Possible future trends for aluminium metallizing.

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ABSTRACT

In the future metallizers, to remain competitive, will have to offer something more than they currently do. Inevitably one of the pressures exerted by the markets will always be price. To compete on price either the same coating has to be offered at a lower price, or something else has to be given to maintain or possibly even increase the price.

To lower the cost per unit area of product there is the basic option of building machines that will coat wider and faster than current machines. This gives an increase in the capital cost of a system but a larger increase in volume of product produced. This progressive increase in system size has been going on for years and it is considered that the expansion process is becoming ever more difficult. My belief is that to further increase the machine size & productivity is going to require a step change in technology.

The metallizing industry in general lags behind comparable industries, such as paper or fibre manufacturers, in terms of coating & winding speeds. It is possible to coat at similar speeds to these industries but to do this will require some radical design changes.

The threat is that unless this happens then customers for low cost metallization will unable to buy from home suppliers, because their machines cannot produce low enough cost material, & will have to buy from overseas suppliers who have a very low cost base.

There is then the question of who instigates the development of these step change technologies. No one wants to take the risk of developing a technology that does not meet expectations. The customer does not want to order a machine that might fail to meet the specification, takes longer to develop & be late for delivery. The machine manufacturer does not want to spend time & money on development without a customer keen & waiting to buy the results.

The alternative strategy, to being the lowest cost producer, is to add more value to the product. This requires that future metallizing machines no longer have only aluminium metallizing within the vacuum system but also other processes. The most obvious processes that are already starting to be included to add value would be one that improves barrier performance and the other is one that can produce patterned coatings.

This paper is aimed at highlighting what future machines might include and the advantages they would give to products.

INTRODUCTION

Business threats

Is the threat to the European & USA markets real or just perceived? If it is real then where does the threat to the metallizing industry come from? There are a few trends that can be seen that would suggest the threat is real.

Countries with low employment costs have been buying second-hand metallizers for years. Many of these machines are situated in various countries in the Asia Pacific region. They initially supplied only the home market. Others have seen the opportunity for using modern machines in low cost manufacturing locations to undercut the competition or increase profits.

Currently the world is looking at China as being the great business opportunity with the growth of high technology business being, on average, greater than 20% per annum for the period 1991 to 2001. However it is also worth noting that the exports from China over the same period grew from £3Bn to $68.1Bn. (1)

If we look at one industry that has monitored the effect of this recent overseas threat the following assessment has been made. In the USA paint industry, imports from China have been attribute to the loss of two & a half million jobs over the last three years. So not only is China an opportunity but it also represents a threat.

Another potential threat, to the small to medium size metallizing companies, is from the film suppliers. Polymer film manufacturers have seen their profits eroding and some are looking to go downstream to take profits elsewhere in the manufacturing chain. One of the ways some have chosen is to take the metallization process in-house. When doing this they are also looking to improve the material efficiency. One simple way of doing this is to match the vacuum system width to the film production width. Hence metallizers would ideally be mill roll (full width) or half mill roll (half width) size. This provides one driving force to increasing the width of new metallizers.

Efficiency of scale

If we look back at the progress of aluminium metallizing over the last couple of decades there are some general trends that are apparent. The winding speed has increased with the fastest of the machines now capable of speeds in the order of 1250m/min. The machine widths have slowly increased and machines of 3.5m - 4m have been built. Similarly the roll lengths have increased and the longest are now in excess of 100km. To try to shave some cost out of the process there have been attempts at down gauging, using thinner substrates for the same applications. The quality of the coating has also improved and whereas the thickness tolerance was once $^{+}/_{-}$10% it is now $^{+}/_{-}$5% or better.

If these trends are extrapolated into the future this would suggest that by 2010 there will be machines of 10m width, winding rolls with a length of 200km, or more, at speeds of 2000m/min, or more, with a uniformity of better than $^{+}/_{-}$2%.

