# 3. KUKA conditioning

## 3.1 Robot Mastering

The Mastering operation calibrates the relationship between the position sensor, attached to each axis motor, and each axis angle defined for each robot. Mastering axes enables the definition of geometric parameters used to describe the analytic parameters of a robot’s geometric model. This helps in increasing the accuracy of the robot and correcting for discrepancies between design parameters and actual values.

Mastering the robot is performed by moving the each axis into a defined mechanical position, which is known as the “Mechanical zero position”. The zero position, which is defined by a reference notch, is an assignment to the axis drive angle. Whenever the robot moves from the mechanical zero position, its deflection represents the change in corresponding axis angle (0 increments for 0 degrees).

To locate the mechanical zero position of a robot axis precisely, the axes must be aligned to their pre–mastering position. The protective cap of the gauge cartridge is then removed and a dial gauge, or the supplied EMD, is fitted to it.

*Note: The robot must be mastered in the same temperature conditions (either always cold or at operating temperature) to avoid inaccuracies.*



Fig. 1 Moving an axis to pre-mastering position

When, on passing over the reference notch, the gauge pin reaches its lowest point, the mechanical zero position is reached. The electronic measuring tool sends an electronic signal to the controller.

Mastering can be performed through several methods; for older Robot versions it is performed using EMT, as for the KUKA AGILUS, mastering is done using one of these methods; EMD, dial gauge or MEMD. For our purpose, we used the MEMD supplied with the robot. The mastering positions are similar, but not identical, for all robots. Exact positions may vary between individual robots or single robot type.

Figure 2 Cross–section of a gauge cartridge

### 3.1.1 Mastering using MEMD

Unlike Dial gauge mastering, which requires moving the robot manually to the mastering position, MEMD mastering offers automatic movement, done by the robot, to reach the mastering position. Mastering is performed first without a load then repeated using a load.

#### Mastering tools

Figure 3 MEMD kit

1. MEMD box
2. Screwdriver
3. MEMD
4. Cables

#### Types of mastering

1. **First mastering** (without a load).
2. **Tech offset** (with a load and with saving the difference from first mastering being saved).
3. **Master load with offset** is based on saving an offset value that can be used to calculate first mastering in case it was lost (used when required, carried out with a load for which an offset has already been taught. This type is used to check first mastering or to restore it in case it was lost).

#### Precondition:

* There is no load on the robot; i.e. there is no tool, workpiece or supplementary load mounted.
* A1 to A5 are in the pre-mastering position.
* No program is selected.
* Operating mode T1

#### Procedure

1. In the main menu, select **Start-up** > **Master** > **EMD** > **With load correction** > **First mastering**. A window opens. All axes to be mastered are displayed. The axis with the lowest number is highlighted.
2. Remove the cover from connection X32.
3. Connect the EtherCAT cable to X32 and to the MEMD box.
4. Remove the protective cap of the gauge cartridge on the axis highlighted in the window.
5. Screw the MEMD onto the gauge cartridge.
6. Press **Master**.
7. Press an enabling switch and the Start key.
8. When the MEMD has passed through the reference notch, the mastering position is calculated. The robot stops automatically. The values are saved. The axis is no longer displayed in the window.
9. Remove the MEMD from the gauge cartridge and replace the protective cap.
10. Repeat steps 4 to 8 for

##### Mastering of A6

1. Move A6 to the mastering position:
2. A6 has very fine marks in the metal. Align these marks exactly with one another.
3. In the main menu, select Start-up > Master > Reference.
4. The option window Reference mastering is opened. A6 is displayed and is selected.
5. Press Master. A6 is mastered and removed from the option window.
6. Close the window.
7. Disconnect the EtherCAT cable from X32 and the MEMD box.

For more information about the remaining mastering types (teach offset and mastering load with offset) and other mastering methods (using dial gauge and EMD), please refer to section **“5.9 Mastering”** in the provided manual **“07-KSS\_82\_Software programming\_en”**.

## Calibration

Robot calibration is defined as identifying certain parameters in the robot’s kinematic structure, as an example; identifying relative position of robot links. Robot calibration can be performed through various methods, two of which are using a predefined & built-in calibration programs, or external methods (hardware and/or software) as RoboDK or advintec TCP. Calibration process differs in complexity from one method to another.

Calibration can be divided into three levels, depending on the type of modeled errors. The first of which models the differences between the actual and reported joint displacement values. This is also known as mastering. The second level, kinematic calibration, is related to the geometry of the robot and performing full geometric calibration, including angle offsets and joint lengths. The third level, non-kinematic calibration, models errors such as stiffness and friction.

