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Through Hole Component Inspection Monitoring System

Deepa P, Anitha D B, Mahesh Rao

Abstract: ***For PCBA with through hole components, there is no easy, automated way of inspection like using AOI and AXI as employed for the Surface Mount Technology (SMT) components. As there is no such specific efficient inspection tool, till date manual inspection is the only solution for identifying defects in the Through Hole technology. Thus proposed work is defined to inspect few of the through hole component defects in an automated approach. Even though AXI is capable of detecting the Through Hole defects, it is rarely implemented due to its inaccurate results and cost. This results in increased cycle time, moderate efficiency, expensive and is very difficult to be focused for the operator on such repetitive task and that in turn affects the productivity and yield. As not much of research work has been carried out to find solution, a simple image processing technique has been tried here. In the proposed system a pattern matching technique is used for inspecting the defects like presence and absence of the Through Hole components in assembled PCB. In this work few different PCB images of same product have taken for inspection, further the inspection result is generated using LabVIEW Software.***

Index Terms: ***Assembled Printed Circuit Board (PCBA), Through-Hole Technology (THT), Surface Mount Technology (SMT), Automated X-Ray Imaging (AXI), Pattern Matching.***

I. INTRODUCTION

PCBA is nothing but assembling of electronic components on the bare PCB. Real time response can be expected by ensuring the efficient assembling of components on to the PCB. Assembling of components on the PCB may be of SMT and/or Through Hole type. The assembling process is mainly based on the product requirements and design parameters. The designed parameters are different for the different application and are dependent on end applications. Always the assembling process need not to be a combination of SMT and Through Hole, sometimes either of the process can be expected based on application. In general, the production of assembled PCB is carried out in three different stages, which involves SMT, Through Hole and Clearance.
The earliest method which is still being used in PCB assembling process is Through Hole Technology. The Through Hole Technology is nothing but the placement of components into the PCB through the drilled holes. The TH components consisting of leads are inserted either manually or by using automated insertion machine and are soldered at the opposite side of the PCB.

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* Correspondence Author
Deepa P*, ECE Department, VVIET, Mysore, India.
Anitha D B, ECE Department, VVIET, Mysore, India.
Dr. Mahesh Rao, ECE Department, MIT, Mysore, India.

A. Through Hole Technology

The various process involved in the THT are shown in the Fig. 1. and the stages are explained in brief. In the whole Through Hole process the main check point is line quality check; this is not automated and is performed through manual inspection. As manual inspection is involved one can expect the less time to set up, no programming and less investment. Thus in general most of the Through Hole process are not automated, but are human dependent [2].

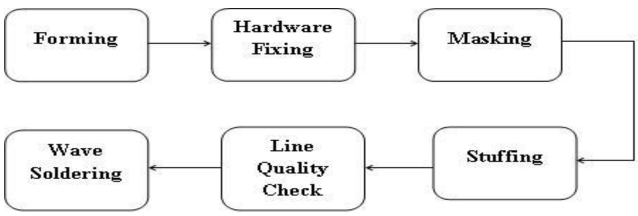


Fig. 1. *Through Hole Process*

- **Forming:** Forming is an initial process, which involves modification of the Through Hole components into the required shape based on the requirements of the PCB design.
- **Hardware Fixing:** Hardware fixing is a process of fixing the mechanical parts on to the PCBs. It is an optional step.
- **Masking:** Masking is a process of covering the unwanted part of the material mounted.
- **Stuffing:** In this process the formed components are mounted on to the PCBs based on the specific locations, by referring Component Assembly Diagram (CAD).
- **Line Quality check (LQC):** In this stage the overall process held in the Through Hole will be inspected manually. The inspection is based on the various set points depending on the first good board passed.

B. Defects Involved in THT

In PCBA technology defects related to SMT and TH components are different. Here one can observe that, most of the defects are common to both SMT and THT, but still there are few defects which are specific and unique to one or the other. Even though the defects are same, but the same techniques can't be applied to both technologies due to the variable size and presentations. There exist various defects in THT, among which few of the important defects are explained in brief [3].

1. **Component Damage:** This defect results due to inefficient forming and improper stuffing operations.