To achieve this progress there will have to be changes to the design of the machines. This should not as difficult as it may first appear. Benchmarking the vacuum coating technology against other industries it can be seen that there are machines that already wind at faster speeds. Slitters with a width of 10m have been built and so there is some knowledge about roll design & bending problems. Technology from these machines, such as use of carbon fibre low-inertia rolls, has already been tried in a few metallizers.

Energy efficiency

In Europe there is already an energy tax and this has increased the interest in improved energy efficiency of new machines. There are several ways trying to improve the energy efficiency of the system. One of the simplest parts of the process that can be targeted is to improve the aluminium efficiency, which, currently, is often <50%.

Adding value

The other way of improving profitability is to produce differentiated products. There are two main ways of producing some differentiation, one is to improve the quality but produce essentially the same coating as everyone else & the other is to not only produce the coating but to also add something else to the process. Generally to achieve the latter there requires to be an additional process added to the aluminium metallizing machine.

There are four technologies that readily spring to mind when considering complementary processes to add value to aluminium metallizing. These are: -

Cleaning technology - to reduce the pinhole level & improve barrier performance

Planarisation layer - to produce pinhole-free high barrier metallization

Patterning - existing roll technology - next generation inkjet customized patterning

Embossing - for basic holographic large volume packaging material

PROCESS OPTIONS

Cleaning technology

It has been well documented that pinholes are primarily as a result of debris on the surface that is coated & when moved after coating leaves an uncoated area known as a pinhole or pin window (2). The effect of these pinholes on the barrier performance is also well known (3). By cleaning the web before metallizing gives the opportunity of significantly reducing the number and size of the pinholes and thus improving the barrier performance of the coated polymer. The physical cleaning technologies such as brushing or wiping cannot be used because they can damage the surface of the polymer. The ultrasonically pulsed, neutralized gas with combined vacuum extract does not lend itself to operating in a vacuum. This leaves the use of tack rolls as the most suitable cleaning technology available for use in vacuum (4).

This technology has been used extensively for atmospheric processes but has only been tested for use in vacuum. I am not aware of any production process that is currently using this process. The system does not remove every particle of debris but only those larger than 0.3 microns. Hence this process can improve the quality but further improvements will still be possible.

Planarisation.

If the debris on the polymer surface cannot be removed then one option is to cover the debris up by adding a coating with a thickness at least equal to the largest diameter particle. The coating will cover the particles and when cured in the vacuum will produce a new, flat & defect free surface. This is the ultimate in cleaning & should be capable of producing a perfect pinhole free coating.

This patented technology has been around for some time (5). However there appears to be limited up-take of the technology for the basic aluminizing process. So far only the applications that require the ultimate in barrier performance such as for the organic light emitting devices (OLEDs) appear to be able to justify the cost of the process (6,7).

There is also some question of the technology being robust enough. The planarisation process has been used at lower speeds & with less onerous cycle times than would be expected of a modern metallizers. Also the issue of speed & ease of cleaning between cycles has been raised as a concern. Although there are indications that a more simple technology would eliminate these issues & might be the more productive route to follow (8).

Patterning

Another technology that has been around for many years that is currently being developed to improve the process. Initially it was used for making simple uncoated stripes in the aluminizing but there was a need for more complex patterns and so modern printing technology has been applied to improve the process. There are at least two manufacturers offering this kind of technology for inclusion in roll coaters (9,10). For some of the slower processes, such as the reactive deposition of transparent conducting coatings, it may even be possible to use direct write inkjet printing technology for computer controlled customized patterning. This would enable the deposition of different electrical circuits, each design being produced in small quantities but all on the same roll without the need to break the vacuum between design changes.

Embossing

Embossing can be viewed in its simplest form as passing the web between a pair of nip rolls. One of the rolls has the structure to be embossed into the surface either etched into the roll or as a shim laminated onto the roll. To help the polymer flow into the structure the rolls may be heated.

Although it is not difficult to imagine incorporating this embossing process into a winding system in a vacuum, it is somewhat more difficult to think of this process working with high efficiency. Problems encountered, such as poor release from the shim, cannot easily be worked on in vacuum. The use release sprays to aid the separation of web & shim may not easily be controlled. This may limit the process to simple embossed structures, with relatively large features, that are quickly & easily released.

