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PRINCIPLES OF MASTERING AT KUKA ROBOTS

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Keywords: KUKA robot, mastering, measurement, SEMD
Abstract: Every robot must be mastered. Only if the robot has been mastered can it move to programmed positions and be moved using Cartesian coordinates. During mastering, the mechanical position and the electronic position of the robot are aligned. For this purpose, the robot is moved to a defined mechanical position, the mastering position. The encoder value for each axis is then saved. The mastering position is similar, but not identical, for all robots. The exact positions may even vary between individual robots of a single robot type.

1 Introduction

Robot mastering is the process of identifying the real geometrical parameters in the kinematic structure of an industrial robot, such as the relative position of joint links in the robot [1]. Calibration is a useful diagnostic method that increases the positioning accuracy of the robotic arm of an industrial robot. Robot calibration is performed to set the correct positions of each robot arm (axis) relative to the base coordinate system. Nowadays, is possible use also ROS mastering for robotics programming as advanced concepts at this area [2]. The method of calibration on different types of robots varies depending on the robot kinematics as well as on the manufacturer's preferences.

Expensive and log calibration methods based on a camera or laser scanning system require specific equipment and accessories, unlike manual calibration, where the financial requirements are minimal, see Fig. 1.

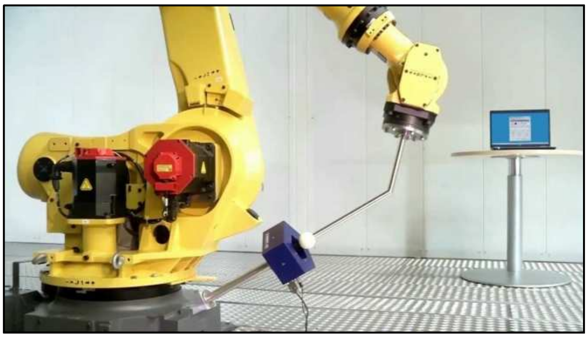

Figure 1 Robot mastering

In practice, it is often used that calibration is most often performed on new robots in production processes [3]. Users, however, want to be sure that machines will achieve required precision after being deployed in the production process. Therefore, it is important to deal with the calibration again after some time.

Regular calibration is very important, because even the best robots tend to lose absolute stability; they show a shift and zero fluctuations, thus losing the ability to accurately position [4]. There are several different calibration methods that are used depending on how many devices to calibrate and what level of precision is required. In some cases, calibration must be carried out directly in operation, otherwise it is appropriate to do it in a workshop or in a calibration laboratory. Consequently, with the help of modern software and camera systems, it is easy to evaluate the calibration result [5].

By calibration we can understand two things. In the first case it is a robot recovery. This process is usually done by the manufacturer as the final step that is necessary for the fully functional product that the manufacturer offers. The revitalization of the robot is based on the unification of individual coordinate systems of robot with their virtual representation, which is stored in the robot's control system [6].

In the second case, the calibration is used to improve positioning accuracy without necessarily or altering of mechanical structure or design of robot. To achieve required positioning accuracy, software that corrects undesirable deviations and optimizes the path is used [7].

Robots, such as mechanical devices, can be affected by minor deviations due to wear of parts, tolerances, manufacturing inaccuracy of spare parts [8]. Calibration reduces the risk of changing the robot program due to these factors. On a general level, the calibration is divided into two groups:

- parametric calibration (kinematics calibration),
- non-parametric calibration (static calibration).

In both cases will be solved following steps:

- model of robot,
- measurement,
- identification,
- compensation or correction.

It should be taken into account the fact that this is a process in which the positioning accuracy of the robot arm is improved by software modification of the positioning [9]. Therefore, it is not necessary to interfere with the robot construction or its control system. This process contains from creation of model that represents real robot at the workplace [10].

Parameters affecting robot precision are precisely defined and measured, see Fig. 2. In next steps, calculated parameter values are inserted into the kinematic model, which exactly corresponds to the actual parameter.

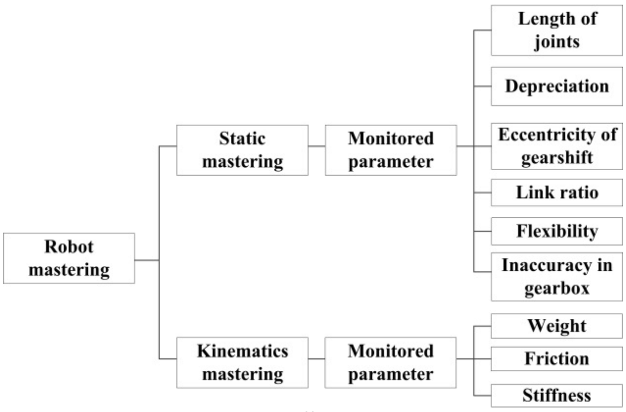

Figure 2 Parameters affecting at robot accuracy

With quick and easy calibration, we can achieve the following benefits:

- If the robot fails, it may be replaced by a new one. Once the calibration has been completed, operation can be restored with minimal downtime.
- Program calibration can be verified at regular intervals. This means that quality is ensured by frequent calibration. Thus savings are a reduction in costs associated with poor quality products.
- Quick calibration also allows you to reduce the insertion or changing of the accessory. Shorter feed-in times then reduce downtime costs.
- Programming is done in such a way that the robot can be replaced without having to reprogram each position.

