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Improvement of an automatic wire feeding machine in a de-soldering process

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Abstract

This paper presents the de-soldering process for rework of hard disk drive head stack assembly (HSA) units. An automatic wire feeder was used to place tin (Sn) onto the product. Improper feeding was determined to be one of the major causes of defective parts that had excessive amounts of Sn on the HSA. The defective parts due to the excessive amount of Sn were found to exceed 30% of production, which led to increased processing time and costs, since additional cleaning steps were needed. From the analysis, the major causes of excessive Sn were: 1) improper cutting of the wire, 2) inappropriate sizes and types of soldering materials, and, 3) inconsistent handling of the de-soldering process. This paper proposes approaches to address these three problems. First, the automatic wire feeding machine used in the de-soldering process was adjusted to properly cut wires into the flux core area. Second, the types of equipment and materials used in de-soldering were changed and optimized. Finally, a new standard method for operators, which could be easily controlled, was developed to allow consistent handling of the de-soldering process. After these process controls and machine adjustments were implemented, these excessive Sn related problems were significantly reduced. Sn contamination was found to be lowered by 41%. The cycle time was also found to be reduced by an average of 15 seconds.

Keywords: Automatic wire feeder, Flux, Tin, De-soldering process, Rework process

1. Introduction

This study deals with Head Stack Assembly (HSA) failures from disk drive units and the subsequent rework required to restore the HSA for use and re-assembly back into the hard disk drive (see Figure 1). This process is called the "rework process". Current Sn contamination levels from the rework process exceed the specification. The three major processes that are likely to cause Sn to exceed the specification are the de-soldering, reflow soldering and dip cleaning processes. Process mapping evaluation shows that the De-Soldering process contributes more particles than any of the other processes (see Figure 2). Therefore, this paper will focus on improving the de-soldering process [1-4] in order to reduce Sn value of rework units.

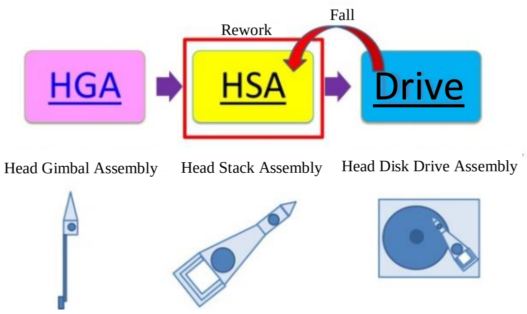

Figure 1 Hard Disk Drive process flow

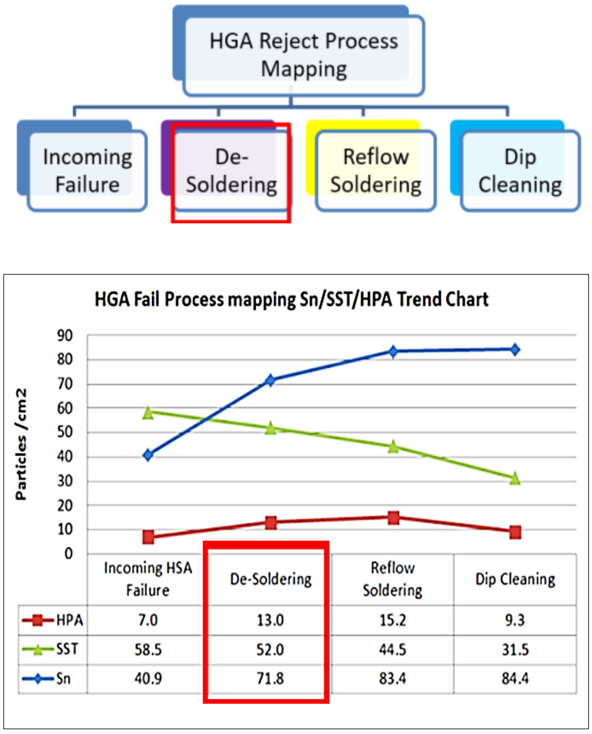

Figure 2 Sn value of rework unit process mapping

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2. Problem statement

Sn contamination is measured by counting the number of particles per cm². Sn is the major element, excluding the flux, that is used in lead-free solder wire. The particle count is determined by using a Liquid Particle Counter (LPC). The upper specification limit for the process is 250 Sn particles/cm². If the number of particles is more than the upper limit, the parts need to be cleaned after re-soldering by using a Foam Swab with isopropyl alcohol (IPA) until the operator does not see any remaining Sn residue when using a 30X microscope.

