

Measurement Good Practice Guide

Adhesive Tack

*Bruce Duncan, Steve Abbott
& Richard Roberts*

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Measurement Good Practice Guide No. 26

Adhesive Tack

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Abstract:

Adhesive tack is the property that controls the instantaneous formation of a bond when an adhesive and a surface are brought into contact. Although tack test methods are generally simple to perform, tack is sensitive to many experimental factors and obtaining reliable measurements can be a problem. This document is intended to give guidance on the measurement of permanently tacky pressure sensitive adhesives (including tapes) and adhesives whose tack requires activation in some way. Standard test methods for pressure sensitive adhesives (rolling ball, loop tack, probe tack and quick stick) are discussed. A tack measurement method developed for the footwear industry is presented as a case study that illustrates the issues involved in measuring the tack of activated adhesives.

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Adhesive Tack

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Glossary of Terms

(Based on BSI and PSTC definitions)

Adherend: An object that is bonded using an adhesive.

Adhesion: A bond produced between an adhesive and a surface (which may be another adhesive).

Adhesive: A substance that will usefully hold two objects together solely by intimate contact.

AFERA: Association des Fabricants Europeens de Rubans Auto-Adhesifs.

ASTM: American Society for Testing and Materials.

Backing: A thin flexible material to which the adhesive is applied. Normally refers to the tape backing in a single-sided adhesive tape but may also encompass the release coating on double-sided tapes.

BSI: British Standards Institution.

Carrier: Tape that is adhesive coated on both sides in a double-sided pressure sensitive adhesive tape.

Coalescence: The merging of two layers of adhesive to form a bond.

Cohesion: The ability of the adhesive to resist splitting or rupture.

Contact Pressure: The pressure used to press the parts together when making a bond or carrying out a test.

Dwell Time: The time between making and separating the bond.

FINAT: Federation International des Fabricants et Transformateurs d'Adhesifs et Thermo Collants sur Papiers et Autres Supports.

Open Time: The time between applying or activating an adhesive and the forming the bond.

Pressure Sensitive Adhesive (PSA): Term used to designate adhesives, which, in dry (solvent free) form are tacky at room temperature and adhere to a variety of dissimilar surfaces on light pressure.

Pressure Sensitive Tape (PST): A combination of a pressure sensitive adhesive and a backing.

PSTC: Pressure Sensitive Tapes Council.

Quick Stick: The property that allows a pressure sensitive adhesive to adhere to a surface under light contact pressure.

Surface Energy: A measure of molecular attraction between surfaces. High surface energies promote good wetting and bonding. In liquids, the surface energy is proportional to the surface tension.

Tack: The property of an adhesive that enables it to instantly form a bond when brought into contact with another surface (which may be another adhesive).

Tack Force: The maximum force required to separate the bonded surfaces. May also be called tack strength.

Tacky: The condition where the adhesive feels sticky.

TLMI: Tag and Label Manufacturers Institute

Wetting: The formation of intimate contact between adhesive and surface.

Adhesive Tack

Executive Summary

This measurement guide aims to provide guidance to technologists, laboratory staff and quality assurance personnel on how to select and perform measurements to determine the tack of adhesives. A general familiarity with laboratory operations, but not specifically adhesives testing, is assumed. The objective of this guide is to familiarise the operator with the options available for testing and the factors that can influence the tack results. Tack measurement procedures should be selected according to the application. Procedures for tack tests should be developed which cover the application and the equipment used. Often, additional controls than those called for in standard measurements may need to be specified or deviations from the standards may be needed to produce data that are more relevant to the bonding application.

Tack is the property of an adhesive that determines its ability to instantly form a bond with another surface under light contact pressure. Tack is not merely a material property of the adhesive but also depends on the adherend properties and the process conditions. Thus, tack is sensitive to a wide range of factors. Tack is one of the most important properties of the adhesive in many applications. It is particularly relevant where bonds must sustain load immediately after assembly. Tack measurement methods tend to be application specific. In general, measurement methods do not control all the factors influencing tack. Therefore, measurement uncertainties can be relatively large and measurements made using different methods are rarely comparable.

This guide describes some of the most common test methods for determining the tack of pressure sensitive adhesives (PSAs). PSAs are permanently tacky and will stick to a variety of surfaces under light pressure. Standard tests for tack of PSAs fall into four categories: rolling ball, loop tack, probe tack and quick stick. The merits of, and potential problems with, each method are discussed. Table 1 summarises the likely areas of suitability of each test type.

Many adhesives require some form of activation, for example through heat or moisture, before they become tacky. The tack of such systems will depend upon the activation conditions and the history of the sample after activation. The techniques developed for activated adhesives tend to be based on the bonding process in which they are used. Many methods have been developed in different industries. Rather than discuss these methods individually, a tack measurement method used in the footwear industry has been used to illustrate some of the issues influencing the results.

Tack tends to be more variable than other properties of the adhesive since it depends on many different factors. Appendix I summarises some of the factors that will influence the tack results. It is difficult to control all of these. Some results from a round robin exercise on the loop tack test and an intercomparison between different tack measurement methods are presented to illustrate the likely degree of accuracy that may be expected from measurements.

Table 1: Tack Method Selection Guide

Application	Adhesive Type		
	PSA Tape	PSA Coating	Activated Adhesive
Quality Control (minimal investment or equipment)	RB, PT	RB, PT	PT
Quality Control (medium investment or equipment)	LT, PT, QS	LT, PT, QS	LT, QS
Material Selection or Specification	LT, PT, QS	LT, PT, QS	LT, QS
Process Development (medium investment or equipment)	LT, PT, QS	LT, PT, QS	QS
Process Development (higher investment)	UDT	UDT	UDT
Research	LT, PT, QS; UDT	LT, PT, QS; UDT	LT, PT, QS; UDT

Key:

minimal investment or equipment: cost of setting up test facilities
no specialised test equipment available;
no specialised adhesive testing expertise;
limited budget (< £500).

medium investment or equipment: cost of setting up test facilities
some equipment available (e.g. motorised test stand and force transducer [50 N range, resolution 0.1 N or better]);
general testing experience;
budget up to £5000.

PT = Peel Test (qualitative measurement of stick)

RB = Rolling Ball Test (Section 4.1)

LT = Loop Tack Test (Section 4.2)

PT = Probe Tack Test (Section 4.3)

QS = Quick Stick Test (Section 4.4)

UDT = User Developed Test - specific to bonding process or application (Section 5) - may be based on an existing standard test (lowest cost option) or a significant departure.

1. Scope

Adhesive tack is the property of an adhesive that enables it to instantly form a bond when brought into contact with another surface (which may be another adhesive). Control of tack is important in operations where instant bond strength is needed. However, in many assembly or packaging applications, tack strengths may need to be limited to allow separation and refitting of parts. Adhesive tack depends on (i) the adhesion between the adhesive and the surface, and (ii) the cohesive strength of the adhesive. Tack properties are thought to depend on the visco-elastic characteristics of the polymer adhesives. Good adhesive tack is normally achieved when the adhesion strength is greater than the cohesive strength of the adhesive (or the substrate).

The adhesive strength (or the bond between adhesive and surfaces) is influenced by:

- surface energies of adhesive and substrate (these depend on materials, preparation, cleaning, contaminants, etc.);
- wetting of the surfaces by the adhesive (depends on surface energies and the flow properties of the adhesive) to cover the bonded area;
- the dwell time (longer times allow more of the contact area to be wetted); and,
- the contact pressure (higher pressures promote better spreading and wetting).

