Characterisation of typical process defects found on an industrial R2R metalliser

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ABSTRACT

Previous studies have characterised typical defects that can be found in a conventional metallising process on a roll to roll, resistance heated evaporator type machine and provided explanations on their origin. The impact of these defects in terms of barrier performance is still not widely understood or documented. This paper will attempt to educate the industry to understand the implications of these typical defects on both oxygen and water permeation.

With the aid of the in-line, in-vacuum Hawkeye™ system it has been possible for the first time to look at defects during deposition in real time on a large scale to gain an understanding of the main effects in the metallising process.

INTRODUCTION

In recent times, increased attention has been given to reducing the number of defects which are inflicted during the metallising process. In particular, pin-holes and pin-windows which occur as a result of evaporating and condensing aluminium on to plastic films. For high end, food grade packaging applications in Europe and South-East Asia there is a focus to reduce the density of defects of certain sizes per area with the assumption it improves barrier properties and also for quality assurance purposes, whilst in India the strict requirements of the yarn grade market desires ideally no pin-holes.

Moreover, it is recognised in the vacuum coating industry that metallising machines with alternative sources such as e-beam or induction heated crucibles, provide significantly lower defects than resistance-heated boat style machines. As part of the investigation it was found that some specifications exist for these alternative sources for larger pin-holes greater than 1mm in diameter, ranging from 0.025 to 1.0 allowable per 100m2.

Quantifying the defect density of metallisers whilst running, historically has not been a simple task. Various camera systems have been developed with mixed success as the vacuum environment provides a unique set of challenges. Electronic systems in modern CCD cameras overheat in vacuum as there is no cooling medium whilst other hardware components suffer from thermal drift which makes them unstable; longevity has also been an issue as materials can delaminate or break down as they outgas in the vacuum environment.

The Hawkeye system was specifically developed for use in vacuum metallising machines and its performance initially quantified in a lab environment. The system was then installed on a production machine and demonstrated to show that it effectively picked up defects of various sizes down to 0.1mm at 1000 metres per minute. Hawkeye categorises defects according to sizes which are selected by the operator.

The Hawkeye system consists of a mechanical mounting beam to which the probes are secured. Along the length of the beam Hawkeye modules are spaced every 100mm, with each module containing four probes each spanning 25mm to provide full coverage of the film area in between boat positions with no overlap [1]. This gives an accurate indication of defect position on the web. Defects are detected when the receiving probe measures a light transmission above a pre-determined threshold, which is set to a certain transmission value above a moving average of the detected light transmission of the metallised film (see figure 1). The measuring frequency of the probes is 80 kHz and data is sampled in every 500ms with detected defects logged into a database. The unit is located after the process drum in the machine. The electronic components inside the modules were developed and optimised to eliminate thermal drift.
To confirm the accuracy and repeatability of Hawkeye, an array of holes of known sizes were made within a metallised web in both the transverse and machine direction. These holes were placed in consistent patterns at known lengths through the web, which was then ran backwards and forwards through a Bobst Manchester K5000 2450mm width metalliser with a Hawkeye system installed. The created holes were counted and their sizes accurately measured with the aid of a microscope, then checked against data retrieved from the Hawkeye system.

After the accuracy and repeatability of the Hawkeye system was confirmed, further process trials were conducted to determine the effects on defect densities by changing machine running parameters. After analysing which factors could have an effect, it was decided to test the following: the effect of changing only the wire feed rate, changing web speed, changing both web speed and wire feed rate to keep a constant 2.2 OD, the effect of wire purity and the effect of boat type and age. Also investigated was the distance travelled by material ejected from boats originating from aluminium spitting as there were some competing assumptions in the market about the cross-web locality of spitting during process.

**Experimental**

Data in this paper includes barrier measurements; microscope images were taken using a Bresser Researcher Trino, with a Bresser 5MP Microcam. Microscope calibration was done using a slide with a micrometric scale. Defect data was compiled by taking raw data from the Hawkeye system, which gives defects detected by each probe during a process trial along with a corresponding position.

