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1 *Mobile CNC based robot for machining large structures.*
2 *ProsihP II plant for machining an A320 tailplane.*

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CNC MACHINING ROBOT

Status quo

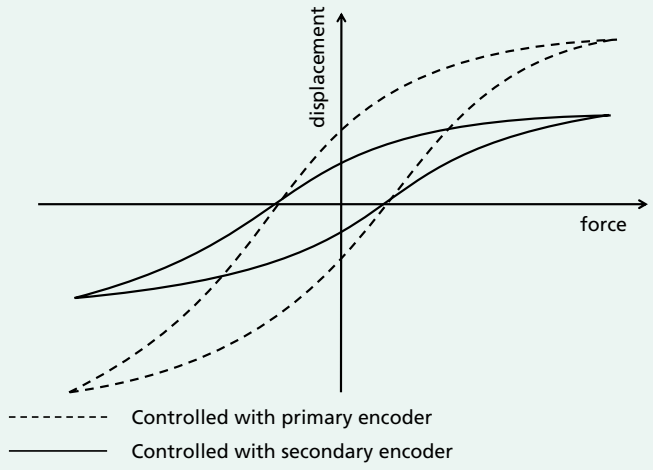
The constant growth in global air traffic is resulting in ever increasing automation in the airline manufacturing industry, away from customized special machinery to universal plant concepts. The ProsihP II research project (»Efficient, highly productive, precision machining of large CFRP structures«), involving Fraunhofer IFAM and a diverse consortium of project partners, was funded by the state of Lower Saxony and has successfully developed a mobile CNC machining robot.

Currently the machining of large structures utilizes heavy and expensive portal machines. The use of industrial robots (IRs) is essentially limited to processes in which the target positions can be taught in advance, with the industrial robots only having to accurately and reproducibly reach these positions.

The aim of the ProsihP II project was to enable industrial robots to meet the specified tolerances of the airline manufacturing industry of a few tenths of a millimeter. This would result in considerable efficiency increase for many machining tasks and would simultaneously result in cost reduction. For this purpose a precision CNC based robot was developed for milling tasks (Fig. 5). In particular, the absolute accuracy and the path accuracy had to be optimized and the stiffness of the system increased.

Innovations

- Secondary encoders on each axis
- Optimized absolute calibration
- Advanced control strategy
- Real time control using external sensors
- Easy operation via G-code programming (Siemens 840D sl)
- Integrated dust extraction
- Mobile platform



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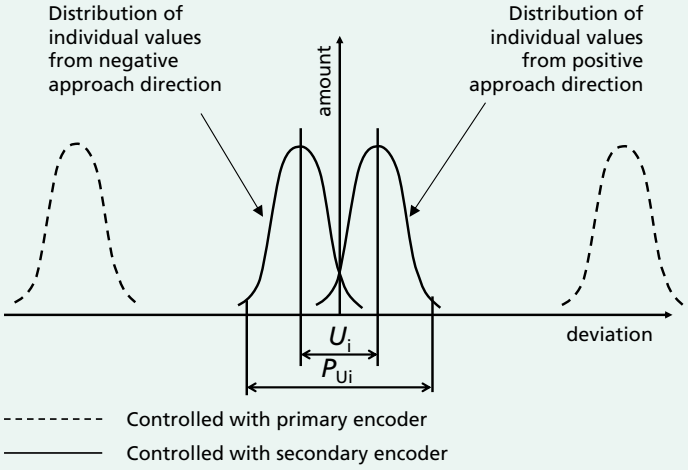

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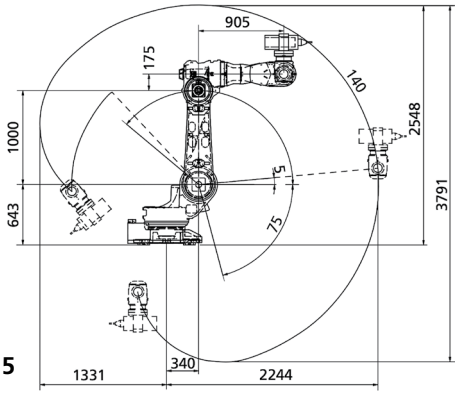

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Secondary encoders

Due to secondary encoders on the rotation axes of the IR, the effects of process forces and the inverse effects of the individual axes when approaching from opposite directions are considerably reduced. Furthermore, the integration of secondary encoders enhances virtual stiffness of the kinematics (Fig. 3). This means that the **deflection of the tool center point** (TCP) can be **reduced by up to 50 percent** for a force at the TCP acting tangentially to the first robot axis. In addition, the integration of the secondary encoders **reduces the positional uncertainty** (Fig. 4). The measurement values were determined in accordance with VDI/DGQ 3441 and the distribution of the measurements was analyzed for repeatedly approaching a target position from opposite directions. The typically large **reversal error** U_i for industrial robots is **considerably lowered**. The secondary encoders also underwent absolute calibration to achieve a **positioning accuracy** AP_p of 0.19 mm in accordance with ISO 9283.

Specifications	
Type (based on)	MABI Max MR-150
Number of axes	6
Reach of the robot	2244 mm
Payload	150 kg
Weight (without control unit)	1050 kg
Control unit	SINUMERIK 840D sl
Spindle	SLQ120 | 19 kW | n_{max} = 30.000 1/min
Positioning and path parameters	
Positioning accuracy (AP_p)	0.19 mm
Positioning repeatability (RP_1)	0.06 mm
Positioning path accuracy at 3000 mm/min (AT_p)	0,35 mm
Path repeatability at 3000 mm/min (RT_p)	0.063 mm
Positional uncertainty (P_{Ui})	0.06 mm

Tab.: *Specifications as well as positioning and path parameters for the CNC based robot.*

Dynamic optimization

The secondary encoders on the output side of the joints also influence the dynamic behavior of the robot. Further optimization steps such as adaptation of the control strategy and compensation of friction effects enable the **contouring performance to be significantly improved**, namely considerable improvement of the circular path and greater repeatability of circular paths from opposite directions. The **reduction of the bi-directional circular deviation** (ISO 230-4:2005) by up to **50 percent** underlined the success of these optimizations.

Project partners

Aicon 3D Systems GmbH, Airbus Operations GmbH, Artis GmbH, CTC GmbH Stade, IPMT at TU Hamburg, Ludwig Schleicher Anlagenbau GmbH, Mabi AG, mz robolab GmbH, Siemens AG, and Volkswagen AG.

The work was carried out in collaboration with the Institute of Production Management and Technology at Hamburg University of Technology:
PD Dr.-Ing. habil. Jörg Wollnack
Research field Optomechatronics
Prof. Dr.-Ing. Wolfgang Hintze
Research field Production Technology

3 *Schematic representation of the resilience behavior.*

4 *Distribution of measurement values for repeatedly approaching a target position from opposite directions.*

5 *Definition of the working space of the MABI MR-150.*