

Optimizing Heat Transfer Parameters for Improved Print Quality

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Abstract

In the realm of printing technology, heat transfer print ranks amongst one of the most versatile and widely used techniques for decorating and customizing various materials such as textiles, ceramics, plastics and metals. This technique involves the transfer of images and designs from a heat transfer paper or film onto a substrate with the use of heat and pressure. The resultant prints are durable, photo-realistic and resistant to fading and wear. This paper provides an overview of the principles, materials and equipment involved in heat transfer printing and the fundamental processes of heat transfer, including the roles of heat, pressure and time are also examined in this essay. The various types of heat transfer papers, films, inks as well as the different heat press technologies are also discussed. The applications of heat transfer printing are diverse and widespread, ranging from textile printing for apparel and home decor to promotional products, signage and industrial labelling. The advantages of heat transfer printing, including its high image quality; durability and versatility are examined within the context of these various applications. However, heat transfer printing also has its limitation and potential drawbacks such as equipment costs, colour fading and substrate compatibility issues. These challenges and limitations are also discussed and potential solutions and way forward for technological advancements are also explored. The objective of this essay is to provide a valuable resource for researchers, manufacturers and practitioners seeking to understand and optimize heat transfer printing processes while the method used included survey and literature review. By examining the principles, application and advancements in heat transfer printing; this article seeks to contribute to the development and innovation in this field.

Keywords: Printing Technology, Photo-realistic, Manufacturers, Principles, Heat Transfer.

Introduction

Heat transfer printing has a long and interesting history that spans over a century. The technique, according to Incropera et al (2020) probably originated in ancient China in the late 19th century when it was used to transfer images onto ceramics and other materials. However, it was not until the mid-20th century that this technique of printing began to gain widespread recognition and acceptance as a viable method for decorating textiles and other materials. As a matter of fact, the early beginnings of heat transfer technology could be traced to the 1800s when ceramic decorations began, using a technique known as “transfer printing” to apply designs onto ceramic wares. This process involved transferring design from a paper or ceramic transfer into a ceramic surface using heat and pressure. In the 20th century, avers Dennis and Jenkins (1990), heat transfer papers were developed, which allowed for mass production of heat transfers. These papers were coated with heat-sensitive adhesive that would release the design when heated. Heat transfer printing began to be used in the textile industries in the 1950s and 1960s; this was made possible by the development of heat transfer papers and inks that could withstand high temperatures required for textile printing. The 1970s and 1980s experienced the advancement in heat transfer technology in terms of new and high definition heat transfer papers, inks and equipment which consequently led to the improved print quality and efficiency.

In the submission of Stephen and Balance (2001), the 1990s to the present saw the advent of digital printing technology and this led to new revolution in the aspect of heat transfer printing. Digital heat transfer printing allows for very high quality, photo-realistic images to be printed quickly and easily

without the need for screens or plates and today, heat transfer printing is a widely used technique in various industries including textiles, ceramics, glass and metal. Modern heat transfer printing technology offers high-quality prints, improved durability and increased efficiency, making it a good choice for customizing and decorating a wide range of products. Lienhard and Lienhard (2020) are of the opinion that one of the key factors that contributed to the growth of heat transfer printing technology was the development of new materials and technologies. The introduction of heat transfer papers and inks made it possible to produce high-quality images with vivid colours and intricate details with the development of heat presses and other equipment enabled printers to produce large quantities of heat transfer jobs on schedule and efficiently.

Despite its many advantages, heat transfer also faces several challenges over the years and one of the limitations of the technique according to Wright (2006) is the need for specialized equipment and material; heat transfer papers and inks are very expensive and difficult to obtain especially for small scale printers; in addition, the heat transfer process itself can be complex and time-consuming and so requires careful control over temperature, pressure and time; however, in recent years, Hyatt-Major (2012) have allayed these fears and submits that advances in technology have helped to overcome a lot of these challenges. The development of digital heat transfer printing machines has made it possible to produce high-quality images within a short time; similarly, the introduction of new heat transfer papers and inks has widened the range of materials that can be printed using this technique. Despite these advancements, this writer thinks that there is still need for further research into the principles and applications of heat transfer printing. Many of the existing studies in this subject have focussed on the technical aspects of the process such as optimization of heat transfer parameters and the development of new materials and equipment. Against this backdrop, this study aims to address some of these gaps by providing a comprehensive overview of the principles, applications and advancements in heat transfer printing. This study examines the technical aspects of the process including the optimization of heat transfer parameters and the development of new materials and equipment. It also explores the creative and practical applications of heat transfer printing, particularly in the context of textile printing and other industrial applications. By examining the relationships between materials, equipment and printing parameters, this study also contributes to the development in the field of heat transfer printing whereas the findings of this study will be of benefit to researchers, printers and manufacturers in this area.