Barrier measurements were conducted using Mocon Oxtran 2/20 and Systech 8001 analysers for oxygen transmission rate (OTR), and for water vapour transmission (WVTR) a Mocon Permatran 3/33 and Systech 7001*. Samples are analysed according to ASTM F 1927 and F 2149 respectively (*Systech 7001 follows ASTM F 2149 except for the sensor, which follows ISO 15106 – 3:2003. Test conditions for OTR were 50% Rh and 23°C, for WVTR 90% Rh and 37.8°C are used.

**Defect Types**

Various defects were researched and identified from single layer metallised film produced on metallising machines such as pin-holes, pin-windows, micro scratching, macro scratching and tramlines and these were closely analysed to understand their details which are provided below. [1,2]
1. PIN-HOLE

Pin-holes are defined as a through hole in the base film. Generally they occur when large amounts of spitting occur from a ceramic evaporator boat, with many spits having sufficient thermal energy to melt the film. Some causes of spitting are, evaporators being too cold or hot, short circuits on wire feed delivery assemblies, wire contamination, loose wire feed connections and potential machine vibration. Pin-holes appear in many shapes; however two types occur more frequently. These are either elongated holes or roughly circular defects with clear signs of the base film being melted and/or stretched (See figure 3). The high thermal energy metal projectiles which cause defects are generally close to spherical in shape. Several of these typical spits have been collected from within the evaporation zone after various trials.

![Figure 2: Solid condensed ball of aluminium which has rolled along the surface removing some aluminium as it travels.](image)

The different shapes of pin-holes are thought to be related to the angle at which an aluminium spit impacts the film upon the drum. Acute angle projectiles tend to leave melted holes which are typically elongated and range in size from 0.05 to 2.0mm (mm = millimetres) in length. Elongated defects tend to have a build up of aluminium around the edges with a mass of aluminium at the end of the defect. The circular defects appear to be caused by aluminium spits which impact the film at a perpendicular angle, leaving an area of partially metallised film with melted edges which can have small masses of aluminium in them.

To confirm the above hypothesis relating to pin-hole formation, an off-line test was conducted in a laboratory whereby molten solder was dropped perpendicular to metallised film taped tight to a stainless steel surface, followed by projecting spherical solder globules at various angles. This yielded pin-holes very close to the images obtained from the metalliser but on a larger scale.

To test the impact of pin-holes or through holes have on barrier performance, a piece of metallised film (12micron single layer Polyethylene terephthalate (PET), coated at 2.2OD, typical OTR and WVTR =0.5cc/m²/day and =0.5g/m²/day respectively) was pierced accurately with a needle of 0.12mm diameter, then analysed for barrier. It was found that the oxygen barrier of the film had failed completely, with an OTR of >50000cc/m²/day. However, when measured for moisture permeation, it retains most of its moisture barrier, measuring at 1.2g/m²/day.

This effect is also seen in AlOx coated films, but not to the same degree. This effect of barrier retention is not seen in plain films, therefore it is theorised that the Aluminium coating could be acting as a moisture scavenger.

There is a defined standard within the plain aluminium foil industry for the definition of pinholes and roll-holes, namely EN 546-4 (Aluminium foil requirements), where pinholes are described as “randomly distributed voids in foil of normally round or oval shape with a maximum diameter of 0.2 mm”, while roll-holes are defined as “voids with a maximum diameter > 0.2 mm which occur at regular intervals throughout the rolled coil length”. Using these definitions, quality measurement and specifications of films can be standardised. It was therefore one of the goals of this project to define a defect density standard for the aluminium metalliser industry similar to what exists above for foils [3].
2. **PIN-WINDOWS**