The cohesive strength (or the capability of the adhesive to resist rupture) is influenced by:

- the mechanical properties of the adhesive (modulus, yield strength, strain to failure, visco-elasticity);
- the failure mode of the adhesive (brittle or ductile); and,
- the proportion of the surface that has been wetted.

The adhesive and the cohesive strength that determine the adhesive tack depend on many factors. These properties are influenced by the environmental conditions such as temperature and humidity.

Adhesive tack is important in many bonding applications. Many test measurements have been devised to assess tack. It should be noted that the test itself can influence the results. Research performed in the PAJ programme has demonstrated how selection of test variables, such as separation rates, stiffness of adherends, substrate clamping or 'standard' surface, can influence the measurements. Some of the factors that can influence tack are summarised in Appendix 1.

This guide focuses on the measurement of tack for applications where rapid bond strength formation is required. Guidance on sample preparation and conditioning issues is given in Section 2. The guide is split into two Sections covering tack measurement methods for pressure sensitive adhesives (PSAs) that are permanently tacky and those for adhesives that require activation to become tacky. It does not specifically address measurements for tack of structural adhesives or hot melt adhesives. However, many of the themes of the measurements discussed in this guide will be equally applicable for these types of adhesives. There are several types of standard test measurement commonly used with PSAs. The most widely used of these are discussed in Section 3. In contrast, tests for tack of activated

adhesives tend to be process specific. Section 4 discusses important aspects of these tests. Section 5 presents some guidance on the accuracy and comparability of different test methods.

Tack measurements can be made for a number of purposes: the most common are quality control in production (particularly adhesive tapes), selection or qualification of adhesives for use, product development and process optimisation. The objectives of the testing, e.g. for quality control, may vary. Commonly quality control may be needed to monitor adhesive formulations (consistency of adhesive material), the manufacture of adhesive tapes (checking coverage, layer thickness) or pre-production checks in an assembly line. The approaches to tack testing would be different in each case. Tack test methods should be selected on the basis of the applications of the results. Some organisations where advice can be sought are listed in Section 7. Relevant publications and further reading are listed in Sections 8 and 9.

2. Specimen Preparation and Conditioning

Specimen preparation and conditioning, of adhesives and surfaces, are factors that will influence tack. This is common to all types of test methods and applies to pressure sensitive and activated adhesives. It is important that preparation and conditioning procedures produce consistent samples. These procedures should be controlled and recorded. In any bonding process, including tack measurements, the quality of the surface and the surface preparation is critical to the bond strength.

For comparative studies or quality control, it is important to have consistent sample conditioning. Normally, the test specimens should be conditioned under the same environmental conditions (temperature and humidity) used for testing. A 24 hour conditioning period is sometimes specified. These environments are normally specified as either $23 \pm 1^\circ\text{C}$ and $50 \pm 3\%$ relative humidity or $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ depending on the standard. There are moves to unify the various standards to a single set of conditions (the tighter specification). In many laboratories such tight control (particularly over humidity) may be difficult to achieve. Where this is not possible - as an absolute minimum - temperature and relative humidity must be measured and recorded. Great care should be taken when comparing results obtained under different environmental conditions.

For adhesive selection or qualification, the environmental conditions may need to mirror the service conditions. It is important that these are monitored and recorded during conditioning and testing. Where material, such as adhesive tape, is supplied in rolls, some methods specify that the first three turns of the roll should be discarded before taking test samples, thus minimising variability due to conditioning. This is probably also good practice for methods where this is not specified.

Surface properties can affect the tack properties. It is important that the surfaces used in tack tests are free from contamination. They should be prepared and cleaned in a consistent way immediately prior to testing. Variability in the surfaces or the presence of contaminants will introduce uncertainties into the measured results. The measurement standards for PSAs specify the surfaces to be used (e.g. stainless steel, float glass) and the way in which they are prepared (e.g. surface roughness, cleaning procedures). Many users use different surfaces since the standard surfaces may not be relevant to their bonding application. Where another

'standard' surface is used, care should be taken with the preparation procedures to ensure that the test surface is stable and consistent for all tests.

Adhesive sample preparation procedures can influence tack. Unless the test is being carried out for a purpose such as checking the quality of manufactured adhesive products (e.g. adhesive tapes or labels), where processing is one of the variables, sample preparation should be carefully carried out to documented procedures. Adhesive coatings prepared for testing quantities such as adhesive quality or bonding performance should have a uniform coverage and coating thickness. The method of applying the coating should be specified (e.g. spray-on, brush-on). Factors such as the temperature of the adhesive during preparation should be controlled as these may affect the tack of the adhesive layer. The times (and environmental conditions) between application of a layer and the performance of tests or the application of further layers (e.g. drying time) should be controlled. These conditions should be recorded with the test records.

3. Methods for Pressure Sensitive Adhesives

Numerous standard tack test methods have been developed for pressure sensitive adhesives by different organisations. Broadly these fall into the following categories [1]:

- Rolling Ball (Section 3.1)
- Loop Tack (Section 3.2)
- Probe Tack (Section 3.3)
- Quick Stick (Section 3.4)

Each of these generic test method types has advantages and disadvantages. It is not the aim of this guide to describe these methods in detail but to advise on how these methods should be used and identify the factors that may influence the accuracy of the results. For details of the standard methods please refer to the test methods listed at the end of each subsection.

3.1 Rolling Ball Test

The rolling ball test is primarily intended for quality control of adhesive tapes but may also be used to investigate adhesive coatings. The motion of the rolling ball is arrested by (i) the adhesion between the ball and the adhesive, known as "grab" and (ii) the "ploughing effect" or energy required to push adhesive from the ball's path. The distance taken for the adhesive layer to halt the ball (with a specified initial momentum, controlled by the height and angle of the incline) is measured. Short stopping distances are equated with high tack. Typical equipment is shown in Figure 1. The test is useful for quality control purposes when manufacturing adhesive tapes or labels as the results are sensitive to both adhesive tack and coating thickness. To improve the reproducibility of the test results, the temperature of the ball and tape should be controlled. Tests should be performed under conditions of controlled humidity. These conditions should be included with the test records.

Advantages:

- simple and quick to operate;
- inexpensive equipment;
- normally gives good repeatability within a laboratory; and,
- sensitive to adhesive formulation and coating thickness for quality control.

Disadvantages:

- because of sensitivity to the thickness of the adhesive layer, comparisons of different systems may be unreliable;
- the softness of any backing material also influences the stopping distance
- the ball becomes coated with adhesive during the test - changing the nature of the contacting surface; and,
- it is difficult to relate stopping distances to other properties.

