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Reducing the Cost of Welding Paste in the Surface Assembly Technology (SMT) Process

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***Keywords*— Surface Mounting Technology, Welding process, Costs.**

***Abstract*—** *The Surface Mounting Technology (SMT) industries have overcome many challenges over the past few years with regard to their position in relation to environmental issues and cost reduction. One of the concerns lies in the fact that the welding procedures for electronic components incorporate lead, which poses risks to operators involved in the production processes, as well as a high value in the cost of solder paste. The most common alloy is lead free, it is a tin-based alloy, which replaces lead with 3.9% silver and 0.6% copper. The alloy is known as (SAC) Sn3,9Ag0,6Cu. The material is applied to the process used in the manufacture of about 70% of the computer boards currently produced. The need to migrate welding processes to this new type of technology requires companies to adopt a strategy of change appropriate to the maintenance of current processes and their gradual replacement by lead-free welding processes and their implications for costs. The main objective of this dissertation is to present the development of the solder process in local paste in order to reduce production costs, maintaining the quality and reliability of the product, especially the main plates of Televisions. This study, in addition to presenting a bibliographic review involving the SMT process, will explore the concepts about the types of solder pastes so that the reader can have a better understanding of what will be proposed as well as, the description of the case study in a factory in the Manaus Industrial Pole (PIM). The results show that the local industry seeks in a planned and consistent way to process innovations and process cost reduction. The cost reduction mainly includes the reduction in the cost of raw material, the main competitive advantage of Chinese companies, usually 30% cheaper than that of competitors (despite the inferior quality). It is concluded that it is possible to evidence the significant reduction in the costs of solder paste in the process of surface assembly technology (SMT) with its manufacture made locally, reducing transportation cost, importation costs and stock (transit and factory).*

I. INTRODUCTION

new standards for the control and elimination of substances considered harmful to the environment have been edited, causing several industrial sectors to review projects and specifications in order to adapt to these new standards (TSUNG-NAN, 2012).

One of the concerns lies in the fact that the welding procedures for electronic components incorporate lead, which poses risks to operators involved in the production processes, as well as a high value in the cost of solder paste.

The most common alloy is lead free, it is a tin-based alloy, which replaces lead with 3.9% silver and 0.6% copper. The alloy is known as (SAC) Sn3,9Ag0,6Cu. The material is applied to the process used in the manufacture of about 70% of the computer boards currently produced. For processes that use higher temperatures, there are two other alloys: Sn0.7Cu, a tin alloy with 0.7% copper, and SN3.5Ag, which has 3.5% silver (HWANG, 2014; ALMEIDA et al ., 2013).

The need to migrate welding processes to this new type of technology requires companies to adopt a strategy of change appropriate to the maintenance of current processes and their gradual replacement by lead-free welding processes and their implications for costs.

Manufacturing objectives are to maximize quality and productivity while controlling costs. Therefore, choosing the right solder paste can achieve the highest process consistency and solder quality. The quality of manufacture can be improved by choosing the paste with good performance in the materials, geometry and heating processes used in the manufacture of a product. Yield can be maximized by choosing a solder product that accommodates the ideal deposition and heating methods.

There are several types of weld products with differences in wetting characteristics, void control, flow residues, alloy strength, alloy flexibility and other performance measures that can play a significant role in achieving quality, yield and cost goals (LAURICELLA, 2010).

Alloy requirements must be assessed so that they can meet all product procedures. Flow types must be identified correctly. In the process, flows with unacceptable criteria are removed from consideration. Then, issues such as difficult-to-weld surfaces, rapid reflux conditions, cleaning options and concerns for voiding the weld joint must be considered before choosing a paste (SILVA et al., 2017).

When choosing a solder alloy, note the lead content, the melting temperature, the size of the alloy powder particles and the tensile strength.

Solder paste technology has evolved from water-soluble to the unclean and lead-free to lead-free variant. This technological evolution is driven by miniaturization, cost reduction and legislation that requires the use of lead-free and halogen-free materials. The industry is also gaining more experience with lead-free alloys, with less silver content, lower costs and better performances (KEITH, 2011).

