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Sublimation intended for small formats: historical dimension, procedural steps, supplies and equipment

Sublimación destinada a pequeños formatos: dimensión histórica, trámites procesales, insumos y equipos

Sublimação destinado a pequenos formatos: dimensão histórica, etapas processuais, insumos e equipamentos

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Abstract

Sublimation is a digital printing process that emerged as a response to gaps left by the graphic limitations of screen printing. But, in the recent history of digital printing, the adaptation of inks in home printers for sublimation of small runs and formats, resulted in the exponential popularization of the technology. However, the scientific knowledge about sublimation is still incipient, especially the one that deals with small formats, common in the workshops of entrepreneurs in the personalized branch. Therefore, this article seeks to present in a detailed way the sublimation of small formats, its historical dimension, procedural steps, inputs and equipment.

Keywords: Sublimation; Design; Digital stamping; Graphic production.

Resumen

La sublimación es un proceso de impresión digital que surgió como respuesta a las lagunas dejadas por las limitaciones gráficas de la serigrafía. Pero, en la história reciente de la impresión digital, la adaptación de las tintas en las impresoras domésticas para la sublimación de pequeñas tiradas y formatos, dio lugar a la popularización exponencial de la tecnología. Sin embargo, el conocimiento científico sobre la sublimación es aún incipiente, especialmente el que se refiere a los pequeños formatos, comunes en los talleres de los empresarios del ramo personalizado. Por lo tanto, este artículo busca presentar de manera detallada la sublimación de pequeños formatos, su dimensión histórica, pasos procedimentales, insumos y equipos.

Palabras clave: Sublimación; Diseño; Estampado digital; Producción gráfica.

Resumo

A sublimação é um processo de impressão digital que surgiu como resposta para lacunas deixadas pelas limitações gráficas da serigrafia. Mas, na história recente da impressão digital, a adaptação de tintas em impressoras domésticas para a sublimação de pequenas tiragens e formatos, resultou na popularização exponencial da tecnologia. Contudo, ainda é incipiente o conhecimento científico sobre a sublimação, de modo especial a que trata dos pequenos formatos, comuns em ateliês de empreendedores do ramo de produtos gráficos personalizados. Portanto, este artigo busca apresentar de forma detalhada a sublimação de pequenos formatos, sua dimensão histórica, etapas processuais, insumos e equipamentos.

Palavras-chaves: Sublimação; Design; Estamparia digital; Produção gráfica.

Introduction

When looking at the current scenario of graphic production, one is confronted with a range of printing processes that every day allow for the most diverse applications. One of the most notable is sublimation. This is an increasingly popular process that, for Ruthschilling and Laschuk (2013), is justified by the easy accessibility promoted by a technology that is already common in domestic environments (inkjet printers), as well as by the low cost of acquiring machinery and other inputs (inks, papers and substrates).

This technique allows the transfer by evaporation of the appropriate ink from the printed resin paper to a substrate, by means of high temperature (between 180 and 220°C), pressure applied by a heat press, for a given time (30 to 180 seconds), depending on the nature of the substrate (SWAIN, 2011; RUTHSCHILLING; LASCHUK, 2013; MENDES; LAMARCA; SÁ, 2015).

The simplification of production processes, quality stamping on a single part and the absence of the need for special production spaces are also factors that contribute to this democratisation. (SETANI; SASAKI; TAKEDA, 1990; KIATKAMJORNWONG; PUTTHIMAI; NOGUCHI, 2005; EL- SAYAD; EL-SHERBINY, 2008; SWAIN, 2011; GLOMBIKOVA; KOMARKOVA, 2014; MENDES; LAMARCA; SÁ, 2015).

However, this leads to a trivialisation, perceived in the improvised way of working that is based on empiricism and superficial or no knowledge on the part of its advocates in relation to materials and equipment.

Guilhon, Silva and Silva (2021) argue that it is the ease of access to sublimation by anyone that triggers or fails to deepen this knowledge of the nuances between each printing process, which will generate doubts about the best way to work on a project. On the other hand, it should be noted that knowledge of the processes and modus operandi is limited only to manufacturers, as there are few scientific articles published on sublimation.

