Tack Measurements for Reliable Adhesive Bonding

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The capability to rapidly and reliably bond two surfaces is a key performance requirement in many applications ranging from adhesive tapes and labels for packaging, electronic component assembly to footwear manufacture. A key property for successful bonding is the adhesives tack or 'stickiness'. Tacky materials can be discerned by touch but for material specification or process development purposes a more quantitative approach is required. Tack is defined as the ability of an adhesive to form a bond with a surface after brief contact under light pressure. It is often thought of as a simple property to measure although in reality tack depends on such a complex interaction of different factors that no single value can characterise tack.

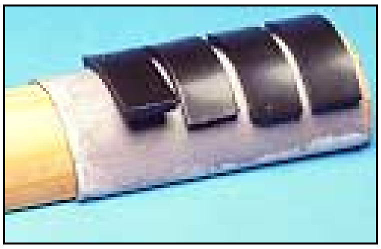
Tack measurement via the forces required to separate two surfaces

Over the years, many measurement methods for tack have been developed by industries for specific applications. Even within a sector of industry there can be a myriad of different measurement methods in use. For example, standard measurement methods for pressure sensitive adhesive tapes include loop tack, probe tack and rolling ball tests. Tack depends very strongly on the method by which it is measured. There is often little correlation between different measurement methods and poor reproducibility between measurement laboratories is common. This was illustrated in a round-robin study where, despite being supplied with a well-specified 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.

A loop tack test

Whatever industry is concerned 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.

Permanent tack is a property of the pressure sensitive adhesives used on tapes and labels. There are many tack test methods for these adhesives and some of these were evaluated further to identify the influences of test parameters. 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. 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 measured tack properties are relevant. Applications of this knowledge have helped a major manufacturer, distributing products worldwide, to develop a label adhesive specification to ensure labels remained attached under all possible storage conditions.



Old footwear tack test

In the footwear industry adhesive bonding is used to join the sole (normally rubber) to the upper (normally leather. The bond must have sufficient strength to maintain integrity of the shoe during assembly. An urgent need existed to replace solvent-based adhesives with more environmentally acceptable materials. However, existing tests, that assessed tack through the rate of peel of adhesive-coated rubber samples stuck to a rounded leather base, had many weaknesses. This method was very sensitive to the amount of pressure used by the tester when pressing the samples to the base. An improved test method grew to qualify new water-based adhesives was needed.

Tack is a complex property

Bond formation depends on:

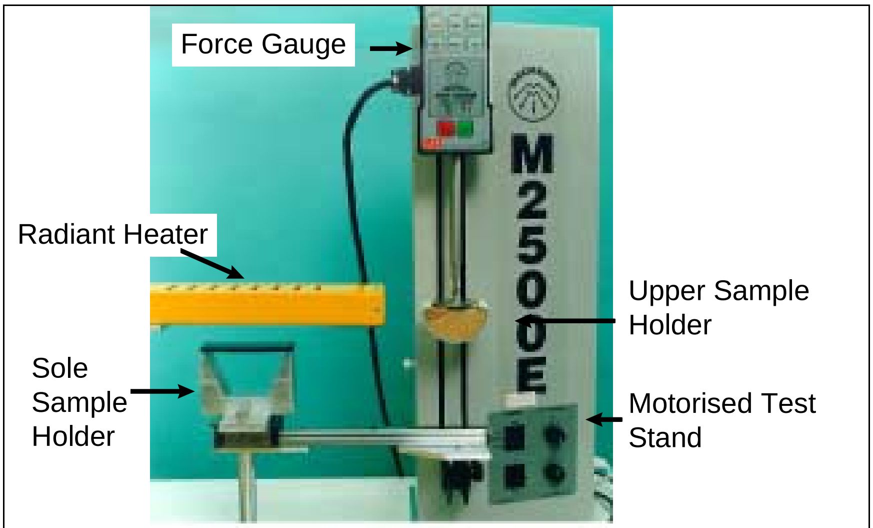
- Adherend surface properties - material, wettability or surface energy, roughness, porosity
- Preparation - cleanliness, pre-treatments, coating weight and uniformity, adhesive application, open or drying time, environmental conditions experienced prior to bonding
- Physical and Chemical properties 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

Measured values also depend on:

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



NPL/SATRA tack tester

The decision was taken to develop a method that measured separation forces as this was seen as more reliable than the measurement of peel rates. Therefore an instrument based on a simple, inexpensive motorised test stand test stand and force cell was developed. The key variables thought to influence the tack measurement were temperature of the adhesive (many of the materials being studied were heat activated), the contact pressure and the duration of contact. Therefore, the instrument was designed to allow control of all these factors.

This instrument was used to assess adhesives for the footwear industry and was an important method for qualifying replacement adhesives. The flexible nature of the instrument proved helpful for establishing optimum processing conditions for these new adhesives - effects of process factors such as bonding temperature, open time and contact pressure on bond strength could be established - thereby accelerating their adoption by the industry.

Tack tests, as with all adhesive joint tests, measure the aggregate response of the bonded system. The mechanical responses of both the adhesive and bonded parts influence the measured tack values. Tests performed with the tack tester using different thickness and clamped lengths of soling rubber gave significantly different tack forces despite identical surfaces 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 should be amenable to analysis by Finite Element mechanics and some work has been performed in this area.

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.

The work described in this paper work formed part of the DTI funded Performance of Adhesive Joints programme. The assistance of Steve Abbott at SATRA and Richard Roberts at Pira is gratefully acknowledged. Measurement research focussing on adhesive bonding, composites and coatings will be continued in the Measurements for Materials Systems programme commencing spring 2001.