With the increasing precision of electronic products and the trend of lead-free soldering, the components of the adhesive are becoming increasingly minute, so the quality of solder paste printing is becoming increasingly important. Solder Paste Inspection (SPI) can effectively guarantee good solder paste print quality and greatly reduce the possible rate of defects in finished products (LAU, 2018).

The aforementioned author also mentions that the introduction of the SPI can effectively reduce the unqualified rate of the original finished Printed Circuit Board (PCB) by more than 85%; the cost of rework and scrap is greatly reduced by more than 90%, and the quality of manufactured products is significantly improved. As a means of quality process control, quality risks can be encountered in time before reflux welding, so that there is almost no possibility of repair and scrap costs, which effectively saves costs. The combination of SPI and Automatic Optical Inspection (AOI), through real-time feedback and optimization of the SMT production line, can make production quality more stable, significantly reduce the unstable experimental production stage that should be experienced when the new product is introduced and the corresponding cost loss is more economical.

Welding manufacturers today understand their customers' demands and offer a range of solder pastes that can be used at reasonable prices to help the industry manufacture highly efficient and durable electronic items. Only the best weld quality can help the electronics industry to produce products that meet industry standards at a reduced cost (OLIVEIRA, 2012).

Given the above, the following problems arise: What are the materials with indirect costs of transport, taxes and stock that make a new source of raw material viable? Are there reliable local suppliers with adequate quality?

Technological advances have proposed to industries a continuous improvement of their processes. Nowadays you can create new products and send them to the consumer market within the shortest amount of time. This type of process fits very well in the electronics segment as it is a consumer product on the rise and depends directly on technological advances to remain in the market.

In view of the great market demand, companies seek to supply the largest number of products and the shortest time. For most companies, this is only possible with the improvement of the quality of their processes, forcing the production chain to be more efficient, thus minimizing losses resulting from production failures due to non-quality. In this way, it is understood that the continuous

improvement of the production process has as main objective to reduce the losses resulting from operational failures, or not, of the quality of the materials, and this process seeks to reach all the manufacturing sectors.

The Manaus Industrial Pole (PIM) is a model of economic development implemented by the Brazilian government with the aim of enabling an economic base in the Western Amazon, promoting the best productive and social integration of this region of the country, guaranteeing national sovereignty over its borders. Several PIM companies use suppliers who are responsible for the certification of the components used in production. Each component manufacturer bears the costs of certification of its goods and, in order to obtain the final certification report for the finished product, the company should invest in a laboratory for conformity analysis, that is, evaluate the final product and issue a certificate of conformity that certifies the absence or presence, within specific limits, of restricted substances.

It is evident that most of the electronic components have traditionally been welded with the tin and lead alloy, the latter being an element that has high toxicity, whose residues produced during their obtaining and recycling of the alloys can contaminate water, air and the soil and have a high cost.

The results of this investigation and the case study prove the relevance of this study, since the greatest impact will be the reduction of failure rates, elimination of rework costs, increased productivity and reduced industrial costs, among others. In the current global and technological scenario, the development of micro components does not allow errors, under penalty of increasing all costs involved in the assembly and manufacturing process. As a result, organizations increasingly seek excellence in their processes, thus ensuring highly positive results in quality indicators.

Thus, the main objective of this article is to present the development of the solder process in local paste in order to reduce production costs, maintaining the quality and reliability of the product, especially the main plates of Televisions.

II. MATERIALS AND METHODS

For the development of this research, the methodological procedure was adopted regarding the path taken by the author to achieve the proposed objective. This section will explain the procedures and instruments used to carry out the research.

Qualitative research was used, as this type is not concerned with numerical representativeness, but with deepening the understanding of a social group, an organization, etc.

Nascimento (2008) emphasizes that qualitative research does not seek to enumerate and / or measure the events studied, nor does it use statistical instruments in the analysis of data, it involves obtaining descriptive data about people, places and interactive processes by the direct contact of the researcher with the situation studied, trying to understand the phenomena from the perspective of the subjects, that is, the participants of the situation under study.

Qualitative research is concerned, therefore, with aspects of reality that cannot be quantified, focusing on understanding and explaining the dynamics of social relations.

In order to follow the above objectives, the investigation will combine the different types of investigation through bibliographic, exploratory and descriptive studies, as well as the case study.