The overview of the de-soldering process station is shown in Figure 3. A key component is the auto wire feeder machine (see Figure 4), which should serve to cut the lead-free solder wire between to 1/3 and 2/3s of the diameter of the wire. Then the component is re-soldered to the circuit connection. If the wire is not cut all the way into flux core area (see the cutting pass/fail criteria in Figure 5), the solder flux will not flow out properly during heating. If the flux cannot flow out properly, the temperature difference between the wire and the core can cause high pressure inside the flux that results in the flux exploding and solder splashing on the workpiece. Thus, having a machine that can consistently cut the wire in the correct manner as part of the feature set could help reduce both the amount of Sn contamination and the follow-up cleaning time.

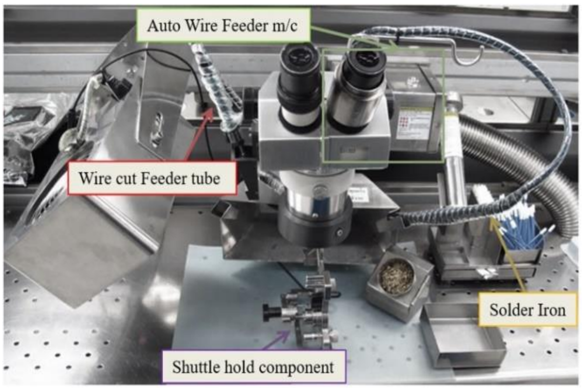

Figure 3 Overview of the De-Soldering process station

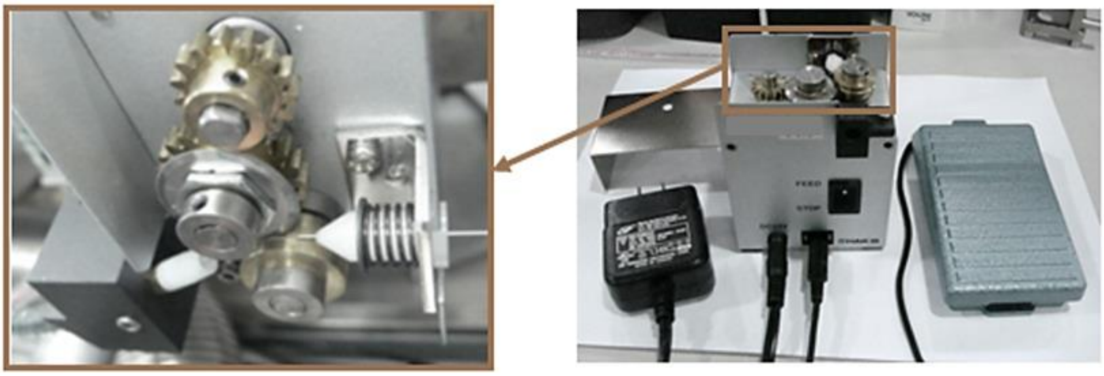

Figure 4 Auto wire feeder machine

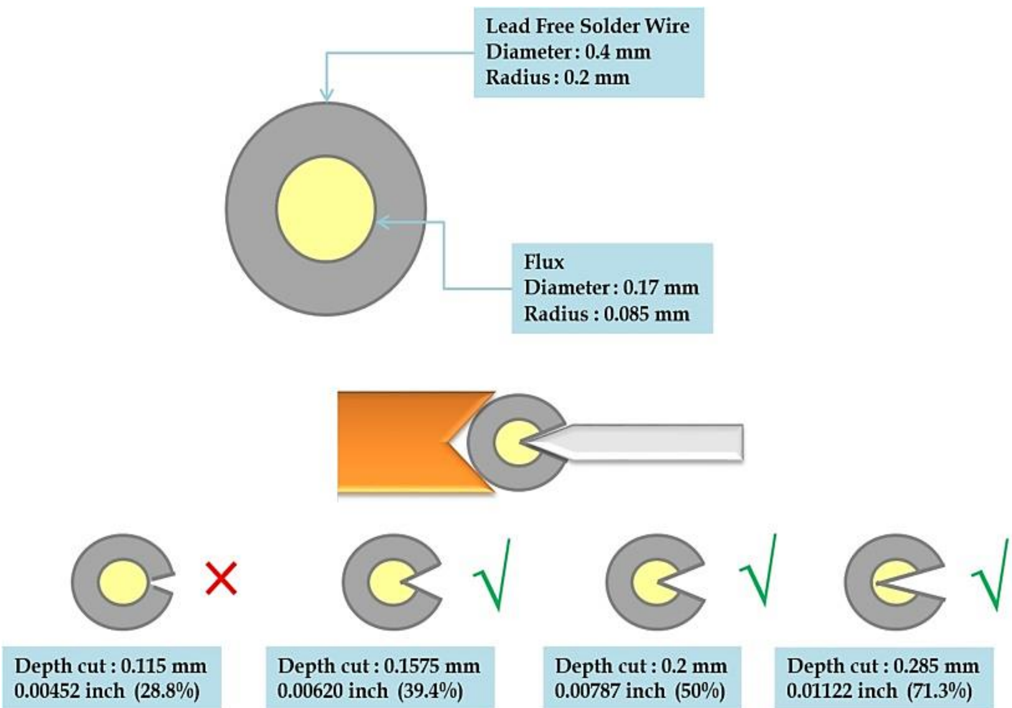

Figure 5 A sample of pass and fail characteristics of lead-free solder wire cutting

Table 1 Failure Mode and Effects Analysis (FMEA) score of an Auto Wire Feeder (S = Severity, O = Occurrence, D = Detection)

Problem	Failure Mode	How to Fix	S	O	D	RPN
Machine	Gap Blade and Groove not match with wire diameter	Adjust Gap to match with wire dia. 0.4 mm	9	7	7	441