In spite of its widespread adoption, heat transfer printing remains a complex and multifaceted process that is influenced by a variety of factors including the type of substrate, ink and heat press used. However, there seem to be some lack of comprehensive understanding of the optimal parameters and conditions required for achieving high-quality heat transfers especially in the context of textile printing. Furthermore, the increasing demand for customized and personalized items has led to a growing need for efficient and cost-effective heat transfer printing solutions; however many heat transfer printing processes are still plagued by issues of colour fading, image distortion and substrate damage which can result in significant economic losses and environmental waste; therefore, this study aims to investigate the optimal parameters and conditions required for achieving high-quality heat transfers with particular focus on textile printing applications. Whereas the aim of this study is to give the reader or others who are not skilled in this art a ready and handy manual on how to carry out a successful heat transfer job, the objectives of this study are to develop a comprehensive understanding of the optimal parameters and conditions required for achieving good quality heat transfer prints and to investigate the practicability of using heat transfer printing for customized items. Heat transfer practice has behind it, a combination of physics, chemistry and engineering in which case it involves the manipulation of heat to create a chemical reaction which in turn culminates in the transfer of design from a surface to a receiving one. This process starts from the printing of a design onto a heat-sensitive material like a special paper or film which is coated

with a film of heat-sensitive ink that might change colour or become visible when it comes in contact with heat and so when heated, the ink changes to vapour and percolates into the surface of the material thereby creating a good print. The inks used in heat transfer printing are composed of a combination of chemicals like colorants, binders and potent compounds such as when exposed to heat undergo some kind of chemical reaction which makes them undergo colour change and become clearly visible. The 'leuco dye' present in these inks makes them change from colourless to coloured forms when they come in contact with heat and become visible to the eye in their impression.

According to Cengel (2002), heat transfer process actually took its roots from physics Fick's Law of diffusion which states that "the rate of a substance's diffusion is proportional to the concentration gradient and the area of the membrane and inversely proportional to the thickness of the membrane", this is the Physics behind heat transfer technology. Sublimation is another important part of heat transfer printing process in the sense that when the heat-sensitive material gets heated, the ink vaporizes and sips into the surface of material in a process known as 'sublimation' and this is the process that gives room for prints to be permanent in whatever material it is printed on. In physics, sublimation is the process by which a substance transforms from solid to gaseous state without necessarily passing through a liquid state and so in heat printing process, heat makes solid ink particles to transform into gas (sublimation) and these particles in gaseous form percolates the surface of whatever material which in turn gets cool, solidify and creates a permanent print. It is not the idea of this researcher to delve into the pure chemistry and physics aspects of equations and calculations of this topic as the main thrust of this research is the aesthetics of graphic design aspect of heat transfer printing.

Materials and Method

This study engaged a mixed-method research approach with a combination of both qualitative and quantitative approaches to collect data. This research is basically studio-based and practice-led research. The data collection methods included literature review, case study, experiments and testing-out whereas the materials for this study included inkjet heat and laser heat transfer papers, sublimation heat transfer papers and inks and pigment inks, dye-based inks while the substrates include fabrics, ceramics, glass, metals and wood whilst the heat press used include auto-operating heat press.

Results and Discussion

Heat transfer, according to Knobbler (1980) is the process by which energy is transferred from one body to another as a result of temperature dissimilarity. Heat transfer is a basic theory in physics and engineering which describes the transmission of thermal energy from a state of higher temperature to that of lower temperature. It is a technique of printing which involves the use of heat press to transfer images or designs onto a surface. This form of printing is used for printing on a wide range of materials such as diverse forms of fabric like cotton, polyester, nylon, denim and canvas including plastics, metals and ceramics.

