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Understanding Textile Washfastness

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As the technologies surrounding printing applications, plastisol ink and curing have improved over the years, so has the washability of the prints. What was considered to be a first quality print (20 years ago) following one to five washings would be considered a complete failure by today's wash test standards. Not only have we become more critical of the performance of our garments, the consumer has also become much more critical in what they expect to see at the end of multiple wash cycles. It is not uncommon for textile garment prints (when properly applied) to outlast the life of the garment itself. In many cases, this becomes an issue of endurance between the two and in this article we will look at the washability and durability aspects of a cured plastisol ink film on a printed textile.

It has amazed me (for many years) the number of garments that are produced with undercured ink films and either retain a minimal washfastness or, in the case of dark 50/50 cotton/poly garments, have signs of dye migration while the garments are still on the retailers rack. The reputation for quality, on which textile screen printers are judged, is primarily dependent on the washfastness and life span of the purchased garment. This holds true for contract printing garments purchased in mass as well as individual garments purchased by the consumer at retail. It only takes one bad experience of poor washfastness for a customer or consumer to write off a current printer/supplier from their supplier resource list. When a consumer purchases a garment, the expectation is that the garment and print will last for years. Printing facilities that live in the here and now print garments for the sole purpose of generating an invoice with minimal thought as to the life expectancy of the garment/print. Those printers living for the future have invested time and research into their production processes, products and techniques to ensure that the print on the garment will last for dozens of future washings down the road.

Durability of Cured Plastisol

The degree to which an ink film will withstand washing and abrasion is based on three factors. First is the quality of the components used in the construction of the ink film. This will hold true regardless of the printing medium, i.e.; water-based, plastisol or special effect ink. The general quality and printing performance of a plastisol is rated on this relationship and affects every aspect of the product, including print ability, shearing characteristics, trapping, viscosity, flashing and curing characteristics, to name a few.

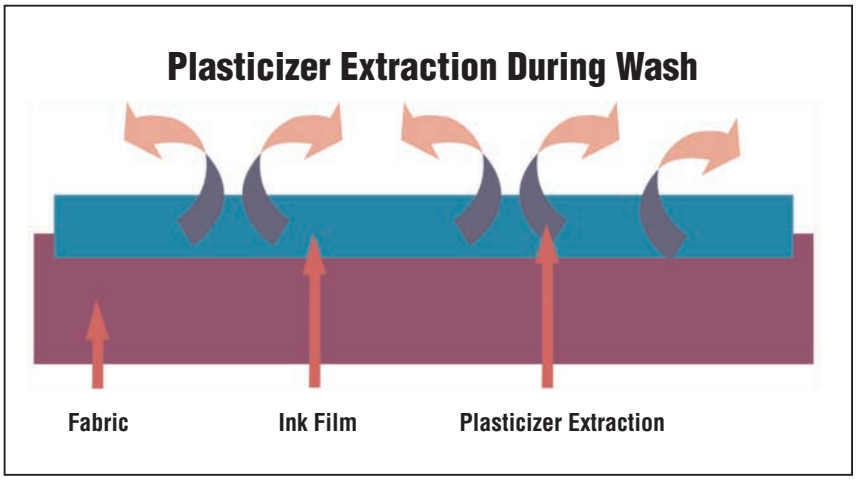
The second factor is compatibility of components to each other. Ink manufacturers will mix thousands of trial formulas in an effort to identify the combination of components that will best fit the printers' and consumers' needs. There are numerous different individual components in any component family within an ink formulation. It is due to this reason that so much trial and error is needed to identify the optimum formulations to meet the market's stringent demands. The one demand that is placed on plastisol manufacturers is the absolute need to ensure that the correct combination of plasticizers and resins are employed in any formulation to ensure that the ink can properly cure. The ink's ability to properly cure is based on the quality of the components that are built into the ink as well as the balance of the components within that formulation.

This is one reason that printers prefer one ink line to another. A printer will not only rely on the printing characteristics of the product but its post-production performance characteristics as well.

The last of the three factors is the degree to which the ink film is properly cured. This is the most commonly mistaken variable of the entire textile screen printing process. When printing plastisol, the proper degree of cure is achieved when the polyvinyl chloride (PVC) resins have absorbed the available plasticizers within the ink film during the curing process. The interpretation of the proper rate of cure is a matter of debate from printing facility to printing facility. The true problem is that there has never been a definitive test developed to determine whether an ink film is properly cured or not.