Process combinations.

To use only a planarisation layer, as a method of cleaning a surface, can require a very thick coating if all of the debris particles are to be covered. It makes sense to remove the worst of the debris first, using the tack roll technology, before then coating with a much thinner polymer planarisation layer. In many cases these two technologies ought to be thought of as complimentary.

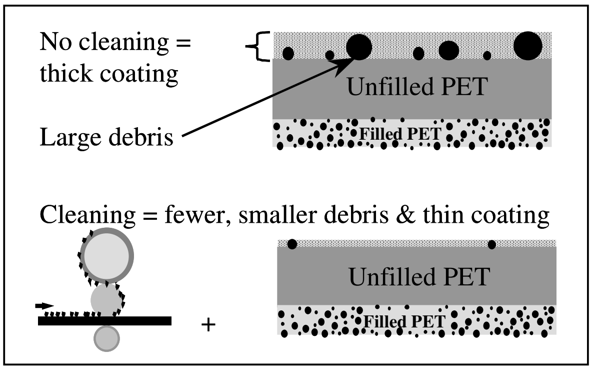

Figure 1. The benefit of cleaning before planarisation.

The planarisation layer might also be used as the polymer layer to be embossed. It could even be possible to divide the curing of the polymer into a partial cure before embossing & a final cure post embossing. This might enable a reduced temperature or pressure embossing process.

SYSTEM CONSIDERATIONS

If we consider having a goal of a 10m wide metallizer running at 2000m/min then it becomes apparent that a number of features that are common on existing metallizers will have to be changed.

Pumping

It is common, in standard metallizers, for the pumping to be hung off the end of the vessel and the pressure gradient across the web has not been seen as a problem. However when this is scaled up to a vessel greater than 10m unless the pumping is more uniformly distributed then the pressure gradient could become much more significant. This may be particularly relevant if at the same time we consider that the coating thickness tolerance aimed for will be tighter than currently produced.

Sources

The down time of the process is always an issue. If resistance heated boats are used there will be, at approximately 10 boats per metre, 100 boats for a 10m wide machine. Either there will have to be more operators to service the higher number of boats & wire feeds in the same turn around time or a duplex source system would be needed. Duplex systems have been produced on occasions but one must assume that they have not been of enough the cost benefit otherwise all new metallizers would have such systems included.

The more radical approach would be to move to full width slot sources that can be exchanged more rapidly. (11)

Deposition drum

The cooling of the deposition drum will also become a significant factor. Typically the drum is cooled by a chilled liquid that is fed into & through to one end of the drum where it is directed to the drum outer walls and returns and is drained out of the other end. Simplistically, moving up from a 3m to a 10m width machine is over a 3x increase in the drum width and this will lead to an increase in the temperature rise of more than 3x, for the same flow. The increased temperature of the returning liquid may be reduced by increasing the throughput of the cooling liquid coupled with a larger capacity chiller to remove the extra heat from the liquid. The additional problem that is of more concern is that there will be a significant temperature difference from one end of the drum to the other. This temperature difference will need to be eliminated. This will require a change in the internal design of the cooling liquid path.

Rolls

In other industries automatic roll exchange mechanisms are commonplace. This has been done in the past with some large metallizers but has not been common, Moving to much wider, longer & heavier rolls would make this technology look more attractive not only to reduce the turnaround time but also as a safer option for the operators.

Material efficiency

The use of slot source would also deliver a step change improvement in material efficiency that would also reduce the need for cleaning. There would also be a reduction in the heat load to the substrate allowing a faster deposition rate and with suitable design there would be an improvement in uniformity (11).

Added value processes

Each of the processes, cleaning, planarisation, embossing & printing could all be fitted into a very large roll coating machine. The alternative is to make the system modular so that there would be a number of smaller standard units connected together. Each machine would have a standard unwind & rewind module. There would then be a choice of modules each containing an independent process.