Whereas the three main types of heat transfer process as noted by Brown and Marco (2023) include:

- (a) Conduction, which is heat energy transfer through contact between particles and molecules.
- (b) Convection is the transfer of heat energy through the flow of fluids and
- (c) Radiation which is the transfer of heat energy through electromagnetic waves, they maintain that the types of heat transfer printing techniques include:
 - a) Sublimation printing: This is the type that involves the use of heat element to make ink sublimate by changing to gas and dissolving into the fabric or other material intended to be printed on and these are materials that can stand very high temperatures. As will be discussed later, the full process is contained in the latter part of this essay.

b) Heat Press Printing: In this technique, a heat press is used to transfer designs into surfaces including fabrics, plastics and metals. Here, a design is made in reverse onto heat-sensitive film and subsequently placed on fabric and heat press applied on it for some few seconds at a particular temperature thereafter the heat plate is lifted and the film peeled off the fabric thereby leaving the design on the fabric.

c) Direct Thermal Printing: This technique is the use of heat to provoke a kind of chemical reaction in heat-sensitive materials thereby culminating in the creation of a design

The heat transfer process of printing offers a lot of advantages over traditional printing methods. Some of these advantages as advanced by Kazi (2023) include:

- a. Quality: Images are rendered in rich and vibrant colours in intricate details.
- b. Durability: Prints are durable and resistant to fading, wear and tear.
- c. Versatility: This is in terms of substrate materials and shapes.
- d. Cost-effectiveness: The process is cost-effective and efficient in production.
- e. Environmental friendliness: This process eliminates the need for screens, plates and other chemicals thereby completely eliminating the issues of littering.

In recent times heat transfer has become a popular business amongst screen printers and T-Shirts producers as heat transfer printing has a lot of advantages; in the same vein there is a specially formulated paper that the transfer process uses which acts as medium for the ink. The designs are printed on the paper with the use of heat and then transferred onto a final product like T-Shirt, Caps, ceramic wares whereas others with irregular surfaces, rather than flat might be easier to handle using transfer process rather than rigging the screen to form round the contours.

Heat transfer printing has a wide range of industrial applications put forward by Lungberg (2016) including the following:

Textile Industry: Heat transfer printing is widely used in the textile industry for customizing apparel, fabrics and other textile products. It is particularly popular for printing logos, designs and graphics onto T-Shirts, hats and other clothing items.

Promotional Products Industry: Heat transfer printing is used to customize promotional products such as mugs, water bottles, key holders and other items with company logos, designs and messages.
Signage and display industry: Heat transfer printing is used to create custom signs, displays and graphics for retail stores, restaurants, hotels and other businesses.

Ceramic and glass industry: Heat transfer printing is used to decorate ceramics, glassware and other tableware items with intricate designs, patterns and images.

Metal and plastic industry: Heat transfer printing is also used to customize metal and plastic parts, components and products with logos, designs and other markings.

Sports and fitness industry: This printing technique is used to customize sports equipment, kits and accessories with team logos, designs and player names.

Fashion and Apparel industry: It is used in this industry to create custom fashion design patterns and images onto fabrics.

In summary, heat transfer printing is a widely and versatile technique that offers a range of benefits and applications across various industries. For the purpose of this paper, the writer would concentrate

on the heat transfer printing of T-Shirts and mugs as these are the commonest materials being printed in this part of the world.

Heat transfer technology is probably one of the few processes of printing without inks and other liquids or powder messing up materials that are being printed on; the process is fast, very durable and indeed profitable to its practitioners. Before this time, it was only heat transfer process that was used in printing sundry materials like fabrics but now, it has gained grounds in the printing of lots of materials including plastics, metal and polyester garments. The process of heat transfer is eco-friendly as there are no harmful by-products it generates and the products are safe to use both as garments or household utensils. Incropera et al (2020) avers that in heat transfer process designs are always first made on the computer, printed on the heat-sensitive material and then transferred onto a substrate which could be fabric, metal or ceramic wares. The most commercial importance of the heat transfer printing methods is sublimation transfer and film release; other processes involve transfer of meltable ink (Melt transfer) and transfer in aqueous film (Wet transfer)

