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A Review of Through-Hole PCB Component Placement and In-Line Repair Processes in the Manufacturing of Industrial Variable Frequency Drives

MSc Industry 4.0 Advanced Manufacturing

Introduction to Industry 4.0

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Assignment 1 – Written Report

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Introduction

This report aims to critically analyse two processes within the current manufacturing system. The chosen processes are:

1. Through-hole technology component placement into PCB at first station.
2. Repair of products failing production test.

By undertaking this task, we can gain insight into how efficiently these processes are performing and if they are still fit for purpose for the current products that are produced. Where there is room for improvement, industry 4.0 technologies will be recommended where such innovations can be fully utilised to mitigate any loss of efficiency and waste.

Background

Process 1: Through-hole technology component placement into PCB at first station

One of the most critical sub-assemblies of a variable frequency drive (VFD) is the printed circuit board assembly (PCBA). These have been carefully designed to be a modular platform so that the fewest printed circuit boards (PCBs) can be assembled into many variants to account for power rating, phases and products. This is done by having PCBAs procured with only the surface mount technology (SMT) components populated onto the PCB and then any difference in design is determined by the through hole technology (THT) components and links fitted by operators within our own facility.

An example of this can be seen in figure 1, where the operator places the PCB into the solder jig at the first station and manually scans the serial number of the VFD that is being produced into the computer. Scanning this will load the associated PCB build manual from the manufacturing database onto the screen to guide the operator where to place the components that have also been provided in the kit box along with the PCB. There can be multiple pages to one manual, of which these pages have a page delay that can be manually assigned so that the pages can turn automatically, if the operator wishes they are able to scan a back or next page barcode to review the information. Once all of the components have been placed they can place the soldering jig onto the conveyor that will then pull the jig into the wave solder machine for soldering the components into place.



Figure 1. Photo of the through-hole technology component placement station.

Process 2: Repair of products failing production test

Upon completion of a fully assembled VFD, the final product immediately undergoes a full functional test. In the event of a failure during testing, the label maker that prints the labels for the product box will instead print a fail ticket that states what has failed, any measured values and the associated result tolerances. The operators are able to press a button on their work station that call for a technician to their location via a pager. Depending on the nature of the failure the technician may be able to resolve the problem in-situ, if not, the product will be taken away to the repair bench so the operator can continue with their duties.

Once at the repair bench, the technician will inspect the product and has access to tools, equipment and circuit schematics in order to facilitate repairing the fault. After the fault has been repaired the technician is required to scan the product serial number into the repair computer program and input what repairs were carried out. This repair information is then stored into the manufacturing database, only then will the test station allow the product to be retested.

Although the product has been repaired, depending on the work load of the technician they may return the VFD to an operator in a fully assembled state ready to be retested or disassembled, requiring the product to be rebuilt.

Procedure

Much of the investigation regarding the two chosen process will be based on collected historical data, observation and experiences of the manufacturing team as well as feedback from the production operatives. At very stage along the whole production process data is recorded into the

manufacturing database in order to achieve a comprehensive traceability of all products. This data will be reviewed from February 2022 to highlight the latest common issues that effect overall efficiency of these processes and the wider implications they have on the production system as a whole.

Findings

Process 1: Through-hole technology component placement into PCB at first station

Reviewing the end of line functional test data and repair comments for February 2022, there was a total of 211 products that failed during the end of line functional test as a direct cause of errors during the component placement and soldering. Figure 2, shows a Pareto chart that represents a the individual areas within the in-house soldering process that were attributed to the cause of these failures. The green bars within figure 2 show the areas which are a direct cause of component placement of which the top 4 most common issues account for 76% of these failures. Although this data has originated from

