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Degree Program in Mechanical Engineering

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GENMARK ROBOT AUTOMATION

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Title

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Abstract

Integrated circuits are produced from wafers of semiconductor material. The industry requires precise, clean fabrication process. In any nanoscience industry, most of the fabrication process is performed in a cleanroom environment.

Handling of the substrates and material is critical and demanding high speed, precise and repeatable robots. Positioning of the substrates without damaging needs precision and accurate teaching of the robot. Various types of wafer handling devices are known for transporting the wafers to and from the cassette and among processing stations. Genmark robots are multi-axis, high precision and high-speed robots, featuring a gimbal positioning platform control. These robots may operate both in cylindrical and cartesian coordinates, on a plane and in space. In this thesis, the detail of the teaching of the Genmark robot has been discussed.

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Genmark Robot Automation

Toimeksiantaja
Karelia-Ammattikorkeakoulu

Tiivistelmä

Integroitujen piirien valmistuksessa käytetään puolijohdemateriaalista valmistettuja kiekkoja. Tämänkaltainen teollisuus vaatii tarkan ja puhtaan valmistusprosessin.

Millä tahansa nanotieteiden alalla suurin osa valmistusprosessista suoritetaan puhdastiloissa. Alustojen ja materiaalien käsittely on kriittistä ja vaatii nopeaa, tarkkaan liikkeensä toistavaa robottia. Kiekkojen sijoittaminen niitä vahingoittamatta vaatii robotin erittäin tarkkaa opetusta.

Erilaisia käsittelylaitteita joilla kiekko voidaan kuljettaa kasetista käsittelyasemaan ja käsittelyasemien välillä, on useita. Näistä käsittelylaitteista Genmark-robotit ovat moniakselisia, tarkkoja ja erittäin nopeita. Nämä robotit on varustettu nivelen asemonnin ohjauksella, ja voivat toimia sekä lieriömäisissä, että suorakulmaisissa koordinaateissa, tasossa ja avaruudessa.

Tässä opinnäytetyössä on käsitelty Genmark-robotin opetuksen yksityiskohtia.

Kieli
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Sivuja 40
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Asiasanat

GenMark, Gencobot, GenMark Comments, GenMark training, wafer handling, End effectors

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1 INTRODUCTION

Robots are machines designed to perform a task by doing a complex series of functions automatically. They are used in variety of applications, i.e., manufacturing, healthcare, and even space for automation of most tedious, dull, and unsafe tasks. Industrial robots are used for welding, material handling, painting, packaging and many other tasks. Robots can be programmed to work 24 hours per day. Robots can be used for improving the production throughput and quality which are two winning parameters in the industry [1].

Most of industrial robots fall into the manipulator category. Robot manipulator is an open or closed kinematic chain of rigid links interconnected by movable joints. Some robots are repeating a task over and over but there are robots that are equipped with sensors, machine vision and programmed to identify the processor task that needs to be performed. While selecting a robot for a process, several parameters such as speed, degree of freedom, repeatability, accuracy, performance, and end effectors requires the special attention [2].

In this thesis, the main focus is on wafer handling and robot teaching methods for different stations. Many brands such as Kawasaki, Fanuc, Yaskawa, Genmark and ABB are supplying robots for handling material. This thesis gives a special outlook and deferent point of view on genmark robot handling, its building blocks and interaction in large area nanofabrication process. Genmark robot's automation system is commonly used in silicon and semiconductor nanofabrication industry. They are primarily designed for integration and handling of the glass and silicon wafers. They perform pick and place operations in complex environments such as cleanrooms.

Robot automation increases the throughput and precision and it decreases the human originated defects by decreasing manual interference in the fabrication process.

Therefore, precise robot teaching is a necessary task. Accurate teaching of the robot can lead to high quality handling of the products with increased speed, decreased yield loss and improved throughput. The motivation of this thesis work is providing the detail of GenMark robot training for a precise and flawless operation in the process.

2 CLEANROOM ENVIRONMENT

Semiconductor applications demand high-precision automation and reliable, predictable performance for wafer transport within clean and controlled environments called cleanroom (figure 1).

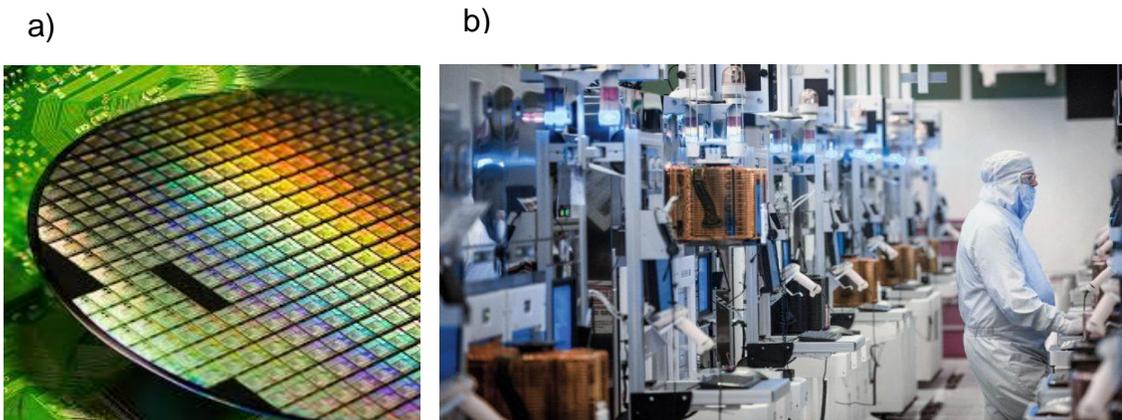


Figure 1: a) A process silicon wafer by nanofabrication, b) working environment in silicon industry.
(Source: angstromtechnology.com/difference-controlled-environment-cleanroom 2019).

Cleanroom is a room in which the concentration of airborne particles, aerosols, and chemical vapors is controlled, and it is constructed and used in a manner to minimize the introduction, generation, and retention of particles inside. In the cleanroom other relevant parameters, i.e., temperature, humidity, and pressure and static energy are controlled, as necessary.

A cleanroom is an environment that is following the standard rules to have a controlled level of contamination which is defined by the number of particles per cubic meter and a specified particle size. The number of particles in the air in a typical environment is about 35 million/m² with the particles that are larger than 0.5 µm in size. In the cleanroom the particles that are in the size of 0.3 µm and larger are filtered by high efficiency particulate air (HEPA) filters [3]. Also, for the cleanrooms that are used for nanofabrication, certain temperature and humidity is needed. Therefore, usually in the cleanrooms there are tools to monitor particle count, environment temperature and humidity precisely.

2.1 Cleanroom classifications

The cleanroom classification is defined based on the particle count and size [table 1]. The main source of contamination in a cleanroom is human, raw materials, working equipment. A static human can produce 100,000 particles and when he is walking the number of generated particles increase 10 times more. Therefore, cleanroom garments and shoes are the most important measures to reduce the contamination. The garments that are used in the cleanroom are following the cleanroom classification. Cleanroom garments include boots, aprons, beard covers, overalls, hairnets, face masks, gowns, glove, sleeve and shoe covers. For instance, a low classified cleanroom, needs only shoe cover, and a coat. Whereas a high-level cleanroom garment is including, overall with hoodie, face mask, boots, gloves and goggles. The fabric of the garments needs to be lint free. The shoes bottom should be selected from smooth material preventing the risk of slipping [4]. In some high-level cleanrooms the personnel must pass through the air shower to remove all the possible particles on the garments. The cleanroom garments can be disposable or permanent. All the garments and shoes need to be stored in proper condition before and after consuming to avoid contamination. Permanent garments and boots are usually washed few times a week to prevent the risk of contamination [4].