Equipment	Use one Solder Iron Type	Smaller Solder Iron for a small pad	7	5	7	245
Method	No standard Soldering method	Find a suitable method for Soldering	5	7	5	175
Material	Use one Flux Type	Find a better Flux Type	3	5	5	75

Failure Mode and Effects Analysis (FMEA) [5] is used to explore causes of Sn contamination due to the auto wire feeder. Table 1 shows the top Risk Priority Number (RPN) score of 441 coming from the machine not being able to cut the wire per specification. This is followed by type of soldering iron, soldering method and flux type, which received RPN scores of 245, 175 and 75, respectively.

3. Methodology

3.1 Machine adjustment

The FMEA of Sn contamination due to the auto wire feeder shows that adjusting the machine is needed to fix the problem. The distance between the blade tip and wire groove was calculated by using trigonometry theory in particular, Similar Triangles and the Pythagorean Theorem [6]. The details of the parameters being measured (see Figure 6) and the functional variables are as follows:

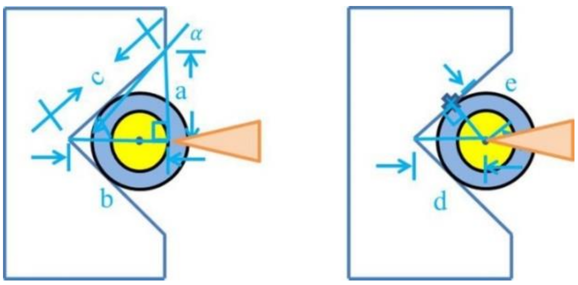

Figure 6 Details of Parameters

3.1.1 Parameters

- a Opposite of Wire Groove slot Height dimension
- b Adjacent of Wire Groove slot Width dimension
- c Hypotenuse of Wire Groove slot
- α Wire Groove angle from center of solder wire
- d Distance from Blade Tip to deepest point in the Groove
- e Solder Wire Core Center to circle tangent

