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POSSIBILITIES OF INDUSTRIAL ROBOT MONITORING BY RENISHAW BALLBAR SYSTEM

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The paper discusses the possibility of using Renishaw Ballbar QC20-W to monitor the condition of industrial robots. Renishaw Ballbar system is a standard tool designed for diagnostics and monitoring of CNC machine tools. Its use for industrial robots results from the experiences at the Department of Automation and Production Systems, Faculty of Mechanical Engineering, University of Zilina and other research institutes. The paper presents a methodology for monitoring industrial robots based on the processing of measured data utilizing the fast Fourier transform.

Industrial robots are widely used in various industries. One of the current trends is the replacement of single-purpose machines or similar devices by industrial robots. Specific areas of application of industrial robots include, for example, precise assembly processes, machining of complex-shaped surfaces, checking the dimensions of the manufactured parts or objects using 3D scanning or measuring probes, and much more.

Using an industrial robot in the mentioned inspection applications, precision assembly or machining tasks, it is not only the selection of the robot with the optimal properties but also the monitoring of any change in these properties. In such a case, there is a requirement for regular measurement of an industrial robot to monitor its technical condition. With a sufficient amount of collected data and evaluation of trends of changes in diagnostic quantities, it is possible to prevent robot failure, production of nonconforming products and prevention of production failure or shortage. Various measuring devices and corresponding measurement methods are used in technical publications to measure industrial robots. Increasingly, measuring devices primarily designed for a different purpose such as to assess the condition of CNC machine tools are also used. Such devices include the Renishaw Ballbar QC20-W or the Renishaw XL-80 laser interferometer. The present article deals with the option to use Renishaw Ballbar QC20-W for industrial robot condition monitoring.

Basis of experiments

The Renishaw Ballbar QC20-W measuring assembly used (Figure 1) consists of a precise linear sensor to measure the variation in the distance between a pair of precisely ground steel balls located at its ends. They fit into two magnetic cups. One is located on the center mount that is magnetically clamped on the table and represents a fixed point of rotation when performing circular paths. The second magnetic tool cup is clamped on the end of the robot's arm using a connecting flange. Consequently, the measurement process itself is based on collecting a set of radius deviations during circular paths of the magnetic tool cup around a fixed pivot point represented by the center mount.

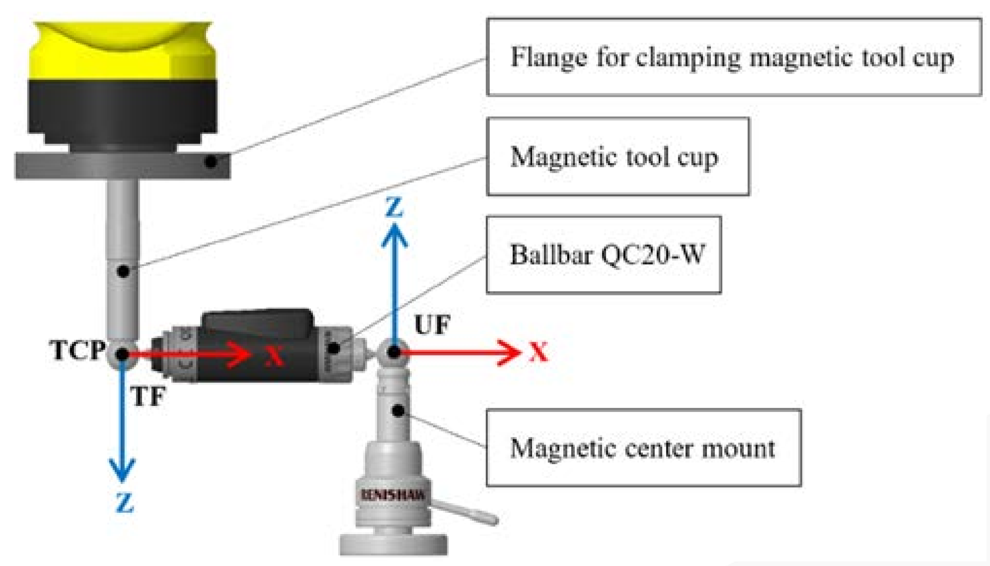

Figure 1. Measuring assembly and location of coordinate systems

Realized experiments

Within the Renishaw Ballbar experiments carried out at the Department of Automation and Production Systems, several series of measurements were carried out with the primary aim to verify the possibility of using the system to monitor the condition of an industrial robot. Individual measurements can be divided into two main groups:
1. determination of measurement conditions and method of evaluation of measured data,
2. verification of the relationship between the shape of the recorded circular path and the calibration of the robot.

