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A Review on Defect Detection of SMT and Through Hole Components in Assembled PCB

[I]Nayana H G, [II]Deepa P, [III]Anitha D B, [IV]Dr. Mahesh Rao
[I,II]M.Tech, Dept. of ECE, VVIET, Mysuru.
[III]Assosciate Professor, Dept. of ECE, VVIET, Mysuru.
[IV]HOD & PG Coordinator, Dept. of ECE, MIT, Mysuru.

Abstract

In the era of advanced technology, PCB is like a backbone for the development of various electronic applications in the field of Automotive, Domestic, Medical, Railway, Defence and Aerospace etc. and thus the assembling process of PCB plays a vital role. The failures must be avoided in order to expect the desired response of any applications, thus it is necessary to produce a defec t free assembled PCB (PCBA). In initial days manual defect detection was the only solution for identifying the faults in PCBA which is very tedious, time consuming and sometimes may result in electric failure too. Automated inspection of assembled PCB is followed t o ensure quality and to minimise the scraps. This paper gives a review on various existing defect detection techniques and the different PCBA defects, specific to both SMT and Through Hole components are listed, which would be helpful for the future works relate d to defect detection of assembled PCB.

Keywords

Printed Circuit Board (PCB), Assembled Printed Circuit Board (PCBA), Surface Mount Technology (SMT), Through Hole Technology (THT), Automated Optical Inspection (AOI).

I. Introduction

In modern electronic world, the continuous advancement of electronic applications, tends to be reliable, multifunctional and portable. Due to lower initial cost, time and with better mechanical performance, Surface Mounting Technology has been widely used compared to the Through Hole Technology. The SMT components on an assembled PCB come in a wide range of size, shape, color and uniqueness which seems to be the major bottleneck in most of the defect detection techniques. Manual inspections are too slow, expensive and have difficulty to be focused on very repetitive tasks. Without Automated Optical Inspection (AOI) system, today's electronic device manufacturing industries are unimaginable. AOI is not a comparison of images but it is lightings and mathematical calculations used for real time statistical process control capability. In order to assure the quality of surface mounted PCB, automated inspection is necessary [1].

1. Surface Mount Technology (SMT)

SMT is a method for producing compact electronic circuits in which the components are mounted or placed directly on to the surface of PCB. The SMT components are differed based on their size and shape. The various SMD packages are chip components (which includes resistors, capacitors and inductors), Small Outline Transistors (SOTs), Small Outline Diodes (SODs), Small Outline-ICs (SO-ICs), Quad Flat Package(QFPs), Ball Grid Array(BGA), Land Grid Array (LGA), MOSFETs, Fuses, Plastic-Leaded Chip Carrier (P-LCC), Small Outline J-Lead (SOJ-L), Thin Shrink-Small Outline Package (TS-SOP), Metal Electrode Leadless Face (MELF), etc.[2].

The Fig. 1 shows different manufacturing processes involved in SMT. Initially baking is the first process involved in the SMT, in order to remove the moisture contents from the bare PCB, then soldering paste or glue is applied on to the bare PCB which is followed by placing surface mounted devices on the board at the appropriate locations, then it is passed through reflow soldering machine to get contact with the conductive tracks through the pads. Finally AOI is an inspection stage which involves various defect detections which are caused in the SMT process [3].

2. Through Hole (TH) Technology

In general the manufacturing steps in the production of Through Hole technology boards are shown in Fig. 2. This involves the use of leads on the components that are inserted into the holes drilled in the PCB and soldered to pads on the opposite side either by manual assembly or by the use of automated insertions mount machines. The various THT packages include axial leads, radial leads, single in line package, and dual in line package [4]. The components are capacitors (fixed & variable), Resistors, potentiometers, connectors, headers, sockets, filters, diodes, crystal, fuse, inductors, transformers, thermistors, switch, LEDs, jumpers, relay, ICs etc.

The manual assembly process involves forming in which the TH components are modified into the required shape based on the requirement of the PCB, fixing the mechanical parts onto the PCB. The masking is based on requirements, stuffing the formed components onto the PCB. The overall process held in the TH will be inspected manually and is passed to the wave soldering in order to solder the stuffed components.

In PCBA technology defects related to SMT and TH components are listed in the Table.1. Here one can observe that, most of the defects are common to both SMT and Through Hole technologies, but still there are few defects which are specific and unique to one or the other.