2. **Reverse Mount:** Placing the components in the direction opposite to that of the markings on the bare PCB.
3. **Component Lift:** It occurs due to the variable lead length and also when passing through the wave soldering the component may get disturbed which results in component lift.
4. **Component Missing:** The component is absent or missing in the pre-defined locations to be

placed, which is defined based on the design parameters.

II. LITERATURE SURVEY

The variation in size and shape of the components results in different technologies under the manufacturing field of PCB assembly. As an outcome of this, todays electronic devices are being more compact, efficient and of low cost. One can note that there is an efficient defect detection device been implemented in SMT to verify the defects and to correct it then and there itself through avoiding future failures. Further the collective work been done on defect detection of PCBAs are discussed and the algorithms or the techniques used to implement them are noted. Thus the proposed work is carried out, through considering few of these existing approaches. The authors [4] present an automated inspection model for surface mount PCBs. The inspection methodology involves locating and finding the different components in the surface mounted PCB image [5]. The different components are identified using gray model which makes use of the technique called Normal Cross-Correlation and template matching respectively. This in turn needs a pattern matching approach in order to feed the input image of the component present in the assembled SMT PCB [6]. Based on the fed input patterns, the genetic algorithm performs searching operations for specific template positions. The template matching is more similar to pattern matching and the patterns are defined within the ROI [7]. The paper [8] specifies an automatic system for detecting the PCB through the basis of single component identification. The author [9] defines a dedicated electronic component inspection system for covering full area of single PCB at a time. As a result of this the inspection time was minimized and which in turn increased the throughput of production, with the concentrated approach for identifying the missing and misalignment defects of components in assembled PCB. The variation in size and shape of the components results in different technologies under the manufacturing field of PCB assembly. As an outcome of this, todays electronic devices are being more compact, efficient and of low cost. One can note that there is an efficient defect detection device been implemented in SMT to verify the defects and to correct it then and there itself through avoiding future failures. Further the collective work been done on defect detection of PCBAs are discussed and the algorithms or the techniques used to implement them are noted. Thus the proposed work is carried out, through considering few of these existing approaches. The authors [10] present an idea for locating and detecting the presence of components on the PCB. The performance of this system is divided into two stages that is extraction of solder joint and protective coating layer [11]. The features are identified using three color distribution process in which the highlighted portions specifies the defect detected and the non- highlighted areas are removed by comparing with the template objects. The highlighted areas are recognized and are considered for further processing and the various solder joints are identified efficiently [12]. The authors [13] define the inspection system for identifying the cosmetic defects, which are very destructive. They use image processing algorithms to verify and identify the defects involved in PCB images. The acquired images are subtracted with the test image and the outputs are specified as +ve, -ve and zero [14]. Where these are checked for noise and are further subjected to XORing of image to obtain the clarified image. Thus the defects specific to PCB are classified and detected. The effective controlling of quality related issues in PCBs by using various image processing techniques are implemented by developing an efficient algorithm [15]. The developed system inculcates the analysis of faulty and defect PCBs. This system uses a digital camera for acquiring the images, these acquired images are considered by varying the colour levels of images. As a colour image is converted into Gray level for identifying missing defects. And the wrong polarity defects are identified in binary level, thus improving the quality in the production process [16].

III. SOFTWARE IMPLEMENTATION AND RESULTS

For inspecting the TH components in the assembled printed circuit board, is by manual inspection. This work gives an automated approach for finding defects in the assembled through hole PCB. Different defect variably affects the quality and yield of the assembled PCBAs. Thus it is important to identify the defects, in order to overcome failures of the systems built through these PCBAs.

There exists different kind of defects in Through hole technology, among which Presence and absence of Components, lifted lead and damaged components are the different defects identified in the present work. The Fig. 2. shows the various defects identified in this implementation part using the pattern matching technique.