Class	maximum particles/m ³						FED STD 209E equivalent
	>=0.1 µm	>=0.2 µm	>=0.3 µm	>=0.5 µm	>=1 µm	>=5 µm	
ISO 1	10	2					
ISO 2	100	24	10	4			
ISO 3	1,000	237	102	35	8		Class 1
ISO 4	10,000	2,370	1,020	352	83		Class 10
ISO 5	100,000	23,700	10,200	3,520	832	29	Class 100
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293	Class 1,000
ISO 7				352,000	83,200	2,930	Class 10,000
ISO 8				3,520,000	832,000	29,300	Class 100,000
ISO 9				35,200,000	8,320,000	293,000	Room Air

Table 1: Cleanroom classification based on the standard regulations [4].

Personnel should change the garments in the changing area and the tools and materials usually are cleaned and transferred through the load locks that are defined separately according to their size. All the personnel working in cleanroom need to take the special training before starting to work. All the walls and working surfaces are cleaned few times of the day to remove possible particles and contaminations. Equipment also collect the particles by time. The sophisticated areas such as the equipment parts and surfaces should be cleaned by professional personnel such as the maintenance.

Pens, papers, printers and wipers in the cleanrooms are also special to reduce the risk of contamination [4].

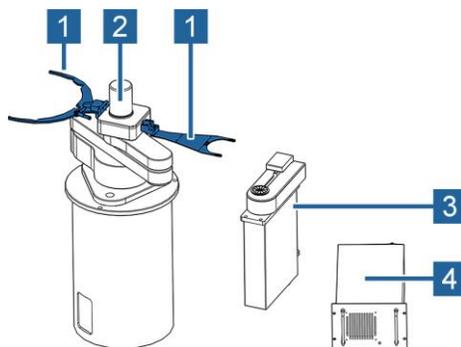
2.2 Handling in cleanroom

Each cleanroom has its no-touch rules for handling the materials. For instance, in semiconductor industry, silicon wafers cannot be handled manually. Usually robots are the best options for handling regarding minimizing the handling defects, particles, precision and increasing the throughput. Cleanroom robots are used predominantly in machine loading, unloading, and parts transfer in the semiconductor industry. The robot arms developed for cleanroom applications are usually designed with ease of use in mind, including through-arm cable and tube technology, standard interfacing with peripheral equipment, and a full automatic wafer handling teaching option for the semiconductor series. Cleanroom robots boast industry leading speed, repeatability, and reliability which are crucial elements in industries focused around increasing demand. [4]

3 ROBOT HANDLING SYSTEM DESCRIPTION

In general, a robot system consists of many different parts. Base parts of an industrial robot are controller, platform, arm, drive, end effector and sensor. Different parts of a Genmark robot with integrated pre-aligner has been shown in figure 3.

Controller is a key part of the robot which controls its performance in terms of speed, accuracy, programability and synchronization in the process. It is the main part for communication between human and robot.



1.End effector, 2. Robot, 3. Optical pre-aligner, 4. Controller

Figure 3: Various parts of a robot (Source: genmarkautomation.com 2019)

direction (figure 4). Some robots have the joints that can also rotate to flip the material if needed. End effector and sensor are positioned on the arm [5-6].

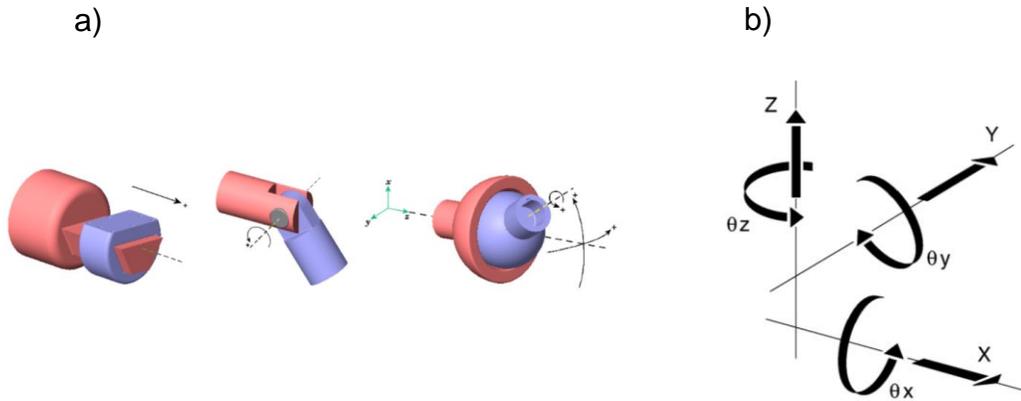


Figure 4: a) Schematic view of arm joints [7], b) motion axes (degree of freedom) [7]

Drive moves the arm to the trained position based on hydraulic, pneumatic or electrical movement. The drive mechanism in the robots in this thesis is electrical motors.

End effectors are installed at the end of robot arm and have the final contact with the material and can increase the degree of freedom. End effectors can be considered as the robot hand and are in the various types such as gripper, vacuum pump, tweezer, spray gun, welding. In this thesis robots end effector are based on the vacuum pump and it is possible to change the end effector without changing the other parts of robot for the process compatibility.

Sensors are sending the information about the surrounding and material status to the controller to enable the appropriate behavior in the process. Depending on the complexity of the robot function, different sensors are needed.[5]

3.1 General safety precautions

Every equipment needs to be used with caution and paying attention to the safety instructions. One must read all safety precautions before turning controller ON. Following the guidelines are important during handling and operating the robot system to prevent any personal injuries. If safety precautions are not followed various dangerous situations which are mentioned in below can occur [6]:

1. End effector may damage an eye or another part of operator's body

When controller is off, it is possible to move end effector manually in front and back direction and rotate 350 degree by hand. (figure 5) However, when controller is on, robot is locked in the latest position. During initialization, any manual interaction can damage operator or robot [8].

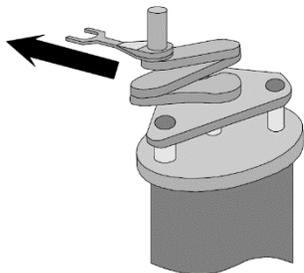


Figure 5: pull toward end effector when controller is off [8].

2. Platform positioning may cause damage under certain circumstances

Robot platform moving up 800 mm from base. When robot moving down, one must avoid being around robot (figure 6).

If Z-axis brake is released without drive power, the robot will move downward in the Z-axis due to the gravity. One must assure that there are no objects in the path of downward direction [8].

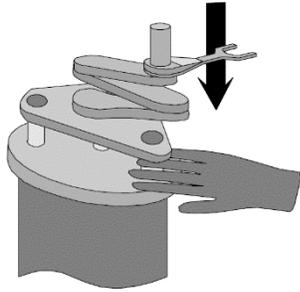


Figure 6: Z- axis movement [8].

3. Placing hand or finger within arms motion area may cause injury

There are three links in the robot which are moving during the handling. Placing the finger between the links can damage the operator's fingers (figure 7). Even in maintenance mode, engineers are not allowed to touch the movement areas when robot is in motion mode [8].

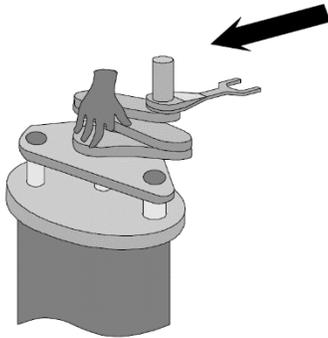


Figure 7: push backward end effector when controller is off [8].

4. Working envelope safety precautions

All robots should be protected by restricted envelope which is managed through interlock function. With interlock option, robot controller is connected to the envelop access door interlock and it automatically turns off by magnetic switch.

Robot will be disabled when the door is open. It will stay disabled still after closing the door and until reset bottom is pressed.