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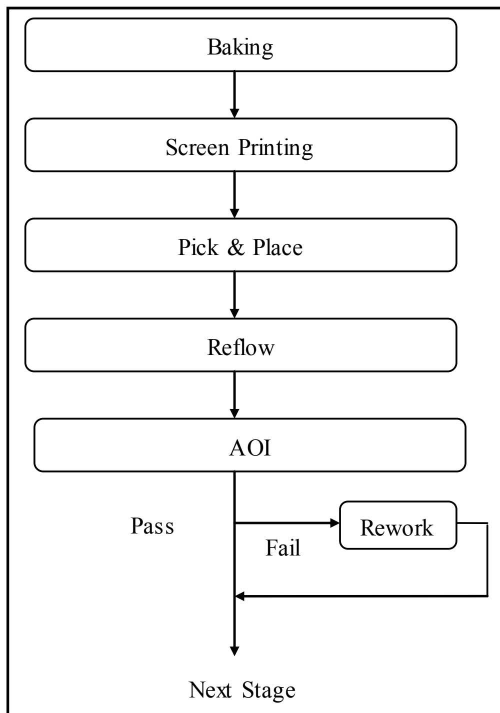

Fig. 1: SMT Process

The various approaches for inspecting the Assembled Printed Circuit Board through automated inspection have been reported for last few decades. This paper presents a survey on different existing approaches. And their limitations are discussed in brief in further sections.

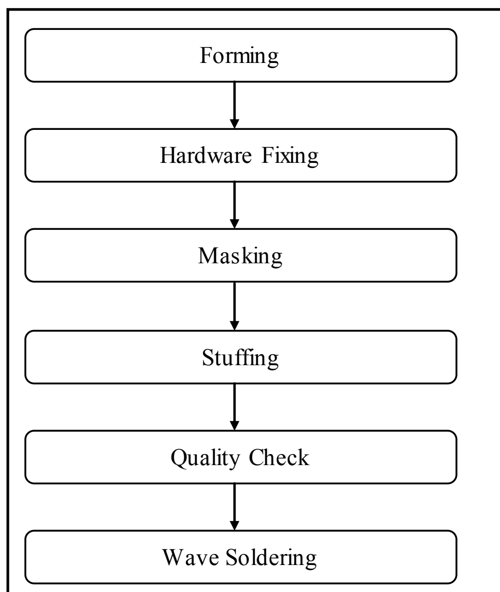

Fig. 2: Through Hole Process

In this paper [5] initially the windowing technique is employed to minimize the amount of processed redundant data. For processed part pre-processing functions such as image processing technique and convolution are applied, which results in saving the computational time. The major steps involved in these techniques are filtering, image segmentation, and feature extraction of the segmented image and classification of the extracted image. The SMT PCBA defects like component missing, component alignment errors, wrong placement chip components, wrong placements of IC chips and insufficient solder joints are detected using these techniques. The inspection speed and inspection accuracy of the specified defects has been calculated and also the authors have experimentally proved that this technique is fast and reliable.

Table1 : Different defects of SMT and Through Hole Components

Name of Defects	*SMT Components*	*Through Hole Components*
Component Missing	✓	✓
Component Shift	✓	X
Component Lift	✓	✓
Component Damage	✓	✓
Component Polarity	✓	✓
Bill Boarding	✓	X
Upside Mount	✓	X
Pin Bend	✓	✓
Wrong Value	✓	✓
Tomb Stoning	✓	X
Solder joint	✓	✓
Solder Short	✓	✓
Less Solder	✓	✓
Non Solder	✓	✓
Excess Solder	✓	✓
Solder Bridge	✓	✓
Defects in Lead Forming	X	✓
Solder balls	✓	✓
Solder Splashes	X	✓
Solder Projection	X	✓

The authors [6] gives the effects of PCB material on interconnect durability of lead free assemblies. The thermo-mechanical properties are examined and are used for simulation of solder joint durability. The temperature-cycling and randomized vibration loadings are the environment loadings used. The results of thermo-mechanical properties like elastic modulus and coefficients of thermal expansion in the PCB materials have straight impact on the durability of solder joints.

Crispin et. al. investigated methods, to identify and locate different objects in an image, required for inspecting the surface mounted device. Here by using grey model fitting method, authors focus on locating different objects by object recognition techniques. This produces a specific template for a group of components. They used the normalized cross - correlation, matching of templates for defect detection and investigate a method to minimize the computational based calculations. A genetic algorithm is used to search the template positions. This algorithm finds edges in the complete image, which is not dependent on the alignment of image which is required for the comparison of defective images [7].