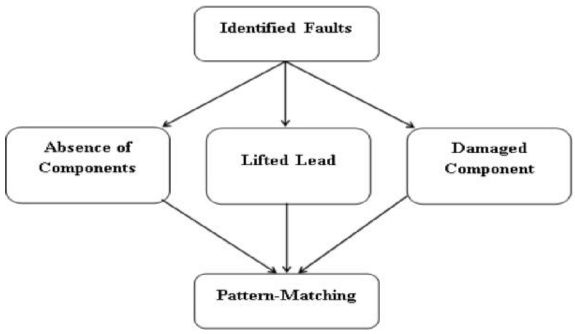


Fig. 2. ***Defects Identified using Pattern Matching Technique***

A. Absence of Through Hole Components

Absence of component is the basic defect, which is identified manually in the line during the quality check. This defect is also called as missing of the TH component. Usually this type of defects are identified and corrected in the assembly line itself, but sometimes due to manual carelessness the defects will be passed to next stage, which results in testing failures. Thus the defect can be identified automatically along with extra added feature of finding no of matches and calculating the overall performance yields. The basic flow diagram of missing defect deployment is explained in the Fig. 3.

Initially the colour images are considered as the input, among which specific best image is considered as reference image in which the different patterns are selected and stored in particular locations. Further various test images are considered for inspection. In these images the nearest trained patterns will be highlighted as a resultant, defining the presence of the component with a status display of ―Pass Count‖. If the test image doesn't matches with the trained pattern, then it is identified as absence of the component along with a status display of ―Fail Count‖. Finally the report of all the inspected boards will be tabulated and represented in excel sheet. Further the implementation steps involved in identification of these defects are explained using the detailed steps.

Step 1: Open the main screen and select Login Control.

Step 2: An authentication window appears, along with the request to enter the user name and password .

Step 3: Select Auto test, then a second window containing results panel will be displayed.

Step 4: Select Start and enter the project name, part number, Batch number and card name of the Test PCBA in a popup window.

Step5: Load the reference image by selecting Load Image.

Step6: On the acquired image, select a portion to be inspected and select Configure control.

Step7: Enter the part number of selected component and select Analyze.

Step8: Nextenterthe part number of the selected component and press ok.

Step9: Further the result window part will be updated along with information of Pass count, Fail count and yield display through the meter representation.

Step10: At the end of the inspection, results will be automatically updated in the Excel sheet.

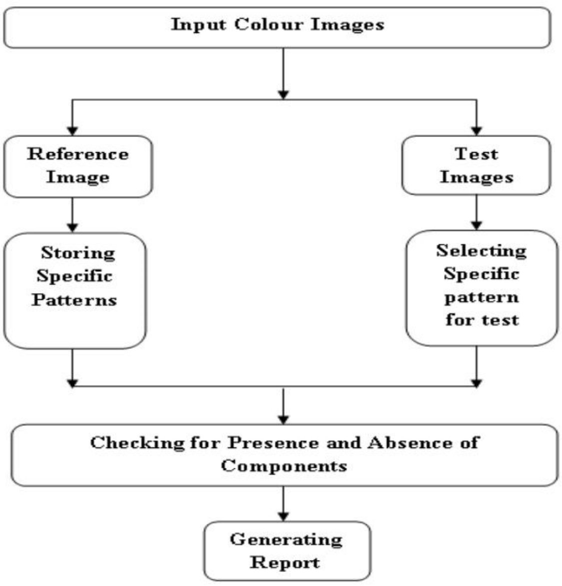


Fig. 3. ***Program flow for verifying Component presence & Absence***

The initialization of main screen with all the initial data's such as, assigning the current date and time linked with the system display. Enabling the event according to the requirement includes Login control management that contains the general function handling, along with the edit step. This is defined for controlling user specific operations such as addition or removal of new operator by the admin.

Training the pattern will appear prior to learning stage. In the training stage the image is trained by defining an ROI. The learning stage includes pattern set up, based on the flow control defined by admin and reading the selected ROI region as read only part. Later the test images are verified with the trained patterns of the image for identifying the absence defect in TH components.

Therefore after the completion of various controlling stages, report generation is the final stage. The report is generated based on the various set points, the set points defines different features related to PCBA. The entitled features defined in the tabulation of the report are, user name, date, time, project name, part number, card name, batch number, component part Number, Selected component present or status and the overall test status. Where username

specifies the name of the user or operator, the batch number specifies the work order and quantity of the project, batch number is used to specify the small variations in the same type of different boards which will be in terms of numbers and the card name will be an alphabetical representation of the specific card in a project.