4 INSTALLING THE ROBOT

Before installing any robot, the serial numbers on the robot and the controller box needs to be checked. Robot is connected to the controller using interface cable. Grounding wires on each end of the cable should be attached to the body of the controller and robot, as shown in Figure 8. Then the controller needs to be connected to a power supply circuitry of the complete equipment. The controller can be turn on after checking the mechanical installation stability, electrical and utility connections [10].

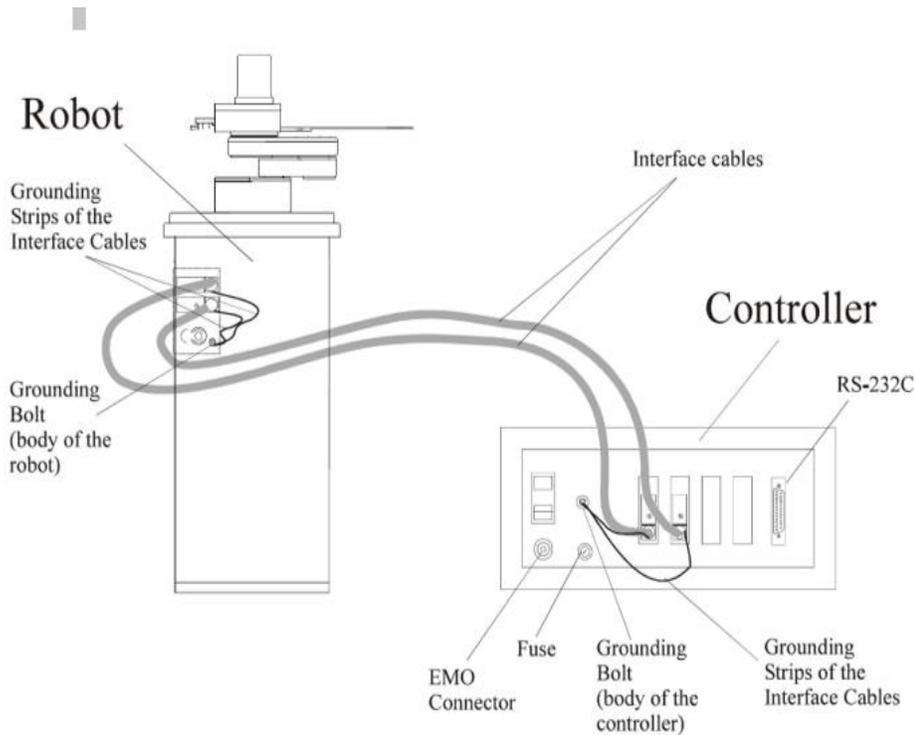


Figure 8: Schematic view if robot and controller connection (Reference: genmarkautomation.com/training 2019)

4.1 Communication with the controller

For communication with the controller, the RS-232C cable between controller and PC serial port (COM1, COM2, COM3, or COM4) is connected [Fig.9 a)]. In case a USB port is used on the PC side, the standard communication cable with a null modem attachment is needed, as shown in figure 9 b).

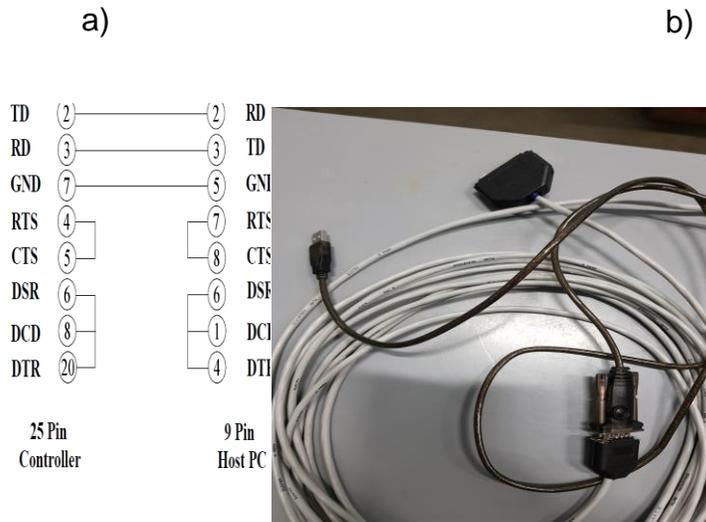


Figure 9: a) Description of controller and host PC connection, and b) RS-232C cable. (Reference: genmarkautomation.com/training 2018)

For communication between PC and robot, first need to install in PC relevant software which is called GBT Tools. The software icon is displayed as shown in the figure 10.

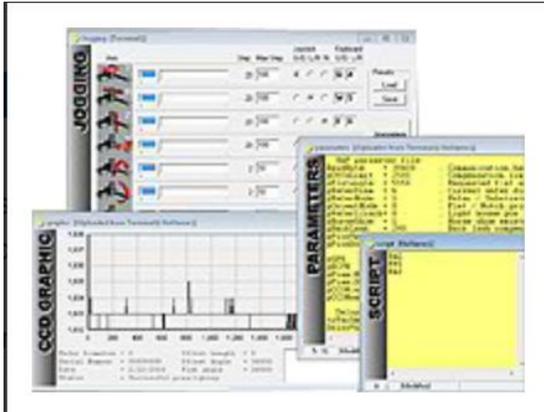


Figure 10: Genmark software GBT(Reference: genmarkautomation.com 2019)

By double right clicking the icon, the gencobot toolbox will open. Following the connect icon and selecting the COM right port number or click properties and choose *Auto Connect*. When robot connected to controller, *Terminal is Online* command will appear on top side of the screen and robot is ready for further process.

5 GENERAL DESCRIPTION OF THE ROBOT

This chapter describes main parts of the mechanical design of the robot: body, physical and logical axes of motion. Also, it includes basic functions and features of the robot.

5.1 Genmark robot design and kinematics

The genmark gimbal positioning robots are high performance robot for wafer transport in a clean room environment. The main design elements of these models as shown in figure 11 are:

- **Body:** The body provides housing for the robot's subassemblies, including mechanical support for the arm, as well as actuators for its motion. The upper flange of the body is firmly attached to the capital equipment.
- **GPR Platform:** The gimbal positioning Platform is supported by three rods in spherical joint Z1, Z2 and Z3. It travels in vertical direction and can be tilted up 2 degrees.
- **Arm:** The platform carries the arm, which is comprised of either two or three links. The links are coupled by rotary joints. The arm can also swing around the central axis of platform.
- **End-effector:** The end-effector is connected to the arm by the rotary joint and rotates independently on the links of the arm. [8]

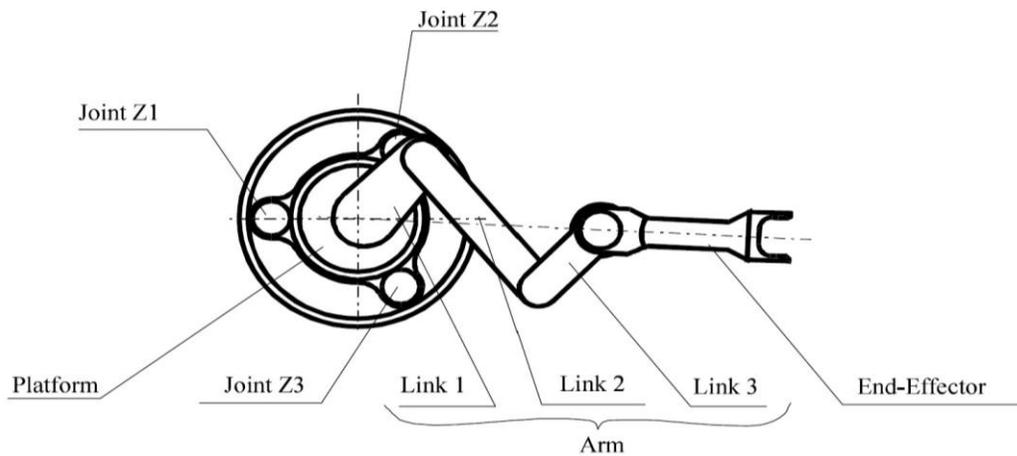


Figure 11: Overview of gencobot with GP[10]

5.2 Motion Axis

Logical axes of the robot which are with access of the end users are different than the motion of the motors. The logical axes in Gencobot are listed in table 2.