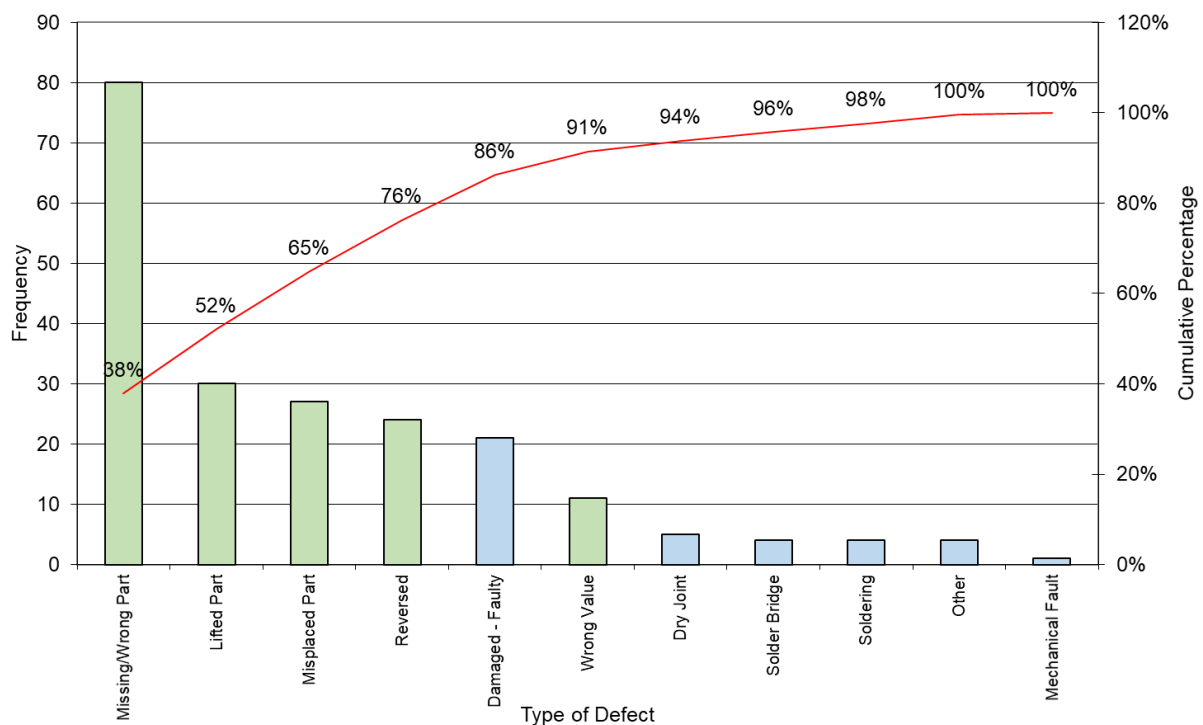


Figure 2. Pareto chart showing the breakdown of first station failures.

From speaking directly to the operators, they sometimes find inconsistencies within the PCB build manual instructions where component descriptions and images are not up to date. This requires the manufacturing team constantly manually updating the build manuals whenever there is a part change. This has caused operatives to often question if what they are doing is correct and if the parts they have received in the kit box are also the correct component, value or quantity. Within the kit boxes that the operatives receive there is no method to separate the components. Although there are partitions, components are randomly placed into the box from the previous process.

Process 2: Repair of products failing production test

Technicians will use their own experience when repairing drives, however, this results in no standardised why of approaching faults, with every technician having their own method. The

technicians will often share knowledge between themselves which is effective when dealing with known faults, but when there is a less obvious issue the time to fault find dramatically increases. For example, if a wrong value resistor has been soldered to the PCB, it is not necessarily obvious at first sight. In the meantime, the production line may have stop producing that product until the fault is found in order to not produce more fault which could result in scrapping material and parts. This delay could have huge efficiency consequences.

When handing back repaired drives to the operators in a disassembled state, on occasions there is a lack of communication. This can cause confused for the operator in regards to where they should restart the assembly from, it is often the case that a step is missed causing the product to fail yet again at the testing stage, and the cycle starts over.

Conclusion

Based on the findings of this report, it has been observed that the greatest factors in loss of efficiency within the two processes is basic human error, lack of training and sometimes an undefined process in which to follow when the process strays from what is the norm. To drive these changes the existing data that is held within the database needs to be extracted utilised in way to begin building a holistic picture of how these processes work and their effect on the wider production environment.

Recommendations

To assist the operatives in placing components computer vision could be utilised in order to “buddy check” that the correct part has placed. Machine learning frameworks such as Tensorflow can now allow developers to train and deploy their own neural networks (TensorFlow, 2022). This will train an algorithm to make the decision making process for the presence of a component that would limit the amount of production failures. Arduino has recently also joined these technological developments and released the Arduino Pro Mini Vision which incorporates a 2MP camera and suite of sensors, and processor onto a single PCB which greatly lowers the prerequisite knowledge level required to get started with machine learning applications (Arduino, 2022). This technology could be implemented passively so it does not distract the operator or it would be integrated into an augmented reality (AR) or virtual reality (VR) user interface to improve the operators accuracy and simplify how data is conveyed to the operator. Companies are already applying this technology to improve existing factory processes and improving the usability of tools (ABB, 2019). This could be delivered through glasses or headset but also a regular display (Gilchrist, 2016). Elements of AR and VR could also be combined with a digital twin of both of the processes described above. This would involve creating a virtual model of the hardware required to perform these tasks (IBM, 2022). Using digital twins in this manner we would be able to provide training and also standardise how the processes are carried out whilst also testing new processes before they are rolled out into production.

References

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