2 Mastering at KUKA

The calibration method used by KUKA industrial robots uses two types of measuring devices [11]:

- Dial gauge – the calibration is fixed over the measuring tip by means of a thread. Previously, you need to set the help lines to overlap at robot.

By gradually moving of robotic arm at the lowest speed from negative, the measuring tip moves, which can be tracked on the watch handles. When the tip reaches the groove bottom and the hand rises, the measurement is completed [12].

Figure 3 Dial gauge

- SEMD (Standard Electronic Mastering Device) – electronic measurement device – works on a similar principle as a dial gauge, except that it is equipped with a connecting cable to connect the robot with a calibration device [13].

The information from the SEMD device is transferred to the robot where the robot is automatically shut off after the calibration position is reached, see Fig. 4.

Figure 4 Adjusting set with SEMD and MEMD

The thinner cable is the signal cable. It connects the SEMD or MEMD to the mastering box. The thicker cable is the EtherCAT cable. It is connected to the mastering box and to the robot at X32.Description of adjusting set with SEMD and MEMD (Micro Electronic Mastering Device)) can be found in table 1.

Table 1 Describtion of parts in adjusting set

1.	Adjusting box
2.	Screwdriver for MEMD
3.	MEMD
4.	SEMD
5.	Cables

2.1 *Basic setup*

Every robot must be mastered. Only if the robot has been mastered can it move to programmed positions and be moved using Cartesian coordinates. During mastering, the mechanical position and the electronic position of the robot are aligned. For this purpose, the robot is moved to a defined mechanical position, the mastering position. The encoder impulse for each axis is evaluated from rotational speed of motor and then saved [14]. The mastering position is similar, but not identical, for all robots, see Fig. 5. The exact positions may even vary between individual robots of a single robot type.

Figure 5 Mastering position – approximate position

A robot must be mastered in the following cases:

- During commissioning,
- After maintenance work during which the robot loses its mastering, e.g. exchange of motor,
- When the robot has been moved without the robot controller (e.g. with the release device),
- After exchanging a gear unit,
- After an impact with an end stop at more than 250 mm/s,
- After a collision.

The axes must be moved to the pre-mastering position before every mastering operation, fig. 6. To do so, each axis is moved so that the mastering marks line up [15].

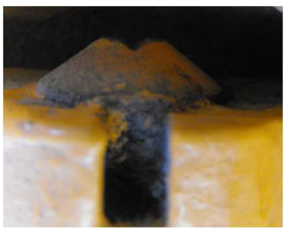

Figure 6 Moving an axis to the pre-mastering position

In some cases it is not possible to align the axes using the mastering marks, e.g. because the marks can no longer be recognized due to fouling. The axes can also be mastered using the probe instead of the mastering marks.

The figure 7 shows where on the robot the mastering marks are situated [16].

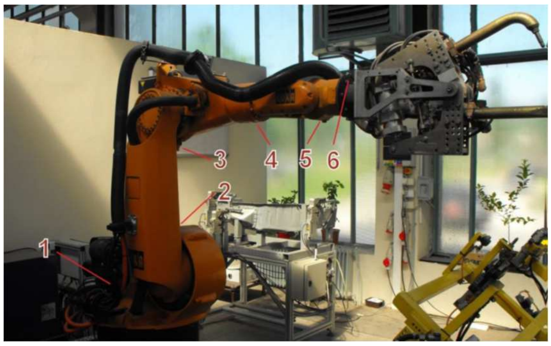

Figure 7 Mastering marks on the robot

To locate the mechanical zero position of a robot axis precisely, it must first be aligned to its pre–mastering position. The protective cap of the gauge cartridge is then removed and a dial gauge, or the supplied SEMD, is fitted to it. The SEMD is now plugged into the robot junction box (connection X32) and thus connected to the robot controller. When, on passing over the reference notch, the gauge pin reaches its lowest point, the mechanical zero position is reached [17].