Notation in commands	Name	Type	Description
T	Theta	rotary	Rotation of the arm around the central axis
R	R	linear	Extension and retraction of the arm in the plane of the platform R-axis always passes through the central axis.
Z	Z	linear	Ascent and descent of the platform in the vertical direction
Z1	Z1	linear	Ascent and descent of Joint Z1 of the platform. The motion is measured with reference to the current position of Z3.
Z2	Z2	linear	Ascent and descent of Joint Z2 of the platform. The motion is measured with reference to the current position of Z3.
Z3	Z3	linear	Ascent and descent of Joint Z3 of the platform. The motion is measured with reference to the body of the robot.
Y	Yaw	rotary	Rotation of the end-effector around its axis. The motion is measured with reference to the third link of the arm.
Y2	Yaw	rotary	Rotation of the second end-effector around its axis (if present). The motion is measured with reference to the third link of the arm.
G	Gamma	rotary	Rotation of the end-effector around its axis. The motion is measured with reference to the platform.

Table 2. Motion Axes in Gencobot [10].

Axes R and T stand for the radius and the polar angle (Theta) respectively. The R and T coordinates are measured with respect to the tip of third link (Figure 12).

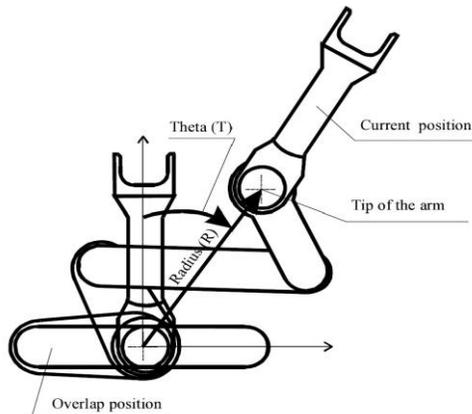


Figure 12: Polar coordinates R and T [10].

5.3 Home position of the robot arm

Home position of the robot is a coordinated position that all links of the arm are overlapped, and the end-effector is perpendicular to links (Fig. 13). For the robot study in this thesis, in the home position, the tip of first link overlaps joint Z1 of the platform. Joint Z1 is the first joint on the left (clockwise) of the interface connector plane. Normally the default home position should never be changed.

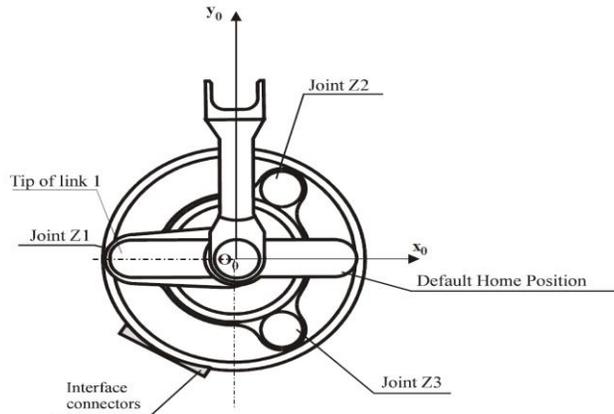


Figure 13: Robot default home (Reference: genmarkautomation.com/training 2018)

6 MOTION COMMANDS

Motion commands of the gencobots may be divided into four large groups:

Basic motion commands: These commands are used for motion along the logical motion axes (T, R, Y, Z) and in cartesian space coordinates (X, Y, Tilt X, Tilt Y) [8].

Calibration commands: This group is comprised of commands which execute specific motion sequences for home switch detection and calibration for example HOM command.

Stations processing commands: This group consists of relatively large motion sequences designed particularly for loading wafer and other similar object in wafer cassette or other process stations. These commands examples are PUT and GET.

Special operation commands: These include special motion sequences specific for scanning and prealigning operations. Example of such commands is SCN [9].

6.1 Move along a given motion axis or axes

Move along the axis, moves the certain axis from the current position to a new position. For the execution of the MVA command the axis and the value of movement is applied. The logical axis can be T, R, Y, Z. The movement in the robots of this study are based on the step motor movement. Therefore, the movement value is in the steps which leads in the movement in the millimeter. The step size should be known prior to the command [9].

Movement in result of the move along R axis and move along T axis is illustrated in figure 14 a) and b).

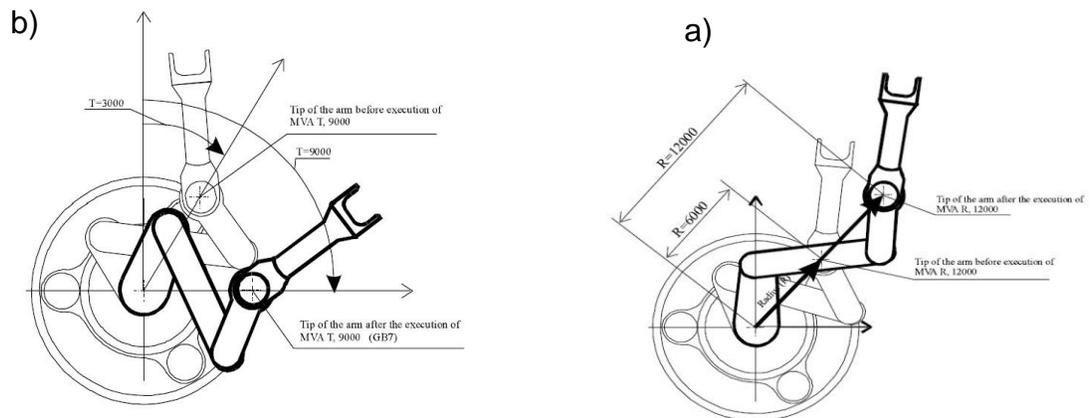


Figure 14: a) Movement of the end effector along R axis with 12000 steps, b) movement along the T axis with 9000 steps.

[Reference: genmarkautomation.com/training 2018]

6.2 Move relative action

The move relative moves specified logical motion axis from its current position to a new position by the specified value parameter and MVA command with the axis and value can be used for this movement.

An example of action of the MVR commands is illustrated in figure 15 a) and b).

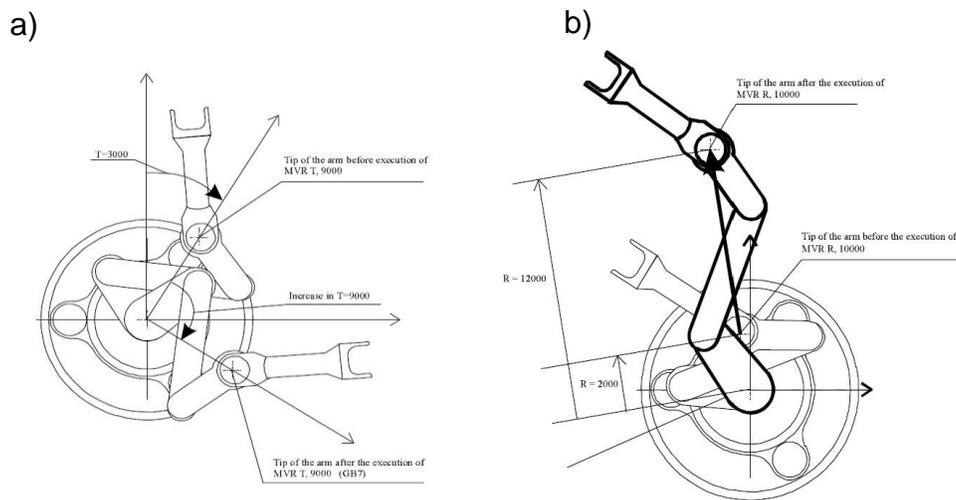


Figure 15: a) Relative movement of the end effector of R axis with 10000 steps, b) relative Movement the T axis with 9000 steps.