Calibration offers higher positioning accuracy for offline programmed robots. Accuracy means that the real position of the robot end effector corresponds better to the actual position calculated from the robot’s mathematical model. In the case of offline programming, pose accuracy is considered an important performance criteria.

The calibration method used in out project is the first; using a predefined & built-in calibration program, which can be performed through different procedures in the KUKA platform, varying for tool and base calibration. For base calibration, these procedures are 3-point method, indirect method and Numeric input, and for tool calibration the procedures are XYZ 4-point method and XYZ reference method, both for TCP, ABC 2-point method and Numeric input. For the purpose of our project, the applied calibration procedures for both tool and base calibration were XYZ 4-point method and 3-point method respectively.

### C:\Users\hmtah\AppData\Local\Microsoft\Windows\INetCache\Content.Word\all.jpg3.2.1 Tool calibration using XYZ 4-point procedure

The TCP of the tool to be calibrated is moved to a reference point from four different directions. The reference point can be freely selected. The robot controller calculates the TCP from the different flange positions. These four directions must be sufficiently different from one another (similar to the positions shown in the provided pictures).

#### Precondition

* A previously calibrated tool is mounted on the mounting flange.
* Operating mode T1

Figure 4 Different orientations for the TCP calibration process

#### Preparation

Calculate the TCP data of the calibrated tool:

1. In the main menu, select Start-up > Calibrate > Tool > XYZ Reference.
2. Enter the number of the calibrated tool.
3. The tool data are displayed. Note the X, Y and Z values.
4. Close the window.

#### Procedure

1. In the main menu, select **Start-up > Calibrate > Tool > XYZ Reference.**
2. Assign a number and a name for the new tool. Confirm with **Next**.
3. Enter the TCP data of the calibrated tool. Confirm with **Next**.
4. Move the TCP to a reference point. Press **Calibrate**. Answer the request for confirmation with **Yes**.
5. Move the tool away and remove it. Mount the new tool.
6. Move the TCP of the new tool to the reference point. Press **Calibrate**. Answer the request for confirmation with **Yes**.
7. Enter the payload data. (This step can be skipped if the payload data are entered separately instead.)

*(>>> 5.12.3 "Entering payload data" Page 138)*

1. Confirm with **Next**.
2. If required, coordinates and orientation of the calibrated points can be displayed in increments and degrees (relative to the FLANGE coordinate system).
3. For this, press **Meas. points**. Then return to the previous view by pressing **Back**.
4. Either: press **Save** and then close the window via the Close icon.

Or: press **ABC 2-point or ABC World**. The previous data are automatically saved and a window is opened in which the orientation of the TOOL coordinate system can be defined.

### 3.2.2 Base calibration using 3-point method

During base calibration, the user assigns a Cartesian coordinate system (BASE coordinate system) to a work surface or the workpiece. The BASE coordinate system has its origin at a user-defined point. In 3-point calibration, the robot moves to the origin and 2 further points of the new base. These 3 points define the new base.

#### Advantages of base calibration:

1. The TCP can be jogged along the edges of the work surface or workpiece.
2. Points can be taught relative to the base. If it is necessary to offset the base, e.g. because the work surface has been offset, the points move with it and do not need to be retaught.

#### Precondition

* A previously calibrated tool is mounted on the mounting flange.
* Operating mode T1

#### Procedure

1. In the main menu, select **Start-up** > **Calibrate** > **Base** > **ABC 3-point**.
2. Assign a number and a name for the base. Confirm with **Next**.
3. Enter the number of the mounted tool. Confirm with **Next**.
4. Move the TCP to the origin of the new base. Press **Calibrate**. Answer the request for confirmation with **Yes**.
5. Move the TCP to a point on the positive X-axis of the new base. Press **Calibrate**. Answer the request for confirmation with **Yes**.
6. Move the TCP to a point in the XY plane with a positive Y value. Press **Calibrate**. Answer the request for confirmation with **Yes**.
7. If required, coordinates and orientation of the calibrated points can be displayed in increments and degrees (relative to the FLANGE coordinate system). For this, press **Meas. points**. Then return to the previous view by pressing **Back**.
8. Press **Save**.

For more information about tool and base calibration, please refer to section **“5.11 Calibration”** in the provided manual **“07-KSS\_82\_Software programming\_en”**.

References

1. Handbook of Industrial Robotics, Volume 1, edited by Shimon Y. Nof.
2. KUKA manual “01-Mastering and unmastering”
3. KUKA manual “07-KSS\_82\_Software programming\_en”