Effect of Joint Configuration and Solder Thickness on the Load Bearing Capacity of Soldered Joints

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Abstract

An investigation of the impact of joint configuration and solder thickness on the strength of joints made using locally produced solder was conducted in this work. This is with a view to ascertaining the strength and reliability of joints made from local solder. Three types of joints (butt. Lap and ring/plug) were studied using the same solder grade and thickness. The results showed that the lap joint has the highest strength (94N/mm^2), while the butt and ring/plug has strength of 85N/mm^2 and 49N/mm^2 respectively. Butt and lap joints have the maximum strength at solder thickness of 0.15mm, while that of ring/plug was observed at 0.20mm solder thickness. Finally, it was observed that joint strength vary greatly with solder thickness and joint configuration. The paper recommends lap joint for soldered joints.

Keywords: Solder, solder thickness, strength, joint and joint configuration

Introduction

The reliability of any joint is a function of the amount of stress it can endure before failure. Solder joint is not an exception. For any joint to be highly reliable it must be able to withstand the load imposed on it. Many factors could affect the performance of joint in service among which include, operating environment, load and method of loading, defects in the joint, joint configuration, solder thickness etc. Soft solders are filler metals for capillary joining with a melting point below 450^{O}C [1]. Solder is mainly use for making joints in the electronic industries and plumbing works. The Romans are known to have used solder to form joint in the plumbing system [2]. Infact, the word plumbing refers to the use of load (from the Latin word plumbium meaning lead) as a joint material. Pure lead plumbing is no longer considered; instead solder which is an alloy of mostly lead and tin and most recent lead free solders aree used. It is interesting to note that some countries have established legislation to prevent lead from being used in any plumbing were drinking water is present [3], [4], [5], because lead gradually dissolves in water and can cause lead poisoning. Lead – tin briary system provides the basis for the production of soft solders. These solders have melting point between 183^{O}C and 325^{O}C. Tin is an expensive metal and so a reduction in the amount used in solder makes cheaper solder. So, a 60% Sn – 40% Pb solder alloy is used in electronic assembly instead of 61.9%Sn – 38.1%Pb (i.e. eutectic composition) [6]. The rapid changes such as the establishment of microelectronic industries, together with the massive introduction of electronic devices into the domestic scene and into process control in manufacturing industries, has resulted in the use of soft solder as a major interconnecting material. The development in solder/soldering technology has mostly occurred in the electronic industries because of the need to ensure high reliability of soldered joints in such applications. Furthermore, the quest for the development in science and technology vis-a-vis sourcing and development of local raw materials has been on the increase in the recent years in our country, Nigeria. In a bid to achieving this different grades of soft solder have been produced from locally sourced raw materials [Ikpeseni and Ovri, 2006]. This work is therefore aimed at investigating the effect of joint configuration and solder thickness on the strength of soldered joints – (butt, lap and ring/plug) made with these local solders. These three types of joints were chosen because they are most frequently encountered in the maintenance/manufacturing process. This is in order to ascertain the strength and reliability of these locally produced solder for design purposes.

Metallurgy of Solder Wetting

One of the requirements of a solder is that it must wet the base material. There are two aspects of wetting. First is the solder's surface tension, which defines how well solder wet a metal. Consequently, one should aim to use solder with as low a surface tension as possible. Second is the cleanliness of the surface to be soldered. If surface is not clean, the solder will not wet, however low its surface tension. When a liquid solder is applied to solid surface, there are three environments that come in contact. They are a liquid (molten solder) a solid (metal surface) and a gas (the surrounding atmosphere). The entire three environments meet at a point. The angle formed between the liquid and solid passing through this point is called 'wetting angle' or 'contact angle' or 'dihedral angle' [2]. This wetting angle is a direct indication of how much the surface of metal has been wetted by the solder. Completely non wetting occurs with wetting angle equal to 180^{0}, for wetting angle between 0^{0} and 180^{0} there is partial wetting. Dewetting occurs when solder initially wets a metal surface, and then withdraws before solidifying as temperature falls below melting point. Finally, total wetting occurs when wetting angle is 0^{0} [3].

The requirement for wetting by solder has necessitated more in-depth studies of the wetting process. The trend in those works had been to make use of measurement of the force acting on a specimen as it is immersed in the solder becomes wetted by the liquid solder i.e. using a surface tension (wetting) balance. Takashi and Nagasawa [7] showed that wetting rate of solder as determined by a surface tension balance increased with tin content. They also reported that wetting rate was sometimes related to equilibrium spreading of solder. Latin [8] worked on the area of spreading of solder on a surface. He found that near eutectic, led – tin solder had the greatest spreading whereas penetration into a vertical capillary space formed by the same surface was greatest for pure tin.