The proper curing of the ink film will provide the greatest degree of insurance against poor washability. One application aspect that many

Plasticizer Extraction



As each washing takes place, small amounts of residual plasticizers are washed out of the ink film, which degrades the ink film's elongation and abrasion characteristics over time

printers do not consider is the issues caused when printing with low-tension screens and excessive squeegee pressure. The excessive squeegee pressure (demanded of low-tension screens) will drive the ink film into the fabric that actually belongs on the surface of the garment.

The fabric that the ink is embedded in will act as a insulator against the heat of the curing process. This is especially true of radiant heat as IR dryers do not have the ability to drive the heat into the garment that forced air dryers do. The entire ink film thickness must reach the required curing temperature of that ink to ensure proper washability and durability. Regardless of the degree of cure that the ink film's surface receives, the entire ink film thickness must reach the required curing temperature to ensure washability and longevity.

It is quite easy to identify a garment/print that has not received a sufficient amount of heat to properly cure the print by the erratic/abraded effects of the post-washed print. Improperly cured prints will give way to the effects of abrasion washing during the wash cycle and will result in light areas where the print did not receive sufficient heat to properly cure. Properly cured ink films will withstand multiple washings while showing little to no effect.

Testing For Cure

Cellusolve acetate was discarded after researchers determined that the test was accurate on some plastisol formulations and not on others. Accurate reproduction of the test could not be ensured from ink line to ink line. This test method was never applied for water-based technology.

Heat tapes have acted (and still do) as a means of determining a reference point although they have proven to be inaccurate for determining absolute cure as the heat tape itself will only tell you how hot the tape got and not the actual ink film itself. The same would hold true for water-based ink mediums as the heat tape only tells you the temperature of the heat tape and not the actual temperature of ink/substrate combination.

Non-contact Pyrometers have also acted as an excellent means of determining a reference point (for plastisols) although non-contact pyrometers are only capable of determining the temperature of the ink film on the ink film's surface. They are incapable of determining the actual degree of the ink film's temperature within or (more importantly) determining the temperature of the ink film in actual contact with the fibers of the substrate itself. They will act as an accurate means for determining the cure temperature for water-based inks. This is due to the low solids content and the fact that the pyrometer can measure the actual surface temperature of the fabric once the water has been driven off.

The (on contact) doughnut probe is the closest we have come to measuring the ink film where the ink comes in contact with the substrate.

Although this method is the most promising from the standpoint of accuracy, it also offers no absolutes. The point many printers miss is that there is only one means of determining the degree to which an ink film will withstand washing and abrasion (the same method as the consumer will use) — the multiple wash test. If the print on the garment cannot withstand 5 to 6 washings, or shows excessive signs of abrasion resistance during the wash test, the greatest possibility for the lack of durability is that the ink film received insufficient amounts of heat to properly fuse the ink film to the substrate and thus, abrades away.

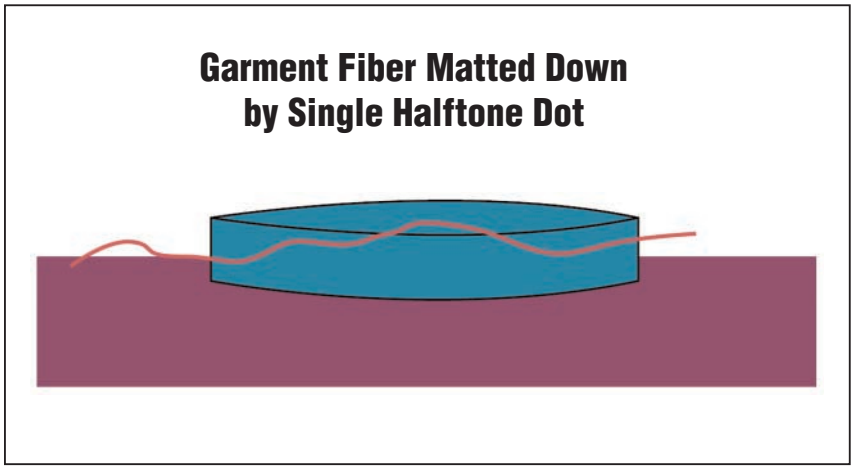
Many large garment screen printing programs will have in-line wash tests to ensure that the print on the garment will withstand a minimum of 5 to 6 washings prior to the shipping of the garment.

Effects Of The Wash Process on Plastisol Inks

While the quality of a print and the printer are primarily determined by the washability and durability of the ink film during the life of the garment, the aspect that many do not realize is that all plastisol prints will abrade and fade in time regardless of the ink film thickness or the degree to which the ink film is actually cured.