3.1.2 Functional variables

$$0.6^2 + 0.5^2 = c^2 \quad (1)$$

$$\sin \alpha = \frac{0.6}{0.78} \quad (2)$$

$$\sin 50.28 = \frac{0.2}{d} \quad (3)$$

$$\cos 50.28 = \frac{0.26}{e} \quad (4)$$

These calculations help determine the right depth of the cut, which indicated that the distance between the wire groove and the tip of the blade should be adjusted from the current spacing of 0.424 mm to a new spacing of 0.407 mm (see Figure 7). Per these calculations, the machine was then adjusted in order to get the distance to 0.407 mm.

Figure 7 The distance of blade and wire groove slot (a) before and (b) after adjustment

Wire cut characteristics were observed under a microscope (30X) comparing before vs after machine adjustment (Figure 8).

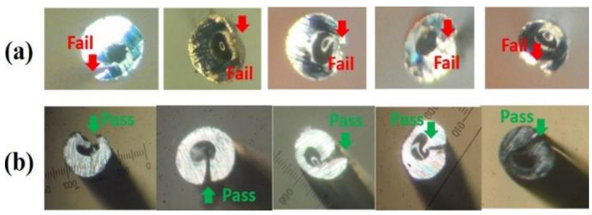

Figure 8 Wire cut characteristic under micro scope (30X) compare (a) before and (b) after machine adjustment

The resulting LPC data showed that Sn particles were reduced by 12% after making the adjustments to the cutting depth (Figure 9).

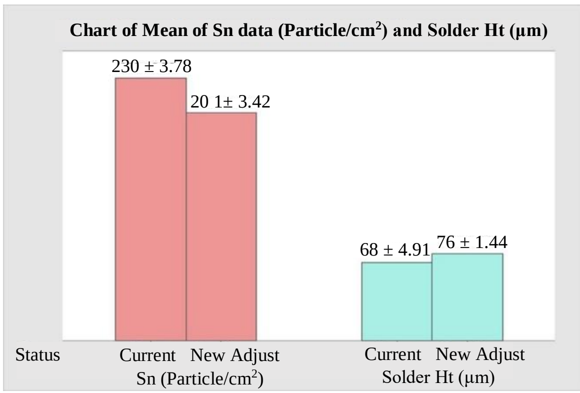

Figure 9 Chart of mean of Sn data (Particles/cm^2) and Solder Ht value (µm)

3.2 Solder iron and soldering method

The current process uses a soldering iron with a tip size of 1 mm. This size is so large that the tip will sometimes contact more than one solder attachment pad during the re-soldering process. Changing the tip size to be 0.1 mm, which is less than the 0.1778 mm spacing between the solder pads, may reduce the risk of accidentally touching more than one solder pad (see Figure 10).

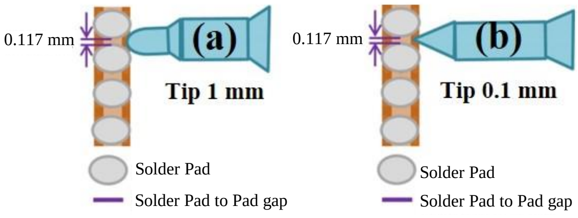

Figure 10 Comparison of Soldering Iron Tip (a) 1 mm and (b) 0.1 mm to pad to pad gap

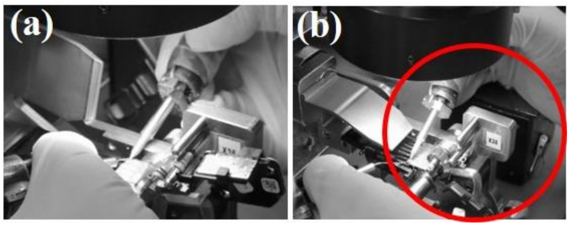

Figure 11 Method of solder refill with soldering Iron on a de-soldering process (a) 10 degrees and (b) 30 degrees

The current soldering method involves having an operator elevate a soldering iron at about a 10 degree angle, which is the most comfortable position for the operator. From process analysis, the angle of soldering iron may affect the Sn contamination. Therefore, different soldering iron elevation angles were observed to see if they would impact the Sn contamination. Since a change in soldering angle might not be a natural and comfortable position for the operator, a fixture was designed (circled in red) to help the operator hold the soldering iron comfortably at an angle of up to 30 degrees (see Figure 11).