This study, in addition to presenting a bibliographic review involving the SMT process, will explore the concepts about the types of solder pastes so that the reader can have a better understanding of what will be proposed.

For Gil (2012, p. 115) "the analysis of documents or analysis of contents consists of the systematic examination of reports or documents as sources of data".

The present research consisted of bibliographic surveys used as a study source for carrying out the work, without the author's interference in the result.

In this way, bibliographic research is one in which primary and secondary documents are used to produce the research.

For Nascimento (2008, p. 37) “the main form of data collection is reading (books, magazines, newspapers, websites, CDs, etc.), which is certainly used for all types of research. This technique is also called bibliographic research”.

An exploratory procedure will also be used, as an integral part of the main research, as the preliminary study carried out in order to better adapt the measurement instrument to the reality that is intended to be known.

According to Nascimento (2008, p. 39) in other words:

[...] exploratory research, or exploratory study, aims to know the study variable as it presents itself, its meaning and the context in which it is inserted. It is assumed that human behavior is better understood in the social context where it occurs.

This type of research aims to provide greater familiarity with the problem, in order to make it more

explicit or to build hypotheses. Thus, the choice of this method is justified according to the purpose of the research, which is to present the development of the solder process in local paste in order to reduce production costs, maintaining the quality and reliability of the product, especially the Televisions main boards ..

Descriptive research requires a lot of information from the researcher about what they want to research.

Gil (2012) points out that descriptive research has as its primary objective the description of the characteristics of a given population or phenomenon, or else, the establishment of relationships between variables.

Descriptive studies can be criticized because there may be an exact description of the phenomena and facts.

As Yin (2010) points out, the use of the case study is appropriate when it is intended to investigate the how and why of a set of contemporary events. The author asserts that the case study is an empirical investigation that allows the study of a contemporary phenomenon within its real-life context, especially when the limits between the phenomenon and the context are not clearly defined.

III. RESULTS

3.1 Process

The main parameters of an effective solder paste printing process are as follows:

- Squeegee speed
- Squeegee pressure
- Squeegee angle
- Stencil separation speed
- Stencil cleaning
- Stencil and squeegee condition
- PCB support
- Printing course
- Type, storage and handling
- Inspection (2D / 3D)

1) Squeegee speed

The speed of travel of the squeegee determines how much time is available for the solder paste to “roll” through the stencil openings and on the printed circuit board pads. Typically, a setting of 25 mm per second is used, but this varies, depending on the size of the openings inside the stencil and the solder paste used.

2) Squeegee pressure

During the printing cycle, it is important to apply enough pressure over the entire length of the squeegee blade to ensure clean cleaning of the stencil. Low pressure can cause paste "stains" in the stencil, low deposition and incomplete transfer to the PCB. Too much pressure can cause “slipping” of the paste from larger openings, excessive wear on the stencil and squeegees and can cause “bleeding” of the paste between the stencil and the PCB. A typical setting for squeegee pressure is 500 grams of pressure per 25 mm squeegee blade.

3) Squeegee angle

The squeegee angle is normally set at 60 ° by the supports to which they are attached. If the angle is increased, this can cause the holder paste to be removed from the stencil openings and therefore less solder paste is deposited. If the angle is reduced, you can leave a solder paste residue on the stencil after the squeegee has finished printing.

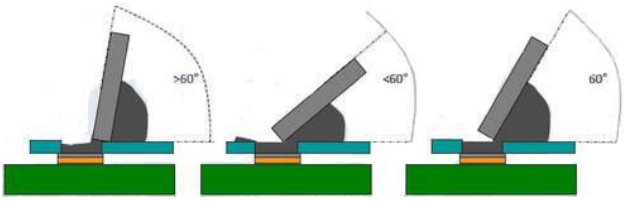


Fig.1: Effect of the squeegee angle.

Source: Case study, 2019.

4) Stencil separation speed

This is the speed at which the PCB separates from the stencil after printing. A speed setting of up to 3 mm per second must be used and is governed by the size of the openings within the stencil. If this is too fast, the solder paste will not be completely released from the openings and the formation of high edges around the deposits, also known as “dog ears”, can be seen in Figure 2.