As the ink film resides in its cured state, a majority of the available plasticizers within the ink film have been absorbed by the PVC resin components of the ink. Contrary to popular belief, there are still residual plasticizers that reside within the ink film even when properly cured. These residual plasticizers are needed to give the ink film its required washfastness — elongation and abrasion resistant characteristics needed to withstand washing and wear and tear to which the

Garment Fiber



garment will be exposed. Without these residual liquid components present in the ink film, the remaining (dry powered) components would simply wash off straight away.

The residual plasticizers within the ink film will reside in the ink until the first washing takes place. During every subsequent wash cycle, a minuscule amount of plasticizer is extracted from the ink film. By minuscule, I refer to an amount that would be too small to measure. Nevertheless, over time, a sufficient amount of plasticizer will be extracted from the ink film during the wash process to affect the ink's ability to retain its elongation and abrasion resistant characteristics. It is for this reason that all (thicker) ink films begin to crack and flake after a given number of wash cycles. That number can range from 10 to 100 (or more) washings, depending once again on the quality of the components and the degree to which the ink film is cured.

Thinner ink films, such as process printing applications where very fine mesh counts are required, minimize the effect since the ink film is composed of a very thin ink layer that is fused to the surface of the fabric. The greatest effect on these thinner ink films is fibrillation, where the fibers — if the garment was initially matted to the surface of the substrate during printing — lift during the first washing and expose the bare underside of the printed fibers. This gives a print the effect that it has faded when in actuality it is the underside of the printing fibers raising from the fabric and exposing themselves.

Yarn Types And Fibrillation

There are two primary types of yarn used in manufacturing knit goods for textile screen printing: Open-end and ring spun.

Open-end is a cotton fiber with a longer staple length that is easily twisted into yarn. These yarns have excellent knitting characteristics and can retain their shape after numerous washings.

Ring spun is a fiber with a shorter staple length that allows for tighter knits and higher stitch counts. The end result is a softer and smoother fabric on which to print, allowing the use of thinner ink films and end products with greater detail. Ring-spun yarns can fray during the wash cycle, allowing the shorter yarns to loosen, rise from the fabric surface and contribute to effects of fibrillation. Most printers prefer ring-spun fabrics due to their superior printing characteristics although still having to combat the effects of that particular yarn type.

Ink manufacturers have modified products/ink lines to include fillers that contribute to controlling the effects of fibrillation. Application variations have also been employed for thin ink film application (such as four-color process) where a thin clear undercoat is applied prior to the colors to also help seal the potential loose fibers to the surface of the fabric.

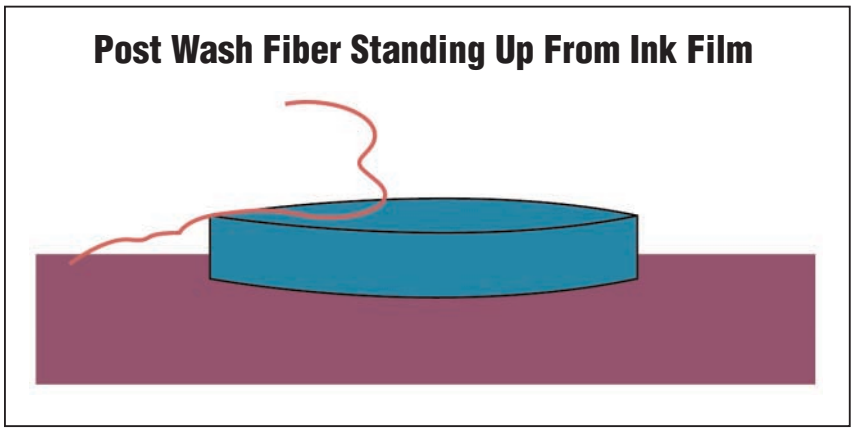
Detergent/Phosphate Effects

Detergents, for the most part, have little to no effect on the majority of plastisol ink film or other textile screen printing inks for that matter. There are, however, products still on the market that — although they have an initial impressive appearance — cannot withstand the contents of some or most detergents. These products are metallic inks that contain straight aluminum or copper powder. When the phosphates in common detergents interact with the aluminum and/or copper components, they instantaneously oxidize the ink film, changing aluminum components to a dull gray or copper components to dull brown.

For the most part, the issue has been eliminated because the newer metallic products on the market today are comprised of either minute polyester particles (in essence very small glitter particles) or polyester-encased aluminum particles that both have excellent visual appearance and are completely resistant to phosphate-laden detergents. Some suppliers, however, still offer the older metallic inks.

