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Optimization of Ribbon Usage in TTO Printer for Reduction of Printing Cost in Food packaging Industry

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Abstract: ***This paper presents an optimization strategy of ribbon to reduce printing costs in Thermal Transfer Overprinting (TTO) for food packaging. This research explores cost-reduction strategies specific to TTO printing by analyzing the impact of optimized ribbon usage. The study evaluates the printing process for*** *Mini MM's Biscuit (33g) SKU.* ***Data was collected from multiple manufacturing facilities to identify key cost drivers and assess the effectiveness of various reduction methods. The study evaluates the printing process for Mini MM's Biscuit (33g) SKU. The current practice involves printing two staggered prints at a 2 mm letter height using a standard 33 mm ribbon width, resulting in significant waste. The study explores reducing the letter height to 1.75 mm and increasing the coding window height by 5 mm to accommodate three staggered prints. The findings demonstrate that three staggered prints can be achieved, improving ribbon utilization by*** *12%.* ***This improvement has been reduced printing costs from ₹0.25/kg to ₹0.13/kg, with potential total savings over ₹50.4 lakh a year.***

Keywords: Thermal Transfer Overprinting (TTO), Ribbon Optimization, Printing Cost Reduction, Food Packaging, Staggered Printing, Coding Window, Material Waste Reduction, Print Head, Legal and FSSAI Compliance.

I. INTRODUCTION

This research was conducted at Narayana Foods Pvt. Ltd. with the objective of reducing printing costs through the effective optimization of ribbon usage in Thermal Transfer Overprinting (TTO) for food packaging. Narayana Foods Pvt. Ltd. is a leading producer of biscuit packaged food products, where TTO printing plays a crucial role in coding essential information such as batch numbers, expiration dates, and traceability codes to ensure product quality and regulatory compliance. Thermal Transfer Overprinting (TTO) is a widely used technology in food packaging due to its high print quality, flexibility, and ability to produce high-resolution, durable codes that meet legal and regulatory requirements. TTO technology is critical for printing essential information such as batch numbers, expiration dates, barcodes, and traceability codes directly onto packaging materials. The precision and versatility of TTO make it ideal for handling diverse packaging formats and materials, including flexible films, labels, and laminated surfaces.

Thermal Transfer Overprinting (TTO) systems consist of several critical components that work in coordination to deliver high-quality and precise prints on flexible packaging materials. At the core of the process is the thermal printhead, which contains miniature heating elements that activate in a controlled sequence. When the printhead comes into contact with the thermal transfer ribbon, it selectively heats specific areas to transfer ink onto the substrate. The platen roller supports this process by holding the substrate—such as plastic film or paper—in place and ensuring consistent pressure and alignment between the ribbon and the printhead. This alignment is essential for achieving uniform print quality across production runs. The ink transfer ribbon, which serves as the medium for transferring print content, is available in various formulations including wax, wax-resin, and pure resin. Each type of ink is suited to specific packaging materials and durability requirements. The ribbon itself is housed in a ribbon cassette, which allows for smooth and controlled ribbon movement during operation, minimizing slack and maintaining tension. The printing parameters, such as speed, temperature, and alignment, are managed via the control panel or interface, which provides operators with full control over the printing process. Additionally, sensors play a crucial role in detecting the presence of the substrate, thereby triggering the print cycle only when material is correctly positioned. This prevents misprints and reduces ribbon wastage. Finally, the coding window frame defines the physical area on the packaging where the print appears. This frame is often customized based on the specific design of the film or label, allowing for accurate and consistent code placement during high-speed operations. However, the rising operational costs associated with TTO printing — including ribbon consumption, printer maintenance, and energy use pose significant challenges for manufacturers.

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Ribbon usage represents a major cost component in TTO printing, as excessive ribbon consumption leads to increased material costs, higher printer downtime due to frequent ribbon changes, and elevated waste generation. Inefficient ribbon utilization not only increases production costs but also contributes to a higher carbon footprint, making cost reduction strategies a priority for manufacturers seeking to enhance profitability and sustainability. This research focuses on optimizing ribbon utilization to reduce printing costs in TTO printing for food packaging. The study targets the Mini MM's Biscuits (33g) SKU, which contributes significantly to the overall printing volume and accounts for a major share of the production cost. Mini MM's Biscuits SKU alone records 66% higher printing frequency compared to other SKUs, increasing the impact of inefficient ribbon usage. Existing printing patterns involve continuous printing with single or double alignment, which leads to substantial ribbon waste and limits production efficiency. To address these challenges, this project explores three key optimization strategies: Letter height reduction, staggered printing and coding window size adjustments. Staggered printing involves aligning multiple prints along the width of the ribbon, allowing for increased ribbon utilization per pass and reducing waste. Adjusting the coding window size by increasing the height creates additional space for staggered printing, which enhances print alignment and reduces the number of ribbons passes required. Furthermore, introducing flexibility in font type selection and letter height ensures compliance with both legal and FSSAI (Food Safety and Standards Authority of India) requirements without compromising print clarity.