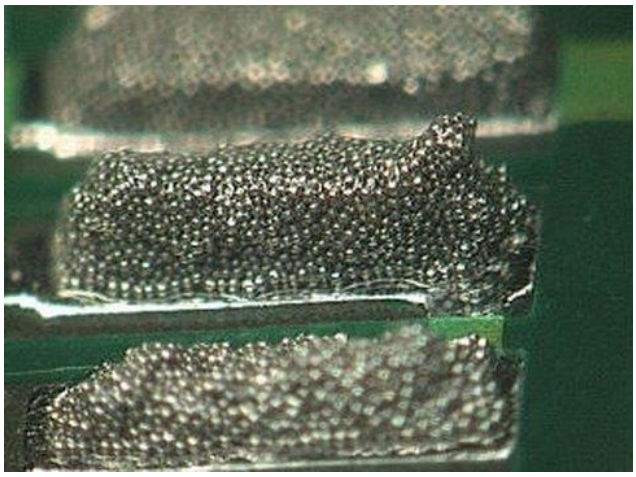


Fig.2: Example image showing high points in the solder paste deposits known as 'dog ears'.

Source: Case study, 2019.

5) Stencil cleaning

The stencil must be cleaned regularly during use, which can be done manually or automatically. Many automatic printing machines have a system that can be configured to clean the stencil after a fixed number of prints using lint-free material applied with a cleaning chemical like IPA. The system performs two functions, the first is cleaning the bottom of the stencil to stop smearing, and the second is cleaning the openings using a vacuum to stop the blockages.

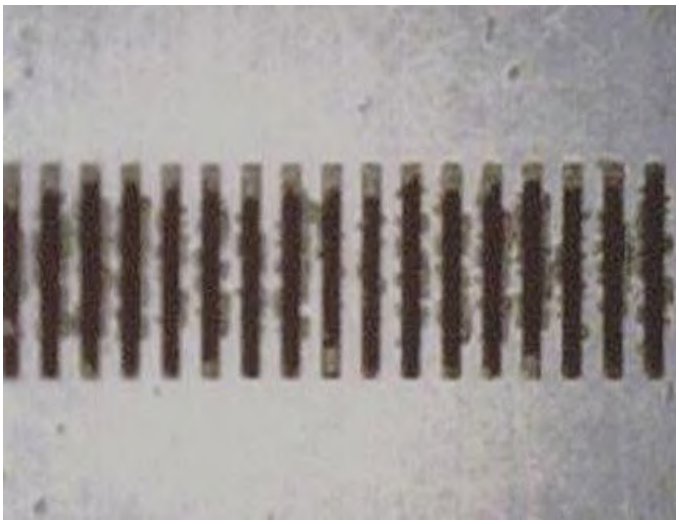


Fig.3: Solder paste 'bleeding' at the bottom of the stencil.

Source: Case study, 2019.

6) Stencil and squeegee condition

Stencils and squeegees need to be carefully stored and maintained, as any mechanical damage can result in unwanted results. Both should be checked before use and thoroughly cleaned after use, ideally using an automated cleaning system to remove any solder paste residue. If any damage to the squeegees or stencils is observed, they must be replaced to ensure a reliable and repeatable process.

7) PCB support

This is an important factor in ensuring that the PCB is kept flat against the stencil during the printing process. If the PCB is not fully supported, it may cause printing defects, such as a paste deposit and bad stains. PCB stands are usually supplied with fixed height printing machines and programmable positions to ensure a consistent process. Adaptable PCB holders are also available with varied designs that mold to the PCB and are useful for double-sided assemblies.

8) Printing course

This is the distance the squeegee travels through the stencil and it is recommended that it be at least 20 mm beyond the most distant opening. The distance after the most distant opening is important to allow enough space for the paste to roll on the return stroke, as it is the rolling of the solder paste bead that generates the downward force that directs the paste into the openings.

9) Type, storage and handling

The solder paste is essentially a powder solder suspended in a thick medium called a flux. The flux acts as a temporary adhesive, holding the components in place until the welding process melts the weld and forms the electrical / mechanical connection.

Solder paste is a 'thixotropic' material and requires energy to be applied in the form of movement of the print head to change viscosity and flow evenly through the stencil openings. A frequently used term is solder paste 'rheology', which describes how solder paste forms a block when no energy is applied, but changes to a more fluid material when energy is applied.