Defined as a region on the metallised film where a small area of the metal coating has been removed but there is no perforation through the base web. These tend to look like small pin-holes when viewed on the rewind roll but when they are examined under the microscope, appear different as the base film can be clearly observed to be intact where the missing metal patch exists. Pin-windows are seen in two common forms, a roughly circular defect often with trails of unmetallised film or elongated tracks. They tend to range in size from 40-500um in diameter on 12μm thick PET film metallised at 2.2OD, but may occur differently on more heat sensitive substrates. They can be attributable to loosely held particles on the film surface which get coated with the metal and fall off subsequently - taking the metal coating away but leaving the base substrate intact. They can also be the result of spitting from the source creating an aluminium projectile which collides with the film surface but not with enough thermal inertia to burn a hole, instead masking a small region of the film from getting coated. In terms of barrier, when e.g. a single sample containing a pin-window of the order of magnitude shown in the picture below is tested, there is no difference in barrier for OTR or WVTR than a single sample which is not perceived to contain any pin-windows. Perhaps if a single sample contained many such pin-windows some difference in barrier level may be detected, but due to the relatively random nature of the formation of pin-windows, it is unlikely to have such a large collection on a single sample of the size generally prepared for barrier measurement equipment. One hypothesis is that a 3nm layer of Aluminium oxide (which is transparent) may be present on the polymer web. Aluminium oxide has been found to have a very high adhesion strength which could explain why it would remain on the web [9].
Table 1: Effect of pin-windows on barrier for a 50cm² sample

<table>
<thead>
<tr>
<th>Sample (n=2)</th>
<th>% Metal removed</th>
<th>OTR (cc/m²/day)</th>
<th>WVTR (g/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>no pin-windows</td>
<td>0</td>
<td>0.517 ± 0.08</td>
<td>0.127 ± 0.01</td>
</tr>
<tr>
<td>two pin-windows</td>
<td>0.00026</td>
<td>0.518 ± 0.07</td>
<td>0.22 ± 0.01</td>
</tr>
<tr>
<td>three pin-windows</td>
<td>0.00039</td>
<td>0.499 ± 0.1</td>
<td>0.237 ± 0.05</td>
</tr>
</tbody>
</table>

As seen in table 1, the barrier properties of metallised PET are unchanged by the presence of pin-windows. The appearance of any micro defects is the limiting factor in barrier levels, i.e. if any micro defects are present on a sample the permeation of oxygen and water vapour through the film will always be at typical levels. The addition of extra micro defects has very little effect on barrier, only having an effect when very large areas of metal are removed (see figures 5 and 6 below).

To fully understand and characterise the effect of metal removal a test was devised whereby sodium hydroxide (aq) was placed on a metallised sample in order to remove the metal coating. After the aluminium was removed the film was cleaned with paper towels and any excess removed with cotton wool. It should be noted that the samples used in the above measurement had a single large pin-window created in the coating, not many micro-holes as implied in previous studies. Samples were then measured and the process repeated to remove progressively larger areas of metal. The sample area which is measured is 50cm². Previously, it has been stated that only takes 5% of the metallized area to be missing in the form of pin holes and the barrier performance will be almost the same as for uncoated polymer film [4]. A previous paper concurred as it calculated from coverage models that a coverage of higher than 95% is necessary to begin to see some improvement on the barrier function of the system [5]. The barrier properties of the plain PET used in this trial are 120 cc/m²/day (OTR) and 40 g/m²/day (WVTR) respectively.

Figure 5: OTR change as Aluminium is removed

Figure 6: WVTR change as Aluminium is removed
It was found that the barrier loss due to demetalisation was a linear relationship. Water vapour was only measured to 30% metal loss due to the measuring limit of the Mocon and Systech analysers. Samples with various densities of starry night were measured (from a ‘normal’ standard sample of 0.9% metal removed compared to a sample with low levels of starry night at 0.6%) and the permeation levels were found to be the same. Further work has been commenced in the laboratory to determine whether many discreet pin-windows follow the same linear relationship as single large-area versions.