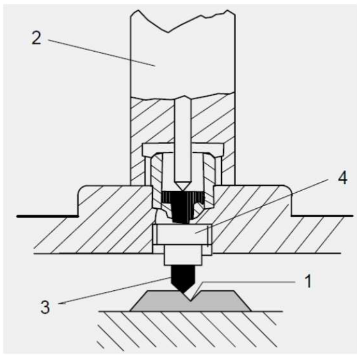

Figure 8 Cross–section of a gauge cartridge

The electronic measuring tool sends an electronic signal to the controller. If using a dial gauge, the zero position can be recognized by the abrupt reversal of the pointer. The pre–mastering position makes it easier to move to the mechanical zero position. The pre–mastering position is indicated externally by a scratch mark or “frontsight/rearsight” markers and is located just before the zero position, see Fig. 9. The robot must be brought into this position before the actual mastering procedure [18].

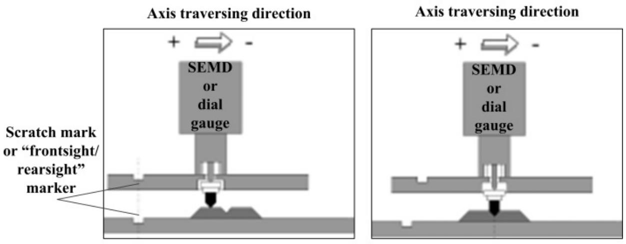

Figure 9 Pre-mastering and mechanical zero position

2.2 *Mastering process*

A number of different functions are available for mastering with the SEMD. These are grouped together under two main points: "Standard" and "With load correction". The difference here is that using the option "With load correction" it is possible to master the robot as if the tool had been removed, but actually leave the tool mounted on the robot. This is done by correcting the weight of the tool "arithmetically". "Standard" mastering is used if the robot is always mastered with the same tool or always mastered with no tool.

- Removing the protective cap of the gauge cartridge and fit the measuring tool to first axis, fig. 10.

Figure 10 Measurement at first axis

- Connectting the measuring tool to the robot controller using the cable supplied with the EMT set., fig. 11.

Figure 11 Connection cable for EMT

- Preparing the robot for mastering and selecting the menu item "Standard" from the submenu "Set mastering", fig. 12.

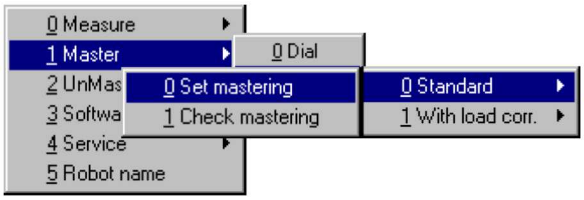

Figure 12 Setting of mastering at Menu

- Oppening of status window (Fig. 13) with describer axis to mastering. The rank of axis for mastering is suited as follows.

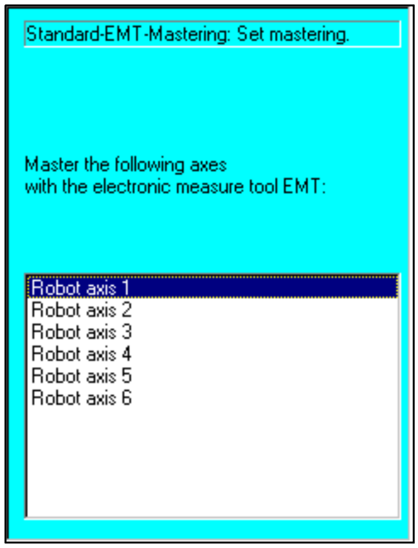

Figure 13 Axis status window

- By pushing of the button for mastering will be setting the first axis. Is necessary to hold "death man" function at the back of the pendant together with green button – start. Blue markered axis will be automatically mastered in direction from + to - .

In case of the finding of deepest point (mechanical zero position) program will automatically stop. Finded values will be stored at memory of robot control system and blue markere axiss will disapear, see fig. 14.

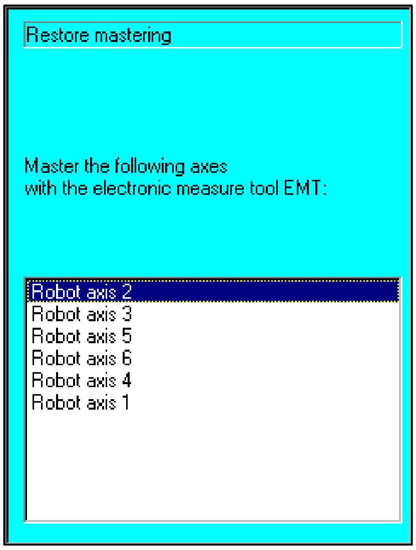

Figure 14 Succesfully mastered first axis

- Repeating the same process at each axis of robot KUKA. If at screen is not displaying any axis, realized mastering was succsesfully.

3 Conclusion

Kinematic calibration can be applied to multiple robots of the same type at the same time. This means that the calibration process is performed once, but is applicable to the robot group. From an economic point of view, kinematic calibration does not require special equipment; on the contrary, static calibration requires special external devices, thus increasing the costs required for static calibration. Constructing of kinematic model requires expert service, unlike static calibration, where trained robot attendants are sufficient.

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