

Loop Tack Measurements

Introduction

The capability to rapidly and reliably bond two surfaces is a key performance requirement in many pressure sensitive adhesive products, particularly adhesive tapes and labels. A key property for successful bonding is the tack or 'stickiness' of the adhesive. Tacky materials can be discerned by touch but for material specification or product development purposes a more quantitative approach is necessary. Tack is defined as the ability of an adhesive to form a bond to a surface after brief contact under light pressure. Often thought of as a simple property to measure, tack depends on a complex interaction of many different factors and, hence, there is no single value that characterises tack.

Tack is a complex property

Bond formation depends on:

- Adherend surface properties - material, wettability or surface energy, roughness, porosity.
- Preparation - cleanliness, pre-treatments, coating weight and uniformity, adhesive application, open or drying time, environmental conditions experienced prior to bonding.
- Physical and Chemical properties of the adhesive - type, functional groups, flow properties, surface energy.
- Bonding process - contact pressure, duration of contact, rate of pressure change, thermal history, penetration into surface.

Separation is influenced by:

- Separation process - rate of separation, angle of peel, specimen clamping.
- Mechanical properties of adherends - flexibility, modulus, cohesive strength of surface layers.
- Mechanical properties of adhesive - rigidity, cohesive strength, extension to failure, visco-elastic properties, creep, stress relaxation.

Determined values also depend on:

- Quantities measured - separation force or amount of peel, sampling rate.

Whatever the adhesive application or industry sector, there are common factors affecting tack and similar measurement processes used - bonds must be made and broken in order to assess the strength of the bond. In collaboration with organisations in the packaging industry (Pira International) and footwear industry (SATRA), the National Physical Laboratory has been taking a more in depth look into the measurement of tack.

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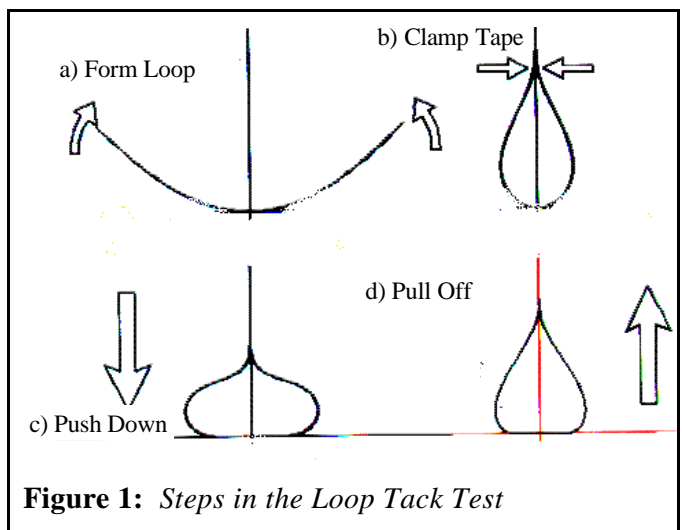
Many measurement methods for tack have been developed by industries for specific applications and even within a sector of industry there can be a myriad of different measurement methods in use. Standard measurement methods for pressure sensitive adhesive tapes include loop tack, probe tack and rolling ball tests. It is often the case that measured tack values depend very strongly on the test method [1]. There is often little correlation, even for qualitative ranking, between different measurement methods. Poor reproducibility between measurement laboratories is common despite well-specified tests. This was illustrated in a round-robin study where, despite being supplied with a detailed test procedure, nearly a third of the participating laboratories were unable to correctly rank three tapes having significantly different levels of tack. This makes specification and control of tack properties difficult.

Pressure sensitive adhesives are visco-elastic polymers whose mechanical properties are strongly dependent on temperature and strain rates. In theory the temperature of tests can be controlled so that differences between methods can be eliminated. However, the rate sensitivity of the adhesive's properties manifests itself in both the spreading of the adhesive to form intimate contact with the surface during bonding and the behaviour during separation. Loading rates and contact times differ between test methods. Hence, the visco-elastic behaviour of the adhesives is a key factor to the poor comparability of different test methods. Understanding this and choosing a method where the stress history approximates that in the bonding application is important to ensure that measured tack properties are relevant.