3.3 Material

The current wire comes from Vendor K and contains an organic flux type. This wire has shown excessive solder splashes in the current process. An alternative solder wire from Vendor I, which contains a resin type flux (see Table 2), was evaluated to compare the performance.

Table 2 Lead-Free Solder Wire of two vendor comparison

Detail	K Wire	I Wire
% Tin (Sn)	95.8%	95.8%
% Silver (Ag)	3.5%	3.5%
% Copper (Cu)	0.7%	0.7%
Flux Type	ORH1 (Neutral Organic Water Soluble Flux)	REH1 (Resin Water Soluble)
Diameter	0.4 mm	0.4 mm

In addition to adjusting the machine to the desired position, other factors that cause high Sn contamination come from methods, equipment and materials. Experimentation is done to find the best procedure for the de-soldering process. Figure 12 show all experiment alternatives.

4. Results and discussion

The major objective of this study was to reduce Sn contamination, as measured by the number of Sn particles per cm^2. However, there are other factors that must be observed to select best alternatives for solder height and the cleaning process [7-8]. For solder height, the solder heights of reworked workpieces should be close to the solder height of the prime material, which is 98.25 µm. For the cleaning process, to the goal is to have minimum cleaning time and cost.

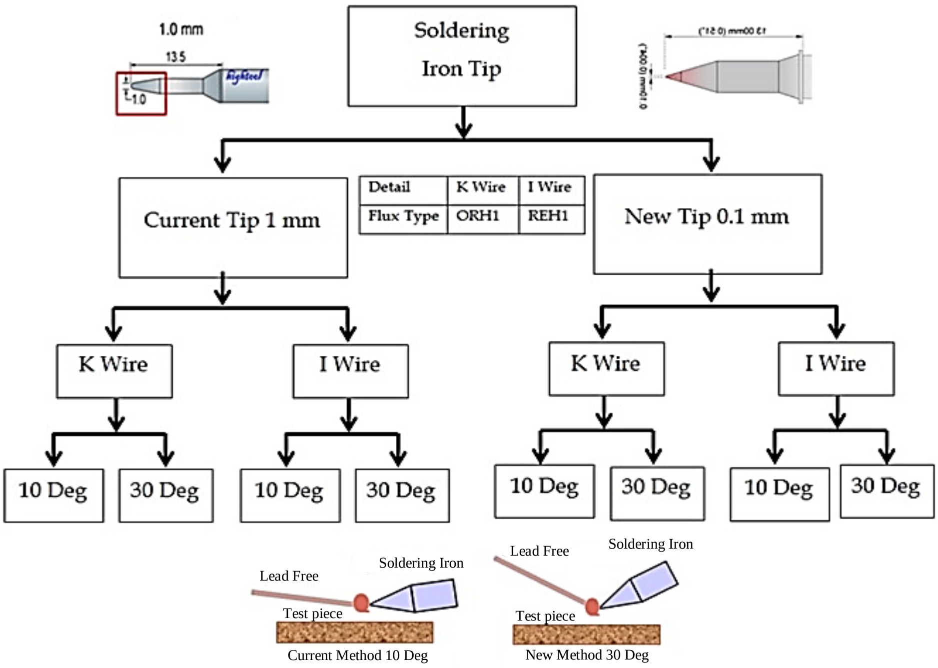

Figure 12 Experiment process Flow chart

The current de-soldering process generates an average of 230 particles/cm² with a solder height 68 µm and re-soldering cycle time including cleaning of 70 seconds. The experiment consists of 8 alternative groups of 8 head stacks in each group. The total of 64 head stacks are used in the experiment. Within each group of 8, 3 head stacks are selected for solder height measurement. Each head stack contains 12 solder pads, so 36 solder pads are tested in each experiment. Other different 3 head stacks from each group of 8 are selected for Sn contamination measurement. All of head stacks are then clean.