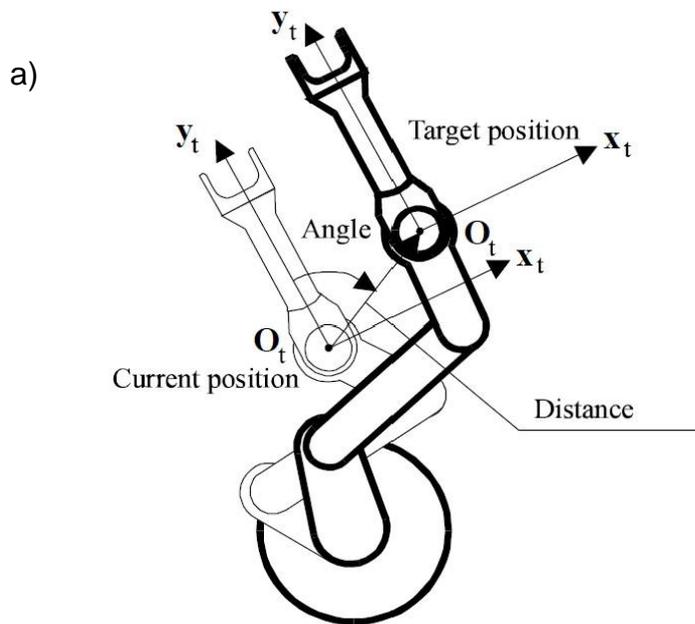
(Reference: genmarkautomation.com/training/manual 2018)

6.3 Move to point action

In this movement action the aim is to move the end effector from the current point to the target point with changing the rotary axis, T axis, Y and Z axis values. With this action T, R, Y, and Z-axes are moved synchronously from their current position to the target position which is specified relative to the zero (home) position of the robot. MVP command is the combination of the move along the axis command separately for each axis. In other words, this command performs all the separate command function at one command [9].

6.4 Movement over a straight line

The action moves the end effector with a distance and an angle. In this movement, the origin of the tool coordinate system, moves over a straight line section. With length equal to distance, beginning from the current position of origin in the direction specified by orientation of the end-effector plus and angular offset equal to angle. Figure 16 a) shows the result of this movement (MVS) by applying the distance and the angle in this command it is possible to write the command with the displacement value without the angle if the target movement is only transversal (Fig.16 b).



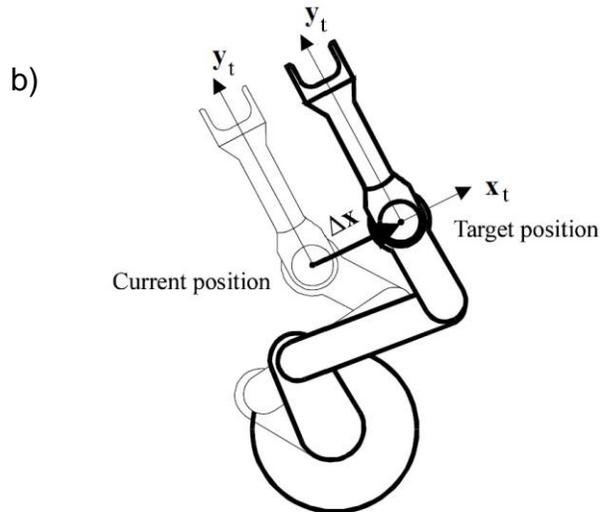


Figure 16: a) Movement of the end effector of with a distance and defined angle, b) move straight with AX offset and 9000 steps [9].

6.5 Tilting of the end-effector

As robot behavior explained in previous chapters, the position of the end effector adjacent of the wafer is critical. In most cases there is not enough space to perform the handling without tilting the end effector. Tilting of the end effector provides a convenient way of the alignment in the stations such as cassette. The command consists of the angle and the angular offset and keeps the position of the origin of the tool coordinate system unchanged. This is accomplished through the synchronous motion of all robot axes [9].

6.6 Tilt around the default axis

The tilt command with the angle value rotates the end-effector around its longitudinal axis (y) (Figure 17) The second parameter of the tilt command (TLT) is optional.

It controls the angular offset of the tilt axis with respect to the Y axis. The tilting axis direction (clockwise/ counterclockwise) needs to be known beforehand [9].

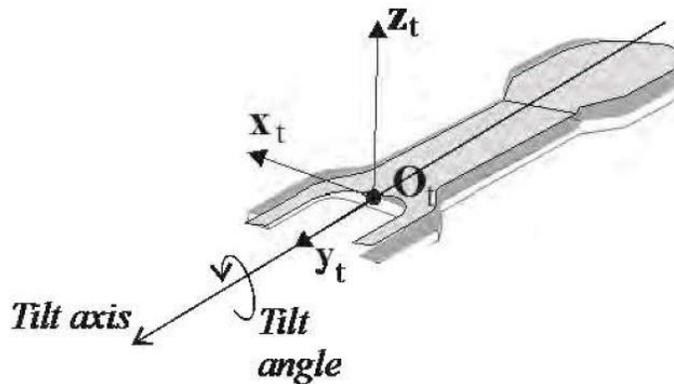


Figure 17: Tilting around the tilt axis (Source: genmarkautomation.com/manual 2018).

Example:

Syntax: TLY Angle

In the robot in this study, tilting can be done only 8 degrees around the Y axis. To calculate the steps, the needed steps for one degree should be calculated. For the robot in this study:

5000 steps is equal to 90 degree \rightarrow 55.556 steps is equal to 1 degree.

Therefore, arm can be tilted maximum \pm 400 steps

Command: TLY -55.556

Description: this command starts a procedure that tilt the end effector around an axis lying on the end effector in counterclockwise direction.

6.7 Tilt around X access

The command tilt tip of end effector up or down, it depends to negative or positive degree (figure 18) [10]. for example if command value is TLX -100, tip of end effector will tilt down.

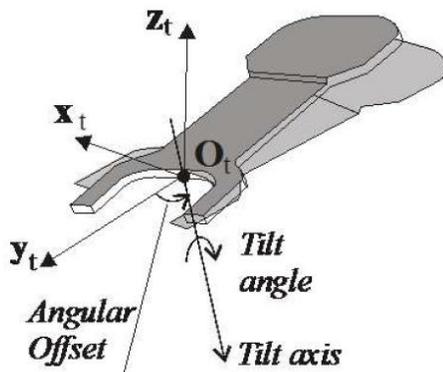


Figure 18: Tilting around the X axis.

[Reference: genmarkautomation.com/training 2018]

Example:

Syntax: TLX Angle

Description: this command starts a procedure that tilt the end effector around the longitudinal of the end effector.

Command: TLX 100

Tip of end effector moving up 1.8 degree

5000 steps is equal to 90 degree

therefore 100 steps $X = (100 \times 90) / 5000 = 1.8^\circ$

Maximum value for tilting X same as y is 400 step or 7.2°

7 MATERIAL DETECTION IN GENMARK

There are different methods for handling the wafers by robots. Robots handle the wafer by mechanical gripping or vacuum. Genmark robot uses vacuum to hold wafer on the end effector. Vacuum line from facility line or a vacuum pump should be connected to robot by pneumatic pipe. The minimum vacuum need for holding wafers by end effector is -500 mbar. There are two types of sensors used for wafer searching during the execution of GET procedure named as pusher sensors and vacuum sensors.

