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A DEVICE FOR AUTOMATIC ROBOT TOOL CENTER POINT (TCP) CALIBRATION ADJUSTMENT FOR THE ABB INDUSTRIAL ROBOTS

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Abstract: *In the process of serial welding, the one place to shorten the process for product finished is to shorten the preparatory process and diagnostic service. The preparatory process is largely to proper apply welded elements in welding devices. Diagnostic process is for example to make validation or calibration of so-called tool central point (TCP), which is attached to welding torch. When this point is incorrectly defined, the tool can wave during work and causes damage of the welding element. This phenomenon is particularly evident when the seam is made near the corner of welding profile, for example bent 90 degrees. In such cases, there are uncontrolled changes in distance contact between tip and work piece. The given phenomenon can be observed in welding arc. This article presents an automatic tool to validate the calibration tool. There are describes main assumptions like integrity with intuitional robots, easy to use, not expensive device, working in heavy environment. Robot program algorithm is also presented in this article.*

Keywords: TCP calibration, Industrial robots, Automatic TCP adjustment.

1. Introduction

To calculate position and orientation coordinates of manipulator in the industrial robot workspace is important to have information about the origin of the robot's tool. In this case, the robot user must conduct tool calibration. In this process operator usually sets only translation vector of the tool coordinates origin (TCP – tool center point) with respect to the last robot joint of the kinematic chain, where default tool is attached. In a few cases, user also indicates the orientation of the Z-axis of calibrating tool, after that the orientation of the other axes is the same as the default tool coordinate system.

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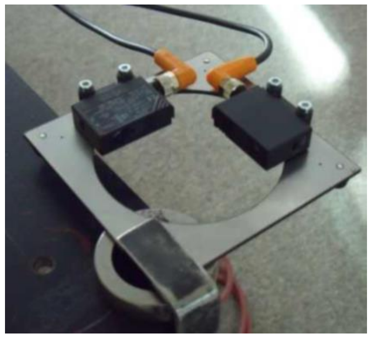
b) 

Fig. 1: Calibration devices: a) ABB Bulls Eye, b) device describe in the article.

Tool calibration is a very important issue in robotics, because it effects on accuracy of the programmed points in the robot program paths. Checking TCP repeatability is particularly important in robotic welding systems. In these cases, the TCP is attached to the end of the welding wire. Invalid eject, bent, unexpected move of the wire after the collision can result in interruption of the welding process, because there would be no arc weld setting up after scrapping, or seam would be forming in the wrong shift place. Those welding interruption, for example, in the middle of the path may cause the welded part becomes worthless.

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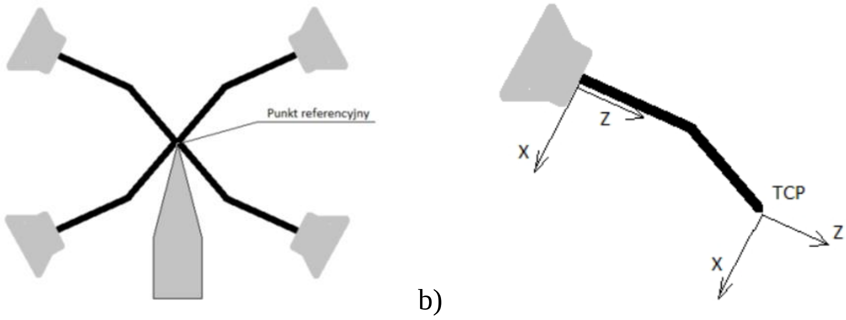
There are commercial solutions, which provide automatically checking position device of the TCP. For example, ABB devices called Bulls Eye is shown in Fig. 1a (1). In contrast, Fig. 1b shows the prototype described in this article. It is also important to mansion that this device can be used in many other work (2-7).

2. Manual tool calibration and design of calibration device

Below is presented 4-points calibration method for ABB IRB1600 robot, which is described in instruction provided by the manufacturer (9). This calibration method is implemented to vast majority of industrial robots. The algorithm is as follows. Find reference fixed point in the robot workspace. Next, determine reference point on the tool. Normally it is end of the welding wire. Finally, indicate reference robot point from four different directions by moving manipulator tool, as shown in Fig. 1a (one position, four orientations). Reference robot point can be any sharp object for example steel rod. The robot control system calculates the TCP based on the different positions respected to robot mounting flange. It is important, that reference points should invade as close as possible to get the best accuracy.