Just as there is no market, neither does the understanding of this subject become superficial in academia. Laranjeira and Moura (2013) argue that it is up to the designer (and the entrepreneur) to know how to make or use the technologies that involve all the production stages of digital printing, if he/she intends to achieve a high level of quality in the product resulting from his/her project.

In view of the problems presented, the aim of this work is to carry out a bibliographical review of the materials and process of sublimation, as well as its history and what can be sublimated, being technical-scientific knowledge that assists the designer in the conception of prints, applications of graphic brands in their visual identity manual and the elaboration of new products.

Historical background

Considering the scenario presented to it, CIE (2015) shows that similar stamping initiatives already existed in the late 19th century to serve as guides for embroidery on fabrics, with non-permanent inks that were attacked by means of pin pricks in soot or carbon dust on the (simple and clean) image printed on the paper.

Noël's creation, compared to the processes used at the time, proved to be revolutionary as it did not require post-print fixation of this type of dye; unlike the usual wet printing dyes (CIE, 2015). In addition, the simplification of the process itself, which is dry, is formulated in the minimisation of cleaning during and after printing, as well as the skill requirements of operators and complexity of equipment. However, the need for specialisation in paper handling and printing remained, but with the achievement of all colours and the simplification of a process as a whole (CIE, 2015).

Meanwhile, Frank (2011) says that the application of this printing process began in 1965 and that it has several applications, such as sample printing (assisting in the design and production process). Cahill (2006) contributes that, in 1973, RPL Supplies Inc., now based in New Jersey (USA), developed a digital process for transferring images onto fabrics, using ink ribbons that reacted to thermopressure, used for personalisation and promotional products.

For Swain (2011), the evolution and popularity of sublimation as it is seen today is precisely conflated with the advent of the first computers and the use of dot-matrix printers that used special ribbons impregnated with sublimation particles to create monochrome transfers in the late 1970s to early 1980s.

He adds that it was during this period that the first computer sublimation system, developed by Wes Hoekstra, appeared. He, who is considered the "father" of the sublimation industry, applied his work through image processing with the Jet Propulsion Lab in Pasadena, California (USA). Later, in the 1980s, such work paved the way for the emergence of electrostatic sublimation (SWAIN, 2011).

In the 1990s, on-demand printing proved to be a compelling advantage for fashion products, according to Cie (2015), to the extent that heat transfer printing regained its popularity as a precursor to inkjet printing. Ching-Li et al. (2016) add that inkjet was introduced, in the same period, as a proposal and answer to dye-sublimation transfer printing, as dye-sublimation ink was easily adaptable to the various models of small-format printers.

Consequently, the technique became popular, as it did not require expensive installations, application on substrates of very different nature (RUTHSCHILLING; LASCHUK, 2013; CHING-LI et al., 2016). And the reasons that led to this "boom" have already been described in the literature in the previous topic.

The process

As mentioned above, sublimation is a process that can be classified as thermo-pressing or thermo-transfer (LARANJEIRA; MOURA, 2013). Thus, it can be said that, for Carvalho and Rüthschilling (2016), this technique uses the transfer of sublimation ink printed on an appropriate paper (support or bridge) to the desired substrate by means of pressure, at a certain temperature, for a pre-defined period of time. Carvalho (2016) adds that the dye dispersed in the paint evaporates due to heat and migrates to the polyester-based surface.

In this case, the process of indirect digital printing is observed. This term is used by both Blauth and Tedesco (2013), because there is a step beyond what is normally seen in digital graphics processes, which has its direct printing commanded by graphics software on a computer CPU (digital image) and decoded and printed on paper by digital printers (final printed image). These authors call the result of this matrix-image printing (our glyph), which will be used as a support for the thermotransfer on the desired surface, transferring the pigment load to sublimate present in the paper.

On their part, Mendes, Lamarca and Sá (2015) reinforce the concept of indirect digital printing due to the fact that digital technologies and old sublimation techniques are mixed to obtain the desired print in a more accessible and practical way as it is known at the moment.

In addition to the concept of sublimation and its type of printing, it is interesting to illustrate the process step by step. Thus, Figure 1 presents a more playful way of understanding sublimation and each of its stages that will be described throughout this article. In the same way that Villas-Boas (2008) divides graphic production processes, it is also possible to break this process down into two main phases: a) creative and b) productive. Although figure 1 represents this first phase in a single step, it is interesting to note that sublimation, like so many other graphic techniques, is a productive and creative process.

