SMD placement

By Brian Sloth Bentzen, SMT in FOCUS

PLACEMENT

In the placement process, SMD components are placed into solder paste or adhesive on the PCBs.

PLACEMENT FACTORS

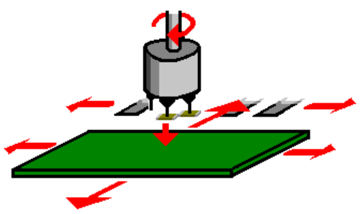
When placing Surface Mount Components onto a PCB there are a lot of factors to consider. In the listing below the most essential factors are mentioned.

Equipment	Method	Materials	Environment	Operators
-Placement machine -Moving axis -Placement heads -Nozzles -PCB support -Vision system -Placement Accuracy & repeatability -Feeders -Progr. Software	-Placement parameters -Vision data -Comp. data -Nozzles -PCB support & clamping -Throughput -Changeover	-Components -PCB -PCB flatness -Solder land flatness -Solder paste -Tackiness -Adhesive -Tackiness	-Production area -Dust & dirt -Air circulation -Air humidity -Temperature	-Training -Knowledge -Awareness -Authority

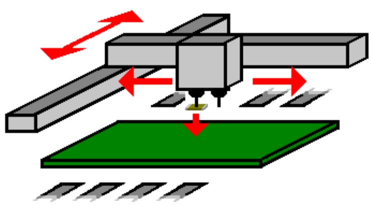
All the factors in the five groups are differently important but all plays a role in the final result and it is important to consider all aspects to reach the quality needed in the products produced.

PLACEMENT EQUIPMENT

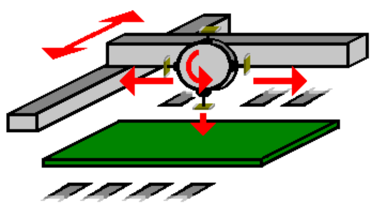
The first SMD placement machines introduced in the early 1980s were of the pick & place type with only one mechanical placement head. They were very slow (1000 – 2000 cph). Soon another type, the turret head machine with vision alignment system, came along. This type of machine was designed for fast placement of small chips and the pick & place machines were redesigned to handle large and fine pitch components. This also changed the production concept from stand-alone machines to complete SMD placement lines. Since the middle of the 1990´s the pick & place machine type has undertaken a huge change. From single headed machines with only mechanical chucks, to multiple head machines with full vision that handles both small and large components and with the highest output per square metre production floor. The pick & place machine type is also the most flexible machine type. It handles a wide range of components from all package types and can be fitted with a lot of options. See schematic drawings of the different types below.



Turret head



Pick & Place



Pick & Place (rotary head)

The major difference between pick & place and turret head machines is the transportation of the components from the feeder to the PCB. Pick & place machines have a pick-up head unit mounted on a X-Y gantry that picks up the component from a feeder placed in a fixed position and moves it to the placement position on the PCB that is also placed in a fixed position.

On a turret head machine the placement heads are rotated, picking up the component in one position and place it in another position. The feeders are then moved to the pick-up position and the PCB is moved in X and Y direction to the placement position.

Most SMD placement machines move the components from the feeders to the placement position on the PCB using vacuum nozzles. Different vacuum nozzles are designed to handle varies component housings. Machines with automatic nozzle change system will change the nozzles during the program run so the different components are handled with the correct nozzle. Some machines has special nozzle with mechanical tweezers for handling of odd-shape components that can not be lifted by vacuum.

The PCB support and fixating system holds the PCB in a locked position during placement and to secure a flat surface for the components to be placed on. On many machines tooling pins fixates the PCB. Tooling holes on the PCB are necessary and must be placed in specific positions.
But most of the new designed SMD placement machines also use edge clamping. Pneumatic pistons pressed against the PCB edge lock the PCB in place. This system is very flexible and no holes in the PCB are necessary. The PCB support is usually done by adjustable and moveable pins or by pins placed in a matrix of holes.

For PCB fiducial recognition and placement data correction two systems are known. The most used is fiducial recognition by camera. Alternatively some machines uses light beam recognition of the fiducial marks. Fiducial marks are small figures in the copper of the PCB. Different shapes can be used: Solid circles, solid squares and diamonds etc. depending on the machines vision system. To secure a good recognition there should be a 1 mm area around the fiducial mark without solder mask. Recognition of PCB fiducial marks (also called global fiducials) is done to compensate for in-correct alignment of the PCB. Usually 2 fiducial marks are used and should be placed diagonal on the PCB. Some machines allow use of 3 fiducial marks with the possibility for a more accurate PCB rotation correction and to check for PCB stretching. For fine pitch (small lead pitch distance) components, component fiducial marks placed close to and diagonal across the component are used to secure accurate placement.

