

Measurement Note

Determining the wettability of substrates to hot melt adhesives

Summary

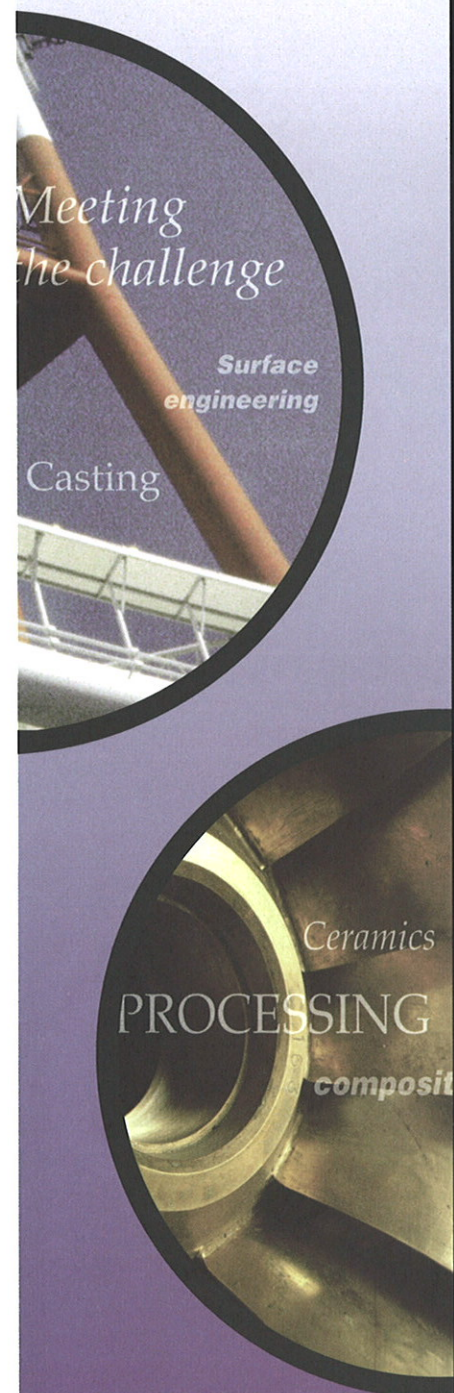
This Measurement Note details measurements of the wetting of hot melt adhesives on various packaging surfaces at elevated temperatures typical of application conditions. The results for an adhesive applied to substrates having different water wettabilities suggest that the contact angle of water on the surface provides a poor prediction of the wetting of the substrates by low surface tension liquid polymers.

A series of measurements on additional adhesives normally processed at much higher temperatures suggests that the higher visco-elastic properties of these adhesives at the measurement temperature (100 °C) could prevent full wetting from occurring.

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INTRODUCTION

Adhesive bonding is a key joining technology in many industrial sectors. Adhesives are widely used for their ability to join dissimilar materials, forming joints which are durable but at the same time are unobtrusive and do not detract from the aesthetics of the finished product.

Hot melt adhesives, thermoplastic polymer based compounds that are applied as hot fluids and harden as they cool, are used extensively in non-structural bonding. One of the key bond formation processes is the wetting of the substrates by the adhesive. Since, it is extremely difficult to measure contact angles at elevated temperatures, a commonly used method of assessing the wettability of surfaces is through the contact angle of water drops on the surface at ambient temperature. This Measurement Note compares this with the measurement of contact angles of hot melt adhesives on surfaces, at typical process temperatures.

CONTACT ANGLE BY SESSILE DROP

A liquid (adhesive) will wet a solid (adherend) when its surface energy is lower than the solid's surface energy. The contact angle is the angle a liquid drop makes when it comes into contact with a solid surface. This angle will vary depending upon the surface tension of the liquid and will initially vary with time as the liquid spreads over the surface (see Figure 1). Force balance or equilibrium at the solid-liquid boundary is given by Young's equation for contact angles:

$$\gamma_{lv} \cos \theta = \gamma_{sv} - \gamma_{sl} \quad (1)$$

where θ is the contact angle, and γ_{lv} , γ_{sv} and γ_{sl} are the surface free energies of the liquid-vapour, solid-vapour and solid-liquid interfaces, respectively. The lower the contact angle, the greater the wetting of the solid by the liquid. Complete wetting occurs at a contact angle $\theta = 0$, ($\cos \theta = 1$).