It is also interesting to report that sublimation (at least in small formats), to a certain extent, contradicts and, at the same time, supports the graphic production process proposed by Villas-Boas (2008), especially in the production phase (in this order: pre-printing, printing and finishing). This is affirmed by the understanding that it is a ready-made and finished product, personalisation, i.e., printing (embossing) becomes the final macro-phase of the process.

However, in larger productions, such as T-shirts and fully printed parts, printing occurs on each individual part before assembly, as well as in smaller products where the finishing phase occurs after both printing on paper and stamping on the object, with the removal of the matrix from the sublimated part and its cooling.

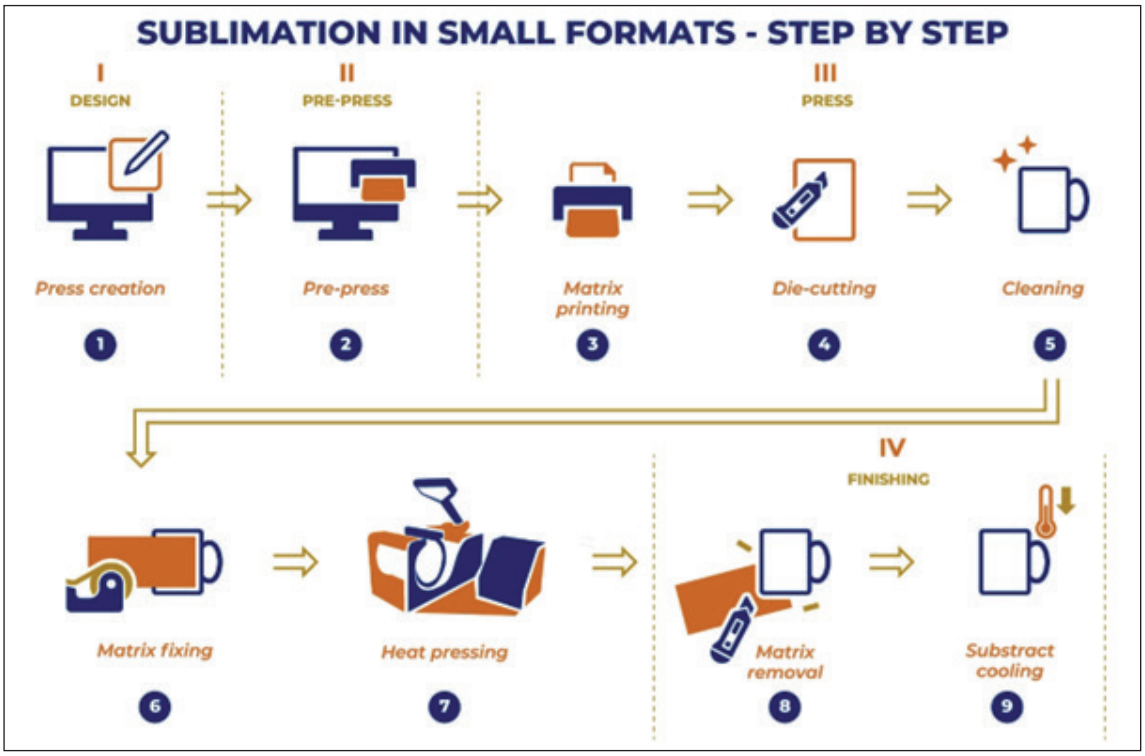

Figure 1: Sublimation in small formats and its steps.
Source: the authors themselves.