Standard Rolling Ball Test Methods:

- PSTC-6, Tack Rolling Ball, Method, Pressure Sensitive Tapes Council, Chicago, USA. [2]
- ASTM D 3121-94, Standard Test Method for Tack of Pressure-Sensitive Adhesives by Rolling Ball. [3]
- BS EN 1721 1999 Adhesives for paper and board, packaging and disposable sanitary products. Tack measurement for pressure sensitive adhesives. Determination of rolling ball tack, British Standards Institution. [4]

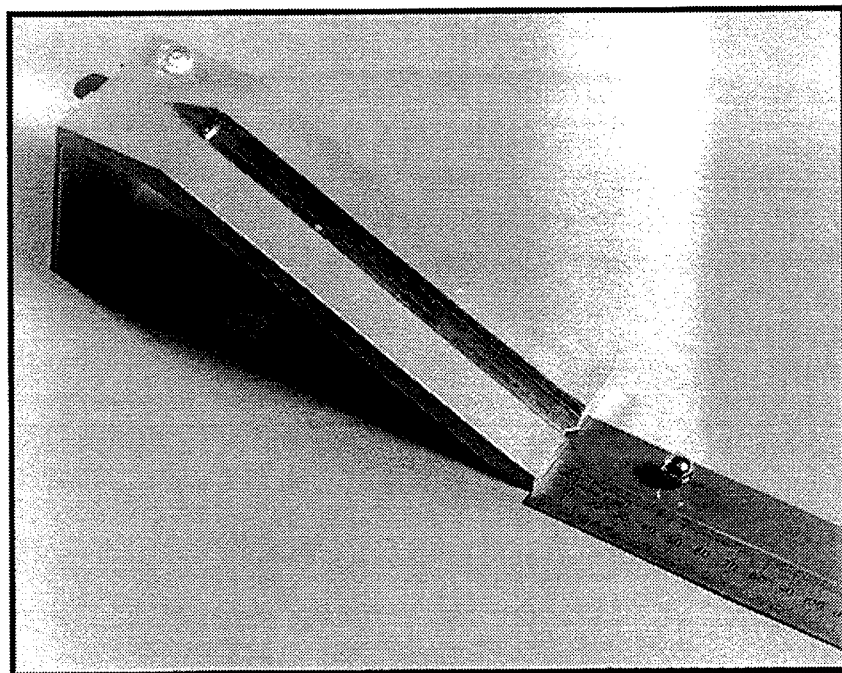


Figure 1: *Rolling Ball Test*

The PSTC and ASTM methods are essentially the same. The BS method differs from the ASTM method. The BS method specifies a 10 mm diameter steel ball whereas ASTM specifies a diameter of 11.1 mm ($\frac{7}{16}$ inches).

3.2 Loop Tack Test

Loop tack tests are intended for quality control and research measurements on adhesive tapes and pressure sensitive adhesives. These standard methods usually specify the length and width (generally 25 mm) of the loop strip, the dimensions (normally 25 mm wide) and material of the base plate and the speed of the test. The standards define the tack as the force required to separate, at a specified speed, a loop that has adhesively contacted a specified area of defined surfaces. The standards normally specify a 25 mm by 25 mm contact area. The tests can be split into two classes depending on which substrate the adhesive coats.

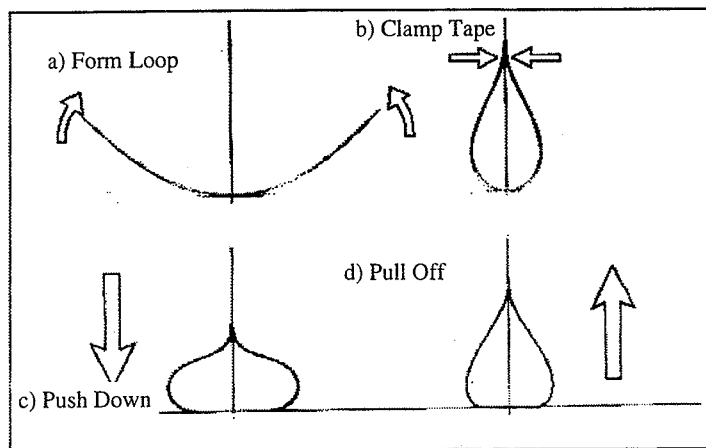


Figure 2: Steps in the Loop Tack Test

- *Class 1*, the adhesive is on the material forming the loop. A standard surface (e.g. float glass or stainless steel) is used as the base substrate. This class of test is used to test adhesive tapes.
- *Class 2*, the adhesive is coated onto the base plate. A standard material (e.g. polyester film) is prepared as a parallel sided strip and used to form the loop. This class of test tends to be used for double-sided tapes, pressure sensitive adhesives and coatings.

Each standard specifies cleaning and sample preparation steps. Once this is done all types of loop tack test can be performed in the same way. The four steps in the test, that are shown in Figure 2, are described below.

Step a: Form the loop from the tape.

The specified length of tape should be bent back until around 10 mm or so of the ends are in contact. Any adhesive coating should be on the outer surface. Tapes with extremely low stiffness can be difficult to handle (particularly if static electricity causes the backings to stick together). To avoid such problems the tape could be bent around a cylinder or tube of appropriate diameter when forming the loop. This shaping device should be removed once the loop is formed. The ends of the tape should be joined (using adhesive tape) to ease clamping. Alternatively, short strips of metal can be bonded to the ends of the tape to reduce problems with handling or clamping.

Step b: Clamp the loop in the movable test machine grips.

These should be connected to a load measuring device with sufficient range and sensitivity (normally specified in the test method). The loop should be aligned such that the edges of the tape will be at a right angle to the edge of the base plate.

Step c: Lower the loop.

The loop should be lowered, pushing down onto the base surface, until the tape contacts over the required area. This is normally the whole width of the base plate except in BS EN 1719 [5] where the base plate is wider than the contact area. Determination of full contact can be subjective (Figure 3). Although the standard test methods do not require it, measurement of the 'push down force' can help check for consistency amongst different tapes. The exact shape of the loop is determined by the stiffness of the tape. Differences in loop shape will alter the peel stress at the end of the tape and cause variations in the results between, for example, tapes with the same adhesive but different backing thickness.

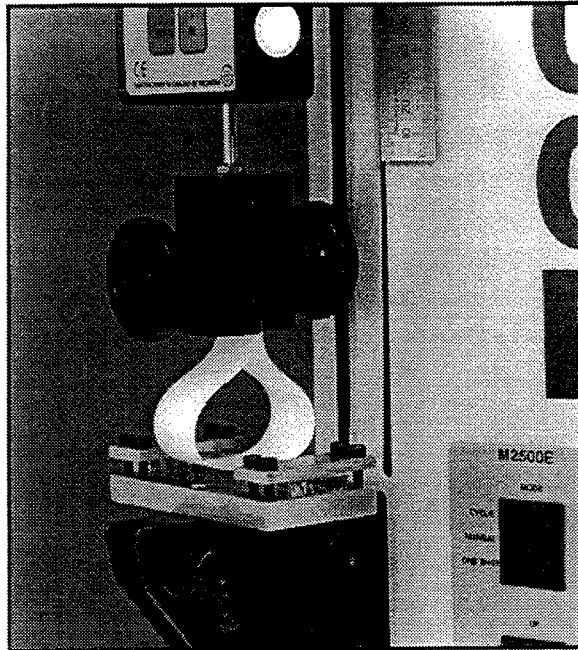


Figure 3: Full Contact is Obtained in a FINAT FTM 9 Test

Step d: Pull the loop off the surface

Once the loop has contacted the required area of the base plate the direction of the test machine should be reversed. The area in contact should be inspected visually for any imperfections in the contact (e.g. wrinkles or bubbles). Any occurrences should be noted in the test records and the results omitted from the analysis. The test should run until the tape is detached from the plate. Typically, the force-time response may show one or more peaks before final separation. The maximum force is normally recorded. The debonding of the loop is a dynamic process. The response rate of the force transducer and logging devices can influence the maximum recorded. Low response rate devices will tend to miss the peak force and record slightly lower tack than high response devices. A study indicated that there may be 3 % to 5 % difference between the maximum forces determined using a force cell sampling at 1200 points per second and the results recorded on a data logger sampling at 10 points per second. The standard methods tend to specify different ways of expressing the tack. The BS methods [5, 6] specify that tack is taken from the peak force (from the median of three replicates). The FINAT method [7] is more ambiguous - the maximum force is recorded but the method then specifies that 'Quick Stick tack is expressed as the average value (ignoring the initial peak) and range for the five strips tested'. The statement 'ignoring the initial peak' is open to different interpretations and does not follow from the rest of the procedure. The statement can be ignored and the tack expressed as the mean of the maximum forces measured provided that this is agreed and recorded as the method for determining the tack.