The method for determining contact angle is as described in BS EN 828 [1]. A flat sample of the substrate material is placed underneath a syringe and a drop of liquid is dispensed onto the substrate. The silhouette of the drop is viewed through a camera connected to a PC to capture video images of the drop, see Figure 1. Image analysis software is used to calculate the contact angle. Water drop contact angle measurements are made using distilled water. Typically the angle is determined 1 second after the drop is placed on the substrate surface.

HOT MELT ADHESIVE RESULTS

In order to determine the contact angles and wettability of liquid hot melt adhesives at elevated temperatures, the substrate and syringe tip were enclosed in a "hotbox" with a temperature controller, as described in DEPC-MN-013 [2]. The substrate and drop of hot melt adhesive were maintained at constant temperature during the tests. The drop was observed by the camera through a viewing panel in the side of the box.

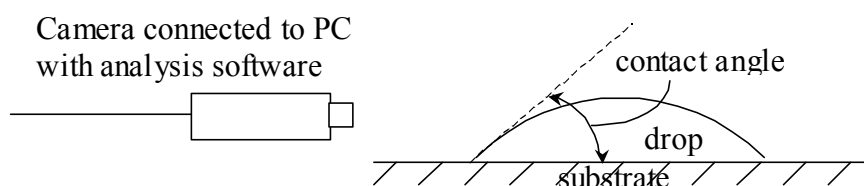


Figure 1 Schematic of contact angle measuring apparatus

Novocal 90, a hot melt adhesive with a low processing temperature, was applied to a series of packaging substrates and maintained at 100 °C. Measurements were taken of the contact angle of the adhesive over a period of time. There is a large fall in contact angle at the start as the adhesive flows onto the surface, Figure 2. Hot melt contact angles, determined 30 s after application, range from 12° to 26°. Water drop contact angles measurements made on the same substrates were in the range 60° to 105°. The better wettability of the hot melt adhesive arises since the surface tension of the adhesive (around 20 mN/m [2]) is much lower than that of distilled water (72 mN/m).

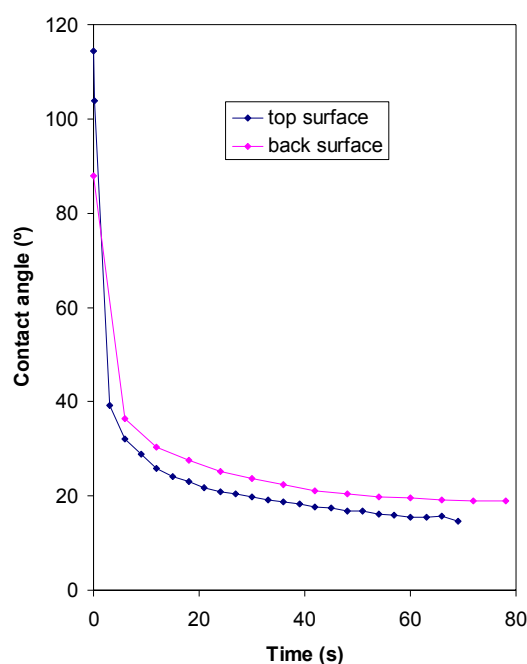


Figure 2: Contact angle of hot melt adhesive

Figure 3 shows a plot of hot melt contact angle against water drop contact angle. Although there is significant scatter, there appears to be a negative correlation between the water drop contact angle and the hot melt contact angle, suggesting that the water drop contact angle is not a good predictor of hot melt adhesive wettability.