![Figure 7: Photos of progressive metal removal. A, b and c are seen through an eye glass with 10x magnification, d is taken from above due to the eye glass being too small to cover the whole demetallised area.](image)

3. **Tramlines**

Tramlines are caused by expansion of the film on the process drum due to the heat of the source and they can be minimised by the use of the gas wedge (introducing an air leak between the film and the process drum) and by increasing tensions in certain parts of the web path. Tramlines can be found in varying degrees based on the severity of creasing on the drum depending on OD, material, web speed and spreading action from the winding mechanism. Tramlines are a phenomenon associated with films which do not give up their heat energy easily making heat sensitive substrates, such as CPP, OPP and PE affected the most while they are not often seen on more thermally stable substrates like PET unless very thick OD coatings are deposited. The lighter OD tramlines are only slightly less in terms of OD than the base metallised material at 2.2OD (it is difficult to quantify how much lighter than the base metal tramlines really are as densitometers are not focused enough to measure such a narrow area). Whilst the effect detracts from the physical appearance of the material, contrary to what a large proportion of the industry believes; the typical tramline has negligible or no affect on barrier levels for OTR or WVTR when measured. A small difference in resistivity can be detected with samples measuring approximately 1.37ohms/sq with no tramline vs. 1.42ohms/sq for a sample with a tramline across its length.
4. MICRO-SCRATCHING

Defined as microscopic scratches inflicted in the metal coating, which may or may not protrude all the way through the metal layer to the base substrate. They are usually caused by incorrect tension settings, movement/interlayer slippage on the rewind roll and scratching on rollers which are in contact with the metal surface, especially if there is any grit or contamination present; even the roller material itself can create this problem. Spreading rollers act to worsen this problem as although they are in contact with the back side of the film, the effect is that the film is still being spread down stream – potentially affecting the front (coated) side in contact with other rollers. These defects can look like pin-holes/windows, but when magnified are seen to be elongated. These can often be found to consist of broken sections of lines instead of a single clear scratch.

Table 2: Barrier data of film with no tramline compared to film with tramline

<table>
<thead>
<tr>
<th>Sample (n=2)</th>
<th>OTR (cc/m²/day)</th>
<th>WVTR (g/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tramline</td>
<td>0.49 ± 0.11</td>
<td>0.19 ± 0.03</td>
</tr>
<tr>
<td>No Tramline</td>
<td>0.51 ± 0.1</td>
<td>0.15 ± 0.02</td>
</tr>
</tbody>
</table>

Table 3: Barrier comparison of typical film and film containing micro scratching

<table>
<thead>
<tr>
<th>Sample (n=4)</th>
<th>% Metal removed</th>
<th>OTR (cc/m²/day)</th>
<th>WVTR (g/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No micro scratching</td>
<td>0</td>
<td>0.575 ± 0.06</td>
<td>0.258 ± 0.01</td>
</tr>
<tr>
<td>Micro scratching present</td>
<td>approx. 0.007</td>
<td>0.455 ± 0.12</td>
<td>0.341 ± 0.11</td>
</tr>
</tbody>
</table>

5. MACRO-SCRATCHES

Macro scratches can occur during metallising when solid pieces of aluminium can become trapped between the exit zone seal and water cooled drum. When this happens large continuous scratches can occur in the metal coating along the machine direction for many metres. When this happens the machine must be stopped and all debris removed before the process can recommence. The impact on barrier can vary not only
based on percentage metal removal and it is hypothesised that the macro-scratch may be compromising the thickness of the base film itself. Through measurement of samples it has been found that a normal macro-scratch will affect barrier properties; however not as much as would be expected.