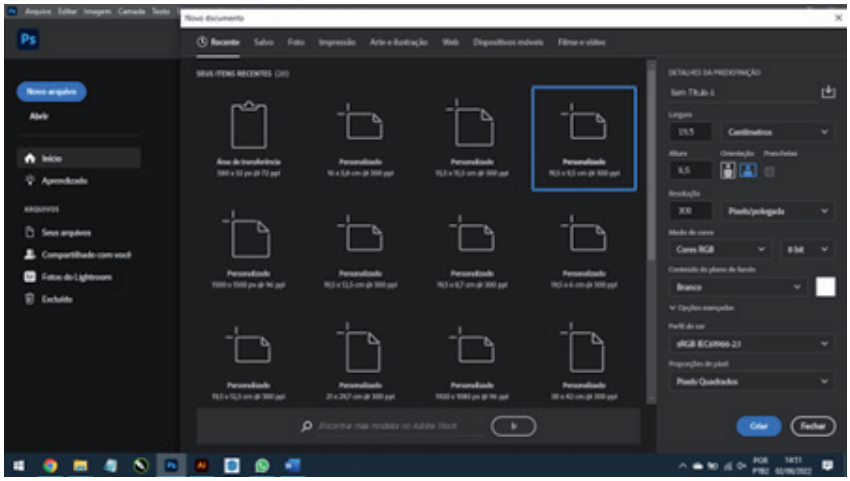

Figure 2: Initial screen of Adobe Photoshop with its specifications.
Source: Print screen of the Adobe Photoshop splash screen.

Stage I - Design

This is the graphic design to be printed, and for Andrei (2021) it is a previous way of reproducing the image on the substrate. For Villas-Boas (2008), it is called projection. It requires knowledge not only of graphic editing software, but also of the assumptions of creativity-oriented graphic design.

Initially, the graphic designer or operator graphically constructs the design of the requested products. The technical attributes that delimit this part of the process are linked to the template generated from the morphology and materials of the sublimatable objects, as well as the behaviour of the colours on the surfaces and the limitation of the printing and pressing equipment. This can already be seen on the initial screen of the graphics software used to create the prints, as shown in Figure 2.

This reinforces Löbach's (2001) thinking about the relationship between design and products through the definition of their technical attributes, formal, aesthetic and symbolic qualities, susceptible to mass production and meeting the needs of their user.

The creative possibilities and the range of different types of products, in terms of morphology and dimensions, will be influenced by machine specifications, such as printing area and width of the printing nozzle, which define the format possibilities.

This is similar to the cut-size formats offered by offset printers described by Villas-Boas (2008). Having said that, small format sublimation is initially restricted to commercially available printers, such as those that support A4 and A3 based formats.

Figure 3 shows the useful working area, guided by the limitation of the press and the print output. In this image, you can see the relationship between this template on which the print is created and the object to be sublimated, according to the specifications the file needs to meet the printing configuration. The image on the right is already different and presents an example of the shape of a conical product that needs more attention in the creation of what will be printed, where the job is based on a curved template that follows the silhouette of the object.

In this sense, the objects subject to sublimation are delimited not only by the creative phase, but especially by the needs of the productive phase.

Figure 3: Assembly with the useful area template and 3D application of a cylindrical (left) and a conical (right) product, as well as their specifications for on-screen production in Adobe Photoshop.
Source: the authors themselves.

Stage II - Pre-printing

This begins with the preparation of the file for printing, subject to approval of the graphic design. This part corresponds to pre-printing, where it is planned how the file will be closed for printing, having already verified the resolution of the images and the number of copies per printing plate. The simplicity of the sublimation process extends this range of file formats by using the graphic editing software itself as a print management platform. It is worth remembering that sublimation is a digital process and the printing is done directly on the matrix, in this case, the sublimation paper.

In small format sublimation, this phase is also about planning what will be printed, considering the number of copies of the same print or prints for different products. All this is guided by the printing area available by the equipment available to the entrepreneur. In this way, the designer, after approval by the client, sends the file created in an image editing program to the software in which his set of equipment and inputs are configured for printing. Thus, it can be seen that in sublimation, the pre-printing phase also requires the designer's knowledge of the printing configuration in the software used.

Depending on the type of printer, adapted or manufactured for the process, some printing characterisation points differ. In the sublimation printer, the options that appear are different and more simplified, since it is, as already mentioned, suitably designed for this type of graphic process. Here, the user can adjust the print depending on the desired quality and the substrate material to be sublimated. With the printer adapted, it takes advantage of the equalisation of the properties that already come with them, such as Colour Correction and Image Mirroring (which is not necessary in sublimation), for example.

In both cases, the importance of calibrating the colour management for printing is perceived, as a quality standard is sought in which what is printed is as close as possible to what is displayed on a screen, having, in a way, established the same dialogue (VARANDA, 2011).

Obviously, it is known that such interfaces are governed by very different colour modes -RGB for screens and monitors and CMYK for printers- and that is not the focus of the discussion of this paper and there are other works that can guide this deepening (CUNHA , 2000; SWAIN, 2011; VARANDA, 2011; FIDALGO; GONÇALVES, 2014).