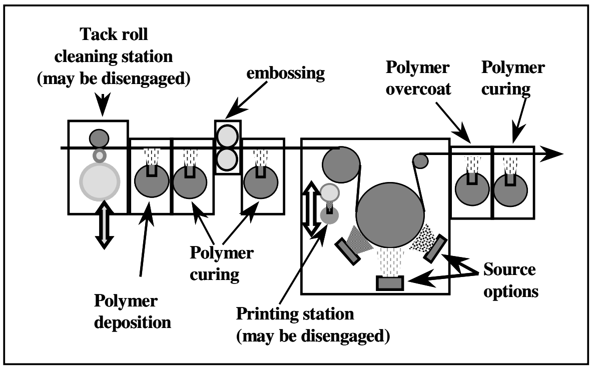

Figure 2. A schematic of some 'typical' modules

This would make the system similar to that of one of the large air-to-air glass coating lines where the number of modules depends on the number of layers in the optical coating design.

If we take as an example a high barrier plus holographic packaging product there might be the following modules; unwind, tack roll clean, planarisation + full cure, plasma treatment, metallisation, planarisation + partial cure, embossing + final cure, plasma treatment, metallisation, polymer overcoating + cure, rewind. This would be a total of eleven modules.

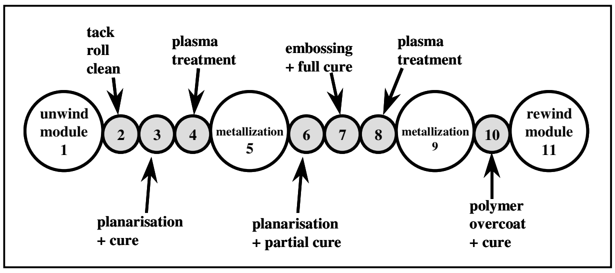

Figure 3. Schematic of 11 modules necessary to make the high barrier plus holographic packaging film as a single pass, in vacuum, process.

Key to this modular approach is the ability to engage or disengage individual parts of the process as required to produce a range of different products. It also requires each process when engaged to operate without problems. There are a number of processes that traditionally have taken some time and much operator intervention to optimise the process sufficient to make an acceptable product. In having these processes in vacuum this would not be possible and so work to make these processes more robust for use in vacuum would be required.

Timescale

There has been work done to combine some processes such as in the manufacture of flake pigments (12). In this process a polymer release coating is applied followed by the desired flake material composition. This sequence is repeated to form a stack of material that is transported into the next module where it is removed and the layers separated into individual flakes with the carrier polymer returning round to receive the next stack of material. The flake material can be as simple as a single layer of aluminium or glass or it can be a multilayer to produce a protected aluminium flake or optical effect flake. In one form of the protected flake the aluminium has a cured polymer coating deposited on either side of the aluminium. Thus for a single layer there is an uncured polymer release, a cured polymer, aluminium & a final cured polymer layer deposited.

This system was designed to reduce the number of individual manufacturing steps by putting all the coating steps into a single machine.

This indicates where the industry is today. One or two extra processes have been added within the existing deposition process vessel.

It is likely to be several years before it is possible to see a machine such as described in Fig 2. This timescale will be even longer if work is not started now to make some of the atmospheric processes, such as embossing, operate well in vacuum

The timescale to producing a 10m wide metallizer running at 2000m/min ought not to be very long as all the technology is available although some of it is in other industries & needs to be transferred across to the vacuum coating industry.

CONCLUSION

The trend of building bigger, wider and faster metallizers will continue. At some point there has to be a step change in source technology to reduce the maintenance time &improve the material efficiency. The rest of the technical issues are engineering design problems that are relatively straightforward to solve.

The more difficult challenge is in the area of adding value to aluminizing film. It will be essential to have additional processes included in the vacuum system. These processes will have to be much more robust than they are currently to make them a cost effective option.

When these processes become more available I would expect the systems will change to a modular design making them more analogous to large glass coating lines.

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