'Cleaning of Polyester Films Prior to Vacuum Coating'

Mark Hodgson
Dupont Teijin Films UK Ltd, Wilton Centre, Middlesbrough, UK

Introduction

It is well known that the presence of surface contamination impairs the quality and function of vacuum deposited layers on polyester substrates. Specifically, the presence of particulate matter on a polyester surface during vacuum coating operations is troublesome, because the discrete particles cause discontinuous coatings to be formed [1-4] (usually referred to as 'pinholes'). This paper describes experimentation undertaken to assess the viability and performance of web cleaning techniques which could be applied to polyester films prior to the vacuum coating operation. The efficacy of the techniques is examined within a robust statistical framework, and the results compared to ascertain the optimum cleaning operation, with respect to the effect on vacuum coating quality.

Experimental Detail

All work was carried out in a class 1000 clean room at the Flexible Electronics Substrate Facility, CPI Ltd, Wilton, UK. A clean room environment was deemed necessary in order to minimise atmospheric particulate deposition during the time period of the experimentation. Polyester film was cleaned using a vacuum web cleaner supplied by Shinko Co. Ltd, (Osaka, Japan) and various configurations of a contact roll cleaning system supplied by Teknek UK Ltd, (Glasgow, UK). Both cleaning systems were mounted on a roll to roll film transport system supplied by Doel Engineering Ltd, (Kent, UK), which provided for easy access of a suitable measuring tool to monitor surface cleanliness.

Surface particle counts were monitored using a Particle Guard PG 01, portable surface particle counter supplied by ACP Technologies (Stuttgart, Germany).

Different air pressures were used on the vacuum web cleaner, and different types of elastomer roll and adhesive roll were used in combination in the contact roll cleaner to yield the optimum cleaning effect (see figure 1). A static eliminator was also used at various positions to remove charge from the film surface.

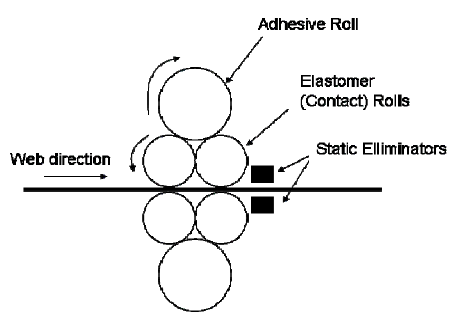

Figure 1. Contact Roll cleaning configuration

The web speed used for all tests was 10m/min. It was assumed that both surfaces of the film were equivalent, so for practical purposes only the top surface of the film was measured. In total, each test constituted 27 uncleaned and 27 cleaned surface particle count readings. This number of readings was considered necessary to provide meaningful statistics for subsequent analysis (based on the assumption that the standard deviation of the particle count readings will be similar in magnitude to the mean of the readings).

Results and Discussion.

Contact Roll Cleaning.

The cleaning efficiencies (i.e. the % of particles removed by the cleaning operation) of several configurations of contact roll cleaner and static eliminator are shown in figure 2. As can be seen the highest cleaning efficiencies were obtained using the paper based adhesive roll. The cleaning efficiency showed little dependence on web position or whether static elimination was employed. Some dependence on the type of contact roll is seen but this is far more pronounced when the filmic adhesive rolls were in use. To investigate these dependencies further, the hardness of the rolls was measured in order to parametise the observed cleaning efficiencies. Figure 3 shows the dependence of the average cleaning efficiency as a function of the roll hardness.

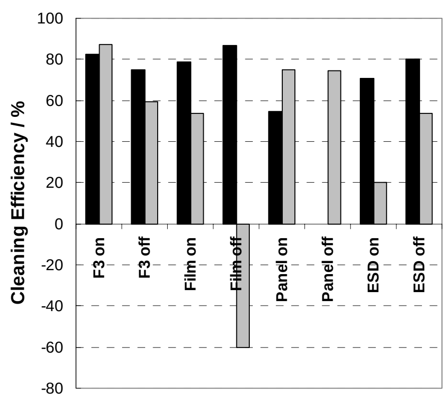

Figure 2. Cleaning efficiency of different configurations of contact roll cleaner. Black bars = paper adhesive roll, grey bars = filmic adhesive roll. Off/on label refers to static eliminator.

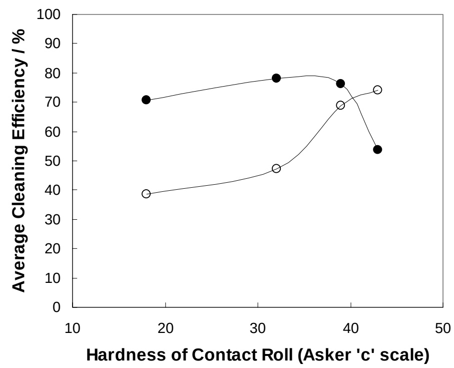

Figure 3. Dependence of cleaning efficiency on elastomer roll hardness. Solid circles = paper adhesive roll. Open circles = filmic adhesive roll.