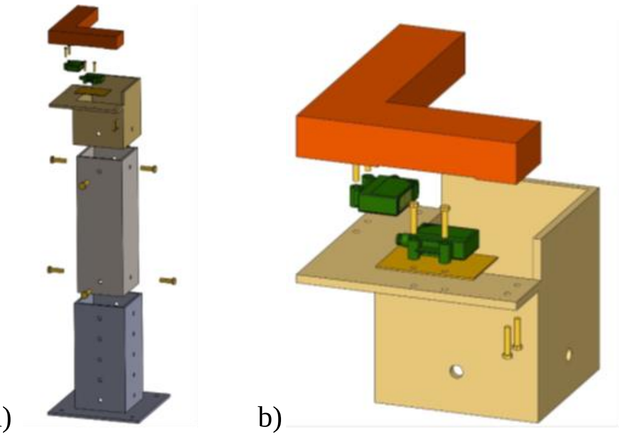
Correctly defined TCP receives default coordinate system related to the previous one attached to the end of kinematic robot chain (in this case: the last robot joint). This is shown in Fig. 2b.



a) b)

Fig. 2: a) manual 4 points calibration method, b) TCP location in welding torch.

Designed device for checking the accuracy of the calibration tool is composed of two laser sensors, in which the beam diameter does not exceed one millimeter. As mentioned in introduction, the device is mainly used in welding, where the thickness of welding wires is great or equal 0.8 mm. The second assumption was that the robot operator may run checking TCP process at any time, for example, between the free moving between welding paths.



a) b)

Fig. 3: Conception of calibration device: a) full view; b) laser location (green).

Third assumption was to obtain low cost device, so there had been chosen laser sensors from IFM Electronic, OJ5 laser type. These laser sensors use reflective diffusion. Beam receiver is located at the top of the lens, while beam transmitter in the lower one. The sensor range is in the range of 7 to 150 mm. Another objective was to design a structure, which can be working in a difficult operating environment and at the same time provides protection against laser beams. Appearance design, Figs. 3a and 3b.

3. Calibration device - principle of operation

In the first stage, should be determined positions and orientations of the calibration device. For this purpose, the robot need have properly calibrated TCP. Using TCP robot, indicate points 1, 2, 3 marked on Fig. 4a. This will allow to determine a straight line passing through the points 1 and 2, and then a straight line perpendicular to first one passing through point 3. The result will be origin of the coordinate system of calibrating device, which is placed in the intersection of the laser beams. Coordinates are calculated with respect to the base of the robot and stored in robot controller memory. These will be used as reference coordinates to calculate the correction values of the TCP. Next step, before first use of the device is also important. Operator must place the TCP in black marked place near the point *P*, as shown in Fig. 4b. The calibration device automatically operates as follows. Robot program moves the TCP along the device local *X* axis. During this movement, it intersects laser 2 beam and determines the *Y* coordinate (*p100.y*). Then the robot moves the TCP close to that intersection point and distances 15 mm from the laser beam 2 in direction of -*Y* axis. Next robot TCP searches the point of intersection with laser beam 1. In this manner, it calculates *X* coordinate (*p100.x*). This operation is performed repeatedly, each time robot moves the tool upward along the positive *Z* axis. This way can be searched for the end of the wire.

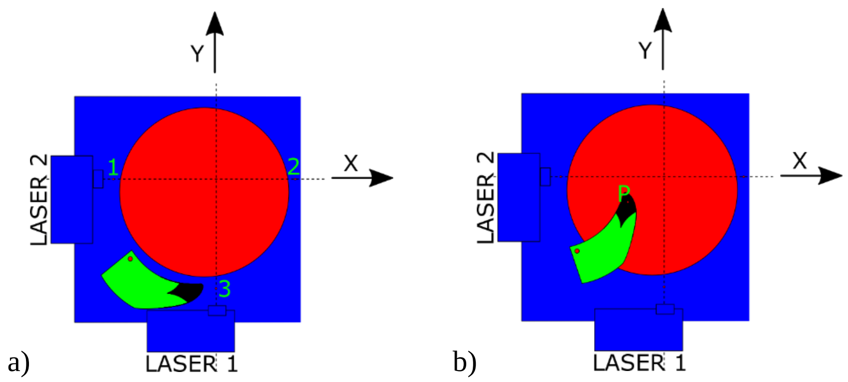


Fig. 4: a) Device calibrating procedure, b) Position P where the user should place robot TCP.

