Effect of Plunging Tape Surface Properties on Air Entrainment Velocity

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The wettability of polymeric tape surfaces such as polystyrene, polyethylene, and polypropylene does not significantly affect air entrainment velocities. However, rougher surfaces, as suggested by Scriven (1982), show significantly higher air entrainment velocities.

Air entrainment velocities are related to maximum coating speeds in coating operations and have been studied using flexible tapes plunging vertically into pools of liquid by Perry (1967), Burley and Kennedy (1976 a, b), Kennedy and Burley (1977), Burley and Jolly (1982, 1984), and Gutoff and Kendrick (1982). These studies indicate that liquid viscosity has the most significant effect on the air entrainment velocity, which decreases with the 0.67–0.78 power of the viscosity. Gutoff and Kendrick found no significant effect on surface tension, but Burley and his coworkers believe that air entrainment velocities increase with the 0.38 power of surface tension. The wettability of the polymers they studied did not vary enough to determine surface effects. This work was carried out to study the effects of surface wettability and roughness on air entrainment velocities.

A number of plastic and paper tapes were slit 16 mm wide and tested in the apparatus shown in Figure 1. The tape first contacted grounded tinsel, and then passed over grounded metal rollers to reduce any static charges (Burley and Jolly, 1984) before plunging vertically into the pool of liquid. Various aqueous solutions and pure organic liquids were used. The tape velocity was increased (using a variable speed DC motor) until air entrainment was observed for the particular side of the tape studied. The velocity at this point was determined by measuring the length of tape passing through the bath in a fixed time interval 10–30 s, and was found to vary between 0.07–1.0 m/s at air entrainment.

To compare the tape surface roughness and wettability effects, all air entrainment velocity data were normalized to that for the polystyrene tape for each particular solution. The root mean square roughnesses of the tapes were measured on a Dektak surface Profilometer. These results are tabulated in Table 1. Although the data show more scatter than one would like, it is very clear that the rough surfaces of the uncoated sides of the paper tapes and the rough surface polyethylene coated paper show very significantly higher air entrainment velocities than do the smoother tapes. The air entrainment velocities seem to increase with root mean square roughness. This agrees with the suggestion of Scriven (1982) that near the dynamic wetting line with rough surfaces, air can "escape" through the valleys between peaks in the surface.

Although not as clearly shown, the data also indicate that surface wettability, which varies from the more wettable polysty-

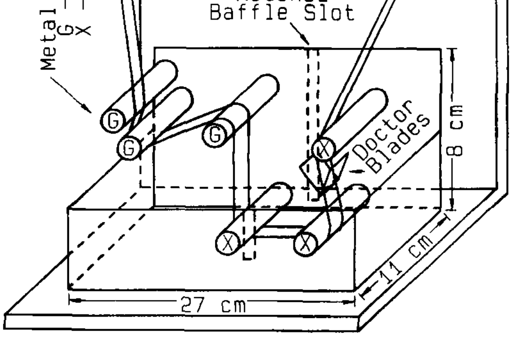

Figure 1. Experimental apparatus.

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Table 1. Normalized Air Entrainment Velocities, Polystyrene = 1.00

		Tape									
		Poly-styrene	Polyester	Polypropylene		Poly-propylene on Paper	Baryta-on Paper	Polyethylene on Paper		Paper *a* Uncoated Side*	Paper *b* Uncoated Side*
		Roughness									
		Smooth						Semi-smooth		Rough	
Liquid	Viscosity mPa · s	0.2	0.3	0.4	1.0	1.0	1.0	1.8	2.4	5.0	5.0
Mineral oil	50	1.00	1.07	0.98	—	1.46	1.04	—	—	1.8	1.60
Mineral oil	130	1.00	0.85	0.88	—	0.82	0.63	—	—	6.6	0.91
Corn oil	80	1.00	0.97	0.89	—	1.21	0.62	—	—	4.3	0.82
Aq. glycerin	60	1.00	1.41	2.32	—	1.51	1.36	—	—	3.3	1.42
Aq. glycerin	600	1.00	1.16	0.97	—	1.06	0.88	—	—	12.2	0.98
Aq. corn syrup	550	1.00	0.64	—	—	1.98	2.39	—	—	2.9	2.92
Aq. corn syrup	1,500	1.00	0.65	—	—	1.20	1.49	—	—	3.5	3.51
Aq. corn syrup	1,650	1.00	0.49	—	—	1.17	0.25	—	—	1.5	0.34
Average		1.00	0.91	1.21	—	1.30	1.08	—	—	4.5	1.56
Mineral oil	100	1.00	1.05	—	0.78	0.83	—	11.2	11.2	11.2	—
Mineral oil	350	1.00	1.28	—	1.22	0.97	—	4.3	4.3	4.3	—
Corn oil	100	1.00	0.92	—	0.87	0.91	—	3.5	3.5	3.5	—
Glycerin	1,080	1.00	0.90	—	1.10	1.81	—	5.6	6.2	5.5	—
Aq. glycerin	400	1.00	1.40	—	1.15	0.91	—	6.1	6.8	6.8	—
Aq. corn syrup	2,830	1.00	0.46	—	1.12	1.17	—	3.6	5.6	4.2	—
Aq. corn syrup	1,650	1.00	0.53	—	1.12	1.05	—	1.49	3.6	3.6	—
Average		1.00	0.93	—	1.05	1.09	—	5.0	5.8	4.9	—

**a*, other side, polypropylene coated; *b*, other side, baryta coated.

rene and baryta to the polyester and the nonwettable polypropylenes, has little or no effect on the air entrainment velocities.

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