Loop Tack Tests

Loop tack tests are intended for quality control and specification of adhesive tapes and pressure sensitive adhesives. Standard methods usually specify the length and width (generally 25 mm) of the loop strip, the dimensions and material of the base plate and the speed of the test. Tack is defined as the force required to separate, at a specified speed, a loop that has adhesively contacted a specified area of defined surfaces. The tests can be performed with the adhesive coating either the tape or the base.

Each standard method specifies surface, cleaning and sample preparation steps. Once this is done all



types of loop tack test can be performed in the same way. There are four steps in the test.

Step a: Form the loop from the tape.

The specified length of tape should be bent back, with the adhesive outermost, until around 10 mm or so of the ends are in contact. 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.

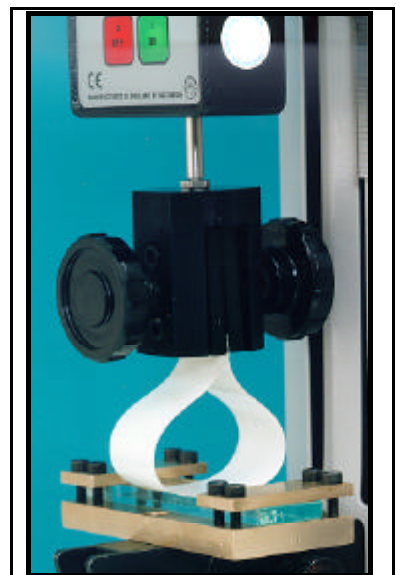


Figure 2: A loop tack test

The ends of the tape should be joined (using adhesive tape) to ease clamping.

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

The grips 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 which is normally the whole width of the base. Determination of full contact can be subjective (Figure 2). 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, and thus the distribution of stress, is determined by the stiffness of the tape.

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 is reversed. The area in contact is inspected visually for any imperfections in the contact (e.g. wrinkles or bubbles) and the results omitted from the analysis should this occur. The test runs until the tape is detached from the plate. Typically, the force may show one or more peaks before final separation. Some methods [2, 3] specify that tack is taken from the peak force whilst others [4] are more ambiguous. The de-bonding of the loop is a dynamic process and response rate of the force transducer or logging device 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 5 % difference between the maximum forces determined using fast (1200 points per second) and slow (10 points per second) devices [5]. The standard methods tend to specify different ways of expressing the tack. A single force value for tack may obscure the more complex behaviour of the system. The height of the peak is one parameter of the tack but the failure energy is also represented in the breadth of the peak.

Effects of Substrates

Loop tack tests, as with all adhesive joint tests, measure the aggregate response of the bonded system. Therefore, the mechanical responses of both the adhesive and bonded parts influence the measured tack values. Differences in the mechanical properties (e.g. modulus, thickness and clamping) of the backing and/or the base can give significantly different tack values despite identical surfaces, adhesives and processing conditions. This

effect of adherend stiffness on the nominal ‘tack’ can be explained by the changes in the forces required to deform the bonded surfaces and the different stress states in the adhesive layers due to changing angles of peel. Such effects can be analysed by Finite Element mechanics and Figure 3 contrasts the predicted peel (at similar peel forces) of a flexible backing, rigid base with that for a stiffer rigid backing, compliant base case. Where the base is compliant there is a large deformation of the base. This significantly changes the stress and strain distribution in the adhesive layer by increasing shear strain but reducing principle strain in the adhesive. Therefore, at the same peel force, adhesive rupture is much more likely in the case of the compliant backing, rigid base than the case where the base is more compliant.