The pusher sensor is an electro-mechanical sensor which is activated when a present wafer pushed. The vacuum sensor is checked for vacuum presence when the vacuum valve is closed. When a wafer is present on the end effector, vacuum sensor detects the wafer. If level of vacuum is less than 500 mbar, there is a risk that wafer is not in the right position and for that reason the robot does not move and alarm sounds rising for notification of the failure.

7.1 Vacuum sensor calibration

The vacuum sensor is a digital gauge located on the top flange or the arm link of the robot. Proper calibration of all sensors needs to be observed during installation.

By pressing the *SET* key on the pressure sensor [11], it returns to sensing unit of pressure like pa, psi or bar. By selecting bar unit, the range would be between (0-1000) mbar which appears in display. Main vacuum line needs to be connected to input connector of manometer. To check the level of vacuum, a wafer will be placed on the end effector and vacuum pipe line will be connected to the output connector of manometer and the value can be compared with vacuum sensor. If the read value is not same as the value shown on manometer,

the correct value can be achieved by changing the potentiometer with a screwdriver.

The initial conditions can be set and stored in the EEPROM. It will not be erased if the power is switched off [10].

7.2 Checking Vacuum by GenMark commands

In some cases, there is a need to check if a wafer is loaded or present on the end effector. There is a dedicated command in the genmark robot command Set for this purpose that solves this task. The WPC (Wafer Presence Check) command detects the wafer presence by measuring the vacuum seal of the end effector.

One can use CVP (Check Vacuum Presence) to check the vacuum presence. The command inspects the vacuum sensor and if it is not activated, all movements are suspended. A special set of motion parameters (speed and acceleration) are used while holding the motion. A picture of a digital pressure switch with a 2-color display shown in figure 16.



Figure 16: A high precision vacuum sensor.

(Reference: SMC.com/sensors 2019)

When vacuum level is above 500 mbar, color of 7 segment display is green, for vacuum level less than 500 mbar, the color is red and error appears in screen [11].

8 SUMMARY OF GENMARK AUTOMATION COMMANDS

HOM	Start home procedure
SVN	Server ON
SVF	Server OFF
STP	Stop motion
RES	Reset Controller
HAS	Set home speed and acceleration
RSA	Restore working speed and acceleration
MVR	Move to relative position

Example MVR R,1000 Radial movement of 1000 steps=1 inch

MVS Move relative on straight line

Example MVS 1000 Move 1000 steps =1 inch in direction EE

NTC New teach coordinate

ENT End of teaching

SAV Save to station file

MTS Move to station retract position

MTC Move the station coordinate

MTA Move to station approach position

PUT Start put wafer procedure

GET Start get wafer procedure

SWD Set wafer Diameter

RWD Read wafer diameter

ALS Align wafer simultaneously

TLX Tilt around X

CLZ Clear Z1, Z2 values [9]

9 TEACHING STATION AND POSITION FOR ROBOT

Before turning the power of the robot controller ON the following should be checked [10].

- a) Mechanical mounting and stability
- b) Electrical connections
- c) Utility connection
- d) Communication connections
- e) Communication utilities installed
- f) Peripheral equipment and system
- g) Limiting devices for restricting the maximum envelope
- h) All personnel exit the restricted envelope prior to applying drive power.

After verifying all necessary items, the controller may be turned ON.

9.1 Station Name

The name of module location is represented by single letter from the english alphabet like coat module location is A,a or bake module location is B,b. It is case sensitive. The station name and parameters are unique for each station. The usage of each station demands a teaching process.

If robot has two end effectors, usually end effector **0** represented by big English alphabet like A, B, C, etc. and End effector **1** represented by small English alphabet like a, b, c, etc.

9.2 Teaching station to robot

For teaching each station and the robot behavior different commands are needed.

Example:

Target is that robot motion from home position to get first wafer from bottom slot one and back to home position (figure 20). The commands that are needed to be used before any other actions are:

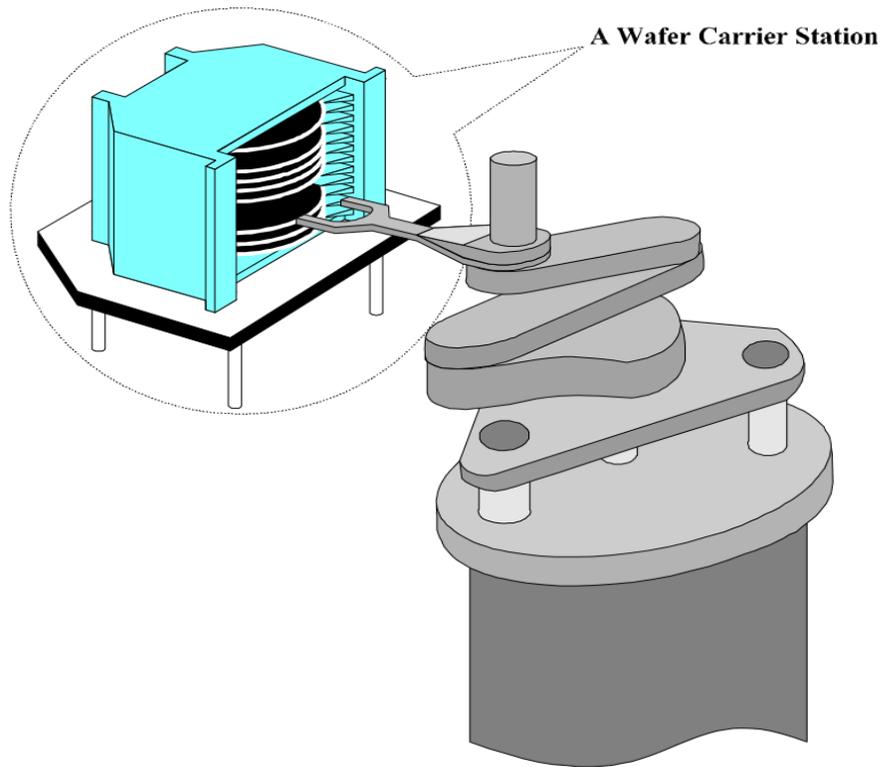


Figure 20. End effector position when approaching to wafer cassette [10].

1. SVN: with this command controller gets ON. check the status of the controller by checking the LED light. green light indicated that the controller is on and red light shows the controller is off.
2. HOM: robot starts initializing and moving to home position.
3. HSA: reduces robot speed from normal speed in which robot moves 10 mm/s. With using this command, robot will start to move 5 mm/s. Usually this command is very useful when there is a need to teach the stations. Lower speed prevents the risk of crashing of the end effectors to other parts of the tool.

After checking homing and reducing the robot speed, the commands that are needed to teach the position will be used.

4. MTA A: move to approach. With this command end effector (EEF) approaches the target position which is station A in this example. Assume that end effector's current position is 200 mm below and 300 mm far from wafer slot 1 inside the cassette.
5. MVR Z, 80000:

$200\text{mm} \times 400 \text{ step} = 80,000 \text{ step}$ (1mm= 400 stapes)

By using this command, EEF will move 80,000 steps from current position.

It should be noted that before pressing enter for all movement commands, it is recommended to be prepared to stop robot immediately by pressing F9. After applying the command, tip of EEF and first wafer in the cassette must be same level.

6. MVR R, 110,000: EEF will move in R direction (straight) to approach the first wafer in the cassette but not exactly touching the wafer.

Let's assume that diameter of the wafer is 200 mm and its thickness is 0.8 mm. If after applying the commands, the EEF is in the same level as surface of the wafer, it should move down in z axis $0.8+0.2$ mm to pick up position.

