The Influence of Water Content on Temperature Rise in Metallized Polypropylene Films

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ABSTRACT

Unlike Polyester (PET), metallized Polyproylene (BOPP) films can exhibit a temperature rise after removal from the vacuum coater. Temperature rises of 5°C or more above the initial temperature following metallization have been reported. The temperature peaks at the centre of the web and gradually decreases toward the edges of the roll. This process can take a few hours to stabilise and often carries the risk of permanent damage to the roll of film. This paper investigates the problem of temperature rise in metallized polypropylene films. The study involves the analysis of water content in the as supplied polypropylene films using infra-red and Karl-Fischer techniques. The results show a good correlation between water content and temperature rise in metallized BOPP films. The results also show a correlation between surface roughness and temperature rise.

INTRODUCTION

Metallized BOPP has proved to be an ideal converting material for packaging applications due to its high moisture and light barrier properties and of course its visual appeal.

In recent years, however there has been considerable concern over the high temperatures experienced in BOPP rolls shortly after metallizing.

Temperatures as high as 35°C have been observed and this has often resulted in the film losing its surface tension level making it unsuitable for printing and lamination. In extreme cases the roll can "block" and become scrap.

Modern day metallizers incorporate many features to enable low rewind temperatures. These include:-
° pre cooling rollers.
° post cooling rollers.
° better contact pressure between film and drum.
° more effective wrap angles on drum.
° chilled drum and rollers to -25°C.

These features are essential but do not provide the complete solution.

The problem is that in some, but not all cases, there is a secondary temperature rise in the roll after metallizing. Because of this phenomenon it is a very common practice to slit metallized rolls immediately after metallizing, in order to introduce air into the roll of film and further cool it.

A freshly metallized roll of BOPP can have a very acceptable measuredexit temperature of say 25°C to 28°C, however if left standing for 3 hours temperatures well in excess of 30°C have been observed in the centre of the roll during the slitting operation.

OBSERVATIONS OF TEMPERATURE RISE

Prior to undertaking some experimental work into this secondary temperature rise we have noticed some phenomena which is of background interest.

Roll Size

Small to medium roll diameters of less than 25" (640 mm) of 30,000 ft (10,000 m) of 30 micron BOPP appear not to be susceptible to the temperature rise [1].

The effect is far more noticeable with large diameter rolls, for example 38" (970 mm) with 72,000 ft (24,000 m).

On a roll of material that exhibited a temperature rise, the temperature was measured across the width and at various points along the length (depth) of the roll using a surface contact thermometer.

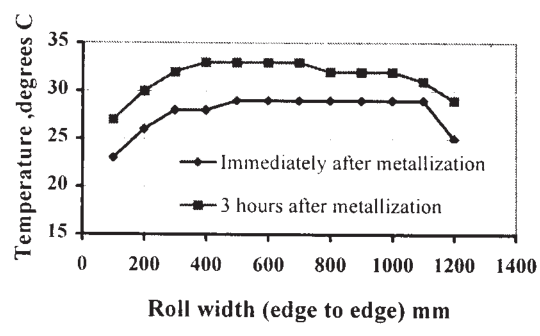

Figure 1. Temperature across width of metallized BOPP

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Figure 1 shows the temperature at various points across the web. Measurements were taken in air immediately after venting and again 3 hours after metallizing. This figure shows a maximum temperature rise half way across the web, while the edges remain cooler but still exhibiting a rise. On this particular roll an average temperature rise of over 6°C was measured.

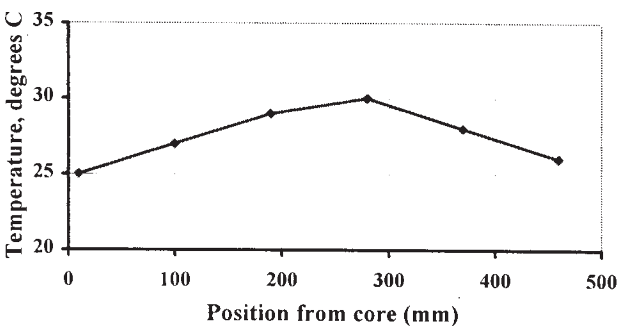

Figure 2. Temperature through depth of roll

Figure 2 shows for another roll of film which was 38" diameter. The average temperature measured during the slitting operation just 2 hours after leaving the metallizer. This shows that the temperature peaks at the centre of the web approximately 30,000 ft (10,000 m) from the core, before decreasing again to the outside diameter.

