the goal was always to program the shortest path. However, energy-efficient robot paths often differ greatly from direct point-to-point motions. The task is to generate a robot path in which the interplay of the axes consisting of repeated acceleration and deceleration and is coordinated so as to create the most energy-efficient motion profile.

The solution is sophisticated software tools in which the user merely defines the start and end coordinates. The software then calculates the energy-optimal path within the specified workspace quickly and with minimum effort.

Robot Design

Functionality and aesthetic appearance are not mutually exclusive. In the development of new KUKA products, industrial designer Mario Selic is consulted at a very early stage. The development engineers implement the

Figure 4 KUKA smartPAD with touch interface

latest robot-specific technology. The close interplay of design expertise and engineering prowess results in robots that not only meet the highest mechanical requirements, but also look good, as evidenced by the KR 270 R2700 ultra which won this year's red dot "best of the best".

For the company, the design reduces costs and energy consumption and increases the service life of the products, while also enabling the customer to benefit from ergonomic and intuitive operator guidance. For example, organically designed components with smooth transitions between structural shapes improve the mechanical force transmission and increase component strength. The nature of the design gives the robots a high degree of stability and stiffness.

Designing with Robots

Today, industrial robots are much more than robotic arms that replace manual labor in the automotive industry – they are present in nearly all industries and are used for a wide variety of tasks – even in various creative industries. KUKA robots have been present in movies such as *The DaVinci Code*, *James Bond: Die Another Day*, and *Tomb Raider*. They can also be found on the other side of the camera, as part of a system that uses LWRs as camera platforms for repeatable, complex camera movements.

With the development of new interfaces such as KUKA|prc, and projects such as the Red Bull arch, where a group of artists themselves fabricated 83 2x3 m foam molds with a KUKA robot, the creative industry has proven to be a serious user of industrial robots, capable of dealing with complex problems themselves. KUKA's open architecture supports these advances by providing users with the opportunity to delve deep into the software and customize the machines to individual needs.

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Figure 5 Cooperating KUKA robots at Automatica


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