<table>
<thead>
<tr>
<th>Sample (n=4)</th>
<th>% Metal removal</th>
<th>OTR (cc/m²/day)</th>
<th>WVTR (g/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Scratch</td>
<td>0</td>
<td>0.53 ± 0.08</td>
<td>0.53 ± 0.08</td>
</tr>
<tr>
<td>Scratch</td>
<td>0.0054</td>
<td>0.81 ± 0.01</td>
<td>0.74 ± 0.01</td>
</tr>
</tbody>
</table>

Figure 9 (From left hand side) Sample after initial measurement, sample with scratch, detail of scratch (40x magnification)

6. **Starry-Night:**

These defects are defined as microscopic voids in the metal layer of sizes between 10μm and 50μm. Starry night often resembles pin-windows, but the individual voids are smaller in nature. They can be seen with as little as 10x magnification but are better viewed under the microscope using 40 or 100 times magnification with purely transmitted light (no top light). Generally, they are in the size range from 10-50μm in diameter. Due to the defect size, starry-night is generally not seen by the operator during machine operation and requires a light box and some form of magnification to be observed. The density of starry night can change dramatically depending on process conditions and base substrate used and is present to some degree on all commercial metallisers in production.

Figure 10: (a) image of typical starry night through microscope (40x) (b) detail of an area with typical hole sizes shown
Figure 11: Increase in starry-night when unprotected, single layer metallised PET is brushed with cotton wool (a) original film (b) light brushing (c) further brushing (d) further brushing (Force of brushing remained as constant as possible)

An experiment was carried out whereby a metallised film sample was very lightly brushed with a soft cotton tip. As the sample is progressively rubbed with a constant force, the numbers of defects which are consistent with sizes typical for starry-night are seen to increase as the number of cycles increases. Most starry night (the type of defect which is created using this method) therefore appears to be due to subsequent pick-off of aluminium from anti-block particles. Anti-block particles are globules of silica embedded in and on the surface of the base substrate and commonly range in size from 1-10μm in diameter. It follows that the adhesion of the metal to these particles is far weaker than the bond of the metal to the areas of the substrate where the silica particles are not present. It is however possible that microscopic dust particles on the film surface are being coated with aluminium and subsequent pick-off occurring but the size of the light regions seen in starry night are more consistent with anti-block particles and corresponding aluminium thickness [6].

Due to the small size limitations associated with starry night, it cannot be detected by Hawkeye; only pin-holes, pin-windows and scratches can be detected. Pin-holes are of primary interest for the barrier packaging and yarn metallising sectors. Hawkeye data is categorised by the user by entering values into a menu. The defect categories used for the following trials refer to approximate diameters below. A limitation of the Hawkeye system is the fact it is unable to distinguish between pin-holes and pin-windows.

- **Category 1:** Defect size 1 = 0.1-0.5 mm (equivalent diameter)
- **Category 2:** Defect size 2 = 0.5-1.0 mm (equivalent diameter)
- **Category 3:** Defect size 3 = 1.0-2.0 mm (equivalent diameter)
- **Category 4:** Defect size 4 = > 2.0 mm (equivalent diameter)

**EXPERIMENTAL FINDINGS**

As part of the research, it was found that for standard commodity food packaging applications, defects below 1.0mm in diameter are generally ignored. However, it was discovered that a significantly high proportion of defects exist below this threshold which can affect barrier considerably. On a resistance heated boat type machine, defects can be detected in densities that range from 3-15 per 100m2 of 1.0mm in diameter or greater. Large numbers of small sized defects are not uncommon on roll to roll machines, typically 250-600 per 100m2 running in production on a standard evaporator boat style machine.

The last section of the paper focuses on a few of the process trials conducted, to try to evaluate and characterise the impact of some of the process variables on defect density.

**CONDITION 1 - THE EFFECT OF CHANGING THE WIRE FEED RATE WHILE ALL OTHER PROCESS PARAMETERS WERE KEPT CONSTANT**

Boats were run in a non-optimised, nominally hot state suitable for a wire feed rate of approximately 7.59g/min. The feed rate was incremented from 4.67g/min to 8.91g/min with little difference in the numbers of pin-holes detected.
The conclusion is that as long as the evaporator boats are not below a critical threshold point of being too cold, the number of defects remains relatively constant. No difference could be deduced from the results based on wire acceleration between increments. For the trials with ‘standard purity’ wire, 99.8%, with 2mm diameter was used.

