Laser Tracker and 6DoF measurement strategies in industrial robot applications

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Introduction

- Efficiency of industrial robot applications are dependent on multiple influences

- Components of the application have to be analyzed separately

- Adjustment of single influences result in evident accuracy increases

>> Even with adjusted components there is still a gap between theoretical (simulated) and practical world
Introduction

• Dedicated measurement strategies for identification or calibration of application components

• Improvement of resulting accuracy by integration of 3D and 6DoF measurement results for correction

• Various possibilities to use laser tracker systems to compensate static or dynamic influences
In this presentation

• How to identify system inaccuracies?

• What are influences on application accuracy?

• Which parts can be measured / calibrated / corrected using laser tracker?

• How can the influences be avoided / reduced to a minimum?

• Is it possible to get rid of all component influences?
Analyzing industrial robots

- Robot accuracy depending on time-variant influences
- Every robot is different due to manufacturing tolerances
- Offline programmed robot movement positions never fit to reality
- Robot model selection for dedicated application tasks is depending on robot accuracy
- Identification of peripheral geometries help to increase the accuracy of the system
Analyzing industrial robots

- Identification of robot base frame by laser tracker measurement
- 6-dimensional measurements for exact tool center point detection
- Check of robot static positional accuracy via residual vectors of best-fit transformation
Analyzing industrial robots

• Determination of robot static & dynamic accuracy via DIN EN ISO 9283

• Evaluation process for customer

• Dynamic 6-dof measurements with a rate of up to 1 kHz

• Path motion behavior analysis even with high movement speed
Linear Tracks

- Used for increasing the robots working range

- 2m to up to 30m for long range application e.g. in aircraft of windcraft industry

- Linear tracks are influencing application accuracy additional to the robot

- Adjusted during the mounting process, robot weight and movement influence is not considered

- Dynamic robot movement on skid causes forces and torques
Linear Tracks

Common techniques:

- Simple two-point measurements for gear factor identification
- Track direction identification in robot coordinate system (alignment)

Laser Tracker method:
- Non-linearity of the track identified by 6-dof measurement
Linear Tracks

Approach 1:

- Measurement of robot base frame for multiple skid positions on the track

- Robot works as “rigid body” based on its repeatability of <0,2 mm

- Cubic spline interpolation of identified base frame along the track

>> Many measurements needed for an accurate description of the track
Linear Tracks

Approach 2:

• 6-dof continuous measurement scan of the linear track skid

• Exact geometrical description of track profile via fine scan

• Positional correction of robot in 6 dimensions for arbitrary skid positions

>> Easy measurement procedure
Copy & Mirror of robot programs

• Robot program construction off-line using CAD simulation tools

• Generation for one robot, mirroring on symmetrical work pieces

• Copying of programs to parallel working cells

>> Integration of acquired measurement results into copy & mirror process to keep the needed accuracy
• Object position identification via vision system

• Multi-camera, laser-line, light-stripe or other methods base on good calibration

• Determination of sensor positions or calibration using 6-dof measurement technology

• Even hidden points e.g. for sensor body reference measurement possible with special tip adapters
Laser tracker as inline measurement system

- Optimal setup of components results in high accuracy for application

- But: Resulting accuracy is still depending on dynamic forces and non-avoidable influences

>> Always existing gap between theoretical world (CAD) and practical movement due to limited accuracy

>> Offline-generated programs always have practical deviations
Laser tracker as inline measurement system

- Laser tracker not only used for accuracy improvement or calibration
- Over-all pose correction via TCP movement identification

Static correction:
- Integration of laser tracker into working coordinate system
- Measurement of TCP-position in dedicated application positions
- Calculation of 6-dimensional correction offset for each position
Laser tracker as inline measurement system

- Offline correction of robot program with processing of movement results

--> Application of robot with repeating accuracy!

--> 10-times better than positional accuracy!

--> Laser tracker not needed all time in the cell!

--> Correction measurements repeated periodicaly!
Dynamic correction:
- Continuous measurement of TCP-position by laser tracker
- Dynamic correction control loop via real time interface to robot
- 6D-online correction of robot movement
- Correction of dynamic effects caused by application forces

>> Complete path motion controlled!
>> Absolute accuracy increased significantly!
Measure Assisted Production

- Example implementation of correction control loop
- Mixture of static and dynamic correction via iterated movement correction
- „Blind“ movement steps between correction points
- System is easily adaptable to high-speed dynamic correction via real-time interface
- Assembling application as example for robot path guidance
• Airplane wing-to-body task

• 6-dimensional measurement of robot tool

• Fixed tool-to-wing transformation

• Calculation of correction values in multiple path positions

• Final blind step for assembling

• Not depending on robot absolute accuracy

--Link to video--
Results

- From optimization up to full movement control usage of laser tracker measurements
- With inline correction control loop all accuracy influences compensated
- Dynamic robot path motion control with up to 1kHz measurement rate
- Resulting accuracy ranges:
  Absolute static: $<0.1 \text{ mm}$
  Dynamic: $<0.3 \text{ mm}$ (depending on speed)