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Sundaraj K [8] presents a prototype Automatic VIS by using a method of colored-background subtraction to detect the missing or misaligned surface mounted components. Initially compares a standard PCBA image and the test image by using background subtraction technique. This algorithm highlights the main problem region in the test image, through this specified defects are identified. The focus of this paper is to detect only the missing and misaligned SMT components. However the model is simple and the accuracy of the system is hardware dependent. The proposed model has a limitation that it does not get satisfactory results, if the component has a same colour as that of PCB background.

Tibor Takacs et. al. [9] proposed a new approach for measuring the similarity in the relative images of AOI. Authors have used the image processing technique of outlier filtering algorithm. This technique creates a reference template that represents the average scale of correct electronic components. Then the test image is compared along with the reference template image sub regions by producing a profile of resultant difference. The detection of the difference fields create results in the 2D similarity degrees that represents the closeness of test image with the reference template, which is nothing but the developing degree of similarity through equivalent value of the measurement. This method uses and obeys the specific conditions and specialized requirements of AOI.

Authors present a solder-joint identification technique depending on the recovery of the image surface. Using Shape from shading technology for 1D gray image, the upper part of the solder joints is corrected. The quality of the solder joint is discriminated using shape distribution method in which various types of solder joints are identified and recovered. Hybrid illumination model is introduced to uphold the level of accuracy for real images. Based on simulated annealing algorithm, reflection component estimation method is designed. By comparing with different defect detection methods depending on the 2D images, the efficiency of the recovery process has improved [10].

The paper [11] presents the techniques to locate and identify the assembled components on the PCB used for inspection. This model focuses on extraction of solder-joint and protective coating. Initial process involves identifying highlighted regions, later it recognizes and removes the non-highlighted regions. The detection technique involved here is colour distribution of highlighted regions. The coated part of the PCB is highlighted and is related with the solder joints of various components mounted on it. The higher extraction accuracy in most of the PCBAs is achieved. This algorithm recognizes almost all of the chip components of SMT. The major drawback in this method involves in the recognition of the colored objects.

Sanveer Singh et. al. [12] emphasis on automatic machine vision system to inspect the missing and wrongly placed components in assembled PCB. The process involves two stages, a learning stage and an inspection stage. The learning stage involves training of the standard PCBA and in the inspection stages involves the inspection of PCBA under test for any missing or miss aligned components. The defect detection technique involves image subtraction. First they compare standard PCBA image with the test PCBA image, through simple subtraction method. Defective areas are highlighted using proposed algorithm. The authors have examined that at which level this method incorporates the identification of defective image. Thus the faulty image identified through the inspection stage is less affected through the noise invariants. The focus of this system follows the defect detection of PCBA and also to see the effect of noise.

Sonal Kaushik et. al. [13] presented detection of missing and misaligned components along with few bare PCB defects. Image subtraction technique is used for the defect detection process. The major steps involved in this technique are filtering, image segmentation, and feature extraction of the segmented image and classification of the extracted image. The template image and the defective images are mainly used in this algorithm. Initially the reference image is buffered then both the images are subjected to the image subtraction operation using XOR logical operation. The obtained resultant image is subjected to thresholding, later this follows the practical analysis by using MatLab. The effect of noise can also be identified in the graphs using the same tool.

Fupei et. al. [14] emphasized on the classification inspection methods for solder-joints of the chip components by using colour-grads and Boolean-rules. The authors proposed new detection and classification algorithm, to improve the performance of the solder-joints inspection. Initially this involves the featured regions like evaluation and color grads are defined. Further these are extracted and characterized statistically to build various special solder joint type images which are obtained by the digital camera. Later by using Boolean rules this is designed and presented. The proposed algorithm results in improving efficiency and provides quick inspection time.

The authors Malge et. al. [15] emphasis on morphological image segmentation method for defect detection of assembled PCB and also for the classification by utilizing simple image processing. The authors have explained the importance of identification, classification and locating the defects in assembled PCB. The various image processing techniques are utilized, in which the main process concentrated is on the image segmentation. They used test and template image to identify the defects of PCBA.