For component recognition and alignment two main vision system groups are available: back-lighted and front-lighted. On back-lighted systems components are lighted from behind and the camera only “sees” a shadow of the component. On front-lighted systems components are lighted from the front so the camera “see” it in all details in dark and light colours. Both system types have their forces and machines with both systems are recommended to secure recognition of all component types.
The operation of the vision systems can also be somewhat different. The term “vision on the fly” is often used for pick & place machine types with the following operation: The components picked up, moves over a camera for recognition and alignment and then moved to the placement position on the PCB. But a few machines use a “real vision on the fly”. Again the components are picked up but are moved directly to the placement position on the PCB. During movement a camera placed on the placement head assembly moves under the components. On turret head machines the component picked up passes by a camera while rotated from pick-up position to placement position.
Some machines use laser or LED systems for alignment of small chips instead of cameras. The components are lighted from one side and a special CCD sensor on the opposite side of the component register the components size and orientation when rotated on the vacuum nozzle.

The placement accuracy & repeatability of a SMD placement machine is a result of a lot of parameters: Accuracy of moving axis, resolution of vision cameras and laser recognition, vision algorithms, PCB fixation, program co-ordinates, component data etc.

SMD placement machines can be fitted and surrounded by a lot of options. To mention some: Barcode verification of component part number, machine & feeder performance monitor, co-planarity check system, feeder trolleys and automatic nozzle change systems.

Feeders

The SMD components are supplied in varies packing types depending of the component housing. Therefore different feeders are needed to feed the components.

Tape feeders are used to feed components packed in paper, embossed or surf tape. Tapes in different width and thickness are used depending on the component size. Tapes width of 8 mm, 12 mm, 16 mm, 24 mm 44 mm, 56 mm and 72 mm are known. The components are hold in the carrier tape pocket by a thin transparent cover tape. Tape specification can be found in EIA-481-1-A. Tape pocket pitch also varies from 2 mm to 72 mm (from 4 mm pocket pitch in steps of 4 mm). Tape feeders from different manufacturer can operate in different ways. They can be mechanical activated, pneumatic activated or electrical operated by motors.

Stick feeders are used to feed components supplied in sticks / tubes. This can be done in different ways. The two main methods are vibrating and ski-slope feeding. The vibrating feeders are usually designed to handle more than one stick. The sticks are positioned side by side with one end open, letting the components move into a special designed top plate guiding them to the pick up positions. Adjustment of a vibrating stick feeder is very delicate and poor adjustment easily results in rejects or failures on the PCB. Due to the different mass of different component housings there are limitations to which components one vibrating stick feeder can handle. E.g. Placing a SO8 and a SOW28 on the same vibrating feeder are bound to cause problems.
The ski-slope feeder usually handles only one component. On some, the stick is placed into the feeder and on others the components are poured into the ski-slope lane. The components are then moved to the pick-up position by gravity or compressed air.
Due to the above mentioned problems and the desired maximum throughput it is recommended to avoid components in sticks for mass production.

Bulk feeders are used to feed chip components delivered in bulk containers. The bulk containers hold up to 50.000 components. The container is placed on the bulk feeder and the components fall into a small chamber where compressed air whirl around the components and force them into a slope channel ending at the pick-up position. The bulk feeder must be designed to a components specific dimension.

Tray feeders are used to feed large components supplied in trays. Different approaches are possible. If only a few trays are used for a job, some machines allow single trays to be placed into the machine feeding area. Another way is to fit the machine with an automatic tray-handling unit. These units have an elevation system for tray "storage" and move the trays needed for the product one by one into the machine .

Programming software
The programming software needed depends on the products produced and frequency of program change. If many different PCBs are to be produced and programs are changed often, a PC based programming system will be necessary. PCB CAD data and BOM (Bill Of Material) file are then used to generate the placement programs. Generating one program in this way can be done in less than one hour.
If the SMD placement line is set-up to produce only one product that are rarely changed, the programming can be done directly on the machine or on simple programming systems. To make one program in this way could take several days.

PLACEMENT METHOD

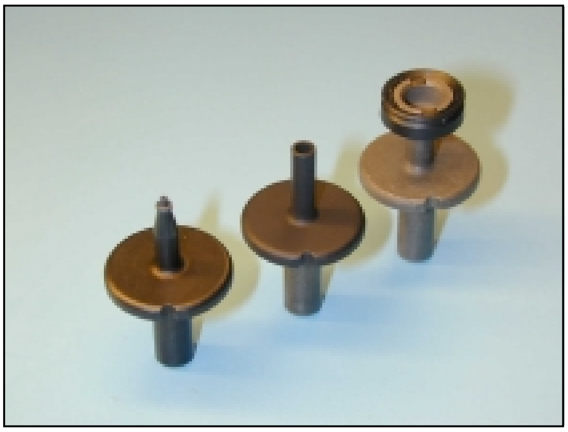
There are 3 different materials used to hold the components after placement; Solder paste, fixating adhesive and conductive adhesive. The material used relates to the "soldering" method chosen for the particular product. However, the placement method is nearly identical. Only some axis speeds might be a little different.