Measurement conditions and data evaluation method

The sole purpose of this group of measurements was to compare two methods of circular path formation. The first method involves creating a circle using standard programming commands, such as joining two semicircles. In the latter method, the circular path is formed as a polygon, representing the most accurate approximation of the desired circle. Based on the results of the experiments, there has been formed a conclusion on the mutual equivalence of the two methods of circular path formation. However, creating a circular path using two semicircles is a more natural and faster way to prepare a control program.

Furthermore, a method of processing the measured data was proposed, allowing us to analyze them in more detail. The method uses fast Fourier transformation (FFT) to decompose the recorded circular profile into individual harmonic components. In Figure 2, graphical processing of the first ten harmonic components of the profile are displayed. The first ten harmonics are commonly used to analyze circularity. In the graph, the second harmonic component, representing ovality, is dominant.

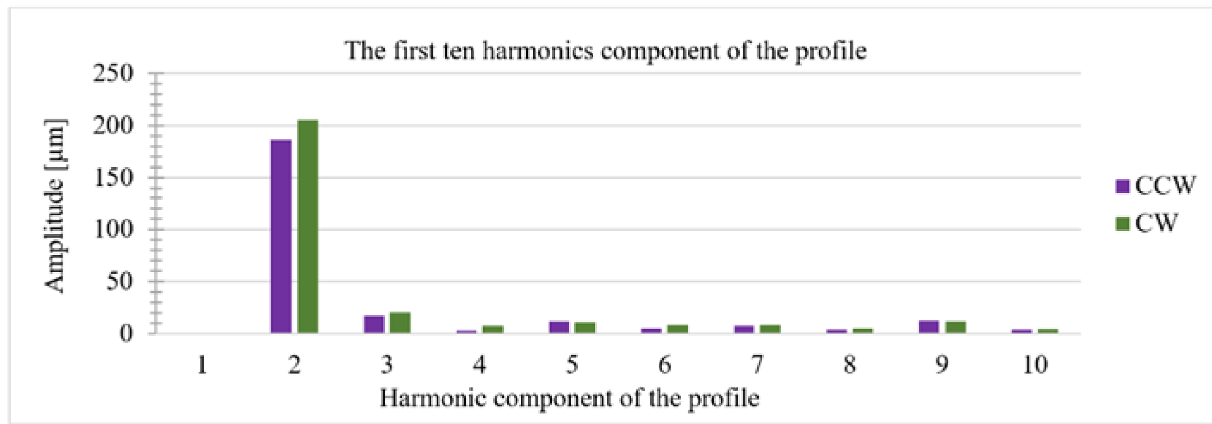

Figure 2. FFT analysis

Verification of the relationship between the shape of the recorded circular path and the robot's calibration

The experiments within this group of measurements were aimed at verifying the hypothesis of correlation of the circular path deformation observed in measurements with the Renishaw Ballbar system and the accuracy of the calibration. The first set of measurements was carried out with an inaccurate calibration of the robot. The shape of the circular path obtained is shown in Figure 3a, where the considerable deformation can be seen. Such deformation, irrespective of the connection to the calibration process, indicates a deteriorated technical condition of the robot, which will most likely affect line accuracy. After refining the robot calibration, the measurement was repeated under the same conditions and at the same place in the robot workspace. A more accurate calibration manifests, in the obtained polar graph, mainly as a reduction of the circular path deformation, see Figure 3b.