10) Inspection (2D / 3D)

To verify the process, automatic inspection can be used to accurately check for solder paste deposits. There are two types of solder paste inspection available: 2D inspection that checks the paste deposit area and 3D inspection that checks the volume of the paste deposit.

3.2 Approval methodology for solder paste used

The qualitative and quantitative validation took place due to the defects presented in the welding inspection (SAOI) in PPM, according to the IPC-610 standard.

The measurement method was calculated using the following formula:

PPM = (Number of defects / (plates produced)) * 1,000,000.

3.2.1 Defects considered by the SAOI optical inspection machine:

Displaced - The component must have its terminal up to 50% on an island (Figure 4).

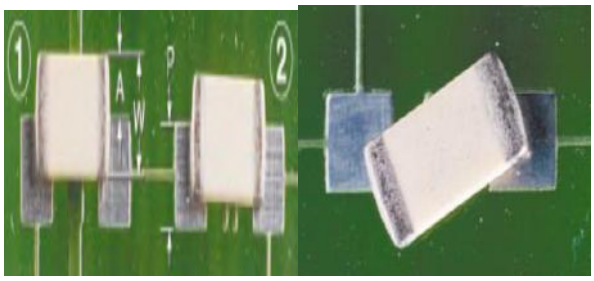


Fig.4: Displaced defect.

Source: Case study, 2019.

Excess weld - The amount of weld may be greater than the size of the component, but it cannot be extend over the component body.

Insufficient solder - The solder did not connect to the component.

Solder ball - Solder balls that can compromise the correct performance of the circuit.

Short circuit - Short circuit, solder connection between two points that should not be electrically connected.

Missing - Missing component.

Component inverted - Component with polarity, mounted inverted.

3.3 Profile of the welding oven

The melting temperature profile is defined by the relationship of temperature and heating time. There are two types of basic temperature profiles: Ramp-Soak-Spike (RSS) and Ramp-to-Spike (RTS). The RTS temperature profile is suitable for most applications to improve weld performance. The temperature profile is appropriate when mounting and has a large thermal mass or a large variation in ΔT.

The temperature profile should be a cross reference between the component manufacturer's recommendation to ensure that the temperature does not exceed the maximum temperature in all materials. It is advisable to check the thermal sensitivity of the components according to the specification of each supplier or to use the IPC-9502, before defining a reflow profile.

As a defined process has already been presented, this means that all these issues have already been verified, it is only necessary to apply the manufacturer's recommendation.

The weld manufacturer recommends a reflow profile for the best welding performance, as shown in Figure 5.

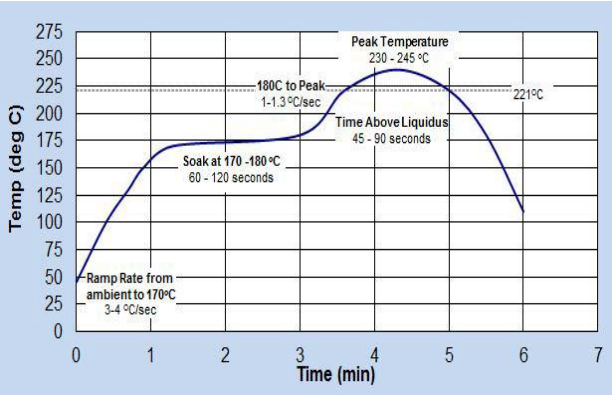


Fig.5: Recommendation of the remelting profile.

Source: Case study, 2019.

Cunha (2013) mentions the types of oven profiles for welding:

Ramp Up: The portion of the profile where the plate is heated from room temperature at a predetermined rate. Controlling the ramp is necessary to prevent thermal damage to components.

Preheat / Soak Time: Time is monitored to ensure thermal balance across the board. The preheat portion is equal to = tsmin to tsmax.

Time Above Liquidus: This is the time that the solder alloy is in a liquid state. The plate must remain at a predetermined time in this phase to ensure that all areas of the plate will be properly fused.

Time Above Peak: Time in which the measured component reaches the highest temperature.