Several things are important to reach a precise and optimum output of a SMD placement machine. Below some of those are discussed. E.g. Placement program / data, nozzles, PCB support / fixating system and throughput & changeover.

Placement program / data
The placement program, vision recognition data and other component related data are of outmost importance to the out coming quality. The data needed of the varies machines and brands are very different. Some machines gets all data via the placement program and others have databases with information about components, tapes, and trays etc stored on the machine. To secure the quality and accuracy of the placement, it is important that all data are set correctly and thereby also handles the components correctly. Most continuos placement failures are caused by faulty data.

Nozzles

The right vacuum nozzle size and type must be chosen for a given component. On full vision placement machines the vacuum nozzles are only used for lifting and movement of the component. The nozzles must fit the component and thereby secure a reliable transportation of the component. On the photograph to the right, 3 different nozzle sizes for vision recognition are shown.



Mechanical placement heads has a number of tweezer arms that align the component on the centre of the vacuum nozzle.

PCB support / fixating system

The PCB support and fixating system must hold the PCB in a locked position to prevent movement during placement. Movement after fiducial mark reading will result in in-accurate component placement. The PCB support must also secure that the PCB is hold in a flat position and in the correct height.
If the machine produces a variety of PCBs the support must be designed for flexible set-up but also in a way so the set-up for one product will be reproducible. In this case it must also be fast and easy to change from one set-up to another to minimise changeover time.

Throughput & changeover

The machine manufacturer always gives a very optimistic and theoretic placement rate for the machines. The stated figure in cph (Components Placement per Hour) will only be possible in optimum situations where a test PCB is specially designed and feeders are set-up for optimum pick-up. The placement rate is very depended on the PCB design and component used on the PCB.
But, the throughput of the SMD placement machines are also depended on the changeover time between product runs, down time due to change of empty component reels and unbalance between sequential set-up placement machines.

To get the most out of the SMD placement line, it is important to minimise down time and waiting time. The keyword in doing that is ***organising***. The Japanese Just in Time philosophy includes a tool called SMED (Single digit Minute Exchange of Die) that describes 3 steps to reduce machine down time due to changeover.

1. Reorganising the work of changeover
2. Small investments in rationalisation
3. “Large” investments in improvements and standardisation’s

The idea is, in steps to move the time used for changeover from “internal changeover” to “external changeover”. Internal changeover is activities that need to be done while the machine is stopped. External changeover is activities that can be done while the machine is still running.

Below, 2 examples demonstrate the effect of SMED methods step no. 1 on the throughput of a SMD placement machine.

In the examples 100 PCBs are to be mounted with 500 components each. The machine placement rate is 10.000 cph and the PCB loading time is 5 sec. (equals 0.0014 hours). 75 feeders are in use, all with component reels with 5000 components. To change tape reels on a feeder takes 4 minutes (equals 0.067 hours) and to place a feeder on the feeder bank or trolley takes 0.5 minute (equals 0.008 hours). To set-up conveyor width and PCB support takes 10 minutes (equals 0.17 hours).

Example 1 (worst case):
Set-up of feeders for next production run is started when previous production is completed. The placement machine has fixed feeder bars.

Change reels on feeders: 75 feeders x 0.067 hours	= 5.03 hours
Feeder set-up on feeder bank: 75 feeders x 0.008 hours	= 0.60 hours
Setting up conveyors and PCB support	= 0.17 hours
Effective placement time: (100 PCBs x 500 comp.) / 10.000 cph) + (100 PCB x 0.0014)	= 5.14 hours
Change of empty component reels: (100 PCBs x 500 comp.) / (5.000 x 0.067 hours)	= 0.67 hours
Total time	**11.61 hours**

Calculated into component placement per hour the result is 4307 cph. Operator work time used: 11.61 hours

Example 2 (Best case):
The same job can be done in less than half the time if organised somewhat different. In example no. 2 I assume that feeders are placed on trolleys forehand and 2 sets of trolleys are available as a double set of feeders also are available. To fit the feeder trolleys to the machine takes 5 min. (equals 0.08 hours). Two operators will be needed: One to operate the machine and one to set-up feeders for the next job. Feeders are prepared forehand for change when empty. To change around two feeder takes 0.5 min (equals 0.008 hours).