Films Metallized in Warm Climates

As you would expect, films produced, stored and then metallized in warmer climates generally have higher rewind temperatures than a cold climate. Warm film in tends to give warmer film out.

However, one of our customers in Egypt [2], with a warm but dry climate, who is a manufacturer of BOPP never experienced major problems with hot film. The pre cool roller, post cooling roller and the clamping of the film on the drum appeared to be very effective. Then suddenly it was reported that the film was blocking on the slitting operation. No parameters of the machine had changed.

The film was the reportedly the "same" formulation but was not produced in Egypt, but from an associated company in Thailand, which has a warm but humid climate. The problem disappeared when Egyptian film was subsequently metallized.

Temperature Measurement While Winding in Vacuum

Simply winding a plain or pre metallized roll in vacuum has no noticeable effect on temperature.

However we have found that if a roll of plain BOPP has been unwound and then rewound in a vacuum and then metallized, the temperature rise is 1° or 2°C less than might have been experienced for that grade of material. This suggests that the outgassing produced this result.

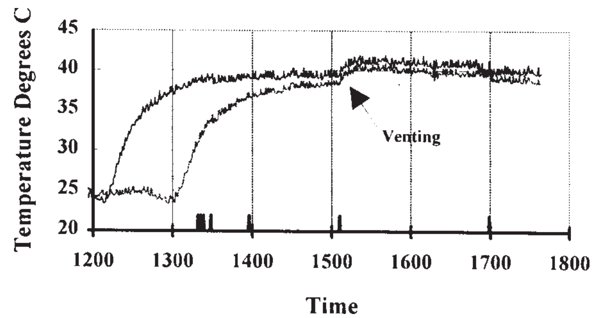

Figure 3. Temp. of side of roll during metallizing

Measuring the temperature on the side edge of a rewind roll with infra red sensors during the metallizing cycle consistency show (see figure 3) a sudden slight temperature rise on venting. (Unfortunately due to background radiation the senso temperatures do not provide a high degree of accuracy, but the results are very repeatable).

WATER CONTENT IN FILMS

Various types of pre-metallized BOPP films, known for "hot" and "cooler" films were analysed for water content using infra red spectrometry. A couple of samples were cross checked using Karl Fischer technique.

IR spectrum provides a rich array of absorption bands that lead to the recognition of the molecules under investigation. Water usually absorbs strongly near 3710 cm^{-1} and 1630 cm^{-1}. In BOPP films however, it is only possible to detect the first absorption band at 3710 cm^{-1} since the second band is obscured by the BOPP's molecules. This technique provides qualitative rather than quantitative results. On the other hand, Karl Fischer technique relies on chemical titration measurement of water content and gives quantitative results. Figure 4 and Table 1 shows a correlation between water content and temperature rise in various types of BOPP films. Table 1 compares measurements obtained by IR and Karl Fischer methods, these results are consistent.

TABLE I
Water content and temperature rise in various samples of BOPP

BOPP FILM SAMPLE	WATER CONTENT IR SPECTROMETRY (ARB. VALUES)	WATER CONTENT % KARL FISCHER	TEMP. RISE AFTER 3 HOURS, DEGREE C
A	1	0.1	0
B	8	1.3	6
C	5.5		3
D	6		8
E	1		2

It is evident that the temperature rise in metallized BOPP films is dependent on water content in premetallized BOPP films. In the present work, the water contents measured using the two techniques represents the total amount of absorbed and adsorbed water in BOPP films.

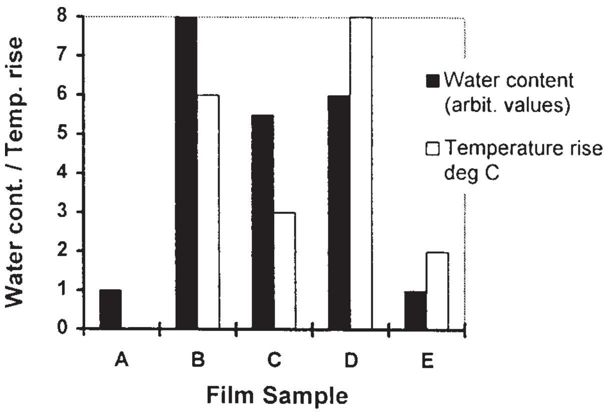

Figure 4. Water content and temp.rise

SURFACE ROUGHNESS

Pre-metallized BOPP films were further analysed for surface roughness using atomic force microscopy (AFM). Figure 5 shows a typical surface roughness of uncoated BOPP film. The surface roughness of three types of BOPP films was measured and plotted as shown in figure 6. This figure shows clearly a correlation between surface roughness and temperature rise in metallized BOPP films. As the surface roughness of the uncoated BOPP film increases, the temperature rise of the metallized film after 3 hours increases.