Ganavi and Mahesh Rao [16] proposed the automatic defect detection of PCBA by using various image processing techniques. The proposed system also provides the comparison results by different methods, which helps to evaluate best suited detection technique for the real time implementations. Initially Background subtraction of the images is done, later the template matching of the subtracted image is performed and finally it is followed by wavelet transform to detect the defects of PCBA. The real time implementation of defect detection and sorting results as a part of classification.

Manasa H R and Anitha D B [17] presents an Automated Inspection for the PCBA. This system is implemented in LabVIEW NI Vision software. The template matching technique is used to inspect the assembled PCB and to find the missing components. Initially the input is fed in the form of two images, that is a reference image and test image, the information of the component specification is stored, then the image pre-processing operations and template matching algorithm are applied for the images acquired, this results in extracting and testing each individual component. Further it verifies the physical dimension of the components then the defect regions are identified and a detailed check sheet or report of processed components is extracted, which is very helpful in maintaining the records too.

II. Drawbacks of The Existing Approaches

A recent trend in assembling of Printed Circuit Board (PCBA) tends to maximum complexity due to compact applications. The major challenge in the PCBA is to place the smaller components or SMT components accurately. Higher cost of each PCBA typically means higher number of components, which results in the higher

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work in process cost and scrap cost.

Most of the existing defect detection approaches are based on the image processing technique. In image processing application the acquisition media like camera system does not produce satisfactory information due to inaccurate resolution of the smaller components and as it works under imperfect illumination conditions. Image difference operations are frequently used in automated printed circuit board assembly to inspect the missing and misaligned components. The performance of the detection is crucial and is dependent on the operational speed, which is the major drawback is difference in the images. Thus overall process turns to an erroneous conclusion. The pixel variations in the automated testing of PCBA results in position accuracy in turn which is dependent on performance of testing.

The limitations of jigs are due to placement parallel components. This is considered as one component during inspection. The various components in parallel connection can be inspected differently for each of the component using different testing techniques. By using specific configuration or specific sensor the polarity of the electrolytic components can be tested, but the quality of electrical contacts and assembly components cannot be tested.

The major defect identified till now is based on single component inspection at a time. The existing defect detection approach mainly identifies only the missing and misaligned SMT components. Due to the complexity of identification of soldering defects, only few works has been done on soldering inspection. The mainly identified solder defects are solder joints extraction of SMT components. After the screen printing process, continuous monitoring of solder paste inspection will results in reducing the soldering defects. Apart from AOI, at a time no work has been done on integration of both the component defect detection and soldering defect detection.

The main bottleneck of these problems is that due to the smaller size of the SMT components. For example, consider an assembled PCB of dimension 32cm X 14cm with a pixel density 6119x2746px acquired through a 15MP camera. In which, consider the small chip components with a package of 0204, 1206 and 7044 which will have a pixel density of 9x13px, 28x60px and 80x130px respectively for vertically placed components. Thus one can notice that the pixel value differs based on the size of the components, which is one of the limitations in the defect detection of SMT components. The image acquisition of body mark and solderability of the SMT component image will not be clear, by considering the whole assembled PCB. Thus these are few of the challenges to be considered for identifying the defects in assembled SMT components.

Apart from the existing approaches of SMT defect detection, very less number of works has been done on the defect detection of the Through Hole assembling process. There is no such automated inspection for Through Hole assembling process. Manual defect detection is followed in order to investigate the defects of Through Hole components.

III. Proposed Work

The major issues for the emerging system designers are desired to configure a product with low cost and less time to market, which is the main motivation for the designers to maximize the use of programmable architectures. Therefore the drawbacks in the present existing approaches are considered and are planned to overcome the existing issues of the image processing dependent testing of automated assembled PCB, using the intervention of embedded systems, which results in the low cost consumption and also in less human intervention.

Parallel identification of both the SMT component defect and soldering defects can be achieved by using image processing techniques. Further this results in

- Low cost
- Reduced cycle time
- Minimum scraps
- Less complexity

Apart from this, one can also try to implement the same image processing techniques to identify the presence of defects in the Through Hole components, which results in

- Increase productivity
- Increase profitability
- Avoid testing failures

IV. Conclusions

This paper presents a review on the various existing approaches of automated assembled PCB. Also proposes the limitations still existing in this field. For now as discussed above, very less work been done on TH technology, thus one can concentrate on specific defect detection of TH components too. The pixel variations of various SMT components are explained in brief. The proposal of the future work to enhance the above mentioned limitations are discussed.

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