The proposed strategy is expected to reduced ribbon consumption by ***49%***, resulting in an estimated annual cost saving of approximately ***₹50.4 lakhs*** for the Mini MM's SKU alone. Additionally, the reduction in ribbon usage is projected to lower the carbon footprint by ***46%***, aligning with broader sustainability goals.

A. Objective

- Reduce ribbon consumption by implementing staggered printing strategies that increase the number of prints per ribbon pass and minimize material waste.
- Optimize the coding window size by adjusting its height to allow for additional staggered prints, ensuring print clarity and adherence to legal standards.
- Achieve cost savings through reduced ribbon usage, extended printer lifespan, and minimized waste generation during the printing process.
- Ensure regulatory compliance by maintaining alignment with legal and FSSAI (Food Safety and Standards Authority of India) requirements, while enhancing print legibility and traceability.
- Improve printing efficiency by enhancing print alignment, reducing ribbon change frequency, and ensuring consistent coding accuracy.
- Enhance sustainability by decreasing the carbon footprint and reducing material waste through more efficient ribbon utilization.

II. LITERATURE REVIEW

An Thermal Transfer Overprinting (TTO) is a widely adopted technology in the food packaging industry due to its ability to deliver high-resolution, durable, and legible prints on flexible packaging materials. Compared to traditional printing technologies like hot stamping or continuous inkjet, TTO provides greater control over variable data printing, making it ideal for batch numbers, expiry dates, barcodes, and regulatory codes. According to Johansson et al. (2012), the reliability and sharpness of TTO printing significantly reduce misprints and enhance traceability, which is vital for compliance with food safety standards such as those mandated by the FSSAI (Food Safety and Standards Authority of India).

We have referred Mark Andy Inc. has extensively explored strategies to reduce waste and costs in label and packaging printing. Their approach emphasizes lean manufacturing principles, digital transformation, and advanced automation. Mark Andy Inc. has developed various methods to cut costs and minimize waste in label and packaging printing. Their strategy centers on implementing lean production techniques, embracing digital innovation, and utilizing high-level automation. The following points highlight some of their most effective practices.

Team go through the SATO program as SATO's European Consumables Program is tailored to optimize the use of labels and ribbons across various industries, including food, logistics, healthcare, and manufacturing. By customizing consumable solutions to meet specific operational requirements, the program effectively reduces excess inventory and the waste associated with it. Additionally, it helps lower shipping and storage costs, while improving productivity by ensuring that high-quality consumables are matched with durable, high-performance printers.

This initiative underscores SATO's commitment to minimizing environmental impact—through waste and carbon emission reduction—while enhancing overall operational efficiency. The study by Mirkovic and Pavlovic (2015), published in the *Journal of Graphic Engineering and Design*, explores the effectiveness of the Grey Component Replacement (GCR) technique in reducing ink consumption during the printing process. GCR works by replacing the gray component formed by the combination of cyan, magenta, and yellow inks with black ink, which not only reduces the overall volume of ink used but also enhances print stability and efficiency. The research demonstrated that implementing GCR can lead to significant cost savings without compromising the visual quality or color accuracy of printed materials. Additionally, the technique contributes to faster drying times and reduced risks of smudging. From an environmental perspective, lowering the use of colored inks also helps in decreasing volatile organic compound (VOC) emissions and minimizing waste, making it a valuable strategy for sustainable and cost-effective printing operations.

To identify the way forward solutions team, cover the research on the "Flexible Packaging Cost Optimization Guide" by Hyflex Pack offers a comprehensive approach to reducing costs in flexible packaging while maintaining quality and sustainability. One of the key strategies discussed is material optimization, which involves selecting materials that meet the necessary performance requirements without over-engineering, leading to cost savings. The guide also emphasizes design simplification, recommending fewer colors and standardized sizes to reduce printing and material costs. Additionally, it highlights the importance of process efficiency by incorporating lean manufacturing principles and automation to lower operational costs through reduced setup times, minimized waste, and optimized workflow. Sustainable practices are also advocated, with a focus on recyclable or biodegradable materials, which not only reduce environmental impact but can lead to long-term savings. Finally, effective supply chain management, including bulk purchasing and local sourcing, can help cut transportation costs and lead times. By combining these strategies, Hyflex Pack provides businesses with a roadmap to optimize packaging operations for both cost-effectiveness and environmental responsibility.