The front panel window is designed in terms of user friendly controls, which enables a user or a guest to make the best use of this system with simplicity and efficiency. The whole system is designed effectively with authentication details and passwords which support implementing a secured and efficient system for monitoring the Through Hole component missing defects. The upper portion of the display specifies the name of the project, the company logos and the current date and time display which is linked with the system date and time display. The left most part describes the Main Menu field, which contains the various fields defined with respect to the program. The next part left in the window is the white row that specifies the path of the stored program. Initially as we run the program, the result window displays along with the enabled Exit and Login options, that is specified in the Fig. 4.

Fig. 4. ***Admin Enabled Window***

After Training entering details of PCBA, import a PCBA image and select a component the selected region will be highlighted in green colour. The good and bad board image considered for operations is shown in Fig. 5. and Fig. 6. respectively. Further select ―Configure‖ button, then select the ―Analyse‖ button to find out the pattern. The Figure 8 specifies the configuration of selected component. The resultant window specifying 1st pass board is shown in Fig. 7.

Fig. 5. ***Reference good Image***

Fig. 6. ***Reference Bad Image***

Fig. 7. Final Resultant window

Final inspection result is shown in Fig. 8. in which the results of 13 boards are defined along with the yield percentage. Based on observation one can define that 2 boards are found defective that is, the defined switch pattern is not matched with that of passed boards. Therefore it can be specified as defective boards and thus the missed Through Hole switch is identified efficiently along with the report generation in excel sheet, through defining a total yield of 83.34% and the report generated in excel sheet.

Through considering an example of an assembled PCB, entitled ―Pic Unit 12‖ which comes under a project of ―Mohlen off 1‖ for inspection of a Through Hole Component

PCBA image. Here thirteen different boards of same project are considered for inspection, in which the card name, project name and batch number are common to all thirteen boards. The parameter which is different is the part number, because the part number specifies the serial number of the card considered for inspection. The Fig. 8. and Fig. 9. both are the combined results, which specifies the report generated in the excel sheet.

SL No.	User Name	Date	Time	Project Name	Part No.
1	Administrator	10-05-2017	19:01:02	Mohlen off 1	60531040140
2	Administrator	10-05-2017	19:02:45	Mohlen off 1	60531040141
3	Administrator	10-05-2017	19:03:39	Mohlen off 1	60531040142
4	Administrator	10-05-2017	19:04:30	Mohlen off 1	60531040143
5	Administrator	10-05-2017	19:05:20	Mohlen off 1	60531040144
6	Administrator	10-05-2017	19:06:10	Mohlen off 1	60531040145
7	Administrator	10-05-2017	19:07:00	Mohlen off 1	60531040146
8	Administrator	10-05-2017	19:07:50	Mohlen off 1	60531040147
9	Administrator	10-05-2017	19:08:40	Mohlen off 1	60531040148
10	Administrator	10-05-2017	19:09:30	Mohlen off 1	60531040149
11	Administrator	10-05-2017	19:10:20	Mohlen off 1	60531040150
12	Administrator	10-05-2017	19:11:10	Mohlen off 1	60531040151
13	Administrator	10-05-2017	19:12:01	Mohlen off 1	60531040152

Fig. 8. ***Generated Report (a)***

Card Name	Batch No.	Component Part No.	Selected Component Present	Overall Test	Inspection Time (Secs)
Pic unit 12	c6053104024	SW 2	Pass	Pass	87
Pic unit 12	c6053104024	SW 2	Fail	Fail	54
Pic unit 12	c6053104024	SW 2	Pass	Pass	51
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Pass	Pass	50
Pic unit 12	c6053104024	SW 2	Fail	Fail	51
Pic unit 12	c6053104024	SW 2	Pass	Pass	50

Fig. 9. Generated Report *(b)*

Inspection Time is the next field defined in the table. This indicates the total time consumed for the inspection of a single PCBA board. Based on observation of inspection time, one can note that the initial inspection time is too long as compared with further PCBA boards. This happens due to the fact that, for first board the inspection starts from Initial stage and then followed by the ―Login‖ stage, but for further boards the inspection starts directly from ―Login‖ stage. The plot of inspection time versus Through Hole PCBA of different part numbers are specified in the Fig. 10. This plot also represents the Pass and Fail Boards differently, which will be helpful in acquiring inspection data through pictorial representations.

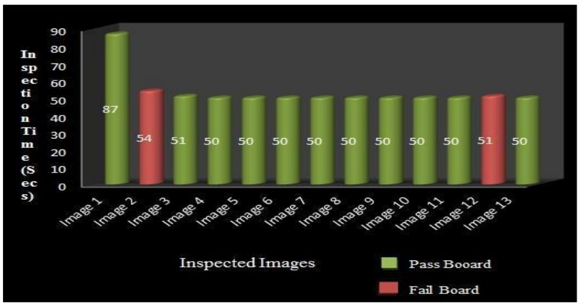
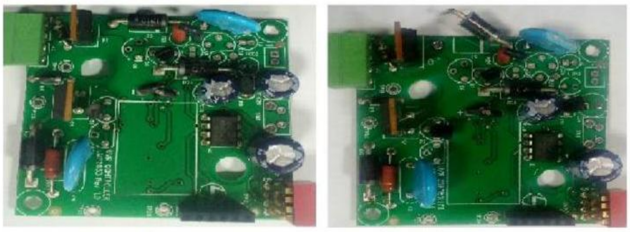


Fig. 10. ***Inspection Plot***

B. LIFTED LEAD & DAMAGED COMPONENTS DEFECT IDENTIFICATION

Identification of lifted lead and damaged component is the next set of defects which are concentrated in the present wo rk. The techniques used in the detection of these defects are all most same, but varies in the programming part. Pattern matching is the method, which is deployed in defect identification. The program part is designed and executed in Vision assistant software. This software is also developed by the National Instruments, which is also supported by LabVIEW.

Lifted lead is an defect which is specifically observed in Through Hole process only whereas component damage can occur in both SMT and TH technology. The overall process followed in programming, is explained in terms of flow diagram which is shown in the Figure 15. After all these steps the patterns are verified with the considered reference image. Thus by following these steps the overall performance of the product can be enhanced efficiently, and the chances of failures or passing defect boards can be minimized. The reference image (a) and the defective image (b) representing Lifted Lead and Damaged Component defects are shown in and Fig. 11. After teaching the specific patterns through defining various parameters, the resultant will be stored and displayed with the control specifying pattern matching 1.



(a) (b)

Fig. 11. *Test Images*

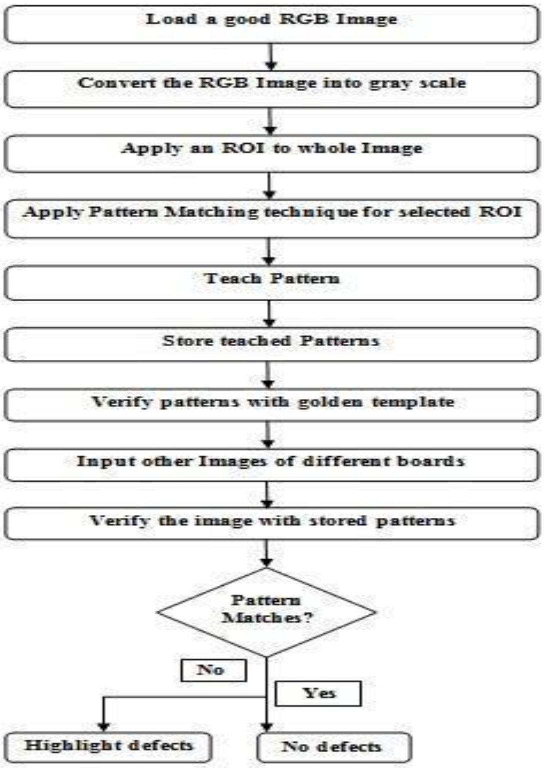


Fig. 12. *Flow chart for detecting defects*

Thus in the same manner the whole board image covered with ROI, will be trained and stored for inspecting every single component. Later various board images of same part number are considered for processing, in which the input image will be compared and verified by the stored patterns of good or reference image. The results specific to the defined logic is shown in the following figures. Here the inspection starts with a gray image and presents output in a binary format, thus only the defect part will be highlighted in binary form.