4.1 Solder height

The solder heights of each experiment groups are compared with the prime (non-reworked) parts to see which alternatives are close to the prime material (Figure 13). The average of solder height of the prime material is 98.25 µm. The solder height specification is between 65 and 135 µm. If the height is out of specification, it will be rejected. For example, in this experiment, the group with tip size of 1 mm, solder wire from Vendor K and solder angle of 10 degrees is shown to be out of specification in Figure 14 (in circled). The alternative that has the best result is the 0.1 mm soldering iron with wire from Vendor K using a soldering angle of 30 degrees, which has the highest solder height average of 90.69 µm. The next best alternative is the 0.1 mm soldering iron using wire from Vendor I and a soldering angle of 30 degrees, which has solder height average of 87.65 µm.

4.2 The number of Sn particle/ cm²

The results of a using a soldering iron with a 0.1 mm diameter with wire from Vendor I and a soldering angle of 30 degrees has an average of 130 Sn particles/cm², which is the lowest amount observed during the experiment. The second best condition is using a 0.1 mm diameter soldering iron and solder from Vendor K with a soldering angle of 30 degrees. This alternative shows an average Sn of 135 particles/cm² (see Figure 15).

4.3 Cleaning process

The amount of consumable cleaning materials (isopropyl alcohol-IPA, and foam swabs) representing the cost per unit were also evaluated during the comparison of the wire between the two vendors. The IPA and foam swab usage were found to be higher when using the wire from Vendor I. The IPA usage is 40% higher. At the same time an average of 2 more swabs were used per unit. In addition, the increase of cleaning material usage also corresponds to a higher cleaning time, which increases the cycle time per unit on an average of 15 seconds.

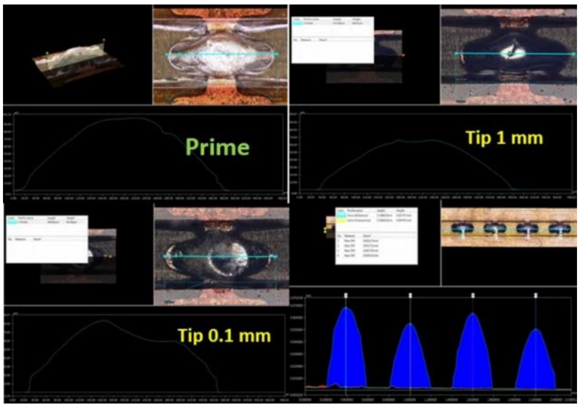

Figure 13 An example of the measurement method and characteristic of Solder Ht

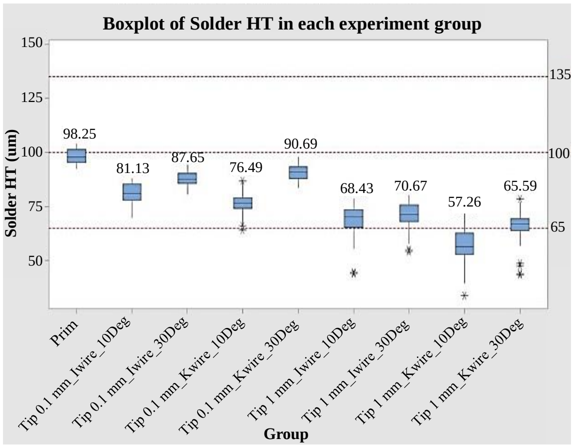

Figure 14 The results of the Solder Ht data in each experiment group compared with Prime data

Table 3 Summary table of each experiment group

Group			Ranking		
Tip	**Wire Vendor**	**Method**	**Solder Ht**	**Sn**	**Cleanliness**
Tip 0.1 mm	I Wire	30 degree	2	1	2
Tip 0.1 mm	K Wire	30 degree	1	2	1
Tip 0.1 mm	I Wire	10 degree	3	3	3
Tip 0.1 mm	K Wire	10 degree	4	4	4
Tip 1 mm	I Wire	30 degree	5	5	5
Tip 1 mm	K Wire	30 degree	6	6	6
Tip 1 mm	I Wire	10 degree	7	7	7
Tip 1 mm	K Wire	10 degree	8	8	8