Abrasion Resistance

Properly cured ink films on printed garments will withstand a moderate degree of abuse over time. The first characteristic that most customers (and many printers) judge the durability of a printed garment by is abrasion resistance. The print must be able to withstand not only the print being abraded against itself in the washing process, but also the wear and tear the garment is exposed to in daily wear. Assuming that the ink film is properly cured (see "Understanding the Variables of Plastisol Curing," *SGIA Journal*, Volume Three, Third Quarter 1999) the amount of abrasion that an ink film will withstand will



Unprinted/underside of fiber stands up giving print a faded effect (fibrillation

now be dependent on the level of the previously mentioned component quality, component compatibility and the rate to which the ink is actually cured. Those components include the PVC resin, plasticizers, pigments and additives such as fillers, reducers, additional pigment concentrates and modifiers.

Since it has never been possible to actually measure the interior temperature of an ink film as it reaches the cure point, the actual degree to which a plastisol ink film has actually been cured has been a turkey shoot at best. Inks that are properly balanced, printed and cured should have no problem outliving the life expectancy of the shirt. The degree to which visible abrasion takes place will be dependent on the ink film thickness and rate of cure. Once properly applied, thicker ink films may not show signs of abrasion for upwards of 30 to 50 washings. Thinner ink films will have greater degrees of visible abrasion depending on the initial ink film thickness of the print and the previously mentioned criteria.

Effects of Flashing Process on Washability

The flashing process offered an entirely new set of variables to the textile printing process from the first day someone dried a color to overprint or apply another color next to it.

As with the curing process, the application of flashing an ink film offers variables due to our inability to actually determine the amount of heat the ink film is receiving or for that matter, to which it is exposed. Typically, when an ink film is exposed to the proper amount of heat during the flashing application, there will be no adverse effects to the ink film itself and the longevity and washability of the ink film will remain intact — assuming that the ink film is properly cured in the dryer's heat chamber.

The greatest negative impact the flash unit has on the ink film is when excessive heat is applied to a plastisol ink film and the surface of the ink film goes beyond desired production parameters. The target temperature for flashing most plastisols ranges from 180 to 250 degrees Fahrenheit. Unfortunately, many printing facilities will flash at excessive temperatures in the name of productivity. In most cases, the end result is the surface of the ink film reaching 320 to 360 degrees Fahrenheit. The potential effect on the washability of the ink film is a negative one. There are a number of scenarios that can take place at this point in the process. First, if the ink film reaches its typical 320 degrees Fahrenheit curing temperature, it runs the risk of absorbing enough additional heat in the drying chamber to reach 360 degrees Fahrenheit, which is the re-melt temperature of the ink. Should this take place, any and all durability characteristics of the ink will be destroyed.

When a plastisol ink film reaches the re-melt stage of 360 degrees Fahrenheit all of the compounds liquid components are typically burned or boiled off. The remains are the dried powdered components of the ink film that will not withstand either elongation of washfastness in that state.

Another aspect to consider is that if only the surface of the ink film reaches 320 degrees Fahrenheit (as opposed to the entire ink film thickness) the available plasticizers required for the proper intercoat adhesion for overprinting will not be available. The result in this case is an overprinted ink film that will not adhere to the over-flashed underbase and will wash off in one to five washings. A final consideration is the effect that the excessive heat can have on the washability of the garment. Should a dark 50/50 cotton/poly garment reach 350 degrees Fahrenheit, the polyester will begin to sublime into the underside of the ink film. Once this process is started, dye migration and discoloration of the ink film will be inevitable.

Best Practices

In conclusion, the best way to ensure the washfastness of your printed ink films is to implement proper procedures to control those variables that affect washfastness.

- **Minimize ink films.** Although many have touted the benefits of thinner ink films for numerous reasons, the benefits are extended to the washfastness as well. Thinner ink films cure more readily, require less heat and will withstand a greater number of washings.
- **Perform in-house wash tests.** Institute in-house wash testing procedures to ensure that the results the end users experience will be the desired long life characteristics required of any printed garment.
- **Monitor dryer heat.** Conduct and document regular checks on the dryer to ensure that the

dryer's settings are currently working and proving positive wash test results. Many facilities lock the dryer's controls out from the production staff in an effort to confirm that the systems settings are not adjusted for any reason.

Although I have mentioned that no temperature monitoring system —including non-contact pyrometers, heat tapes or doughnut probes — is absolute, they are all excellent reference points for dryer monitoring once the optimum dryer settings are achieved in relation to the washfastness.

The temperature that most high-energy dyes used by large garment manufacturers begin to sublimate from a solid to a gas is 350 degrees Fahrenheit. Lesser dyes can sublimate at lower temperatures.