Stage III - Printing

It is the transformation of the project created, imported or edited in graphic editing software into a stamp, a printed image. There are three important actors in this phase of the process: printers, paper and inks (ANDREI, 2021, p.41). The printing of sublimation matrices, in general, can be done by offset printing (large scale) or by inkjet (in smaller demands, which is the case of this article), by means of a command generated by graphic software.

Inkjet printing is, according to Li (2003), a matrix printing technology in which the print head nozzles deposit ink droplets directly onto the surface of the substrate, forming the desired image. In detailing the process, the author describes that the printhead prints horizontal strips on the sheet of paper, using a motor and gears to move from left to right, while another motor drives the rollers so that the paper passes vertically after each strip is printed and the final design is completed.

Being even more precise and specific, small format sublimation makes use of Drop-on-demand (DOD) technology printers, especially those categorised as piezoelectric. Li (2003) describes that this technology, as the name suggests, consists of the emission of ink droplets according to the need and demand for print generation.

Further elaborating on the category, a piezoelectric inkjet printer is equipped with a system of ceramic parts plates connected to electrodes that are controlled by electrical pulses. Reacting to an electrical command, the plates deform, generating enough pressure to change the volume of ink in the chamber and cause the ink to drip onto the substrate (LI, 2003; WILLIAMS, 2006). It is a system widely used in homes and offices and allows many companies to experiment with different types of inks, as its printing mechanism does not heat up, as Williams (2006) points out.

In this regard, Andrei (2021) points out that, in order to work with sublimation-driven printing, the chosen printer models cannot use heat in their mechanisms. The author justifies that heat during printing can cause pre-gasification of the ink before it reaches the paper, which makes sublimation unfeasible. This helps to understand why "tabletop" sublimation has managed to develop and gain a foothold.

Printing systems

Within this small format printing system, the market offers two types of printing systems, which can be classified as: a) adaptive printing and b) original printing. For these systems, it can be said that the printing quality is influenced by three points that are directly related to each other: type of printer, nature of the sublimation ink and printing configuration. It is a type of classification and description that is not mentioned in academic works; however, widely used in the commercial field.

Adaptive printing involves the use of parallel sublimation inks inserted into the bulk of a desktop inkjet printer, which is widely used for commercial

and residential purposes. In addition, it has a complex printing configuration, with the mandatory installation of a colour profile. This whole scenario varies from one ink manufacturer to another, both in terms of print configuration, ink formulation, colour fidelity and product values.

As it is well known, this type of system emerged as a gap left not only by graphic processes in relation to colour restriction, as in screen printing, but also for smaller scale and dimension productions, such as industrial sublimation.

It is also recalled that the compatibility, albeit in the short term, of the MicroPiezo inkjet system with parallel inks contributed to this system being the most widely used, also justifying the low acquisition cost.

Original printing is, as the name suggests, a system that uses a printer (actually) designed for sublimation, whose ink kit (from the same manufacturer as the printer) is compatible and warranted by the corporation that sells it. Unlike the first type, the printing configuration tends to be simpler, as the way these printers are used is similar to the printing of inkjet equipment with its respective inks.

This means that when the printer is installed on the computer or notebook, the colour profile is also installed and its printing parameters are automatically adjusted.

It is a more expensive system, compared to the adapted one, as both the printer and the ink are not as well known, as well as there are few models and companies working with this particular type of product.

Specifications and supplies

The files generated for small formats support the printing of A4, A4+, A3 and A3+ formats, as well as the printer tray, both adapted and designed for sublimation inks.

In both processes, the paper, preferably sublimated, is mirror printed on its more porous side. Its reverse side is resinated, being smoother and generally provided with a commercial differentiation colour, and/or the watermark of the manufacturer's logo. The quality of the print seen on the paper is much lower in terms of the vividness of the colours and the fidelity of the same, not being at this stage a phase to be taken into account in these aspects, as they will have the expected definitions after being subjected to pressure at high temperature for a certain time (DING; ZHAO; HAN, 2016).