For this trial, the web was run at 800m/min metalizing at 2.2OD, with a wire feed rate of 115cm/min. The web speed was decreased in 100m/min increments while keeping boat temperature and wire feed rate the same. The OD therefore increased up to 4.4OD at the lowest web speed of 300m/min.

It was found that the total number of defects decreased from 420 to 286 per 100m². There appears to be a threshold speed where the number of defects trails off below 500m/min.

It was also found that category 1 sized holes, 0.1mm – 0.5mm, decreased from 414 defects/100m² down to 290 per 100m² as web speed decreased. (It is thought that this is because the higher deposition and longer dwell time in the source could actually enable coating over the pin-window defects to prevent them being detected).

The differences are thought be due to vibration increasing at higher speeds, possibly because of eccentricity from lobbing of heavy unwind and rewind rolls. It does not appear to be due to wire feeder vibration (see condition 1 test). Further analysis is planned to measure actual machine vibration levels with reference to defect size and density.
As the machine speed was increased along with wire feed rate accordingly, the number of defects increased markedly. This is seen again when the same trials were repeated on other similar machines. There is a significant combined effect contributing towards defects of all categories. From this and previous results it can be shown that web speed and not wire feed rate has a greater effect upon defect numbers. This is in agreement with the fact that many producers of high barrier and yarn grade metallised film reduce the speed of the machine to levels of 200 – 400m/min to keep defect densities as low as possible.

![Graph showing effect on defect numbers when web speed is increased and keeping OD constant](image)

**Figure 14:** Effect on defect numbers when web speed is increased and keeping OD constant (achieved by increasing wire feed rate with web speed)

**CONDITION 4: HOW FAR EJECTED ALUMINIUM PARTICLES TRAVEL FROM ONE BOAT WITH SPITTING**

Below, the wire feed spout was electrically shorted to ground for boat 8 to simulate a short circuit condition. This type of condition typically occurs when aluminium debris has fallen on top of the wire feed spout and creates a path to the machine’s electrical ‘ground’. Some electrical current gets diverted from the boat up through the wire and causes some arcing and physical jolting of the wire which in turn, causes spitting. From the results it can be seen that when the spitting is severe, it can travel up to 60cm from its source to create defects. Each size category of defect was affected [7].

![Graph showing distance spits travel](image)

**Figure 15:** Plots showing distance spits travel (a) total amount of defects along web length, showing spits can travel up to 50 cm (b) defects between 1mm and 2mm, the distance travelled by larger spits is less than smaller spits (c) smaller spits (0.1mm to 0.5mm are able to travel almost 60cm from the source boat.
CONDITION 5: HOW MUCH EFFECT DOES WIRE PURITY HAVE ON DEFECT COUNTS?

Most commercial metalliser machines run aluminium wire of grade 99.80% purity although it is known that higher purity grades are used commercially for different applications. If higher grade wire of 99.99% purity (2.0mm diameter) is used it has been found that the number of defects reduces significantly. A comparison was done using 99.80% pure wire vs. 99.99%; the result can be seen in the graph below. It is hypothesised that the differences in the vapour pressure of the impurities affect the way the aluminium cloud evaporates off the boat surface; or the crystalline formations around the outside where the impurities collect and re-cristallise in the form of borides may conflict with the aluminium pool [8].

![Erosion due to chemical attack by wire](image1)

![Borides, oxides and wire impurities](image2)

Figure 16 Image detailing impurities left on a standard Sintec 2 component, group 7 resistivity, 125x40x10mm boat after metallising.

![Figure 17 Comparison between defect numbers for standard wire and high purity wire](image3)

CONDITION 6: STANDARD BOATS VERSUS T-VAP SELECTS

A standard set of boats and a comparison set of T-Vap select boats which have a trapezoidal cross section and circular recesses to assist aluminium wetting, were installed and conditioned for the same amount of time (1.5 hours at 45cm/min wire feed rate) before coating PET film at 2.2O.D at several different speeds. This data was compared against that obtained from an aged set of standard boats. (Note: aged boats refers to a set of standard rectangular cross section Sintec res group 7 125x40x10mm same size as standard conditioned boats and they had been run for approx. 8 hours in production type situation at high-end wire feed rates but cleaned prior to the trials being carried out).

