

Scrap Loss Reduction using Root Cause Analysis

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ABSTRACT: Reducing scrap production is something that all the firms are trying to achieve. Producing something that does not have any economic value is a huge loss to the company. Labor cost, equipment cost and material cost are some of the losses a firm needs to bear while producing scrap.

Printed circuit boards are widely used in almost all the electronic and computer devices. Drilling of holes in the printed circuit board is necessary to make path for establishing contact between different layers and to make locations for mounting the electrical components. In this context, Single Hole offset is a defect which comes into picture during the process of drilling holes in printed circuit boards and it contributes to a larger quantum of scrap production.

The main aim of this research study is to make use of root cause analysis technique to find out the factors influencing Single Hole offset defect in Schmolli drilling machine, correlating it with the equipment to find its involvement, and preparing a check list which needs to be followed to subsequently reduce scrap production.

KEYWORDS: Printed circuit boards, single hole offset, root cause analysis, scrap reduction

I. INTRODUCTION

Almost every electronic and computer devices comes with a printed circuit board built in it. Basically in a PCB there are three parts insulating core, copper cladding and solder resist layer. Insulating core or base is of epoxy material and on top of epoxy a thin layer of copper is coated based on the customer requirement. Copper is coated on to the base material through electro less and electrolytic plating.

The PCB can be of single sided, double sided or multi layered up to 18 layers. Multi layers are formed by pressing several layers together. Holes are drilled in the PCB/Panels for two purposes. Initially to make path for establishing contact between different layers and furthermore to make locations for mounting the electrical components.

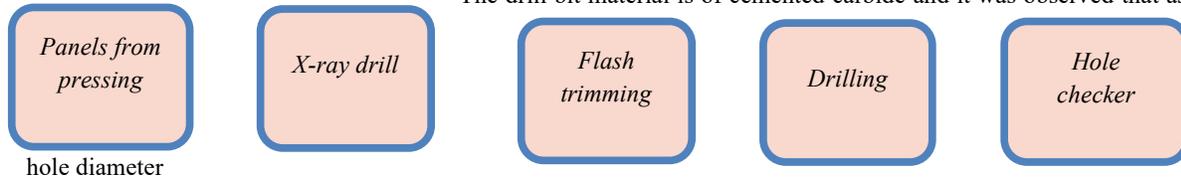
Drilling of holes in the panels is based on the customer requisite and the holes may vary from smaller to larger diameter and also differ in depth. Various defects comes into picture during the drilling process, some of them can be reworked and remaining cannot be reworked which leads to scrap production.

II. RELATED WORK

In the paper [1], it describes the use of different entry materials for PCB drilling. Various materials like Copper, Aluminium, Bakelite and wood were used as entry materials. The operation was performed for different diameter drills keeping cutting data, clamping conditions and drill geometry constant. It was concluded that Aluminium is better entry material than others as it provides better hole quality, reduced drill burrs and also plain surface finish.

In the paper [2], it describes the impact of tool material, cutting force, geometry and temperature on the drilling process.

The drill bit material is of cemented carbide and it was observed that as the



hole diameter

decreased, the strength of the drill bits reduced which demands to strengthen the drill bits. Even if there are various process like EDM, laser drilling and vibration drilling, mechanical drilling provides high hole accuracy. It pointed out that when the temperature rise is too high, drill bits wear out which reduces the dimensional accuracy and also some drilled holes had smaller diameter than the drill bit used.

Procedure



- Panels are pressed for multi-layer requirement based on the requirement of the customers.
- In x-ray drilling, two holes which are necessary for mounting the panels during the drilling are drilled.
- Excess copper foils attached along the edges are removed and the panels are brought to the correct size.
- Punching holes of required diameter, in the exact coordinate, in correct number is drilling.
- The Hole Checker will detect and locate missing holes, extra holes, oversized holes, holes that are undersized and displays it in the monitor.

Drilling process

For drilling of printed circuit boards, Schmoll drilling machines are used. The drilling machine consists of six stations which can operate simultaneously. The range of spindle can be varied from 60,000 rpm to 300,000 rpm, the holes can be drilled with high accuracy combined with low maintenance and energy cost. The maximum size of the panel that can be drilled is 25x28 inch. A monitor is provided to operate the equipment and to run the program.

A wooden backup is loaded on to the bed to ensure that drilling through hole is achieved without conical end at the bottom and also to avoid damaging of the bed from drill bits.

The PCBs are loaded on top of the backup and mounted firmly using collet so as to resist the distortion.

A thick aluminium foil also known as entry is mounted on top of the panels to avoid burr formation due to drill bits.

Defects in PCB drilling

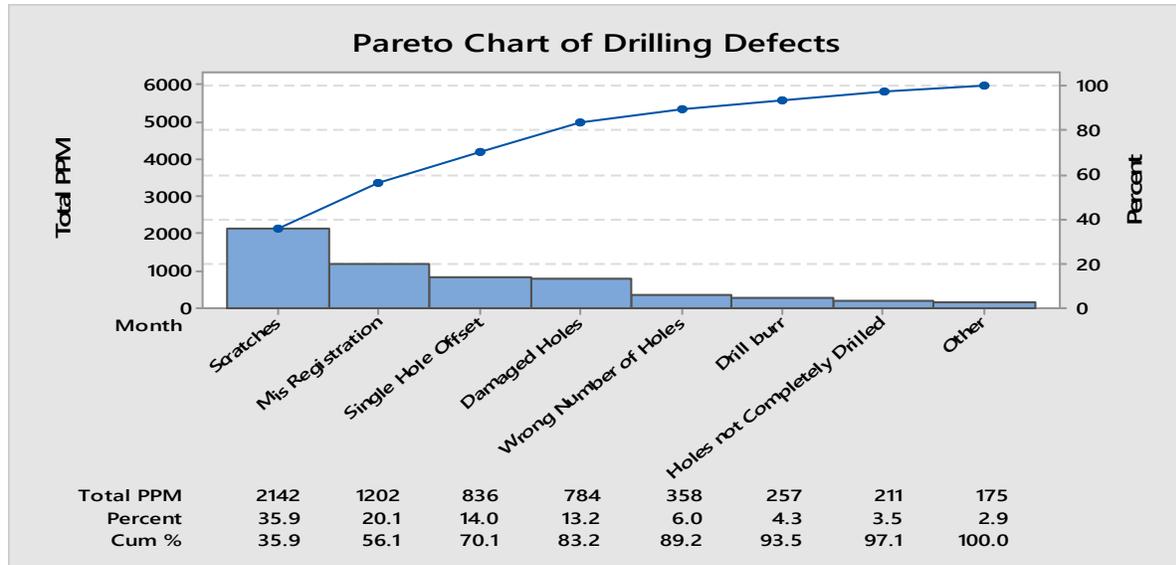


Fig1: Common defects observed in drilling of PCB

The trend shows various defects which may occur during drilling process. Among these scratches, mis registration and single hole offset contributes maximum to scrap production. Scratches are mainly due to improper handling of the PCBs without gloves and mis-registration of hole occurs when there is a minute error in the program or improper mounting of panel in the drill bed. The causes of these two defects are well known and it can be minimized by following proper guidelines and proper handling. But single hole offset is that kind of a defect which don't have a root cause, neither don't show any proper trend how they occur and it cannot be reworked.

A single hole offset is such kind of a defect in which every hole is drilled exactly in its designated locations but only one hole will be shifted slightly from the drilling location.

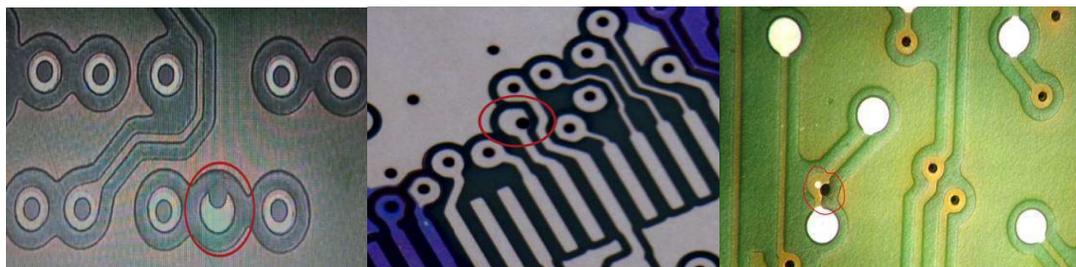


Fig2: Shifting of hole outside the annular ring

The designated area where the holes need to be drilled is called annular ring. As you can see in the fig, only one hole has been shifted outside the annular ring thus causing single hole offset.



Trends in single hole offset

Project input	Reduction of single hole offset		
Month	Start square meter	Defective square meter	PPM
Oct-19	35869	31.16	868.7167192
Nov-19	34569	28.56	826.1737395
Dec-19	35478	29.84	841.0846158
Average	105916	89.56	845.5757393

PPM=(Defective sq m / start sq m) x 1000000.
 For example consider Oct-19, total 35869 sq.m of panels are manufactured among which 31.16 sq of panels are found to have single hole offset.
 So PPM =(31.16/35869) x 1000000 = 868.7167192 PPM

Fig3: Occurance of single hole offset

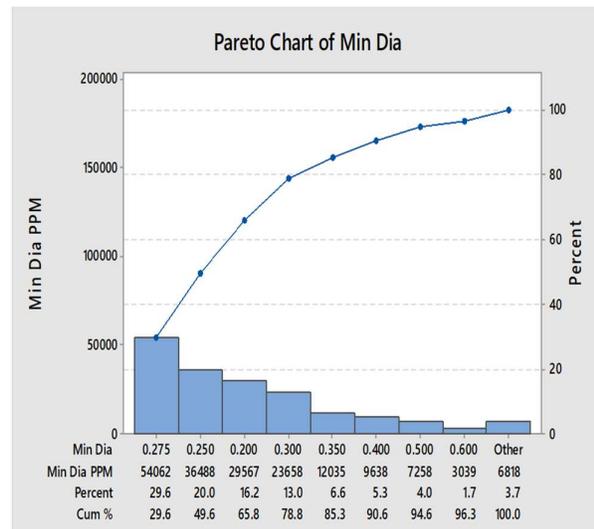
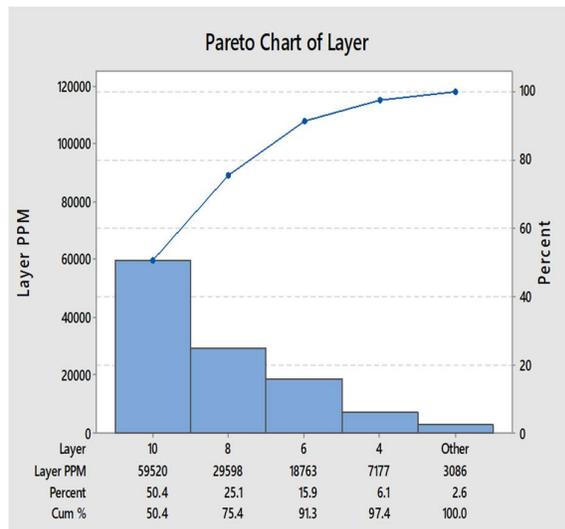


Fig4: Single hole offset vs layers and hole diameter

Fig4 shows two graphs which were plotted between different layers of PCB vs percentage of single hole offset and diameter of holes vs percentage of single hole offset.

It is observed that:

Higher layers tend to have higher chances of single hole offset.

8 layers and 10 layers contributes around 75% single hole offset.

Lower diameter holes tend to have higher chances of single hole offset.

Lower diameter upto 0.3mm contributes around 78% single hole offset.

From both the above graphs we can conclude that lower diameter holes which are drilled in higher layers tends to have higher chances of single hole offset.

Parts of Schmolli drilling machine

Collet:It is used to hold the panel, entry as well as backup in the exact position to tolerate the vibration.

Pressure foot:It is the part where the vacuum is created which holds the drill bit and which stands directly above the panels.

Pressure foot cylinder: Pressure foot cylinder helps the pressure foot to move up and down relative to the spindle movement.

IPF: Insert for pressure foot. These are the drill bit inserts of smaller and large diameter, and they are inserted on to the pressure foot.

Slider: While drilling of PCBs both higher diameter and lower diameter need to be drilled. Different higher diameter and lower diameter IPF is actuated with the assistance of slider.

Encoder and Scale: There are two scales X and Y axis which along with the encoder is responsible for communicating coordinate value to the spindle where exactly to drill.

III. METHODOLOGY

Root cause analysis technique

As shown in Fig5 all the potential causes for the occurrence of single hole offset are listed. Around 12 causes were identified and the probable causes were classified in to four categories.

- Machine related defects.
- Improper method used for drilling.
- Fault approach by man.
- Defects caused by materials.

Cause and effect diagram

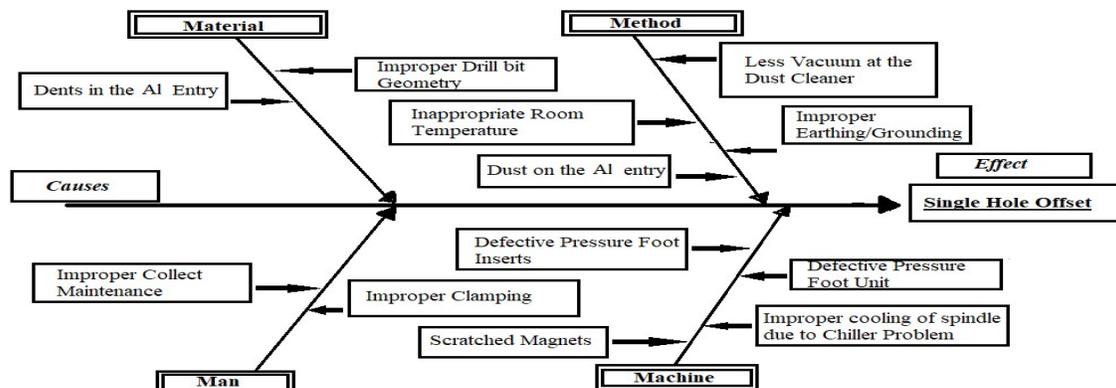


Fig5: Probable causes for single hole offset



Reduction of single hole offset

All the probable root causes recorded in the cause and effect diagram was analysed, the defects those causes will bring into the process has been listed below and the corrections to overcome the causes is also discussed

Cause	Effect	Correction
Defective collet	When the collet is defective, it is impossible to hold the workpiece in a fixed position which further results in shifting of holes.	Regular collet maintenance
Damaged pressure foot units	Damaged pressure foots will lead to vibration of the spindle during drilling leading to Drill bit deflection which will result in the single hole offset defect	Check for pressure foot defect units frequently
Damaged Pressure Foot inserts	The Damaged IPF will give poor support to the spindle collet leading to deflection of the drill bit which will result in Single hole offset defect	Ensure drill bit inserts are not broken, worn out or damaged.
Less vacuum in dust cleaner	The dust from drilled laminates needs to be sucked, if left untouched they cause accuracy issues which lead to single hole offset.	The vacume level must be > 50cm of water
Improper Cooling of spindles due to Chiller Problem	The spindles will be operating at high Rpm, chilled water helps to maintain the expansion and contraction of spindle rotor.	Chilled water must be supplied at 20 ⁰ c(±2 ⁰ c) and flow rate > 50liter/min
Scratched magnets	Linear and servo motors travels on the magnet. Scratched magnet hinders their movement. Magnets can be scratched from dust laminates or broken drill bits. So its important not to use scratched magnets	Check for the scratches in the magnet
Inappropriate room temperature	The panels are made of copper, so there are possibilities of expansion and contraction	Maintain the room temperature at 22 ⁰ c(±2 ⁰ c)which is ideal for copper
Earthing/ grounding	Static accumulation of charge causes fluctuation in DC volts where the encoder and scale will be affected and inturn the precision and accuracy gets impacted which results in single hole offset	Proper earthing/grounding need to be maintained and monitered every month

Check list

To ensure that all the corrections made during the study is properly followed, a check list has been designed. A check list is a fool proof tool to minimize the defect.

All the required parameters of the causes is listed in the check list along with their specification The frequency with which the parameters need to be checked is also stated.

Any operator within the drilling department at the beginning of their respective shifts should check whether the parameters are matching the specification mentioned in the check list based on the frequency



IV. EXPERIMENTAL RESULTS

The check list was followed over a period of 3 months and the result is very much evident as shown in Fig6. Single hole offset from an average of 846 PPM has been reduced significantly by 350PPM to 496PPM. By following the checklist, occurrence of single hole offset has been condensed by more than 41%.

Month	Starting sq m	Defect sq m	Ppm
Jan 2020	34985	18.64	532.7997713
Feb 2020	34752	16.48	474.2173112
Mar 2020	35684	17.14	480.3273176
Average	105421	52.26	495.7266579

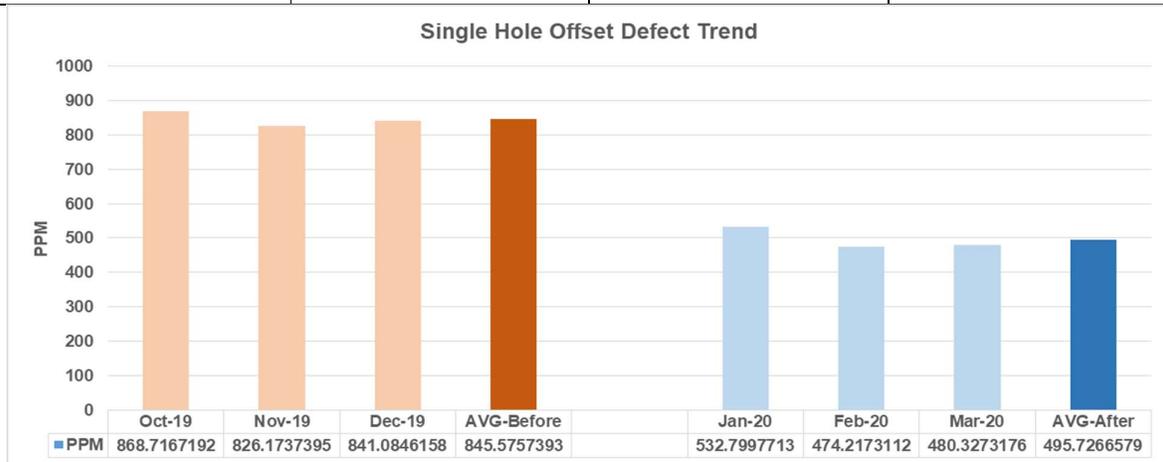


Fig6: Reduction of single hole offset

Project input	Previous defective / quarter	New defective / quarter	PPM reduced	Net sq m savings / quarter	Cost per net sq m	Cost savings/ quarter (INR)
Reduction of single hole offset	846PPM	496PPM	350PPM	52.53 sq m	9100	478,023

V.CONCLUSION

Scrap loss problem is a major problem in industries and single hole offset is one of the defect which is difficult to detect. Using root cause analysis technique, some of the causes of single hole offset were identified, corrections were made which lead to the reduction of single hole offset significantly and also decreased the scrap loss which was caused by single hole offset.

Using the check list as a fool proof tool it ensures that all the corrections were made during the study is properly followed and necessary corrections for the parameters will be fulfilled. Thus the production of scrap has been reduced which saves a lot of time, labour cost, material cost and equipment cost.



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