Paper is an important element of the sublimation process. Guilhon, Silva and Silva (2020, p. 3) state that it is an "intermediary between the composition printed on it and the material of the object where the print will be applied". Moreover, its transfer properties, praised by El-Halwagy, El-Sayad and El-Molla (2001), point to this element as very important in the thermal transfer printing process, as such attributes (weight, porosity and type of coatings) have a direct influence on the fidelity and colour intensity of the printed pieces. Not surprisingly, Guo et al. (2011) state that the quality of what is printed in sublimation depends on the quality of the paper.

However, the popularity of the process has also led to the trivialisation of the quality of the elements and inputs used. With paper it was no different, as many people and even companies, when using common paper such as sulphite, rely on the quality provided by the right paper in search of the wrong economy. Guilhon, Silva and Silva (2021) comment on the disadvantage that this easy access can trigger, since the process can be accessed by anyone and indiscriminately, due to a lack of knowledge of the appropriate characteristics for the desired purpose, the process ends up being carried out by choice.

In fact, the difference in value between the two is great, especially the ease of access in which the ream (500 sheets versus 100 sheets of sublimation paper) of bond paper is offered, as it is sold in different types of shops. Thus, the use of bond paper is a "treacherous" choice, especially if the quality of what you want to print is respected. Therefore, the quality of the paper in this process is, according to El-Sayad and El-Sherbiny (2008), its main requirement.

But for printing to work properly, the importance of ink in sublimation must also be emphasised. It is a special paint that, according to Pacheco (2015), are solid pigments invisible to the naked eye that float in a liquid environment, designed to adhere to the substrate when exposed to high temperatures. With the aforementioned advent of sublimation, especially in small formats, adaptations of inkjet printers appeared to receive so-called parallel inks, inks manufactured by companies other than the printers. However, it is worth mentioning that there is also a printing system for this mode, in which the inks are developed especially for the machinery by the same corporation.

What cannot be forgotten about sublimation is the type of material on which it can be applied. It only occurs on surfaces where there is, at least, one film containing

Figure 4: 3d of some of the manufactured products available on the market for sublimation.
Source: the authors themselves.

polyester in its composition, known commercially as resin (ANDREI, 2021). This material allows printing on objects such as cups or tiles, which are made of white ceramic, or thermos flasks, which are made of stainless steel, as shown in Figure 4. About this, Andrei (2021) adds that due to this, it is not possible to print any object purchased on the market, indicating resin products by specialised companies and a process limiter in relation to the variety of products.

Die-cutting and fixing

Die-cutting and fixing are phases that depend on the format of the product and the type of press to be used. For example, an A4 printed T-shirt does not require its die to be reloaded, as the printing is in the same format; and it does not require fixing to the part (depending on the sublimator's experience), as it is a flat part with fast thermopressing. However, a range of promotional products, require their dies to be trimmed and fixed to their surfaces in order to be properly stamped.

The most common example is the white ceramic mug. When planning a print run of 30 units, it is possible to print three copies per A4 sheet. Therefore, trimming is essential to save material, which can be done with the help of scissors or a stylus with a metal ruler on a flat glass surface.

Thermo-pressing

Thermo-pressing or thermal printing is one of the most representative phases of sublimation, as it is precisely here that the physico-chemical process of the pigments contained in the ink takes place. The name suggests the coordinated presence of three physical variables to make it all happen: exposure for a certain time (30 to 300 seconds) of a print set at a certain level of pressure (50 to 150 psi or light to heavy) on an object at a high temperature (between 170 and 200 °C).

It turns out that this part of the work also depends on the fourth variable: the geometry of the product to be sublimated. Thus, it is the shape of this object that will define the type of machinery and techniques to be used, as well as the printing area of the product, so that these three physical properties can work properly (ANDREI, 2021).

It is interesting to observe, by the format of the products, the type of press to be used. For this purpose, Andrei (2021) helps to describe the six most commonly used types of presses, according to the demand for sublimation products and the representation in figure 5.

Flat press: is a piece of equipment used for materials with a flat surface, such as tiles, slippers, mousepads, stones, picture frames, mdf boards and metals, jigsaw puzzles, fabrics and other substrates that point to a two-dimensional relationship. It is undoubtedly the oldest of the presses, probably due to the initial need for alternatives for transferring pigments to polyester-based fabrics. Andrei (2021) says that there are three types of flat presses,

Figure 5: Examples of described press types used in sublimation.
Source: adapted from Live Sub (2022).

considering the operating mechanism, such as Alligator Mouth, Drawer and Swing.