7. MVR Z, -400: EEF will move 1 mm down to pick up position.

8. MVR R, 1000: surface of EEF moves forward to be 200 μm under the wafer.
9. MVR R, 80000: EEF is under wafer and ready to pick up
10. OUT 1,2: EEF 0 vacuum on to keep wafer in place during the EEF movement.
OUT command means vacuum and first value after out indicates, EEF number and second value turning vacuum valve ON or OFF.
11. MVR Z, 800: picks up the wafer by moving up and holding wafer on EEF.
12. NTC: new teaching station.
13. SAV: saves the station.
14. END: end of teaching position.
15. MTS: moving back to home position.

Now in controller station A is saved.

For checking new trained status, the robot can be adjusted to normal speed by using the (RSA) Command. By applying the commands that are mentioned below, the trained position can be checked.

GET A,1: with this command robot will pick up the wafer from station A slot 1.

PUT A,1: robot will put the wafer back to station A slot 1.

Usually the cassette has several slots which makes the teaching process for each slot difficult and time consuming. Genmark software has very useful option for this situation. PITCH option as shown in figure 21, facilitates the teaching process for all 25 slots in the cassette.

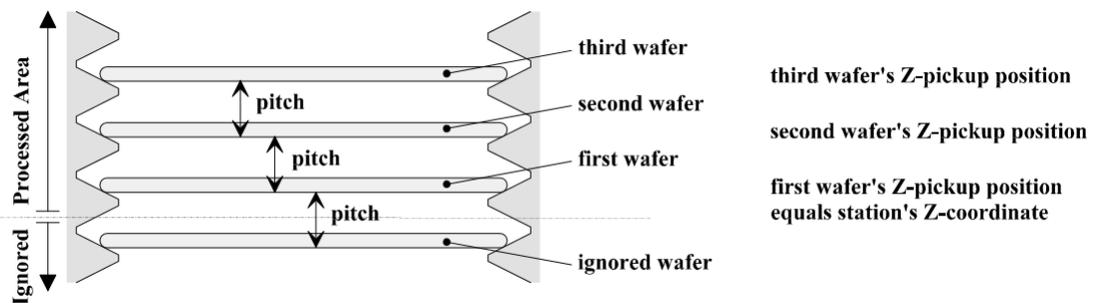


Figure 21. A schematic view of the pitch definition in the cassette [10].

By using the pitch, the pickup position for wafer in slot i , is calculated according to the following formula:

$$Z_{ppi} = \{Z_{pp1} + (i-1) * \text{pitch}\} / 25$$

in this formula Z_{ppi} is pickup position and pitch value divided by 25 wafers inside the cassette.

9.3 stroke and coordinate

Stroke represents the distance between the Z-coordinate at which the arm enters and exits as it has been shown below figure 22.

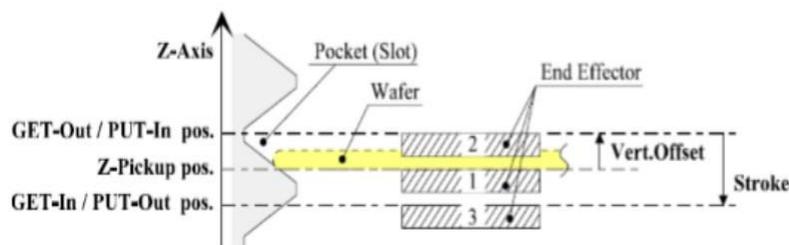


Figure 22. Explanation of get and put algorithm [10].

As it is shown in figure 19, end effector enters to cassette in position 3, moves up to position 1 to pick up wafer and then goes up to position 2 and finally exits from the cassette. This movement is called stroke.

In preventing maintenance, stroke is the parameter that needs to be checked in the critical stations such as cassette or aligner.

Stroke commands are as below:

RST: read stroke

RST A,1: stroke of the specified station. This command will read the stroke for the first wafer inside the cassette in A station.

SST: set stroke

Total distance from between get in, pick up material, move up and get back is called stroke. usually material is same coordinate position as end effector.

For example, SST A 600 means that from coordinate position 300 steps down (pick up position) and 300 steps up (get out and back to home position).

10 ROBOT END EFFECTORS

End effectors are the parts of robots that are in contact with the wafers. End effectors can employ different methods for product handling. These methods include, but are not limited to, clamp style, fork style, vacuum style and other custom designs.

Two types of end effector as shown in figure 23 and 24 designed in PTC software for handling process.

10.1 Edge handling end effector

In this study, handling of the wafers is performed by end effectors with vacuum suction pads. Since the handling are performed for dual side wafers, an edge handling end effector has been designed and implemented in the process. In edge handling end effector, the wafer is hold from the edges to avoid touching of the active areas. In the designed end effector, the edges of the end effector also tapered to avoid the damage on the wafer due to its bending by gravity during the handling.

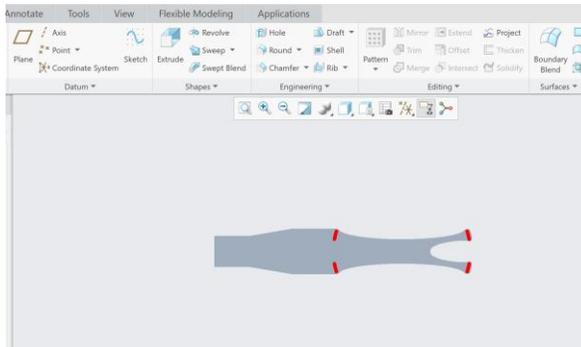


Figure 23. Edge Handling end effector.

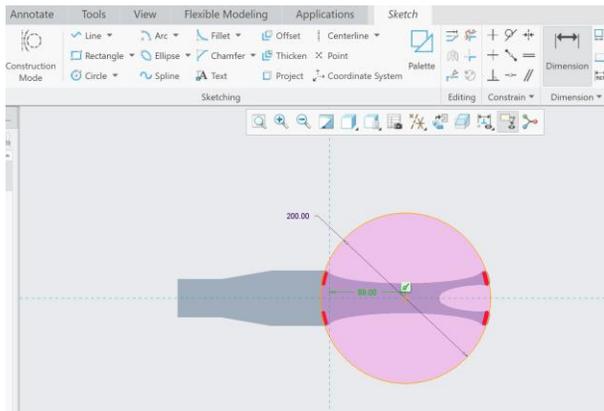


Figure 24: Edge handling end effector holding the wafer.

Red silicon suction pads on the end effector are used for supporting vacuum in wafer handling. Vacuum pads are in 4 mm distance from the edge of the wafer which are called exclusive zone. Wafer aligning is critical in this design. Misalignment of the wafers on the end effector leads to vacuum leak and dropping the wafers from end effector and process will stop.

10.2 Center handling end effector

This kind of end effector is handling wafer from center. Since it is in contact with the back side of the wafer, it is mostly used for the single side process (figure 25). However, these kind of end effectors are more robust compared to edge handling end effectors. Center handling end effectors are less sensitive to aligning wafers during the handling (figure 26).

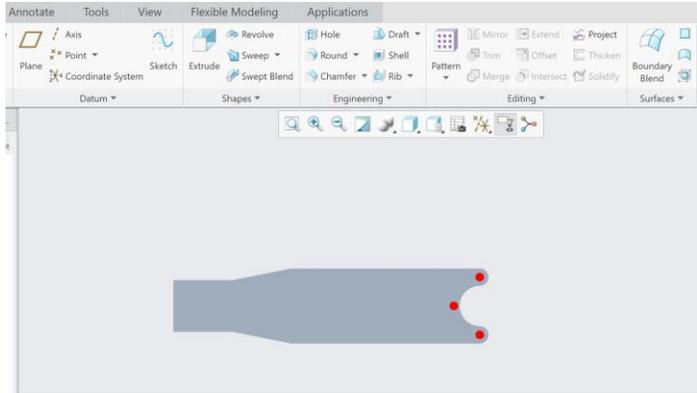


Figure 25. Center handling end effector.