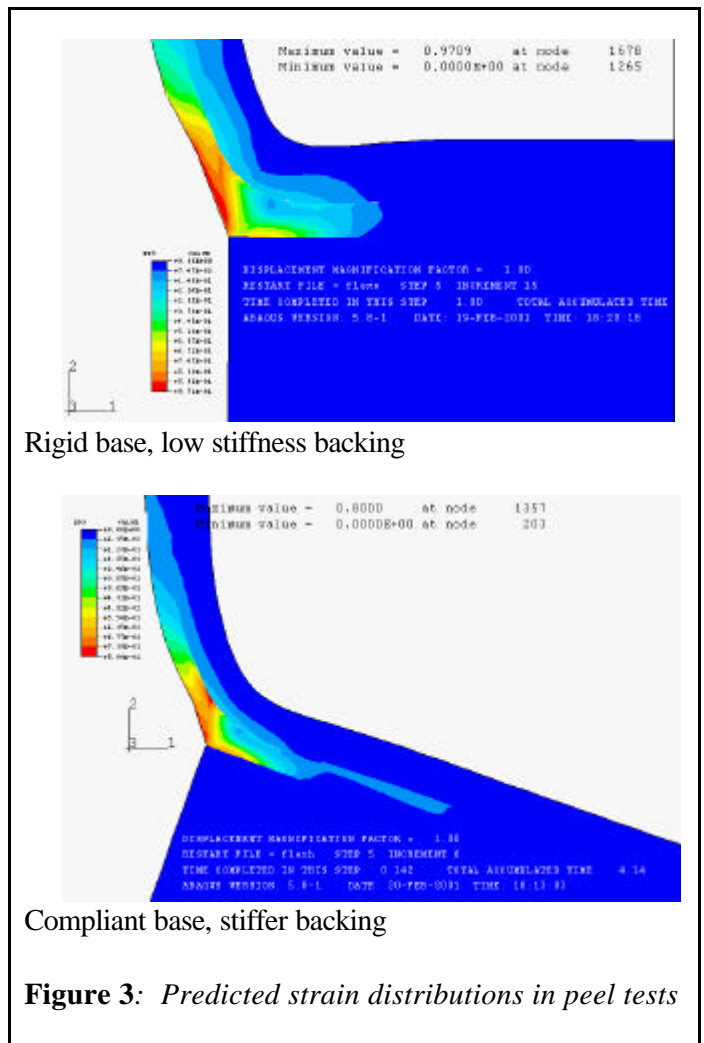


Figure 3: Predicted strain distributions in peel tests

Figure 4 shows plots of maximum principle strain in the adhesive layer against peel force, illustrating the influence of backing stiffness and substrate compliance

There can be large differences in peel forces required to achieve a consistent level of peak strain in the adhesive layer. If this strain is a rupture criterion for the adhesive then different properties for the backing and base will lead to different measured tack values despite consistent adhesive and adhesion properties.

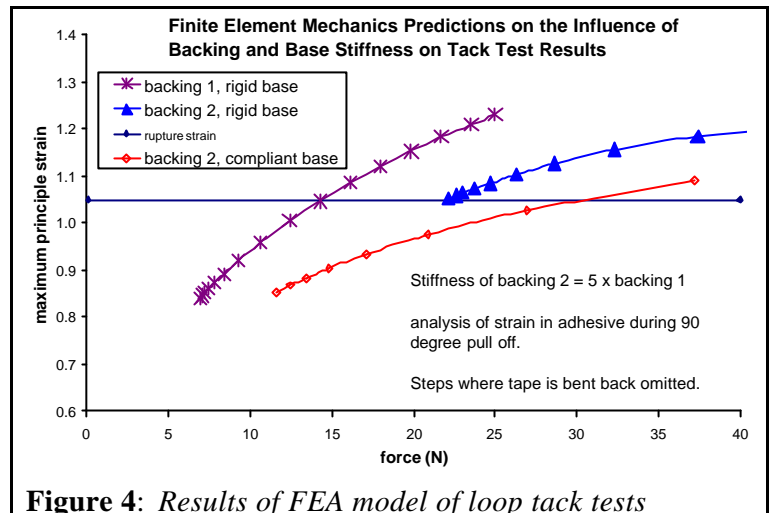


Figure 4: Results of FEA model of loop tack tests

Materials properties data and reliable models to characterise the deformation and failure of flexible visco-elastic adhesives under complex states of stress are lacking. Normal measurement techniques for visco-elastic properties, such as dynamic mechanical analysis or oscillatory rheometry, operate predominantly in the low strain region whereas tack strength is also determined by the large strain, failure behaviour of the adhesive. Methods for determining the mechanical performance of flexible adhesives are the subject of a current research programme.

In conclusion, loop tack tests are often seen as simple tools for quality control. However, interpreting and correlating these tests is complicated by the visco-elastic nature of the adhesive and the significant influences of the mechanical properties of the components bonded. Improved materials properties data and mechanical modelling tools will enable a better understanding of this 'simple' test method.

References

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