Table 4 Summary table compare the current process and selected group

Parameter	Before	After	Spec	Improvement
Solder Height (µm)	68	90	100±35	33%
The number of Sn (particle/ cm²)	230	136	<250	41%
Cleaning Process (sec)	70	55	-	15

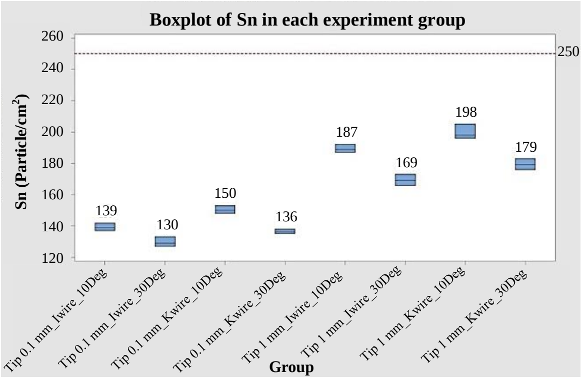

Figure 15 The Sn values results of each experiment group

Each of the experiment alternatves werer ranked across the three categories of Sn particle count, solder height and cleanliness (Table 3). The combination using a 0.1 mm soldering iron with wire from Vendor K and a soldering iron angle of 30 degrees scored the best for both solder height and cleanliness as compared with prime material. Although the average Sn particle count is not the lowest, it is close to the group with the lowest average Sn value, which is an acceptable result.

After adjusting machine, process and material, the solder height increased by 33%, which brings all parts into specification, Sn contamination was reduced by 41% and cycle time was reduced by an average of 15 seconds (see Table 4).

5. Conclusion

This research presents an approach to improve the machine, equipment, raw materials and methods in order to reduce both the time to clean parts and the amount of Sn particles resulting from the de-Soldering process. The calculations show that adjusting the distance between the blade and wire groove slot so that the blade cuts into the flux core of the lead-free solder wire core by 1/3 to 2/3 of the way into the wire, requires changing the distance from 0.424 mm to 0.407 mm for a wire with a diameter of 0.4 mm. In conjunction with changing the blade distance, changing the size of the tip of a soldering iron from diameter of 1 mm to 0.1 mm, will reduce the chance of the iron tip touching adjacent solder connection points during the rework process. Increasing the angle between the soldering iron and unit part will reduce the amount of solder remaining on soldering iron tip. This makes the components have solder heights that are close to with a prime unit. As for the type of lead-free solder, the evaluation showed that using wire with an organic flux type resulted in parts that are easier to clean than if a resin type flux is used. This can help to reduce the cleaning cost.

6. Acknowledgement

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7. References

[1] Arra M, Shangguan D, Yi S, Thalhammer R, Fockenberger H. Development of lead-free wave soldering process. IEEE Trans Electron Packag Manuf. 2002;25(4):289-99.

[2] Aziz M, Abdullah M, Khor C, Ani F, Adam N. Effects of temperature on the wave soldering of printed circuit boards. J Appl Fluid Mech. 2016;9(5): 2053-62.

[3] Carlos L, Aldea P, Brown M. Innovated soldering iron with desoldering vacuum. Int J of Mech Ind Tech. 2016;4(1):1-7.

[4] Wang C, Zhao W, Wang J, Chen L, Luo C. An innovative approach to predict technology evolution for the desoldering of printed circuit boards. Waste Manag Res. 2016;34(6):491-501.

[5] Stamatis D. Failure mode and effect analysis. Milwaukee: ASQC Quality Press; 1995.

[6] Zhmud′ L, Windle K, Ireland R. Pythagoras and the early pythagoreans. Oxford: Oxford University Press; 2012.

[7] Guth LMorris J. No-clean soldering processes. AT&T Tech J. 1992;71(2):37-44.

[8] Okuya K. Flux and solder paste used in soldering and cleaning method of their flux residues after soldering. Circ Tech. 1991;6(5):288-95.