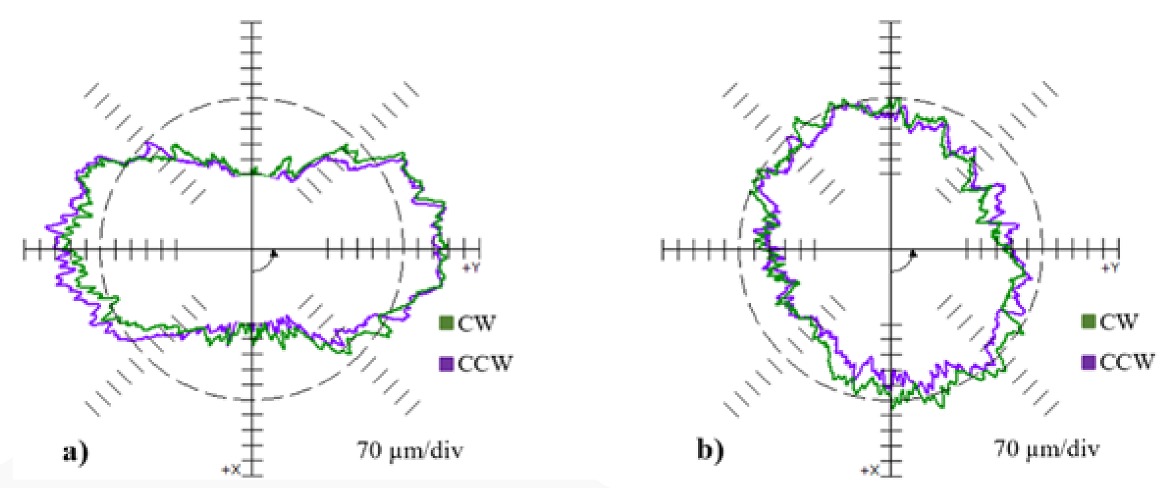

Figure 3. Circular path profile before (a) and after (b) robot calibration

Monitoring of the industrial robots' condition

The proposed monitoring methodology is based on the assumption that if periodic measurements are always performed at the same location, within the working space of the robot and its technical condition does not change, then the shape of the circular path remains constant. For this purpose, reference data, characterizing the correct or required technical state of the industrial robot. The recorded data is processed by a circular profile decomposition process using a fast Fourier transformation. The reference data takes the form of a circular profile formed from the first ten harmonic components (Figure 4).

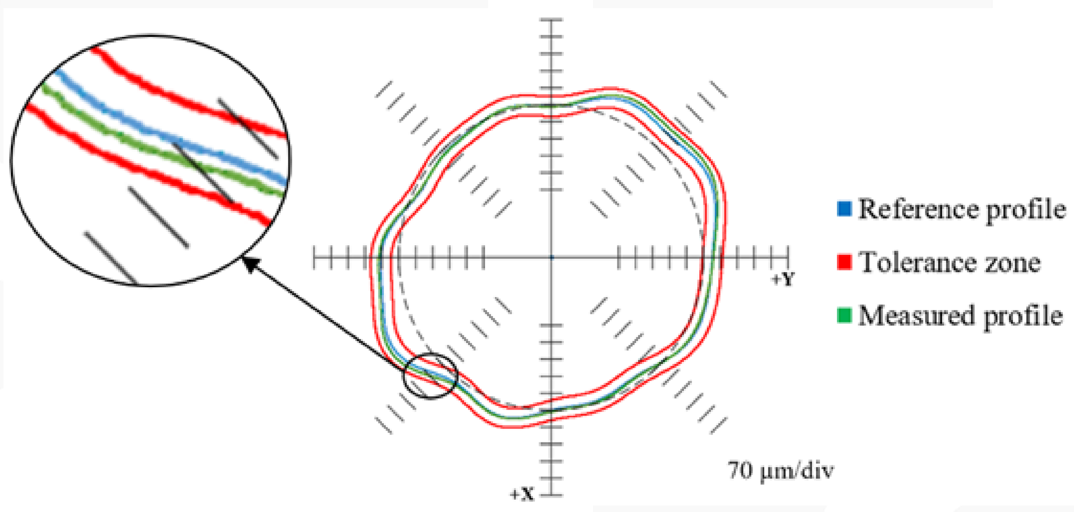

Figure 4. Polar graph with a reference profile for industrial robot status monitoring

In the polar graph (Figure 4), in addition to the reference profile, there are also two profiles representing the tolerance zone within which each repeated measurement carried out in the monitoring process will be considered. Values for the tolerance zone can be determined, for example, as plus / minus three sample standard deviations from the average mean of the base radius. Consequently, if the circular profile obtained as part of the monitoring is in the middle of the tolerance zone in the polar chart, then the status of the industrial robot can be assessed as unchanged. Conversely, if the circular profile is outside the tolerance zone, for example due to a change in its shape, it is necessary to look for a particular reason.

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