Advantages:

- control over separation rate;
- quantitative measure of tack force; and,
- uses standard test equipment.

Disadvantages:

- results depend on stiffness of the backing material (class 1 tests) which;
 - determines loop shape and, thus, peel stress concentrations; and,
 - determines contact pressure.
- contact area may not be constant;
- subjective decision as to what constitutes full contact;
- dwell time differs (e.g. between centre and edge of the tape);
- reproducibility may be poor; and,
- multiplicity of test methods.

Standard Loop Tack Test Methods:

- BS EN 1719 Adhesives - tack measurement for pressure sensitive adhesives - determination of loop tack, British Standards Institution (Class 1: adhesive is coated on a standard 50 μm polyester film that is used to form the loop). [5]
- BS 7116: 1990 Double sided pressure sensitive adhesive tapes, Method G, British Standards Institution (Class 2: tape is attached to base plate, standard 23 μm polyester film used for loop). [6]
- FINAT test method no. 9 (FTM9) “Quick Stick” tack measurement (loop tack), FINAT, Den Haag, Netherlands (Class 1: test for adhesive tapes). [7]
- TMLI LIB1, Tag and Label Manufacturers Institute, Naperville, IL, USA (Class 1: similar to FTM9 but uses a stainless steel surface not glass). [8]
- TMLI LIB2, Tag and Label Manufacturers Institute (Class 1: same as LIB1 but allows a use of an adapted tensile tester rather than specific apparatus).[9]

The FINAT FTM9 method is widely used in the adhesive tape industries. A round-robin exercise found that the reproducibility of results produced by the FINAT FTM9 method can be poor [10]. This is particularly the case where the tape is extremely flexible and it is difficult to form the loop. Some of the scatter may also have been due to the ambiguity in the FTM9 instructions for expressing the results.

Many organisations use their own test methods based on the standard loop tack tests. One difference between methods is the choice of the standard surface. The FINAT method specifies float glass whereas the TMLI methods specify stainless steel. A set of tests carried out using both surfaces for one type of adhesive tape indicated that the steel surface gave results 20 % lower than the glass surface. This difference is likely to be adhesive specific and may vary with different adhesives. Many organisations select a material used in their bonding operations as the test surface to produce tack results relevant to their process.

The BS tests, by stipulating the loop material, avoid the variability in results that may be due to the stiffness of different adhesive tape backings. Finite Element Analysis (FEA) simulations of the loop tack test [11] have indicated that the stiffness of the loop tape (determined by material modulus and tape thickness) is likely to significantly influence the measured tack.

3.3 Probe Tack Test

The probe tack test, as shown in Figure 4, is designed for use with adhesives attached to flexible or rigid backings. The test can be used for quality control or research purposes. The standard method was developed from the Polyken Tack Tester [12]. Different probes can be employed. The standard probe is a 5 mm radius, stainless steel probe. This gives a contact area of approximately 20 mm². The probe can be slightly domed to reduce the probability of trapping air between the probe and adhesive. The standard test settings are contact pressure (100 g cm⁻²), dwell time (1 s) and test speed (1 cm s⁻¹). There are three stages to the test.

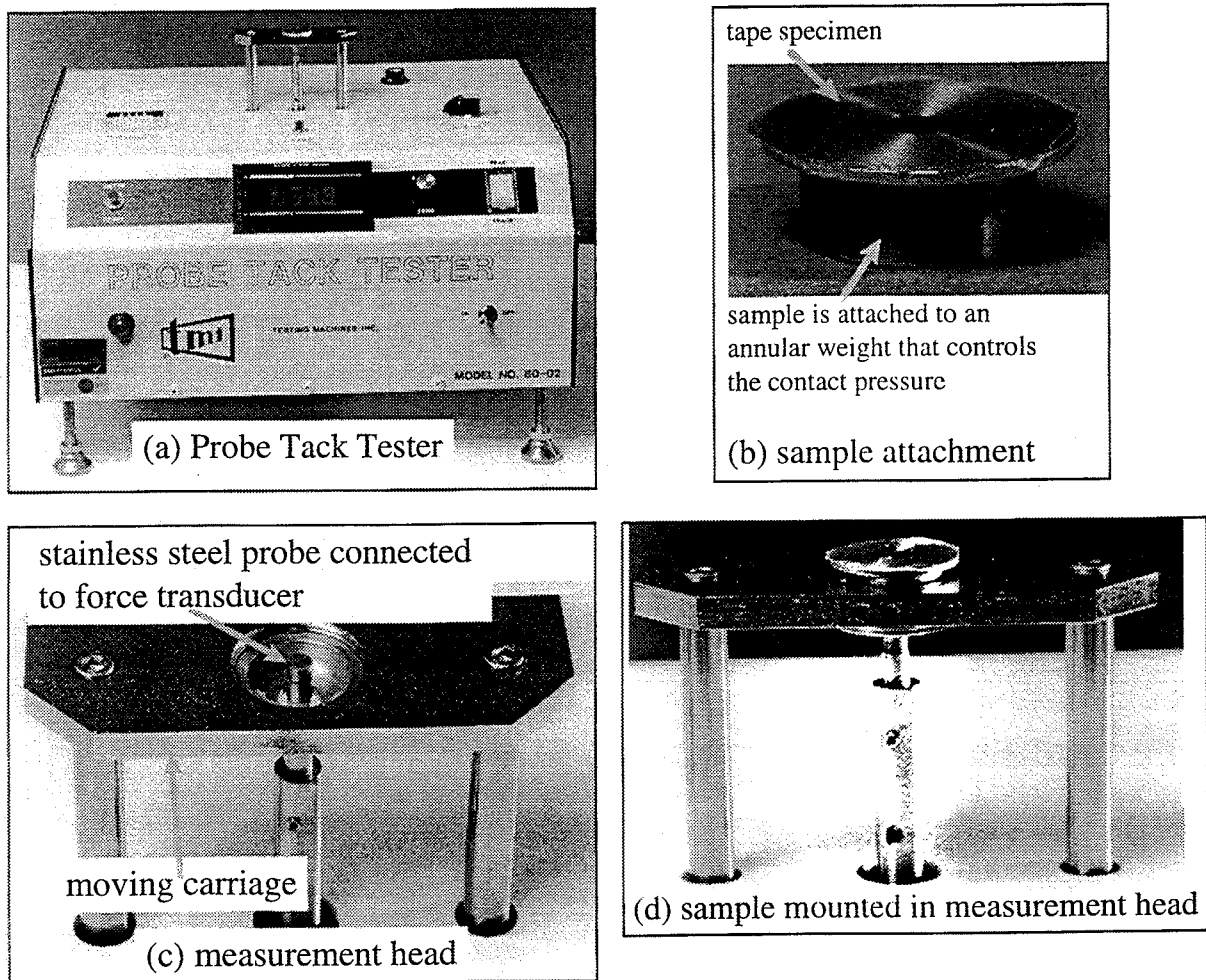


Figure 4: *Probe Tack Test Instrument*

1. The adhesive tape (or adhesive coated surface) being tested is attached to an annular weight with the adhesive layer facing the inside of the annulus (Figure 4(b)). This is placed on the carriage of the test machine (Figure 4(d)). The mass of the annular weight supplies a known contact force (additional weights can be placed on top of the specimen to increase this force).