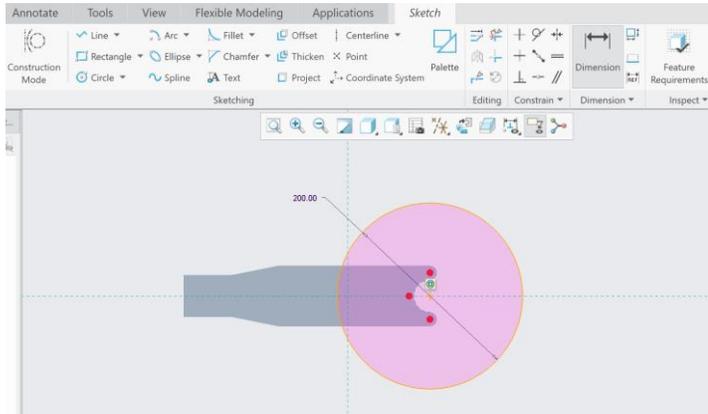


Figure 26. Center handling end effector holding the wafer.

Also depending on the process, wafers are prone to physical changes during the handling. For instance, in the used process in this study, wafers are heated up to 120 °C in hot plates which cause hanging of the wafers from center. Therefore, using center handling end effector is preferred to avoid the scratch or breaking of the wafers during pickup process from hotplates.

11 END EFFECTOR REPLACEMENT

End effectors can be changed due to damage in the process or replacement with new design. Changing the end effector is very challenging process due to requirements for mechanical replacement as well as retraining the end effector

for all the process stations. Usually, replacement of the end effector requires the 24 hours of tool down time. Here, the replacement steps are explained in detail:

1. Drive end effector to prealigner in coordinate position.
 - run genmark software and click train mood and write SVN. With this command controller turns on.
 - MTC P: with this command end effector will move to coordinate position to prealigner.

2. Disassembling:

End effector mounted to the link by four hex head cap screw and four hide head screw for leveling and adjusting (figure 27).

For disassembling, first loose a little bit four adjustable screws then open completely mounting screws. during disassembling end effector must be minimum force to link and robot.



Figure 27. End effector mounting to the link.

3. Assembling new end effector:

- loose all adjustable screws and close smoothly mounting screws (do not over tighten).
- two back side adjustable screws affect to level the tip of end effector up/down.

- two front adjustable screws affect to tilt of end effector in clock or counterclockwise direction (figure 24).
- MTC P drives robot to coordinate position of pre-aligner and by straight edge tool check the level. Surface of end effector aligner must touch straight edge tool as shown in (figure 28).

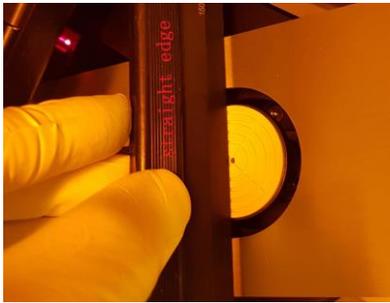
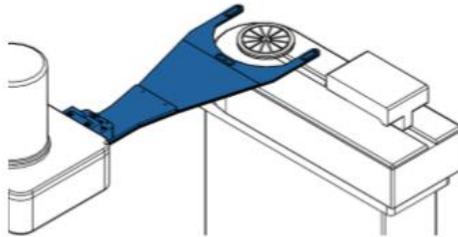


Figure 28. End effector and aligner chuck in coordinate position.

- when leveling is done, mounting screws should be tightened.
- pick up wafer from loading cassette and drive to prealigner several times to check or investigate the leveling of the end effector.
- now check all stations and reteach station if it is necessary.

During the replacement, there are several parameters should be taken to the consideration:

- ✓ Avoid placing cassettes near the boundaries of workspace.
- ✓ When the tip of arm needs to pass near the singularity area, it is better to make it directly pass all tree links overlap position. (figure 20)

- ✓ Check for the radial placement of cassettes in radial steps, after using TLT. If the mechanical design includes E-axis, use MVA E instead of TLT command to compensate the gimbal misalignment of the cassettes.

12 PREVENTIVE MAINTENANCE FOR ROBOT

Robot handling is one of the critical parts of the process which impacts the quality of the product. Therefore, maintenance scheduling is important to maintain the quality of handling during the process. It also increases the robot lifetime.

Preventive maintenance steps:

1. Clean all end effector surfaces with a sealed border or lint free wipe and isopropanol. Since the end effector is a moving part in the process, it can increase the risk of particle contamination on the wafers. However, end effectors are sensitive to applied pressure and their position might change by pressure. Therefore, cleaning process should be performed smoothly.

2. Inspect the vacuum sealing lips of each end effector.

Wafer is held by suction pads on the end effectors. The quality of the pads guarantees the vacuum support on the wafer. Depending on the suction pads material, there is a need to change the vacuum pads in certain intervals.

3. Clean and Lubricate robot

Robot has three bonds to hold and move platform in Z direction (up/down) through the vertical bearings. Bearings need to be cleaned from old grease and renewed in monthly intervals.

4. Check vacuum level.

Vacuum line, filter and valve need to be inspected for preventing the blockage of the lines by particles every three months. Vacuum level will be checked by manometer and the vacuum filter will be replaced.

13 CONCLUSION

In this thesis, Genmark robot installation and handling process for dual wafer handling are reviewed. Robot movement mechanism and different mechanical parts of the robot is explained. Also, installation of robot has been reviewed. Ramping of the robot was briefly discussed. Robot needs to be trained for wafer handling and it depends on the process. The teaching commands for the wafer handling by using vacuum handling end effectors were explained in detail.

I explained that the robot handling is very sensitive to other involved modules and its scheduling depends on those modules performance. Robot handling is also playing an important role in the cycle time of the process. If the scheduling and teaching is not defined in an appropriate manner, it becomes as a bottleneck in cycle time. Since robots are providing the handling without manual interface, the teaching is critical in the quality. For instance, if teaching is not accurate, the handling causes defects such as scratches and breaking the wafer which will decrease the yield dramatically in the production. In the robot teaching, various examples from different commands were provided. The process dependency of the robot teaching such as the wafer thickness, environment, requirements for accurate alignment has been discussed.

REFERENCES

1. M. Edwards, Robots in industry: An overview, Appl. Ergonomics. 1984. Vol.15. P 45-53.
2. O. Khatib , J. Burdick, Motion and force control of robot manipulators. Proceedings in IEEE International Conference on Robotics and Automation.1986.
3. www.integritycleanroom.com [cited on 16.12.2019]. D. Ensor, R. Donovan, B. Locke, Particle size distributions in cleanrooms.J.Environmental Sci. 1987. Vol 30, P. 44-49.
4. Cleanroom classification, <https://www.mecart-cleanrooms.com/learning-center/cleanroom-classifications-iso-8-iso-7-iso-6-iso-5/>. [Cited on 25.8.2019].
5. S. Premkumar, K. Surya Varman, R. Balamurugan, Design and implementation of multi handling pick and place robotic arm. International Journal of Engineering Trends and Technology (IJETT). March 2016. Vol. 33.
6. www.genmarkautomation.com [cited on 16.12.2019]A. Elfasakhany, E. Yanez, K. Baylon, R. Salgado, Design and development of a competitive low-cost robot arm with four degrees of freedom. Modern Mechanical Eng. 2011. Vol.1. P.47-55.
7. V. Hlaváč, Robot kinematics, <http://people.ciirc.cvut.cz/~hlavac/TeachPresEn/55AutonomRobotics/020KinematicsEn.pdf>, [Cited on 10.4.2019].
8. www.genmarkautomation.com 2019.
9. Z. Sotirov, high-performance wafer handling systems for semiconductor automation, Genmark Automation, Inc.
10. EVG Group Company, <https://www.evgroup.com>. [Cited on 4.4.2019].
11. SMC Company, <https://www.SMC.com>. [Cited on 18.9.2019].