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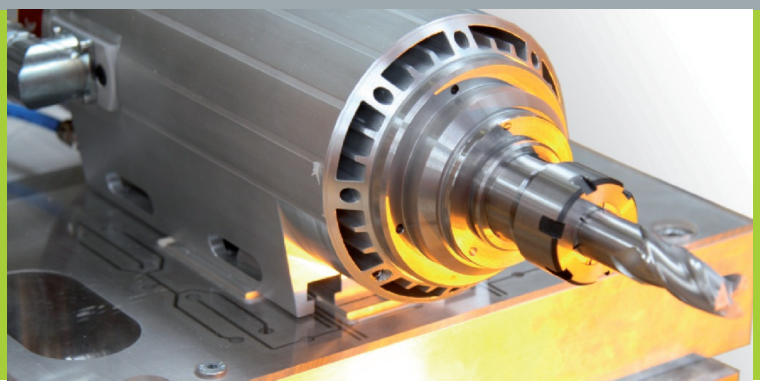

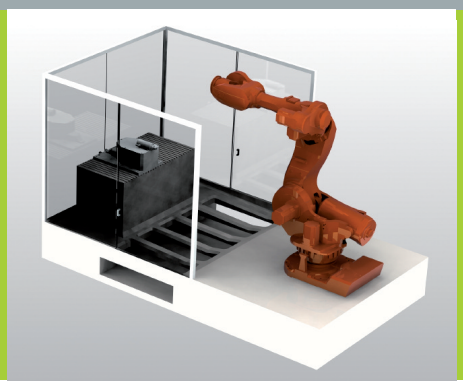

1 *Milling spindle on kinematic compensator*
2 *CAD view of a production setup*

MACHINING

Industrial robots with error compensation allow the highly accurate machining of materials

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Potential savings of time and money through the use of robot machining: lower capital costs, higher flexibility with regard to working space and handling. And piezo actuators for error compensation now also provide the required degrees of accuracy.

Background

In series production, components are manufactured from a wide range of different materials using conventional machining processes, such as machine tools or CNC-controlled machining centres. Such processes are characterized by the very high costs of a high-accuracy machine tool and the geometrically determined limits with regard to component size.

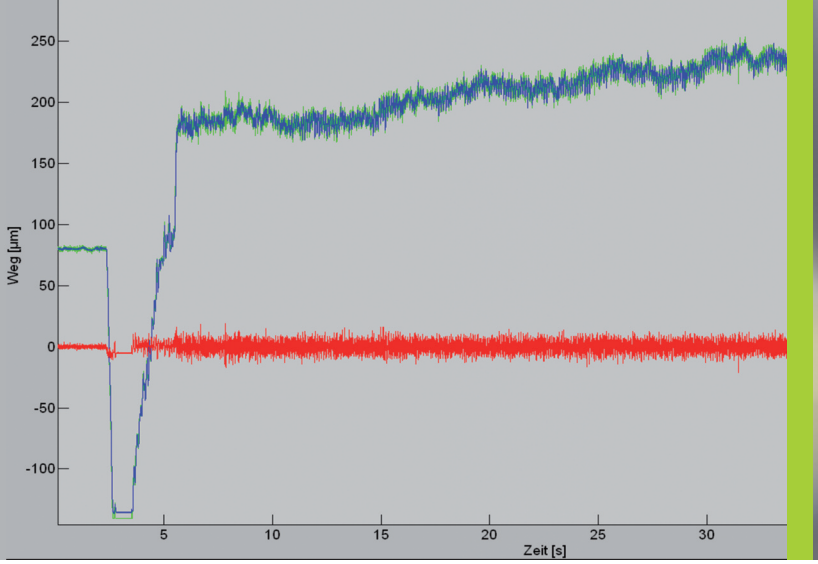
The use of industrial robots, the capital costs of which are significantly lower, has so far fallen down on the low stiffness, which is caused by the long serial kinematic chain. There are additional problems with regard to the execution of NC code and because the transmissions are optimized for other tasks.