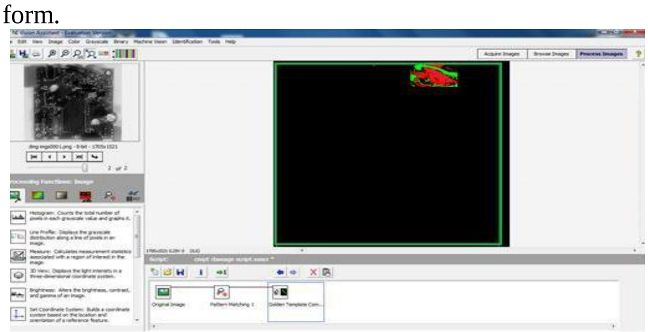


Fig. 13. *Area of identified defect*

The green highlighted part forms an interested region of the image and this portion is considered for verification. In the test figure a Through Hole capacitor is damaged, the correct portion of it is highlighted in red box and just the defect portion of it is expressed in binary form. In Fig.13. the whole board is verified for the defect and here a defect portion is highlighted in binary form. The performance details are estimated by the built in icon and the inspection time required for identifying the lifted lead defect is 6.79ms.

The Lifted lead is the next type of defect which is programmed to verify the PCBA board. During the process of stuffing the components will be placed on to the PCBs and during this there may be possibilities of improper stuffing which may result in this defect. These lifts are not expected and must be identified in the prior process of wave soldering.

The inspection result of Fail board is represented in Fig. 14. The resultant is the image in the green region, and the red boxes indicate the inspected component and the defect component portion will be highlighted in binary form. In the defective images considered one a diode is stuffed in only one part and the other part is lifted, which is identified through this logic and the corresponding output is specified and 4.68ms is the total inspection time required for identifying this defect.

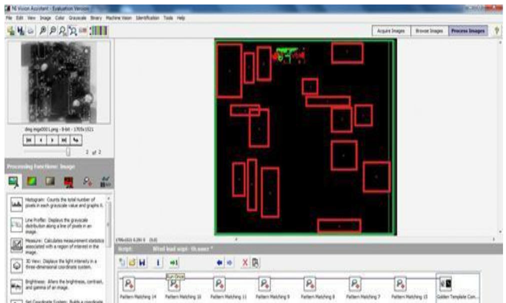


Fig. 14. *Inspected defect board image*

TABLE I. COMPARISON OF PROPOSED SYSTEM WITH OTHER EXISTING SYSTEMS

Performance Parameters	Performance of Proposed system	Performance of Existing system
Accuracy	High	Moderate
Stability	Medium	Less
Automated system	Not Fully Automated	Manual handling
Complexity	Moderate	Less
Inspection Time	Less	Medium

IV. CONCLUSION & FUTURE WORK

The proposed work is more efficient and provides consistent quality results. The work identifies three defects of through hole components, namely

- Absence of Components
- Lifted Lead
- Damaged Components

The designed inspection monitoring system for TH Components is executed effectively through identifying the defects by verifying the components specified in the good board PCBA image compared with the test PCBA images. The verification is done by using pattern matching method, in which all the TH components are defined in terms of patterns and are stored in specific user defined locations. The incoming test images are verified with these stored patterns. And a report of result is generated automatically in excel worksheet.

Future work could include designing an integrated method for identifying all defects collectively. An automated system for specifically identifying the TH defects can be defined. A software supporting camera could be used for acquiring the images of the test PCBAs. And the number of defect identification can be maximized by using the related techniques for effective implementation of the set works.

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AUTHORS PROFILE

Deepa P B.E, M.Tech, Currently working as a Asst. Professor, in Department of ECE, VVIET, Mysore. And has an Industrial experience in EMS Company.

Anitha D B B.E, M.Tech, Working as an Associate Professor since from 15 years in the Department of ECE, VVIET, Mysore.

Dr. Mahesh Rao B.E, M.Tech, P.HD, Currently working as an Head of the Depaertment & P.G Cordinator, MIT Mysore. Has an industrial experience of 2 decades.