2. The cylindrical probe (of specified material and dimensions as shown in Figure 4(c)) is raised until it supports the specimen and mass (the contact pressure is the mass over probe area).
3. This is held in position for the set dwell time and, then, the probe is removed at the set test speed. The force required to separate the probe from the adhesive is measured. Tack is expressed as the maximum value of this force.

Advantages:

- sample alignment is simple;
- tests require no specialist expertise;
- contact pressure, separation rate and dwell time are all variable and controllable;
- substrate deformation less significant; and,
- constant bonded area.

Disadvantages:

- requires specialised equipment (only one supplier);
- equipment is relatively expensive and has little application beyond tack measurement;
- contact area is low - many tests may be needed for statistical certainty;
- difficult to vary probe material to suit specific applications; and,
- the raising and lowering speeds are the same - at slow speeds the actual time that the adhesive is in contact with the probe will be large, and in addition to the set dwell time; this is also a feature of other tack measurement methods.

Standard Probe Tack Test Method:

- ASTM D2979-95, Pressure sensitive tack of adhesives using an inverted probe machine. [13]

3.4 Quick Stick

Quick stick is the property of a pressure sensitive tape that causes it to adhere instantly to a surface. Quick stick tests measure the resistance to peel at a 90° angle from a standard surface. Tests are carried out in a tensile test machine using a special fixture to ensure that the edge of the peel is always directly beneath the grips. The initial 25 mm of peel are ignored and the quick stick is measured from the force required to peel the remainder of the tape. The BS [14] and the AFERA [15] methods are equivalent. The PSTC method [16] is essentially the same. However, the BS and AFERA methods specify applying the tapes with a 25 g roller whilst the PSTC method only allows contact pressure due to the weight of the tape.

Advantages:

- the constant force required to peel tape is measured and averaged rather than taking a maximum peak value, this should improve repeatability; and,
- the contact pressure and separation rate are specified.

Disadvantages:

- requires a special loading stage to maintain 90° peel angle;
- the dwell time is not controlled but depends on how long specimen attachment takes;
- the dwell time is likely to be longer than in the loop tack test or probe tack test - less of an instant tack measurement; and,
- peel angle at the end of the tape will be controlled by the mechanical properties of the backing and, hence, different backings will give different results.

Standard Quick Stick Methods:

- BS EN 1945: 1996, Self adhesive tapes - measurement of "Quick stick", British Standards Institution. [14]
- AFERA 4015. [15]
- PSTC 5, Quick Stick of Pressure Sensitive Tapes, Pressure Sensitive Tapes Council, Chicago, USA. [16]

4. Methods for Activated Adhesives

Activated adhesives differ from pressure sensitive adhesives in that they are not permanently tacky. They must be activated in some way before they become tacky. The most common methods of activation are heat or moisture activation. Tack properties will vary with time after activation. Any tack measurement method used with these adhesives must take into account the likelihood that the properties of the adhesive are changing with time after activation. For comparative studies (e.g. quality control) the activation and conditioning of the adhesive must be controlled as part of the test procedure. Provided that this control can be achieved then the test methods described in Section 4. for pressure sensitive adhesives can be used to quantify tack of activated adhesives. Methods have been developed in different industries for measurement of substances such as remoistenable gums that are used to seal envelopes or attach stamps [17, 18].

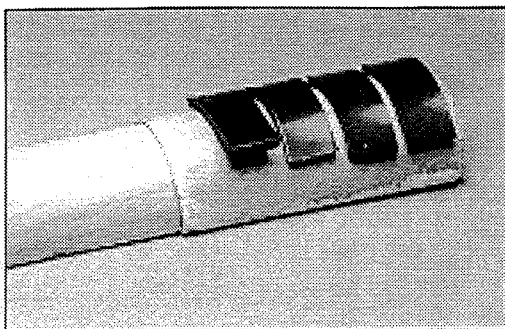
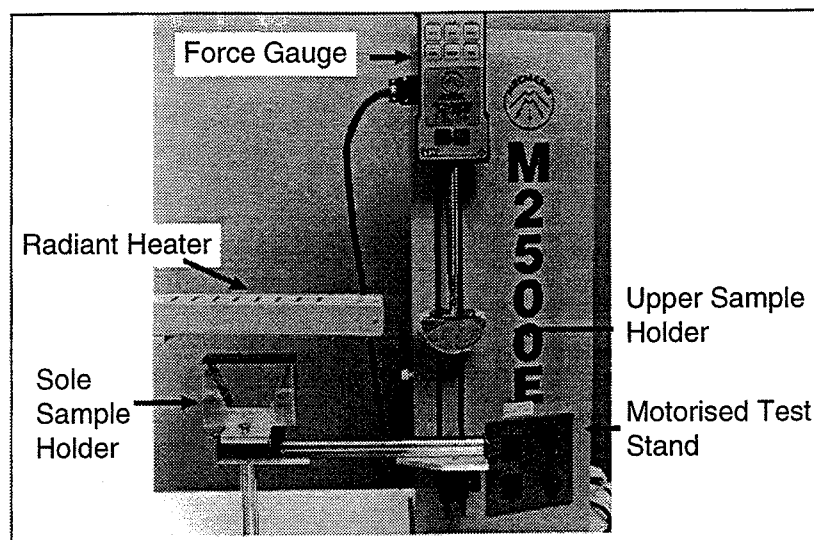


Figure 5: SATRA Test Method AM19

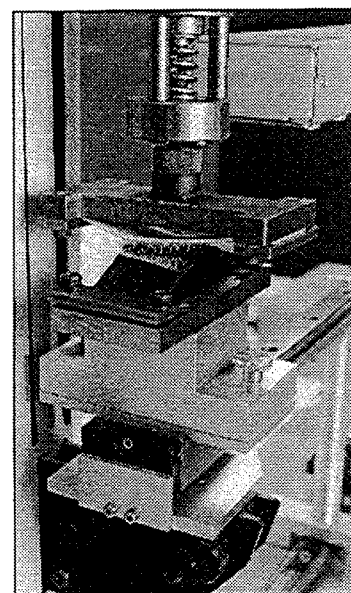
Traditional test methods are ‘spotting’ tack methods. Two surfaces are bonded or ‘spotted’ together then pulled apart. The operator gauges tack from the effort required to separate the surfaces. This type of test can be subjective. Many of the requirements for tack testing arise from process development needs. There may be a need to select an adhesive for a particular process or to optimise a process for a particular adhesive. In this case the method chosen should closely follow the bonding operation. These requirements tend to produce qualitative test methods such as the SATRA Shoe Tack Test [19]. This test will be discussed in some detail as a case study of such industry specific tests.

In footwear manufacture the sole and the upper are spotted together during the manufacturing process to position them for final assembly. The adhesive needs sufficient strength to hold the shoe together as it passes through the assembly line. Tack is therefore a critical property for the trouble free assembly of footwear. The SATRA Shoe Tack Test AM19 (Figure 5) was designed to assess whether an adhesive was suitable for the shoe bonding process, for example as part of adhesive selection trials or in production to check the quality of material batches. The test mirrors the shoe bonding process in that similar materials (e.g. upper leather, sole rubber) are used. The leather is nailed to a half round wooden mandrel. The sole rubber and leather upper are coated with adhesive and activated using the production procedure. The sole is bonded to the leather by pressing down using ‘finger pressure’. When released, the rubber sole will attempt to spring back. The adhesive should prevent this. The quality of the tack is assessed from the proportion of the sole peeling from the leather in a set time. The mode of failure is noted from the appearance of the separated surfaces. The failure can be classified as: adhesive (adhesive separates from one surface), cohesive (rupture in the adhesive layer - fracture layer looks rough and ‘stringy’ - known as ‘legginess’) and non-coalescence (fracture in the adhesive layer through failure of the layers to bond - fracture layer will tend to look smooth).