Heat transfer is a way of adding one's own artwork to a clothing item or other accessories. A well-designed graphic image, bitmap photo or vector graphics or even text are transferred onto shirt, face cap, tote bag or other fabric material using heat pressure and adequately timed to make sure that the transfer is well-registered. This process is as analysed below. Figure 1 shows a typical design done on computer, according to Osaigbovo (2024) various computer software such as CorelDraw, Adobe Photoshop, Adobe Illustrator and Harvard Graphics could be used to make designs taking note of all useful design principles.

Step 1

Fig 1. Design on computer



Source: screenshot by F. Osaigbovo (2023)

The desired design is made on the computer using the appropriate design software; in Nigeria, Corel Draw and Adobe Photoshop are popular design software that designers love to use; this is because of the simplicity and user-friendliness of this software. Images can be photographs, an abstract piece, drawings or a slogan. Designs could also be edited using Adobe Photoshop software. After the design is completed, it is horizontally flipped and printed in reverse.

Figure 2 shows where the designed is being reversed on the computer. Reversing the design on the computer is applying a default setting to flip the design horizontally and vertically or by deliberately tweaking and manipulating the position until it is reversed.

Step 2

Fig 2. Reverse printing with Deskjet printer



Source: screenshot by F. Osaigbovo (2023)

After the design is done and reversed on the computer, it is printed on a heat transfer paper, this paper has both opaque and transparent type and it is like film in which case the transparent are more appropriate for white or grey colour fabrics whereas the opaque film is appropriate for coloured fabrics; the paper is loaded into the printer in such a way that when printing, the film side of the material receives the ink.

Step 3

Fig 3. Cutting out of unwanted areas



Source: screenshot by F. Osaigbovo (2023)

After the printing is done, the design is carefully cut along the outermost lines of the design; this is to avoid unnecessary parts being transferred onto the fabric as shown in figure 3.

Step 4

Fig 4. Laying of the mirrored artwork face down



Source: screenshot by F. Osaigbovo (2023)

Figure 4 above shows how the artwork is laid face down on the fabric before taken to the electric heat transfer machine.

Step 5

Fig 5. Application of heat from the heat transfer device



Source: screenshot by F. Osaigbovo (2023)

Figure 5 shows the artwork placed on the T-Shirt faced down between the plates of the electric heat press, thereafter, the machine is set to a default temperature meant for the fabric type and switched on; the heat could be adjusted in case of electric current fluctuations until the light indicator of the machine shows that it is ready, and so it is switched off, brought out and the design by product paper carefully peeled off as shown in figure 6.

Step 6

At this finishing stage, after the design has been transferred onto the shirt, it is brought out from the machine and the unwanted paper peeled off.

Fig 6. Peeling off of the waste paper



Source: screenshot by F. Osaigbovo (2023)

Fig 7. Printed fabrics and caps



Source: screenshot by F. Osaigbovo (2023)

Fig 8. A typical heat transfer machine



Source: photograph by F. Osaigbovo 2023)

Fig 9. A ceramic heat transfer printed mug



Source: photograph by F. Osaigbovo (2023)

Findings and Conclusion

In the course of this study, the following findings were observed:

1. Precise temperature control is crucial to achieving optimal print quality as excessive temperature can result in defects and inconsistencies.
2. Optimizing heat transfer coefficient can greatly improve print quality by ensuring uniform heat transfer and minimizing thermal gradients.
3. The Thermal conductivity of materials plays a crucial role in determining print quality and selecting materials with optimal thermal conductivity can significantly enhance print outcomes.

Heat transfer printing process is predicated on four components which are temperature, time, pressure and snow Trans and the industry standard of temperature is 350°F and so this study successfully dealt with the issue of optimizing heat transfer parameters to improve print quality by providing valuable insights into the relationships between temperature, heat transfer parameters including heat transfer coefficients and thermal conductivity, the writer identified optimal parameters that significantly enhance print quality and so by optimizing heat transfer parameters, this study contributes to the advancement of printing technologies and provides a foundation for future research in this field.

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