There is a clear dependence when using the filmic rolls, but the paper adhesive rolls show similar cleaning efficiencies with all but one of the elastomeric contact rolls. This difference in behaviour between the two types of adhesive rolls is thought to be due to differences in the texture and hardness of these rolls.

In these tests the static eliminator was placed immediately after the contact roll cleaners so as to remove any surface charge imparted to the film by contact with the elastomer cleaning rolls. Some of the test configurations were also run with the static eliminator placed immediately prior to the contact rolls and these tests yielded much lower cleaning efficiencies (~30% as opposed to ~80%, see figure 4). This is to be expected. Although, static is removed prior to cleaning the contact with the elastomer rolls imparts a surface charge which then attracts airborne particulates the film surface, resulting in higher surface particle counts.

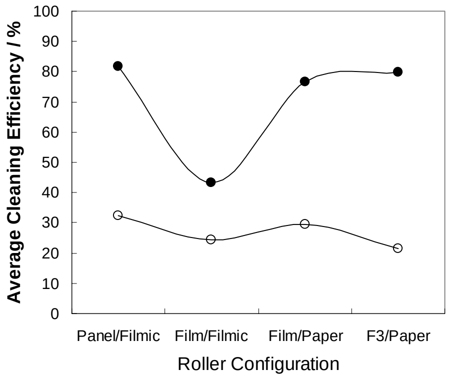

Figure 4. Effect of the position of the static eliminator on average cleaning efficiency. Solid circles = static elimination post cleaning. Open circles = static elimination immediately prior to cleaning.

Vacuum cleaning

The web vacuum cleaner was also employed to ascertain the effect of particulate removal via a non-contact method. Here the cleaning efficiency was seen to be dependent on the pressure differential of the vacuum system (see figure 5) and cleaning efficiencies of ~50% were achieved. There was some evidence that varying the pressure differentials influenced the removal of different particle size ranges.

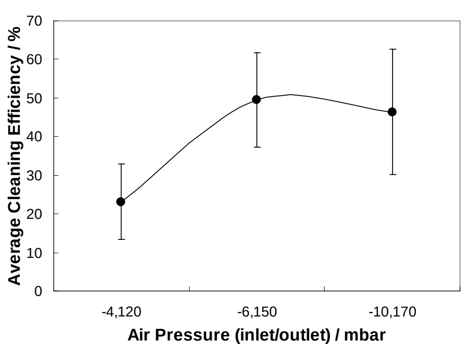

Figure 5. Average cleaning efficiency as a function of the air pressure differential of the Shinko web vacuum cleaning system.

It was hoped that a combination of vacuum cleaner and contact roll cleaner would have a synergistic effect; i.e. the benefits of both cleaning systems would be additive when run sequentially. However, a maximum of ~80% cleaning efficiency was still observed, indicating that cleaning from the two processes is not additive.

Effects of Cleaning Operation on Vacuum Coating.

It has been shown that the density of pinhole defects in vacuum deposited metallised films is directly related to the surface density of particulate debris immediately prior to coating [4]. In order to ascertain whether the benefits of cleaning could be maintained through a vacuum coating operation, uncleaned and cleaned films were sputter coated with ~50nm of aluminium and the pinhole density measured using light microscopy. The results were compared to commercially available metallised film produced via thermal evaporation and sold as food packaging material, and also to film which was plasma treated immediately prior to sputter coating. The results are shown in figure 6.

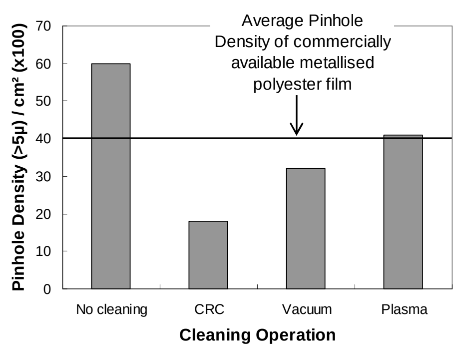

Figure 6. >5µ pinholes in Al metallised film as measured by light microscopy. The commercial sample tested had a pinhole density of ~ 0.4/c m². CRC=contact roll cleaner.

Conclusions

It has been demonstated that surface particulates can be removed from polyester films prior to vacuum coating by contact roll cleaning or by vacuum cleaning, with efficiencies of ~80% and ~50% respectively. However, in these experiments there appeared to be no synergistic benefits by combining the two systems. It has also been demonstrated that the position of a static eliminator has a significant influence on the cleaning efficiency.

The benefits of cleaning for vacuum coating operations has been demonstrated by showing a significant reduction in the number of pinhole defects in a 50nm sputtered Al layer deposited on a cleaned film compared to the same on an uncleaned equivalent.

References

[1] Gudimov, M.M. et al, Fiz-Khim, Mekh. Mater., 1971, 7, (2) p. 59-63

[2] Jorgensen, C.V., Wehner, G.K., Transactions of the Xth National Vacuum Symposium of the American Vacuum Society (G.H Bancroft, Ed.) MacMillan, N.Y. 1963

[3] Steele, G.N., Int. Comm. Opt. Conf., 9th, 1972

[4] Jamieson, E.H.H., PhD Thesis, Cambridge, 1980