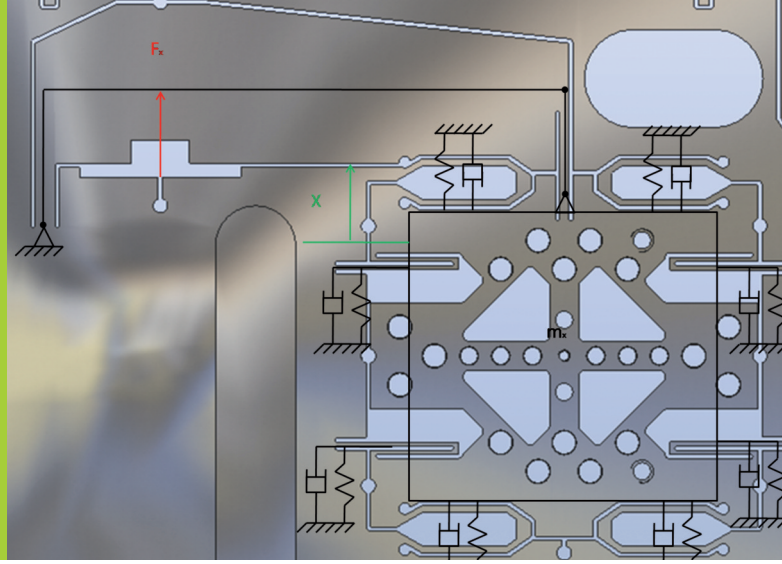
Innovation

In order to achieve the required accuracy of machining with an industrial robot, Fraunhofer IPA has developed a separate compensation actuator with machine tool spindle. The inaccuracies occurring in existing robot milling systems are measured and compensated directly by the compensation actuator. With reduced capital costs thanks to the use of a robot, this milling process allows the flexible production/machining of components.

Principle of operation

In the newly developed process, the component is clamped on the industrial robot and is guided by the robot during machining. The component is machined at speeds





of up to 30,000 rpm by means of a milling spindle. The spindle is mounted on a compensation actuator based on solid mechanical joints. During machining, the milling unit is so deflected in the relevant axis that, having been measured, the robot's inaccuracy of movement can be compensated by means of feedback control, thereby allowing the component to be machined with high accuracy.

Advantages of robot-guided machining

- The use of standard industrial robots results in low capital costs with a large working space.
- Unlike when being machined by a CNC machine, the component is not fixed on a table, but is gripped by the industrial robot, which guides the component while it is being machined. This means that the workpiece can be handled and machined by a single machine.
- The feedback control allows highly dynamic movement of the compensation actuator and a residual static error can be virtually ruled out.
- Piezo actuators allow highly dynamic movements in the µm range. Piezo actuators are capable of applying high forces and require virtually no power in static operation.
- The use of solid mechanics for the transmission of force and movement has numerous advantages: while providing comparable loading capacity, solid mechanics is lighter, quieter, stiffer, more dynamic and more accurate than conventional compensation mechanisms.

Moreover, solid mechanics is non-wearing, low-maintenance and cost-effective in production. A simple lever is used to increase the travel of the highly dynamic piezo actuators.

Area of application

- Milling of aluminium and other light alloys as well as plastics
- Ideal for use on production lines thanks to the combination of component handling and machining
- Production of small and medium batches
- Highly accurate robot machining

Technical data

Tool-/process-specific:

• Speed:	≤ 30,000 rpm
• Mounting diameter:	≤ 16 mm
• Working space:	approx. 1 m³
• Feed rate:	≤ 18 m/min

Workpiece-specific:

• Materials:	Light alloy, plastics
• Weight incl. fixture:	≤ 400 kg

Compensation actuator:

• Compensation direction:	y
• Travel:	± 200 µm
• Control frequency:	1 kHz

The existing setup compensates errors in one axis; a 3D kinematic compensator is under development.

Customer benefits

- Industrial robots can be used for machining
- Reduced costs thanks to low capital costs and combination of handling and process
- Large working space
- Creation of new areas of application for robot-based machining
- Creation of new positioning methods for microproduction and flexible application possibilities in positioning

What we offer

We develop customized manufacturing systems based on industrial robots with kinematic compensators. Equally, parts of the technology can be applied to other tasks, more particularly:

- High-accuracy position measurement
- Actuators in the µm range
- Real-time feedback control
- CAM-based control

3 *Robot signal, compensation actuator and residual error during milling*

4 *Mechanical equivalent diagram of the system*