The effect on wetting rate of the surface roughness of the rest samples was examined by Warwick and Rubin [9] using stainless steel and by Judd and Brinidley [6] using tin plate specimens and these workers reported that an inverse relationship existed.

Materials and Method

Materials

Materials used in this work include: soft solder, mild steel, flux, copper wire, water, universal testing machine, soldering bit, solder bath, etc.

The solder used for producing the joints was produced from locally sourced raw materials [1]. The alloying elements (99.5%Pb and 99.9%Sn) used for the production of the soft solder were got from project Development Authority (PRODA), Enugu.

METHODS

Ring and Plug Joint Preparation

An 18mm diameter mild steel rod was cut into twenty four pieces of 5mm lengths. These were drilled and reamed to produce a ring with an internal diameter 10mm. Copper wires – 0.05mm, 0.10mm, 0.15mm, 0.20mm, 0.25mm, 0.30mm, 0.40mm, 0.50mm diameter, were wound round the ring to form three equidistant spacer wires and mild steel rods of length 45mm (plug) were machined down to give a tight fit assembly. The individual rings and plugs were washed in distilled water, fluxed with "Baker" soldering fluid No. 3. The joint was them assembled and dipped into a bath of molten solder at a temperature 50^{o}c above the liquids of the alloy; residual fluxes were washed off in water.

Butt Joint Preparation

Mild steel plate was machined into twenty four standard rectangular tensile test specimens. Each of the test specimens was cut into two halves. Both pieces were degreased, cleaned, etched and fluxed as in ring and plug joint preparation above. The pieces were then held by different vices and brought in close contact with copper wire of different diameters as in ring and plug above at their interface to create space equivalent to its diameter. The pieces were then joined together with solder using bit (soldering iron). The assembly was held firm until the molten solder has solidified.

Lap Joint (Single Overlap) Preparation

The same procedure used in butt joint preparation was used; except that in this case, the two pieces overlapped. The copper wire created space equivalent to its diameter between the two overlapping pieces of the sample.

TESTING

The testing of the joints' strength was carried out on the soldered joints using a Monsanto universal tester. The joints were tested to fracture at room temperature.

Results

The results of tensile test carried out were used to plot a graph of strength against solder thickness as shown in Fig. 1.0.

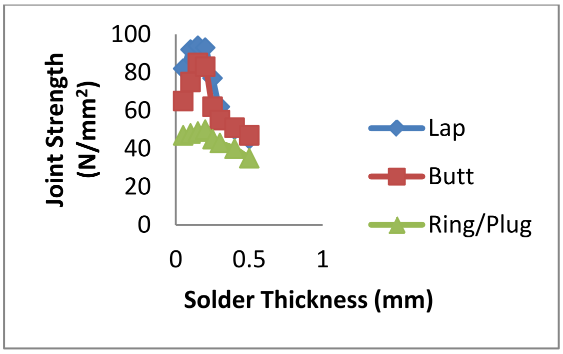

Fig. 1.0: Joint Strength versus Solder Thickness

DISCUSSION OF RESULTS

The butt joint is stressed perpendicular to its interface under loading and thus, it is the best indicator of tensile strength. However, the other two types of joints (ring / plug and lap) are stressed parallel to their interface, hence they demonstrate sheer strength. The maximum strength obtained was with solder thickness of 0.15mm for lap joint ($94.0N/mm^2$). Generally, the ring/plug joint showed lowest strength at all the solder thicknesses studied. But the lap joint, however, showed higher strength over the butt joint at smaller solder thicknesses up to 0.30mm before a fall in strength below that of butt joint (see Fig. 1.0). The high strength exhibited by the lap joint could be attributed to the overlapping configuration of this particular joint assembly.

The results revealed the fact that even though correct wetting angle, surface tension, clean surface, and proper flux is used, the joint gap (solder thickness) should be as narrow as possible (between 0.10 and 0.15mm) in order for the surface of the material to be properly wetted and to obtain optimum strength.

CONCLUSION

It can be concluded from the foregoing that:

- The lap joint possesses the highest strength, followed by butt and lastly ring/plug, hence joint configuration affects joint strengths.

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- ❖ Solder thickness influence joint strength.
- ❖ The lap joint is recommended for soldered joints except where it is impracticable.

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