![Figure 18: Sintec T-Vap select evaporator boat](image4)
7: COMBINATION OF HIGH PURITY WIRE AND T-VAP SELECT BOATS

After investigations into the effects of high purity wire and T-Vap select boats, it was decided to metallise a roll at 420m/min, 630m/min and 840m/min at 2.2OD. This combination of parameters showed the lowest defect numbers seen at these speeds. Combining optimised boat and wire types can reduce the defects of a standard run at 840m/min from 550/100m² to 43/100m² for small sizes of 0.1-0.5mm in diameter whilst total defects can be reduced from 590/100m² to 45/100m².

Figure 19 Lowest defect numbers achieved

NEW DEFECT STANDARD

Table 4 values determined for defect standard at 2.2 OD

<table>
<thead>
<tr>
<th>Category</th>
<th>Diameter</th>
<th>420m/min</th>
<th>630m/min</th>
<th>840m/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defect size 1</td>
<td>0.1mm - 0.5mm</td>
<td>250</td>
<td>370</td>
<td>600</td>
</tr>
<tr>
<td>Defect size 2</td>
<td>0.5mm - 1mm</td>
<td>2</td>
<td>3.5</td>
<td>8</td>
</tr>
<tr>
<td>Defect size 3</td>
<td>1mm - 2mm</td>
<td>1.5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Defect size 4</td>
<td>&gt; 2mm</td>
<td>1.5</td>
<td>2.5</td>
<td>7</td>
</tr>
</tbody>
</table>

By utilising the Hawkeye system and the ability to quantify the numbers of defects within a coated web, it is intended to create a set of standard values, similar to the standard values already set for the defect densities of aluminium foil. The data is limited in that the numbers are taken from the average of a restricted number of trials. As further data is gathered a more robust value can be achieved which will be useful when applied to a customer’s standard. The values could also be used to indicate if a machine is performing as intended; if a large deviation is seen in the defect numbers within a roll it could point to possible issues in a
machine or the operation of a machine. We have observed that the age of a boat also has an effect on associated defect generation on a metallised web, which potentially allows the Hawkeye system to be used as a viable tool to inform operators when to replace boats.

SUMMARY

From a barrier perspective, defects in aluminium coating have less impact than previously thought. Tramlines have been shown to have no effect upon the barrier properties of metallised PET. Micro scratches appear to have minimal effect on barrier properties. Similarly, pin-windows, unless large, have negligible effect on barrier. Macro scratches do not affect barrier as much as expected. Any through hole completely removes the oxygen barrier of a film, whilst retaining most of its water vapour barrier. This effect is also seen in AlOx coated films, but it is not seen in plain films, suggesting that the aluminium coating could be acting as a moisture scavenger. High purity wire leads to a significant reduction in all defects sizes, with defects of 0.1mm – 0.5mm being reduced the most. This is likely due to the decrease in impurities which may affect the amount of spitting which occurs. T-Vap Select boats reduce the number of defects which are greater than 0.5mm. Combining optimised boat and wire types can reduce the defects of a standard run at 840m/min from 550/100m² to 43/100m² for small sizes of 0.1-0.5mm in diameter whilst total defects can be reduced from 590/100m² to 45/100m². A pin-hole standard is proposed which will allow producers and customers the ability to quickly check the quality of a produced roll and to identify any issues occurring with production.

Proposed Further Work to be carried out:

- Measure machine vibration levels vs. defects at various speeds
- Continued work to reduce levels comparable to E-Beam or induction heated machines
- Impacts of defect densities on electrical and optical coatings
- Effect of planarization and encapsulation layers on barrier performance of common defects
- Use of other substrates to investigate if higher or lower melting points have an effect on defects

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References:


