

Tack Testing: Critique and Recommendations for a New Test

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January 2000

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ISSN 1361-4061

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ABSTRACT

Current tack testing methods are widely accepted as showing poor correlation with performance in the placement process. One of the major deficiencies of the test is the inability to measure extraction forces in the horizontal axis. Current international tests reflect the early approach to tack measurement and fail to meet the demands of modern electronic assemblies. These standards and other work are reviewed and recommendations made for future areas of work in tack measurements.

1 INTRODUCTION

All production processes are optimised and improved with time to maximise output at the highest quality. The production of electronics assemblies is no exception, and product volumes can be truly phenomenal. To attain these high rates all raw materials entering the process must meet required specification to avoid the costly action of rejecting manufactured product. Since production is simply too fast and human resources too limited, *tinkering* with a process in real time is an unaffordable *luxury*. Hence, there is an increasing requirement to qualify the various parts prior to use in production.

Solder paste is an essential and important part of electronics assembly. It is a multicomponent system and its performance is adapted by the manufacturers to meet all the subtleties required by the user. Of prime importance is the requirement of the paste to print well, at high print speed and for long stencil life. But, also important is the tack properties of the wet paste prior to reflow. Solder paste must have the right level of tack in the component placement stage of the process. The requirements for successful component placement is that the paste provides sufficient adhesive forces to retain the component, and that stable positional registration during rapid translation in the placement process is maintained.

Solder paste users are now finding that the tack properties are becoming more important from a process view point. At the same time however, the paste properties are changing for other reasons which are not always favourable from a tack perspective. Hence, it is timely that the method for tack testing be re-visited and updated.

1.1 MEASURING TACK

The structure of solder paste, a dispersion of irregularly sized solder spheres in flux, solvents and rheology modifiers, is applied as a thin layer (100 - 200 μ m), which presents unique challenges in terms of tack measurement. Tack instruments and a test methodology were first developed more than 20 years ago, and have remained unchanged since. The deficiencies in the method and the demand for a more realistic test and credible data have provided a large impetus to developing a new tack method.

The two existing test methods, used internationally, are the American IPC TM 650 2.4.44 and the Japanese JIS-Z-3284. Both methods follow a similar procedure which is shown schematically in Figure 1. Solder paste is printed as a 6.5 mm diameter deposit onto a pad through a stencil, and a slightly reduced diameter probe, in the form of a bar, is inserted into the paste under a controlled force. NB. the schematic in Figure 1 is realistic in the number of solder particles in the height of the deposit for a type 3 paste, where the particle size varies from 25 to 45 μ m. The peak force during extraction of the probe is the measured criterion used to assess tack. The probe is inserted

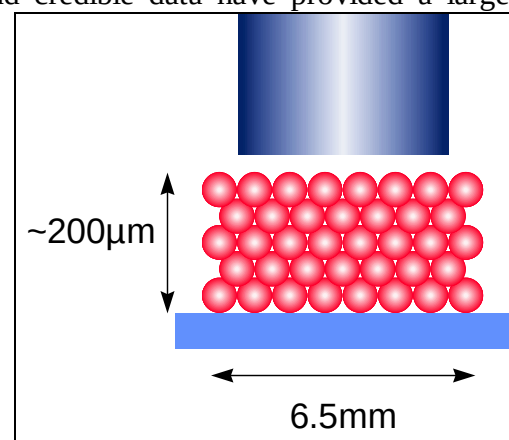


Figure 1 Schematic of probe and solder paste

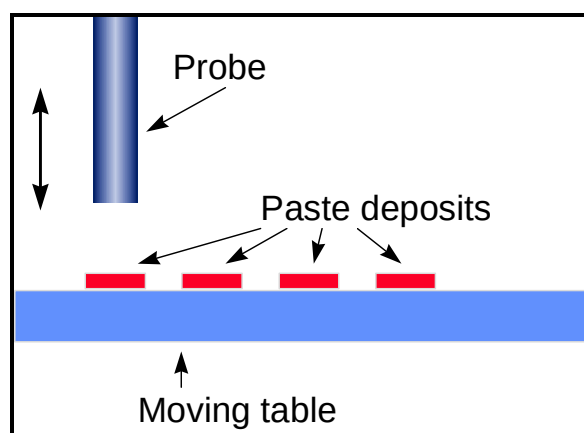


Figure 2 Schematic of sample arrangement

and extracted in the vertical axis. For convenience the test arrangement usually comprises a series of paste dots which can be measured in quick succession as shown in Figure 2. Paste deposits are printed onto a substrate, which is then attached to the table. Movement of the latter allows subsequent alignment of each deposit under the probe.

2 COMPARISON OF THE IPC AND JIS STANDARDS

The two main measurement methods have attracted criticism with respect to both their procedures and test parameters, neither of which reflect modern manufacturing practices. Moreover, the test results provide little correlation with practical performance in the placement process.

Test parameters for the two test methods are compared in Table 1.

Table 1 Test Parameters from IPC and JIS

Parameter	TM 650 2.4.44	JIS-Z-3284
Contact Speed	2.5 mm/min	2.0 mm/s
Separation Speed	2.5 mm/min	10 mm/s
Contact Force	300g	50g
Contact Depth	No spec	No spec
Contact Time	<5 sec	<0.2 sec
Deposit Diameter	6.5mm	6.5mm
Probe Diameter	5.1mm	5.1mm
Deposit Thickness	250µm	200µm
Test Temperature	25°C	not specified
Humidity	50 %	not specified
Output	Peak Force	Peak Force

Although there is a general similarity in the approach and some of the details of the two methods, there does however remain some marked differences between the two methods.

There appears to be little general understanding of the significance of these differences, or of the appropriate areas of application for the two methods.

2.1 DETAILS OF PARAMETER DIFFERENCES:

- Contact and separation speeds differ markedly between the two methods. The two values are fixed and so a very different response from the two methods can be expected with some pastes. The JIS method inserts the probe much faster and is more realistic of current production processes.
- Contact force is remarkably different between the two tests as well. The lower insertion force of the JIS test is also coupled with the higher insertion speed, a more demanding mechanical performance of the instrument. The difference in forces will result in different insertion depths for the two methods, which will undoubtedly lead to different extraction forces. Some placement machines now insert components to known depths, and the failure of either test to accommodate this loading method is considered as inadequate.
- Contact time is fixed at a nominal value and is different in the two tests. Again this difference may well result in different adhesion between the probe and paste. Clearly the contact time will also be a critical factor as the paste ages and the tack drops.
- The test paste deposit and probe diameter are large and are very much at the upper end of typical modern day pad designs. However, the geometry and volume of the paste will affect the ageing characteristic of the paste deposit. A larger deposit will have a lower surface area to volume ratio and so the rate of loss of solvent will be lower per unit volume, than for a smaller paste deposit. Hence, the test data may not represent the true industry picture.
- The deposit thickness is defined, but in both cases it is rather on the thick side. Most stencils are now 150µm, and for fine pitch work stencil thicknesses are as low as 100µm. Similar arguments regarding surface area and volume apply as discussed above.
- The test environment is specified in the IPC test but not the JIS test. Environment will clearly be important to ageing and deterioration of tack, eg. all solder pastes are influenced by humidity. It is likely that tack could prove sensitive to humidity and this test parameter should be controlled carefully. Being able to vary the humidity (and temperature) of a tack test would prove a useful asset.
- For both tests the measurement criterion is based on the extraction force. Plotting the extraction force with time is useful but the maximum extraction force is the most useful criterion.
- None of the tests can accommodate measurement of tack at elevated temperature, typical of the preheat during reflow.

2.2 SUMMARY OF IPC AND JIS PARAMETERS

The JIS test applies the probe faster, with a lower force and a shorter time than the IPC test. With an aged paste, that is less viscous due to evaporation, the JIS test will probably generate lower adhesive forces between the paste and the probe. It is therefore likely that the JIS test will indicate a more rapid deterioration in tack with ageing than does the IPC test. Both tests use large and thick paste deposits, which will not age as fast as small deposits of paste. Testing today should use smaller paste geometries typical of industry practice. Test environment is also an important parameter, and future developments could well see the test environment more

closely controlled over a range of values. Collecting the complete force curve during insertion and extraction may provide useful data and any future evaluation of the tack method should investigate the performance against measurement criteria extracted from the force curves.

A major deficiency of the current test methods that has not already been discussed above is that the extraction force is always measured in the vertical axis. In the placement process the components are placed in the vertical axis but the load on the paste is in the horizontal axis due to a shear action, resulting from rapid translation of the PCB under the placement head. Any tack test therefore should be able to simulate the loading in the vertical axis and measure the adhesive forces in a shear mode.

3 WIDER ISSUES IN TACK MEASUREMENT

The current limitations of the tack test are widely recognised and a number of organisations are currently considering possible improvements. Most significant of these is the American IPC organisation, which via its J-Standard 005 committee, is revisiting the IPC tack method. Its premise for developing a new method follows the discussion above very closely. In its work it has defined two aspects of tack which it refers to as:

“Open Tack” which is defined as : *the length of time after printing on a circuit board, during which parts can still be placed in the solder paste deposits without either falling off, or causing an “open joint” on subsequent reflow.*

“Retention Life” which as defined as: *the length of time after placement during which a part will remain in place prior to formation of the final reflowed joint.*

These two aspects of tack could clearly be included in any testing protocol to establish the tack after the various exposure regimes. IPC does discuss a simple method which does not require any equipment. A part is placed onto printed solder paste and then the board is rotated. The time after which no parts fall off is used as a functional tack time.

Work at the State University of New York⁽¹⁾ looked at tack with surface mount components. They evaluated the IPC method and also developed a test using a shear arrangement. Their work showed that whilst the IPC method gave poor correlation with paste retention properties of real components, the shear test exhibited a much stronger correlation.

Work at the Fraunhofer Institute IZM in Berlin has also looked at paste retention properties. They looked at the issues of component retention in the preheat stage during reflow. Although their technique allowed them to follow the tack properties of the paste as a function of temperature there were certain limitations using the vertical extraction arrangement. In an attempt to introduce some shear component into the extraction they introduced a pivoting table, hinged along one side, on which the substrate was mounted. As the probe is extracted the table lifts, with the adhesive force between the probe and paste, in a rotating motion, and hence the extraction action has some shear component.

Discussion with the wider industry and the SSTC confirms the dissatisfaction with the existing tack test. This most significant cause for concern is that the extraction is not in the shear direction. More specifically the actual values of the test parameters are not appropriate to modern electronic assembly techniques.

4 FUTURE WORK

Any development in the method must ensure a good correlation between the measure of tack and the retention of components during the placement process. Consequently the test instrument must have flexibility in the application and measurement of forces. Clearly the most important area is the extraction regime.

4.1 EXTRACTION OF THE PROBE

The test probe should be able to be extracted in the vertical and horizontal axis to provide tension and shear extraction forces. The speed of extraction should be varied in the range from 1mm/min to 20mm/sec. The probe geometry must also be considered. In the past a round bar has been used, but most components have square profiles. A range of probe sizes should be used with both square and round outlines. Monitoring of the extraction process is critical. It should be continuous and pass/fail criteria should be developed in consideration with establishing a correlation with the placement behaviour.

4.2 LOADING REGIMES

In the past loadin has always been carried out at a constant force. With the smaller paste deposits envisaged for future work the insertion force should be variable, and extend to much lower forces than has hitherto been the case. It is anticipated that a suitable range will be 10 mN to 10 N. As discussed above some placement machines now place components to a prescribed depth. It is proposed that in this work the insertion depth be controlled and varied over the range of 10 to 200µm.

4.3 SOLDER PASTE CHARACTERISTICS

For solder paste applications the deposit should be printed with various stencil thicknesses in the range of 100 to 200 µm, and have square or round shapes to match the probes.

4.4 TEST ENVIRONMENT

It is well known that solder paste characteristics are sensitive to environment. As a minimum the test environment should be specified. However, an understanding of how tack changes with environment should be established. It is proposed that the test environment be varied over the range of 20 to 30°C and 40 to 80% RH.

5 CONCLUSIONS

The current tack tests are flawed with a number of inappropriate test parameters. The principal problem is that existing methods only use vertical extraction, whereas there is an important requirement for the extraction to be measured in the horizontal axis. Other issues arise relating to how the probe is applied and then extracted, the amount and form of the solder paste deposit to be measured, and the test environment.

These parameters and how they influence the tack measurement have been reviewed. From this starting point a range of parameters (with suggested values) are proposed which are thought to be relevant in the development of a new tack test.

6 REFERENCES

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7 ACKNOWLEDGEMENTS

The work was carried out as part of a project in the Measurements for the Processability of Materials (MPM74) Programme of the UK Department of Trade and Industry. The author is also grateful for many useful discussions with John Porter of Multicore Solders and Mathais Nowottnick of the Fraunhofer Institute IZM, Berlin.