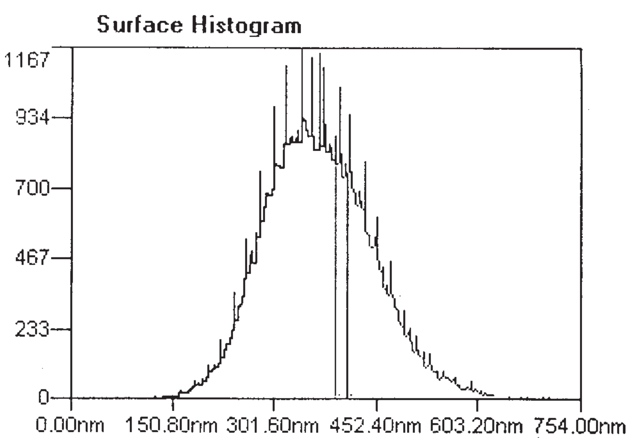

Figure 5. Histogram of surface roughness.

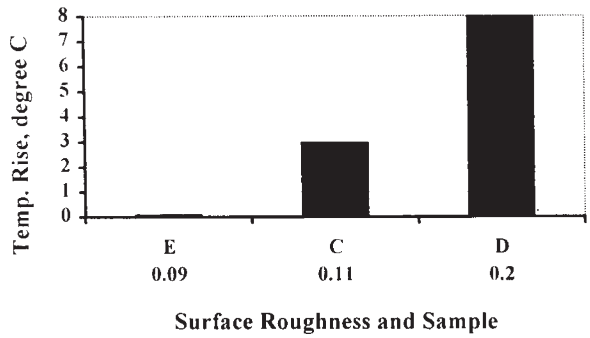

Figure 6. Surface roughness and temp. rise

DISCUSSION

The results have so far indicated a correlation between temperature rise and water content. There also appears to be a correlation between temperature rise and surface roughness.

Surface roughness can influence the water content in BOPP films. Rough wettable surfaces can trap more water than a smooth un-wettable surfaces. The increase in surface roughness and water content in BOPP may well be due to variations of manufacturing procedures such as anti-block additions which can be hygroscopic, corona treatment and storage conditions.

Absorption of water may occur during manufacture when film is warm and in a humid climate.

Adsorption of water can take place after corona treatment and during storage. In this case, physical adsorption, where monolayers of water condenses on the film would be important. Furthermore, rough surfaces have more cavities to serve to trap more water than smooth surfaces.

Exothermic Reaction?

The temperature rise in BOPP films following metallization may be due to an exothermic reaction between aluminium and the water left in the film after metallization due to diffusion from the bulk.

For the formation of 30Å of aluminium oxide film on 20µ BOPP, the calculated temperature rise is in the order of 5°C assuming a specific heat of 2030J/kgK for BOPP and 16.6 kJ/g heat of reaction. This range of temperature rise is consistent with present experimental work.

A simple conduction loss model can explain why the main temperature rise occurs in the bulk of a 72,000 ft roll at 30,000 ft, however it does not fully explain why the temperature rise is not more noticeable on medium size rolls.

Furthermore the extent of the exothermic reaction should be greater in films which exhibit this phenomena compared to films where the temperature rise is minimal. X-ray analysis was carried out to measure the oxide thickness between "hot" and "cold" films using an EDX technique. The exothermic theory would suggest a greater thickness of oxide with "hot" films. But this analysis showed no difference in the oxide thickness between the "hot" and "cold" films. It may well be that the reaction is time dependent, but X-ray analysis has not substantiated this theory.

CONCLUSIONS

As far as we are aware, a secondary temperature rise after metallizing has not be reported on other commonly metallized films such as PET, PVC and LDPE, some of which have noticeable quantities of water on the surface.

There is a strong correlation between the water content and the high temperatures.

An exothermic reaction between water and aluminium may be partly responsible for this phenomena, but it would appear it may not be the only contributing factor.

At this moment only a relatively small number of different grades for various manufacturers have been tested. More work still needs to be carried out in order to verify our experimental work and to consider other theories for "hot" metallized BOPP.

REFERENCES

1. UCB UK, private communications.

2. Technopack SAE, Egypt, private communications.