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ROBOT ACCURACY CHARACTERISTICS MEASUREMENT METHOD BASED ON TEST RESULTS

Summary. The paper presents the method of measuring robot accuracy parameters with the usage of combined displacement probe and laser interferometer measuring system. The method was developed in order to determine robot performance characteristics in accordance with relevant ISO Standard, which requires the measurement of pose, path and velocity accuracy of the inspected robot.
The described method will be further developed so that all accuracy parameters defined by ISO 9283 can be determined within one measurement cycle.

1. Introduction

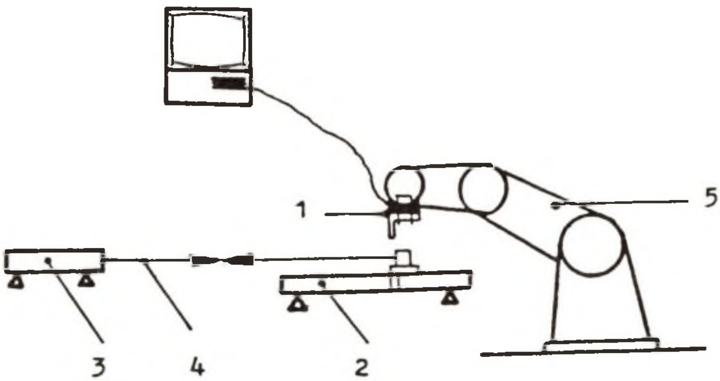
Industrial robots play an increasingly important role in the manufacturing environment. Evaluating their functional characteristics is a necessity as a complement to this development. The Metrology Laboratory of the Production Engineering Institute has developed a method of measuring performance characteristics of industrial robots according to ISO 9283 : "Manipulating Industrial Robots - Performance Criteria and Related Testing Methods".
The above mentioned Standard defines all the parameters which are to be used to comprehensively describe robot accuracy. It includes parameters concerning positioning, trajectory and velocity of the robot end effector. The method of assessing some of these quantities is presented in this paper.

2. Measuring method

Taking into consideration the necessary accuracy of the measurements and the available instrumentation the method of measuring robot accuracy characteristics has been developed.

The method allows the following parameters to be determined :

1. unidirectional pose accuracy and pose repeatibility for position and orientation ,
2. distance accuracy and repeatibility ,
3. path accuracy and path repeatibility for position and orientation,
4. path velocity characteristics (velocity accuracy ,velocity repeatibility and fluctuaction) .



1 - measuring head

2 - reference steel beam

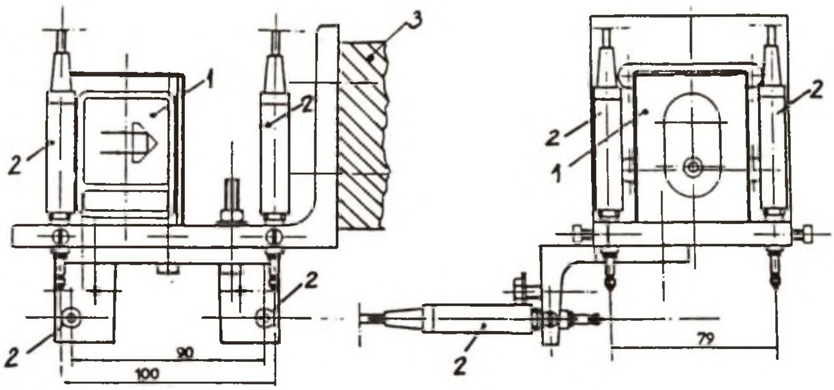
3 - laser interferometer

4 - laser beam

5 - tested robot

Fig.1. Measuring system layout

Fig. 1 shows the layout of the measuring system. It consists of three main components : measuring head with a set of inductive probes (1) , reference steel beam (2) and laser interferometer (3). The measuring head, mounted on the robot end effector, comprises five linear displacement probes fixed as shown on fig.2 .



1 - laser interferometer reflector

2 - inductive displacement probes

3 - robot end effector

Fig. 2. Measuring head

Prior to the measurements the head is calibrated - i.e. the positions of the probes with respect to the robot tool coordinate system is measured. They are then used to assess the real position and orientation of the robot end effector moving along the reference beam. The probes are adjustable for easy range setting. Data read from the probes are transferred into the PC to calculate the position and orientation of the end effector. To determine the actual position of the end effector along the beam the measuring head is equipped with the interferometer reflector. It enables also to measure the orientation and linear velocity (or acceleration) of the robot . Robot is programmed in teach-in mode to execute linear motion between two "taught" points defining ideal trajectory . Measured positions and orientations of the end effector at both "taught" ends of the path are recorded and then treated as command points of the robot, referenced when comparing the actual path with the ideal represented physically by the steel beam. The reference beam has two perpendicular measuring surfaces along which the probes are slid. Both of them have been calibrated by measuring their flateness using the laser interferometer ,the results being used as reference beam correction values . With the measuring probe calibrated it is possible to determine all six coordinates of the end effector in external coordinate system (represented by the steel beam) : three orientation angles and two displacements in the plane orthogonal to the motion direction (readings from the five probes) and the displacement along the axis of the beam(laser interferometer). According to ISO 9283 the robot accuracy parameters shall be determined for the tool coordinate system in the base coordinate system. This requires transforming probes and interferometer readings so that the actual "base" position and orientation of the end effector (its central point is the origin of the tool coordinate system) can be derived. That involves solving a complex nonlinear system of 5 equations, the 6th coordinate being directly read from the interferometer. Additionally, simultaneous interferometer measurement of the end effector velocity (or acceleration) can be performed.

3. Example results

The method outlined above was verified during identifing the accuracy parameters of the SMART 3-S COMAU 6-axis industrial robot. The method proved to be very effective both in respect of speed and accuracy necessary for end effector position, orientation and velocity measurement. The measuring system is easy to set up (once the reference steel beam has been calibrated) and operate due to the computer aided data acquiring and processing. This enables to easily carry out measurements in various points of robot's working space, changing if necessary the end effector velocity or load. On-site robot accuracy identification may provide useful data on its actual performance for a given application .Below are enclosed example results of the measurements of pose and velocity characteristics.

Velocity = 30 % Vmax	Velocity = 60 % Vmax
Pose accuracy AP = 0.025 mm	AP = 0.010 mm
Pose repeatibility RP = 0.053 mm	RP = 0.020 mm

Orientation accuracy and repeatibility

(axis "z" : along the path)

APAz = -8.6 e-5 rad	APAz = -1.4 e-4 rad
RPAz = 2.1 e-4 rad	RPAz = 1.1 e-3 rad

Velocity characteristics [mm/s]

V [% Vmax]	1	5	10	20
V	10.047	51.844	125.303	246.333
Velocity accuracy AV	0.001	0.003	0.048	0.213
Velocity fluctuation FV	0.055	0.979	3.946	5.315

REFERENCES

[1] ISO 9283 : "Manipulating Industrial Robots - Performance Criteria and Related Testing Methods" .

Revised by: Jan Darlewski