Below, in a few steps is shown program algorithm implemented into robot controller.

- User places the TCP at point *P* and stores it. It is done once – calibration procedure.
- Robot moves TCP down of 10 mm, because minimum welded wire eject is 17 mm. It is protection from tip hit of torch. (*P[x, y, z-10]*)
- Robot moves TCP along the *X* axis at distance of 15 mm. Calculates the average of 5 repetitions. (*P [x, y, z - 10] -> P [x + 15, y, z - 10]*)
- Controller remembers *X* position, when the Laser 1 signal changed from logical 0 to 1.
- Robot moves the TCP to *X* - 15 mm position, but not more than 30 mm.
- Robot moves along *Y* axis by 15 mm. Calculates the average of 5 repetitions.
- Robot moves TCP to intersection point with the axis *Y*.
- Robot moves TCP upward along the axis *Z* + 0.5 mm, the system checks end of wire using signals for Laser 1. Waves no more than 50 mm in *Z* axis direction and in the range between ± 2.5 mm in *X* direction.
- Robot again searches end wire area along *Z* axis in distance ± 0.5 mm.
- Controller saves *Z* coordinate and enter tool correction only if the deviation of wire is lower than 5 %.

Positioning accuracy of designed device was tested in Kielce University of Technology in the station with ABB IRB1600 industrial robot. For the purposes of article were carried out 10 test series. Each series contained 20 test measurements. Before each series, the wire deviation was changed slightly. In this manner was changed the physical TCP compared with stored in the system tool values. Such approach simulated the work of the real welding torch. It should be noted that, the real wire ejects from the housing of the welding tip is not more than 27 mm. We tested this with 40 mm wire ejection, in case to increase the possible error. During research sought to ensure that the deviation is minor and direct only in one plane. Test robot speed was set to 1 mm/s and each laser intersecting movement was performed twice (average). For each result was add value of 0.5 mm which is the value of half of thickness of the tested wire. Fig. 5 shows obtained results of *X* axis discrepancy. Other results were similar.

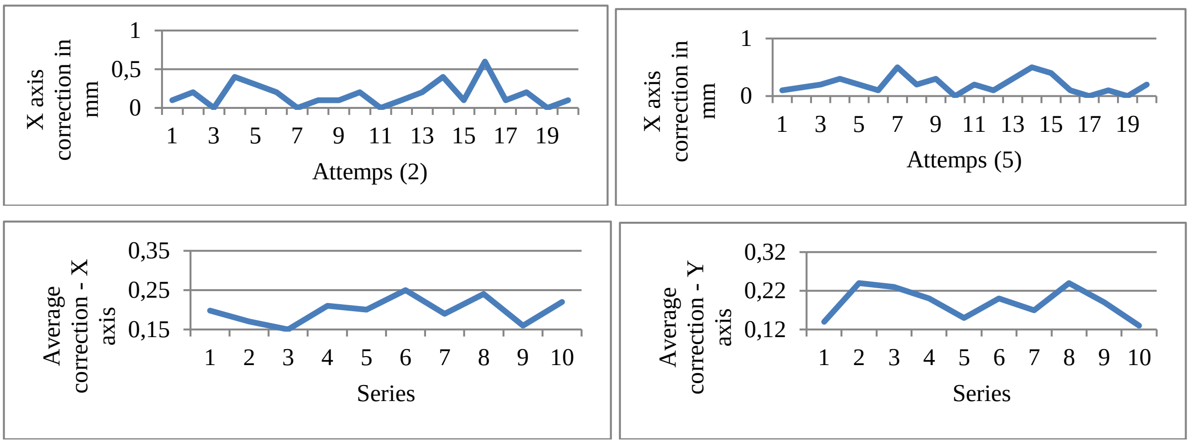


Fig. 5: The TCP X axis accuracy results calculated in calibrating device.

4. Conclusions

Designed device always correctly detected the torch wire. Discrepancy of wire intersection position points were small and ranged on tenths of a millimeter. There was assuming, that the system is used to determine the adjustment of the welding wire, so results are better than expected. Only much wire deflection was a problem, that is above 10 degrees, because the wire extends beyond the boundaries of the vertical scan (search for tilting wire along the *Z* axis of the tool). However, each time in such situation system informed the user correctly and displayed measurement error. It should be noted that, if the wire deviation excides above 3 degrees, the system cannot make TCP adjustment. It can only display a message to the system operator of an invalid wire load. The operator should cut the wire and pull out it again to the required length.

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