Drops of three additional adhesives, which have higher processing temperatures (165°C – 180 °C), were applied onto a PET surface studied in the Novacol 90 tests. Contact angle measurements were made at 100 °C. The results are shown in Figure 4(a) and appear to indicate that, at this temperature, there is a considerable variation in the contact angles for the different adhesives despite their similar surface tensions [2]. However, the flow properties of these adhesives, represented by the complex visco-elastic modulus G^* , are very different near this temperature. Figure 4(b) suggests, as there is a strong correlation between contact angle and G^* , that the higher resistance to flow prevents the adhesive wetting out on the substrate. Thus, the changing rheology as the adhesive cools will influence the bonding process.

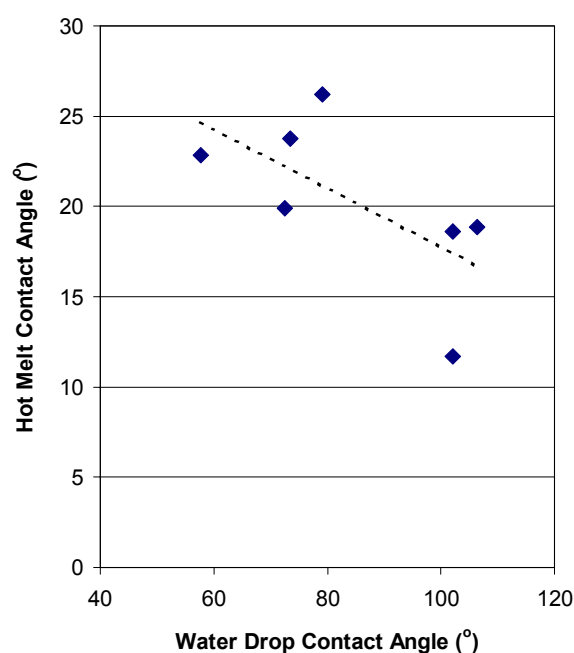


Figure 3: Correlation of hot melt and water drop contact angles

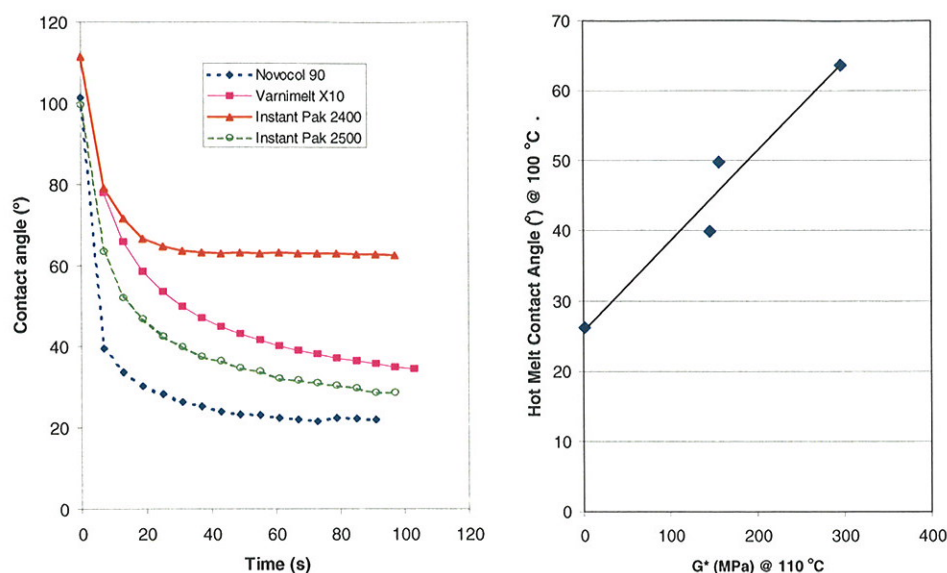


Figure 4: (a) comparison of four hot melt adhesives (b) correlation of contact angle with visco-elastic properties

REFERENCES

- [1] BS EN 828:1997, *Adhesives – Wettability – Determination by measurement of contact angle and critical surface tension of solid surface.*
- [2] DEPC-MN-013, J S Nottay and M Rides, *Methods for characterising surface tension of hot melt adhesives.*

ACKNOWLEDGEMENTS

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