3.4 Local solder pastes

In the case study presented, two folders produced locally were developed, the AIM produced by ALFATEC and ALPHA from Apha Assembly, with international specifications, composition and performance. Table 1 shows the costs per kilogram of the local pulp.

Table 1: Costs per kilogram of local pulp.

UNIT COST (US$)	
AIM	ALPHA
71,5	65

Source: Case study, 2019.

Folders are used worldwide in large companies. Pastes are Lead Free with lead-free composition. The L / F composition is as follows: 96.5Sn / 3.0Ag / 0.5Cu.

It should be noted that the paste imported from Korea used previously was HEESUNG. The FOB cost of this paste is $ 46.56. This cost does not include transportation costs, taxes, inventory costs and services. The cost analysis of this case study was based on an import of 360 kilos of paste. The dollar rate used was R $ 3.6874. The total cost of the weld, considering all expenses, is US $ 92.71. Almost double the FOB value of US $ 46.56, as shown in Table 2.

Table 2: Total expenditure costs

TAX	COST (R$)	TAX	COST (R$)
DI	360 Kg	SEGURO INTERNACIONAL	37,32
II	13.383,80	SUFRAMA	340
PIS	2.007,57	ARMAGENAGEM	554,26
COFINS	9.225,26	DISCONSOLIDAÇÃO	202,81
SISCOMEX	214,5	DESPACHANTE	76,54
FRETE INTER.	33.749,30	FOB	61.812,00
FRETE LOCAL	225,15	FTI	1.236,24
SUB Total	58.805,58	SUB Total	64259,17
TTL DESPESAS BRL	**123.064,74**	TTL DESPESAS USD	**33.374,40**

Source: Case study, 2019.

The savings of this localization process include the difference in the final value of the imported solder paste, the costs of inventory in transit and local in the year value of US $ 698,834.57 in the first year. Economy of local stock and transit considering the value of US $ 92.71 / Kg. Direct daily delivery to the production process (Table 3).

Table 3: Economy of the local stock and transit process.

ESTOQUE	QTDE (Kg)	US$
LOCAL	2.000	185.420,00
TRANSITO	495	45.891,45
TOTAL		**231.311,45**

Source: Case study, 2019.

The annual savings considering the use of ALPHA Solder with a consumption of 1,406 Kg / Month is shown in table 4.

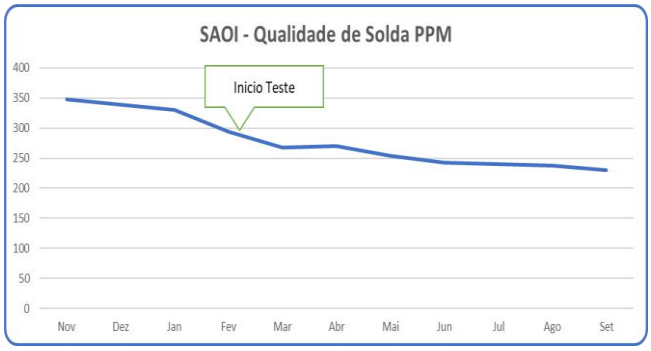
Table 4: Annual savings on the use of ALPHA solder.

Consumo mês (Kg)	Custo HEESUNG (US$)	Custo ALPHA (US$)	Economia mês (US$)	Economia Ano (US$)
1.406,00	130.350,26	91.390,00	38.960,26	**467.523,12**

Source: Case study, 2019.

The test carried out in the process was evaluated according to IPC-610-A Weld quality indicator, automatically evaluated was as shown in the result of graph 1.

Nov	Dez	Jan	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set
348	339	330	294	268	270	254	243	240	238	230



Graph 1: Result of tests performed and Defects in PPM.

Source: Case study, 2019.

IV. CONCLUSION

At the end of the work, it is possible to evidence the significant reduction in the costs of solder paste in the process of surface assembly technology (SMT) with its manufacture made locally.

The solder paste, which mainly serves as a means of connecting the interconnection features of the device and the PCB, is fundamental to the product's performance in an SMT line. The poor impression of the solder paste results in a large number of defects. The components of a solder paste are designed to provide excellent reflow and print characteristics. When choosing a solder paste, it is important for the buyer to ensure that the paste offers long hours of printing, has the right particle size for the tone of the components and is of the appropriate flow type depending on the assembly application.

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