This test has the advantage of being cheap and simple to carry out in a production environment. However, there is a lot of subjectivity in carrying out the test and interpreting the results. For instance, concepts of ‘finger pressure’, which controls the important contact pressure, could vary significantly amongst operators giving poor reproducibility. Carrying out more sophisticated work, such as optimising process conditions, identified the need for an improved test method. The acquisition of quantitative data was a particular need.



(a) Tack tester



(b) Clamps for ‘flat’ samples - compliant substrates bend during separation.

Figure 6: NPL/SATRA Tack Test Instrument

An improved test method (Figure 6) has been developed around a motorised stand and load cell (this basic apparatus could also be used for loop tack or quick stick tests) to measure ‘pull-off’ or tack forces. Interchangeable fixtures allow use of different test configurations (including flat plates or half rounds) or surfaces. The motorised stand allows control of the pressure application (including push-down force) and separation stages. The equipment incorporates heating and temperature measurement units that allow close control of the activation and conditioning steps. The sample can be slid on a track between the heater and the test stand to minimise delays between activation and testing. Many areas of subjectivity or uncontrolled factors in the old test are therefore controlled or quantified in the new test.

The instrument can be operated with specified test settings and surfaces for quality control and material selection. For example, standard test settings of pressure (200 kPa), loading/separation speeds (10 mm s^{-1}), dwell time (1 s) and clamp positions were chosen for most tests. The ability to vary these parameters enables studies into the optimum process conditions for bonding to be conducted. Some results of such studies [20] are presented which illustrate how preparation and test conditions can influence the measured bond strengths.

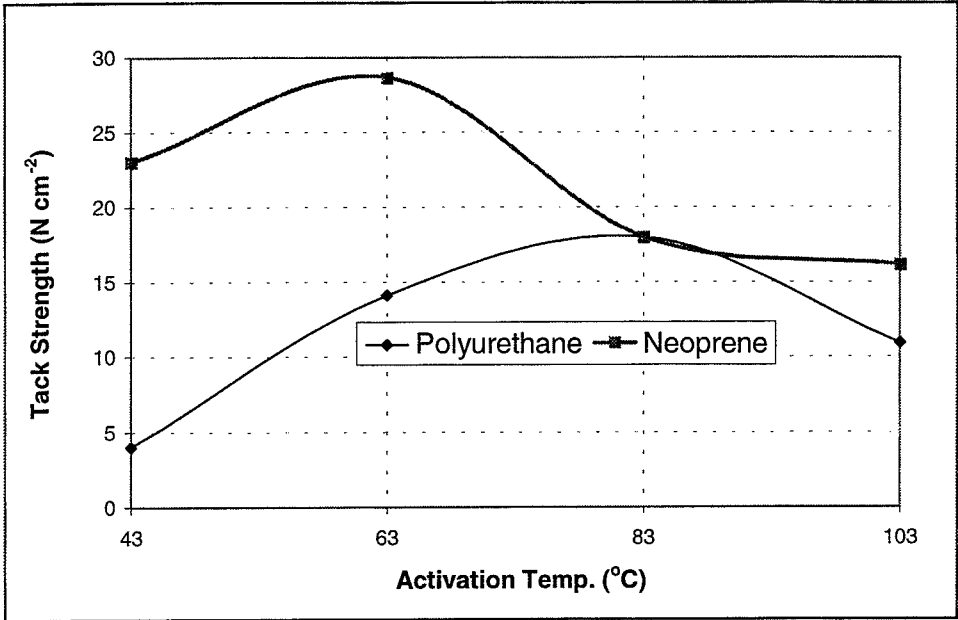


Figure 7: Dependence of Tack on Temperature

Measured tack strengths were sensitive to temperature at bonding/testing (Figure 7) and contact pressure (Figure 8). In both cases, there seems to be an optimum level. This type of study could be used to improve manufacturing processes. It also helps identify factors to which the tack is most sensitive. Thus, test or bonding conditions can be selected to improve repeatability. The work also demonstrated how the compliance of the substrates (through different clamping positions or number of layers of substrate) could influence the measured results (Figure 9). Care should be taken when comparing tack if using substrates of differing flexibility.

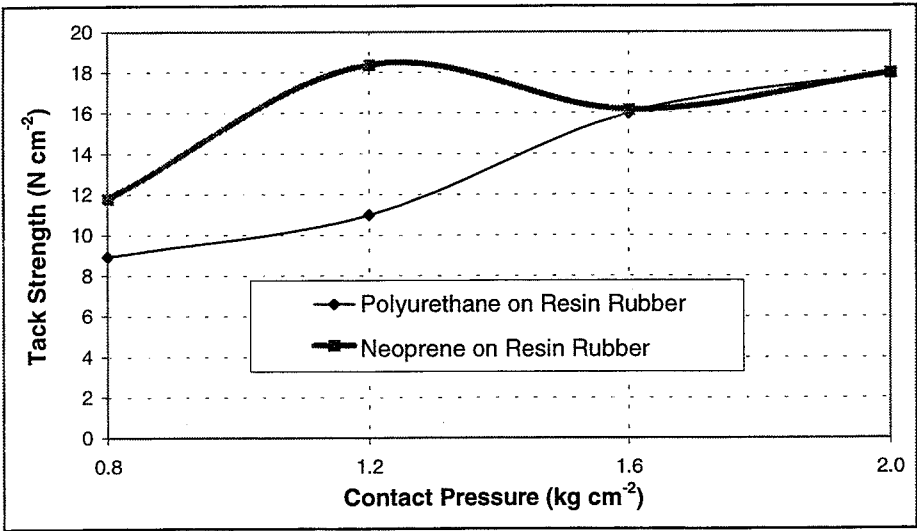


Figure 8: Dependence of Tack on Contact Pressure

An area where the new tack tester has been used successfully was the selection of water-based adhesives for footwear bonding. Shoe manufacturers needed to replace solvent-based adhesives with water-based adhesives to comply with regulations limiting the release of volatile organic compounds (VOCs). The tack test was one of the methods used to prove the performance of these replacement adhesives.

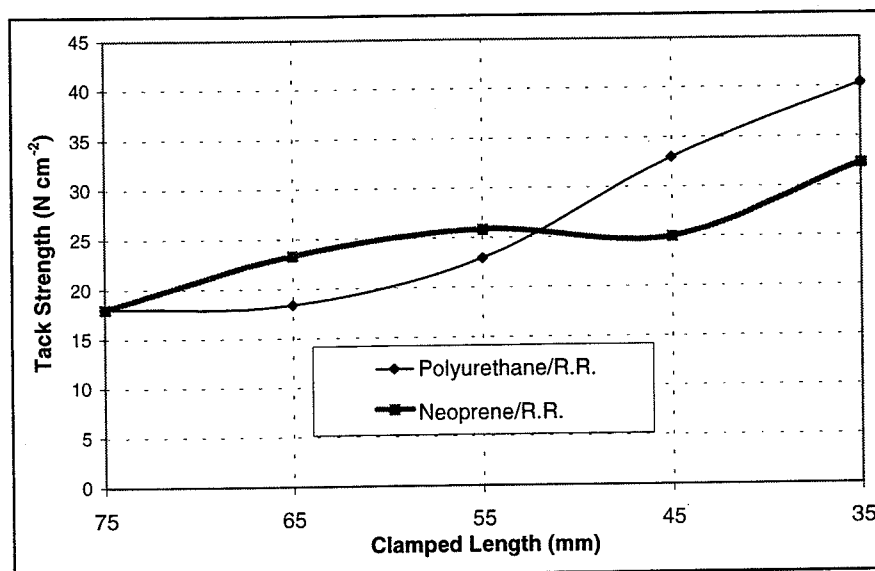


Figure 9: *Dependence of Tack on Substrate Compliance (closer clamp separation constrains the substrate more)*

5. Assessment of Measurements

5.1 Round Robin Assessment of Loop Tack Test

Thirteen laboratories took part in an intercomparison exercise to assess the accuracy and repeatability of the loop tack test method [10]. All the organisations were supplied with three tapes (tape 1; high tack, tape 2; medium tack and tape 3; low tack) and a copy of the FINAT FTM 9 test method. Tests were performed using the organisation's own tack test apparatus. Table A in Appendix II contains a summary of the results from this study.