Plate press: the machinery specially used to stamp the flat part of the bottom from 8 to 12 cm in diameter.

Lid press: the equipment aims at stamping the front of the lid.

Cylindrical press: this is a machine intended for pressing cylindrical shaped artefacts and has a retractable variant for conical parts, such as cups, glasses, bottles, bottles, cans, juicers and cups.

Multi-purpose presses: this is an option that combines the use of several different shrink resistors on a single machine. Thus, it is possible to produce with a single machine stampings that previously required several machines for each particularity. Some of these are 2 in 1, 5 in 1, 8 in 1.

3d press: of the three, it is certainly the newest, in view of the innovations arising from the growth of the sublimation process that sought to print in more complex shapes. It is a kind of thermally insulated electric oven that presents the alternative of printing up to 12 mugs (for example) at a time, using a kind of silicone strap on its silhouette - which can be applicable to other objects already listed that would be printed - one at a time.

It also makes possible the transfer of pigments to objects with more complex shapes, as well as the full coverage of cylindrical or conical surfaces where traditional presses generally cannot, due to the limitations of the machinery itself.

Finishing

The phases after heat-pressing are the removal of the matrix from the sublimated object and its cooling.

These phases are defined as finishing phases because they are understood to be stages after printing and they involve the elimination of materials that are not necessary for the fulfilment of the objective of the graphic process.

At first glance, sublimation finishes seem to be non-existent in comparison to offset printing

where after the paper goes through the printing process, it is cut to the desired format and may receive some protective coating, such as Bopp resin or some varnish application.

In fact, if that is the point of view, sublimation literally ends right after heat-pressing. However, it is necessary to remove the matrix-bridge of the sublimation pigments from the surface of the printed object, which can often remain stuck to it, requiring special attention from the sublimator not to remove the polyester film in this process.

The nature of the materials may influence the ease or difficulty of removing the sublimation paper from the surface of the printed products. It should also be noted that the quality of these products, especially the resin and its application to these objects, can also help or hinder the progress of the process. Obviously, prolonged exposure of the object beyond what is indicated for its material type can also be a negative factor by impairing not only the matrix removal process, but also the final quality of the print.

As far as cooling is concerned, it can be said that it is a relevant step in the process and must be respected, depending precisely on the nature of the material on which the print was applied. This justification becomes even stronger when comparing a ceramic mug with a stainless steel bottle, for example. These are different materials that obviously have different thermal behaviour when subjected to high temperatures and subsequent cooling.

Ceramics are hard and, at the same time, brittle, vulnerable to thermal shocks, thermal insulators and refractories, as well as good thermal conductors (COSTA, 2006). Metals, such as stainless steel, differ in terms of heat because they are not thermal insulators, as they absorb heat as easily as they spread it, as well as being resistant to thermal shocks.

Thus, it can be stated that a ceramic product such as a mug has greater exposure to temperature so that sublimation can occur in the resin layer on its surface, as it has greater resistance to heat. And it cannot undergo an abbreviation of its cooling time by using cold water, and sublimation can be cut off by immersing the artefact in a bucket of water at room temperature.

Metallic and even plastic products do not suffer structural problems, with cracks, crevices or fractures, with the cold water immersion thermal shock process. Metallic materials require less time of exposure to temperatures and cool down quickly, while plastics cannot be exposed for a long time to the process, as they are more sensitive to exposure to temperatures above 150°C, justifying the short pressing time.

Final notes

Finally, the process, despite the limitations presented, is still advantageous because of its very low implementation cost, the simplicity of the few steps and the low need for space preparation, when compared to other similar processes, such as screen printing and laser transfer. The photographic quality already described and the possibility of using it at an affordable cost on a single piece are also factors that further boost the growing use of this printing technique.

It is believed that the objective of elucidating in greater detail the sublimation process (phases, elements, inputs, applications and characteristics) was duly accomplished, considering the existence of scarce bibliographical and research references in the area, mainly in terms of technology combined with creativity, process and design.

It is suggested, as future work, the investigation of

different inputs and materials from other areas that may be related to sublimation, (e.g. inputs for 3D printing, or natural materials). As well as other commonly used graphic production processes that also have little related research or literature sources, such as transfer, cut vinyl and foil.

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