Feeder trolleys fitted to the machine	= 0.08 hours
Setting up conveyors and PCB support	= 0.17 hours
Effective placement time: (100 PCBs x 500 comp.) / 10.000 cph) + (100 PCB x 0.0014)	= 5.14 hours
Change empty feeder with full (100 PCBs x 500 comp.) / (5.000 x 0.008 hours)	= 0.08 hours
Total time	**5.47 hours**

Calculated into component placement per hour the result is 9141 cph. The effort for the operators is fairly the same but the throughput is now more than doubled. Operator work time used: 11.69 hours.

On placement lines with more sequential set-up machines, it is important to balance the line. To reach the highest throughput, each placement machine must work for approximately the same time. If not, the placement rate per hour will drop dramatically.

Conclusion: Investing a little more in feeders, feeder trolleys, line balancing and reorganising the work of changeover, will easily in throughput equals the investment in one more machine but for under 20 – 30 % of the cost. Also operator work time can be saved if some of the components are stored on feeders eliminating the reel change.

MATERIALS

"Three" important materials are involved in the SMD component placement process. Components, PCBs, solder paste or adhesive.

Components
A variation of dimensions, shapes and coloration of the components can play a role in the placement performance. Components that exceed the maximum or minimum tolerance set-up in the vision parameters will be rejec-ted. Components from different vendors can have different colours and surface. This can cause problems in vision processing resulting in mis-alignment or rejection.

PCBs
The flatness of the PCBs and the solder land are both essential to the placement quality. If the PCBs are bend or twisted, the result can be mis-aligned components or missing components. Unequal height of HAL (Hot Air Levelling) of solder pads can result in mis-aligned components. The component leads will slide to the side and down from a too high solder pad. Unequal HAL layer can also cause mis-reading of fiducial marks.

Solder paste / adhesive
The tackiness and positioning accuracy of the solder paste or adhesive is essential to the placement quality. The solder paste or adhesive must hold the component in place until reflow soldered.

ENVIRONMENT

Dust and dirt on the PCBs and in the ambient air can clog the filters in the vacuum system used in component pick-up and placement and result in pick-up errors. It is therefore very important that the PCBs are stored in sealed packages and if necessary cleaned before use. The production area must also be fairly clean.

Air draught and high temperatures in the production area, can speed up the evaporation of the solvents in the solder paste and thereby make the solder paste dry out. In relation to SMD placement this problem can result in missing components on the PCB. If the solder paste is not tacky enough the components could be lifted out of the solder paste again after placement.

OPERATOR

The SMD placement process is a very sensitive process with respect to set-up of components, PCB support, nozzles etc. Operating a SMD placement machine is also a very technical job. There are a lot of parameters that has to be understood. Therefore the operators has to trained and experienced. They should also be able to correct faults that can appear in the daily work.

The operators must be good at organising the work around the SMD placement line to get a high throughput.

LIST OF FAILURES RELATED TO SMD PLACEMENT

Solder balling	**Solder beading (side balls)** are often a result of a combination of to much solder paste present at the pad, and out-gassing of solvents during the reflow pre-heat phase. But, it can also be a result of a too forceful placement of chip components. The solder paste will then be pressed far under the component and form a side ball when reflow soldered.
Tomb stoning & Skewing	**Tomb stoning & Skewing** is caused by an unequal wetting at the two termi-nals of a chip component. In relation to SMD placement, this can happen if a chip component are mis-aligned and only touches the solder paste at one solder pad. The surface tension of the melted solder alloy will then make the component rise and stand up on its end. Are usually seen for component size 0805 (inch) and smaller.
Bridging	**Bridging** is often seen on fine pitch components and is usual caused by in-accurate screen-printing. But mis-alignment or fine pitch components will also cause bridging.
Missing component	**Missing component** after placement can be caused by dried out solder paste. The component does not stick in the solder paste and will stay on the vacuum nozzle. Too little or none blow off will increase this risk. But also a too high blow off after placement can also blow the component away from the solder paste on the pads. This problem can also be seen on twisted or bend PCBs due to a wrong placement height.
Mis-aligned component	**Mis-aligned component** after placement can be a result of faulty reading of fidu-cial marks due to poor HAL (Hot Air Levelling) of the PCB or if the PCB is not fixated correctly and moves after fiducial mark reading. Also poor calibration of the placement machine or worn parts can cause this problem. This problem can also be seen on twisted or bend PCBs or PCBs with unequal HAL pad surfaces. Poor vision set-up for the particular component or bend placement shaft can also result in mis-aligned components.