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1 *Plant layout for the external laser tracker control system.*
2 *End-effector design with 6D measuring probe and retroreflectors.*

PRECISION MACHINING ROBOTS USING EXTERNAL GUIDANCE TECHNOLOGY

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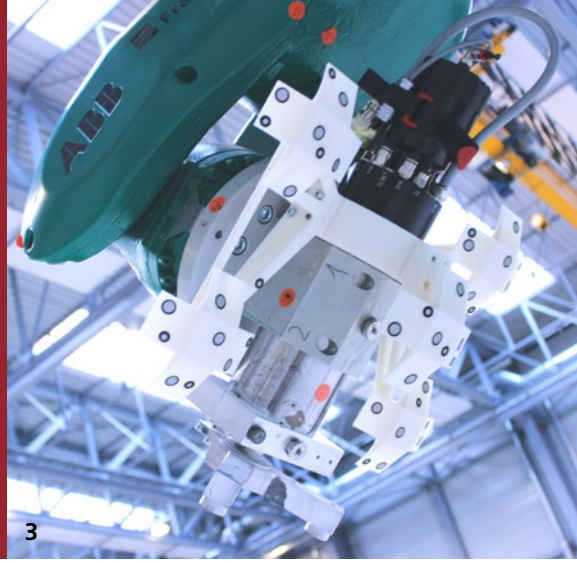
Status quo

The high demand for the efficient machining of large components – with the particular aim of reducing cycle times and costs – is leading to increased use of industrial robots as an alternative to currently employed special machinery.

The main disadvantage of industrial robots for machining applications is the poor system-related absolute accuracy – caused by the serial design, the flexibility of robot components, and external influences. In addition, high processing forces such as those that arise when machining carbon fiber reinforced plastic (CFRP) components in the aircraft manufacturing industry lead to significant deviation of the tool center point (TCP) from the target path due to the poor structural rigidity of the robot kinematics. These deviations cannot be measured by the internal motor encoders, meaning that calibration routines and internal robot control systems are not able to take account of the effect of external error influences.

External camera control system for static positional correction

The use of a stereo camera system and measurement target enables precise determination of the position and orientation of the robot end-effector and the deviation from the target pose. This deviation is taken into account in the form of path compensation values via a direct communication interface on the Siemens CNC control of the industrial robot. Independent of the calibration of the robot, the load, and the ambient



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parameters (e. g. temperature) – this enables a **static positioning accuracy** of **better than 0.1 mm** to be achieved in the entire workspace. This technology is therefore particularly suitable for high-precision drilling applications of large components.

Dynamic path correction via laser tracker

The use of dynamic measuring laser tracker further extends the external guidance by allowing dynamic path correction to be performed. For the position measurement it is necessary to use additional measuring technology in the form of a 6D measuring probe fitted near the tool center point on the end-effector. The EtherCAT real time bus system enables the positional data of the end-effector to be transferred in milliseconds to the robot control system and calculation of any path error.

The implementation of an extra controller cascade in the robot CNC system enables accurate path correction in real time, so allowing the highest industrial machining requirements to be met. **The positioning accuracy of 0.02 mm** that can be achieved is significantly better than the repeatability of most serial robots.

For simple positional correction the use of a retroreflector as target makes sense, so simplifying the system considerably. A **positioning accuracy of 0.08 mm** is then still achievable. These approaches are particularly suitable for dynamic machining processes such as the milling of large-volume components.

The work is carried out in collaboration with the Institute of Production Management and Production Technology at Hamburg University of Technology:
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Research field Optomechatronics

The use of external measurement technology for guiding industrial robots has the following benefits

- Utmost precision
- Insensitivity to external influences such as
  - non-considered loads
  - constant processing forces
  - temperature fluctuations
  - calibration or measurement errors
- Application-specific design of measuring systems

3 *Measurement target for the stereo camera system on the end-effector.*