The results suggest that the repeatability of results within a laboratory tends to be good. In the main, the coefficients of variability (C_v = standard deviation divided by average) tended to be around 0.1. The main exceptions were the tests, especially with tape 1, where significantly lower than average tack measurements were obtained for a given tape. The reproducibility between laboratories was poor. There was particular difficulty with tape 1 which had the highest tack but the most flexible backing. Tape 1 caused more problems in the loop formation step than the other tapes. The results for this tape showed the most variability. As a consequence, only 9 of the 13 organisations ranked the tapes in accordance to their nominal tack.

5.2 Comparison of Methods

A study [21] of the rolling ball (ASTM D3121 [2]), loop tack (FTM 9 [7]) and probe tack (ASTM D2979 [13]) methods was conducted using the three tapes used in the round-robin exercise (tapes 1-3). Five extra tapes were studied with the loop and probe tack methods (tapes 4-8). The results are summarised in Appendix II, Table B. The measured results and standard deviations are given. The figures in the brackets refer to the relative ranking position of the tape as measured by the test method.

The results obtained from the rolling ball tests did not correlate with the other methods. Tape 1 is clearly ranked as having the highest tack of the first three tapes by both the loop and probe tack methods. However, according to the rolling ball test the tack is the lowest. The

rolling ball test ranks this tape poorly as the thin backing does little to absorb the kinetic energy of the ball.

The loop tack and probe tack tests tend to give the same general ranking of the tapes. Each distinguishes between tapes with high tack and those with low tack. However, discrimination between tapes of similar tack is not so good and minor differences in the rankings are observed. This may be partly due to the measurement uncertainties. There are a number of differences between these test methods which are summarised in Table 2. These differences may lead to different rankings of the tapes. For example, Figure 10 shows the probe tack results for tapes 1-3 measured using different dwell times. The tack increases with dwell time which is expected. The sensitivity of tack to the dwell time differs between the tapes. Tape 2 is much more sensitive to dwell time than tape 3. Consequently, the ranking of tapes 2 and 3 reverses between 1s and 10s dwell time. The data in Appendix II were determined using the standard dwell time of 1s. The loop tests and the probe tack tests rank these tapes oppositely. However, if probe tack results for 10s dwell times (comparable with the dwell times in the loop tack test) were used then the test methods would produce the same rankings for tapes 1-3.

Table 2: The practical differences between the loop tack and probe tack methods

	Loop	Probe
Adherend surface	Glass	Stainless steel 304
Adherend roughness	Smooth	280 grit abrasive finish
Contact area	625 square mm	20 square mm (approx.)
Contact pressure	About 0.2 - 5.0 g/ sq. cm	100 g/ sq. cm
Dwell time	Variable, 20 - 30 s	Fixed, 1 s
Speed of separation	5 mm/sec	10 mm/sec

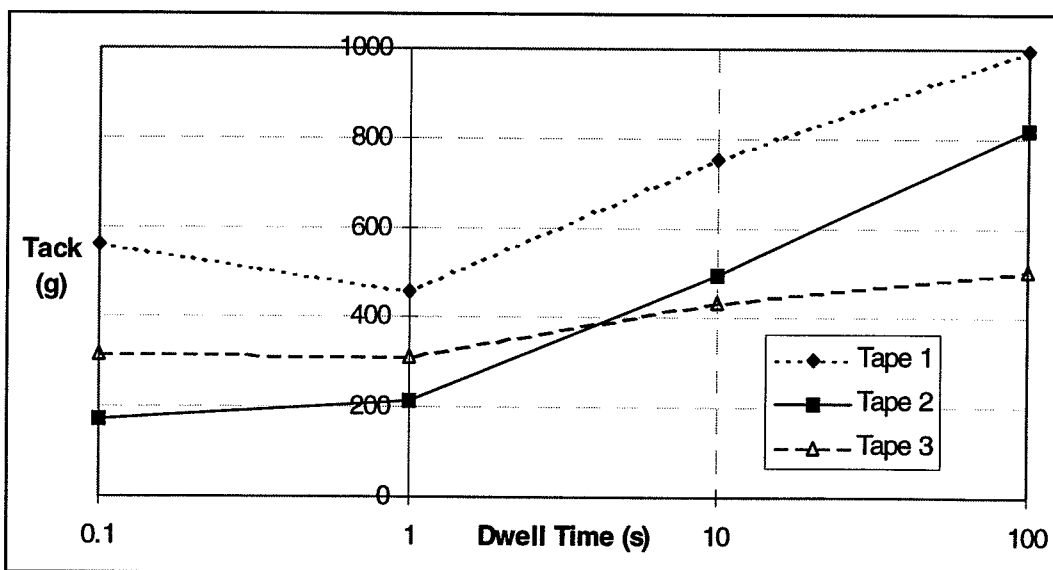


Figure 10: Probe Tack as a Function of Dwell Time

5.3 Measurement Accuracy

The coefficient of variability (Cv) results from the intercomparison of the test methods and the round robin suggest that the standard deviation of the measurements is typically around 0.1 times the mean value measured for the tack. Higher values for Cv either suggest problems with making the measurements or a high degree of variability in the samples being tested. Discussions with organisations that routinely measure tack suggest that 0.1 is a reasonable value for repeatability. For some applications Cv values up to 0.3 can be tolerated.

The repeatability of the loop tack and probe tack tests (from the data in Appendix II) appears to be similar. Inherently, the probe tack test ought to be more repeatable as more of the test variables are controlled during the test. However, the area of contact with the probe is much smaller than the area of contact in the loop tack test. Some of the uncertainties in the probe tack values may be due to variability of the properties along the adhesive tape.

6. Summary

Tack is an important property for adhesive systems. However, tack is not a single property of an adhesive but will also depend on the surfaces and the bonding process. Therefore, tack measurement methods may tend to be specific to the application of the adhesive. Tack is sensitive to a wide range of factors and, therefore, measurement accuracy may be less than that for other mechanical properties. This guide has outlined the most popular tack measurement methods. Factors that influence the accuracy of the measurements have been discussed.

7. Useful Contacts

NPL

National Physical Laboratory
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Tel: 020 8943 6701

SATRA

SATRA Footwear Technology Centre
SATRA House
Rockingham Road
Kettering, Northants, UK, NN16 9JH
Tel: 01536 410000

PSMA

Pressure Sensitive Manufacturers Association
Sysonby Lodge
Nottingham Road
Melton Mowbray, Leics, UK, LE13 0NU
Tel: 01664 500055

TWI

(formerly The Welding Institute)
Abington Hall
Abington, Cambridge, UK, CB1 6AL
Tel: 01223 891162

PSTC

Pressure Sensitive Tapes Council
401 North Michigan Avenue,
No. 2200, Chicago, Illinois, 60611426, USA
Tel: 00 1 312 644 6610

AFERA

Association des Fabricants Europeens de Rubans
Auto-Adhesifs
60 Rue Auber
94408 Vitry Sur Seine Cedex, France
Tel: 00 33 1 45 21 03 50

PIRA

Pira International
Randalls Road
Leatherhead, Surrey, UK, KT22 7RU
Tel: 01372 802000

ATMA

Adhesive Tape Manufacturers Association
C/o Crane & Partners
Rutland House, 44 Masons Hill
Bromley, Kent, UK, BR2 9EQ
Tel: 020 8464 0131

BSI

British Standards Institution
British Standards House
389 Chiswick High Road
London, UK, W4 4AL
Tel: 020 8996 9000

FINAT

Laan Capes van Cattenburch 79
NL-2585 EW, Den Haag
Netherlands
[FINAT stands for Federation International des
Fabricants et Transformateurs d'Adhesifs et
Thermo Collants sur Papiers et Autres Supports]

TLMI

Tag and Label Manufacturers Institute
40 Shuman Blvd, Suite 295
Naperville, Illinois, 60563, USA
Tel: 00 1 630 357 0192

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Appendix I: Factors Influencing Tack

For each factor an indication of what are essential controls to apply and those which are desirable to optimise the accuracy (but not necessarily economically feasible to incorporate) is listed. The sensitivity of tack to these factors will vary with the type of adhesive, surfaces and general processes.

Factor	Optimum	Essential	Effects
Adhesive Application	measure coating weight and thickness;	procedures to coat adhesives in a repeatable way; visual inspection of adhesive layer; repeatable times between applications of different layers	tack is sensitive to uniformity and thickness of the adhesive layer; the amount of drying between application and bonding may influence tack significantly;
Contact Pressure	measure pressures; controlled within tight limits; pressure should be uniform over the bonded area;	procedures to ensure repeatable contact pressures;	tack will increase with increasing contact pressure (will eventually have no further effect);
Dwell Time	control dwell time within strict limits; contact time should be the same for all the bonded area;	procedures to ensure repeatable dwell times; measure dwell times; consider time to apply pressure;	tack will increase with increasing dwell time (will eventually have no further effect); long dwell times may not actually measure tack but bond strength (tack by definition relates to short contact times);
Test Speed	control test speeds within strict limits; use different contact and separating speeds;	procedures to ensure repeatable test speeds; measure test rate;	there will be a speed for optimum tack, increasing test speeds may increase or decrease tack;
Test Temperature	control over test temperature using a local environmental chamber;	test temperatures to be consistent; measure test temperature;	there will be a temperature for optimum tack;
Humidity	control humidity using a local environmental chamber;	test humidity to be consistent; measure humidity;	tack is sensitive to moisture content of the adhesive; condensation on the surfaces can interfere with adhesion;

Factor	Optimum	Essential	Effects
Adherend Surfaces	use specified materials; quantify surface properties - roughness, porosity, chemical composition; use a specified surface treatment;	use consistent materials (i.e. same material, consistent roughness, porosity, absorbency, stiffness, hardness, etc.); surface preparation to be repeatable; follow appropriate cleaning procedures; visual inspection of surface before testing; surface must be clean; cleaning fluid should be specified; avoid silicone impregnated cloths;	tack is sensitive to the bonding surfaces; surface energy affects wettability and adhesion strength; the surface energy will depend on the preparation given unless no preparation is used, in which case it will depend only on the material; roughness will increase the contact area; porous surfaces may absorb the adhesive;
Adherend Compliance	control through the use of movable clamps; use materials of specified stiffness;	use substrates of consistent compliances where possible; awareness required of how compliance compares with other samples; procedures to ensure that loops are formed with the correct shape (loop tests);	the compliance of the adherends determines the shape of the edge of the bonded area and, hence, local peel stresses;
Specimen Conditioning	condition in a tightly specified environment;	ensure environmental conditions in storage environment are stable and consistent with the test conditions;	conditioning history (e.g. temperature, humidity) will influence tack;
Expressing Results		clear, unambiguous method for analysing the data; statistically valid number of tests performed (at least 5);	measurements will be variable to some degree and this variability should be quantified; single measurements may have large uncertainties - better to work with means of measured values.
Adhesive Activation	measure activation conditions and level before testing;	consistent activation procedure; consistent time/conditions between activation and testing;	activation and changes in the adhesive after activation are likely to have a significant effect on the tack;

Appendix II: Data From Tack Studies

Table A: Results from the Loop Tack Round Robin [10]

Laboratory	Tape 1		Tape 2		Tape 3	
	Tack (N)	Cv	Tack (N)	Cv	Tack (N)	Cv
1	18.5 ± 3.1	0.17	10.8 ± 1.0	0.09	7.3 ± 0.5	0.07
2	6.0 ± 2.2	0.37	12.5 ± 1.1	0.09	4.5 ± 1.0	0.23
3	15.0 ± 4.0	0.26	13.5 ± 1.1	0.08	7.3 ± 0.7	0.10
4	14.7 ± 1.9	0.13	11.4 ± 1.8	0.15	7.2 ± 0.5	0.07
5	16.5 ± 1.0	0.06	12.9 ± 0.8	0.06	7.5 ± 0.7	0.09
6	12.2 ± 2.7	0.22	12.8 ± 0.9	0.07	6.6 ± 1.1	0.17
7	20.8 ± 0.9	0.04	13.1 ± 1.2	0.09	9.0 ± 0.7	0.08
8	11.0 ± 0.7	0.06	13.4 ± 1.4	0.11	5.4 ± 0.2	0.04
9	11.6 ± 3.5	0.30	13.0 ± 0.9	0.07	8.4 ± 0.7	0.08
10	18.6 ± 2.0	0.11	14.6 ± 0.8	0.05	8.6 ± 0.9	0.11
11	20.4 ± 2.2	0.11	11.8 ± 1.0	0.09	4.4 ± 0.7	0.15
12	17.2 ± 2.4	0.14	12.7 ± 0.3	0.02	6.5 ± 0.8	0.12
13	23.0 ± 2.8	0.12	14.8 ± 0.7	0.04	9.3 ± 0.9	0.09
average	15.8 ± 4.7	0.30	12.9 ± 1.1	0.09	7.1 ± 1.6	0.22

uncertainty is the standard deviation (sd) of 10 repeats
coefficient of variation (Cv) = sd divided by average

Table B: Tack Measurements on Adhesive Tapes [21]

Tape	loop tack (initial area 625 mm ²)		probe tack (initial area 20 mm ²)		rolling ball	
	Force (N)	± 1 sd	Force (N)	± 1 sd	distance (mm)	± 1 sd
1 (S)	23.01 (4)	2.83	5.33 (4)	1.52	652 (3)	88
2 (S)	14.80 (6)	0.65	2.13 (7)	0.35	21 (1)	6.7
3 (S)	9.25 (7)	0.87	3.21 (6)	0.32	190 (2)	18
4 (S)	7.87 (8)	1.61	1.26 (8)	0.23		
5 (D)	35.70 (2)	5.48	10.61 (1)	1.70		
6 (D)	35.12 (3)	4.64	9.37 (2)	1.52		
7 (D)	43.64 (1)	3.38	9.04 (3)	1.29		
8 (S)	28.46 (5)	2.27	3.96 (5)	0.63		

sd = standard deviation from 10 repeats

The figure in brackets is the ranking of the tape relative to the rest of the tapes as determined from the results given by the test method.

(S) = single sided tape; (D) = double sided tape

ENERGY