Mark Andy Inc.'s article, "Reducing Waste and Costs in Label and Packaging Printing," outlines a comprehensive set of strategies aimed at improving efficiency and minimizing waste in the printing industry. One of the central strategies discussed is the integration of inline processing, which combines converting and finishing processes to reduce unnecessary transportation and movement of materials, effectively reducing waste. The article also emphasizes the importance of addressing "invisible waste," which refers to small, often overlooked inefficiencies that accumulate over time and can result in significant costs. By identifying and eliminating these inefficiencies, companies can optimize their processes and achieve cost savings. Additionally, Mark Andy highlights the value of real-time monitoring through their sMArt link system, which allows for immediate adjustments during production. This data-driven approach helps reduce waste and improves overall operational efficiency. The article also explores the benefits of hybrid digital-flexo presses, such as the Digital Series HD, which combine the advantages of both digital and flexographic printing. These hybrid presses offer up to 50% reduction in waste on short to mid-length jobs and consume less energy compared to traditional flexo presses. Overall, the strategies presented by Mark Andy Inc. provide a holistic approach to reducing waste and costs in label and packaging printing, promoting more sustainable and efficient manufacturing processes. We have also referred A Guide to Graphic Print Production by Kaj Johansson, Peter Lundberg and Robert Ryberg., Business Transformation: A New Path to Profit for the Printing Industry by John Foley, Food Safety and Standards (Packaging and Labelling) Regulations, 2011, The Legal Metrology (Packaged Commodities) Rules, 2011., Markem imaje printing smartdate X40 & X60 Manual., Printing 9020 Books for service engineer by Markem Imaje.



Fig 2.1 TTO coder

III.METHODOLOGY

All paragraphs must The project adopted a structured methodology to analyse and optimize ribbon utilization in Thermal Transfer Overprinting (TTO) for food packaging, specifically focusing on the Mini MM's Biscuits (33g) SKU, which constitutes a substantial portion of the company's overall printing volume. The study began with the identification of key problems in the existing TTO setup, where analysis revealed that only 17 mm of a 33 mm ribbon width was being utilized to accommodate two staggered prints. This under-utilization resulted in significant ribbon waste. To understand the scope of the issue, data was collected from various manufacturing units. This included monthly production data for the Mini MM's SKU, which averaged 3,500 metric tons, along with technical specifications such as letter height, print length, and the dimensions of the coding window. Additionally, operational cost data covering ribbon usage, machine maintenance, and production downtime was gathered to evaluate the financial implications of inefficient printing practices. The collected data was then analysed to pinpoint inefficiencies in the current process. It was found that high ribbon consumption stemmed from suboptimal print alignment and limited use of ribbon width. As a result, only two prints per ribbon pass were achieved, leaving nearly half of the ribbon unused. Based on these findings, a series of optimization proposals were developed. These included reducing the font height, expanding the coding window area, and increasing the number of staggered prints to enhance ribbon utilization. Subsequently, controlled trial runs were conducted using the new font size and adjusted coding window dimensions. These trials were evaluated through both visual inspections and compliance checks to ensure the print quality met industry standards. A detailed cost-benefit analysis was then performed, comparing ribbon consumption and operational costs before and after implementation. This analysis quantified the ribbon savings and projected the potential annual cost reduction. To ensure the proposed changes were viable for long-term use, the new process was validated for compliance with FSSAI and legal packaging regulations. Lastly, the environmental impact of the optimization was considered. The improved ribbon utilization led to a 46% reduction in material waste and carbon footprint, aligning the initiative with the company's sustainability objectives. Overall, the methodology ensured a comprehensive approach to enhancing cost-efficiency and operational sustainability in TTO printing.

IV.PROBLEM STATEMENT

At Narayana Foods Pvt. Ltd., the Mini MM's Biscuits (33g) SKU contributes significantly to the company's total printing volume, making it a key focus area for operational optimization. However, the current TTO (Thermal Transfer Overprinting) practices associated with this SKU are characterized by inefficient ribbon utilization.

This inefficiency primarily stems from suboptimal print alignment and a limited coding window size, which together lead to considerable material waste and elevated production costs. Frequent ribbon changes, necessitated by high consumption rates, contribute to increased machine downtime, thereby reducing overall productivity and raising operational expenses. The high rate of ribbon consumption, high printing cost 0.25Rs/kg results from inadequate use of the ribbon's full width, causing excessive material waste. Improper print alignment contributes to ribbon wastage and inconsistent print quality, often requiring reprints and further increasing printing time.

Third, the existing coding window has a restricted height, which limits the number of prints that can be produced per ribbon pass, further reducing utilization efficiency. In addition, the frequent need to replace ribbons disrupts production flow and adds to labour and maintenance costs. Finally, this inefficient use of consumables negatively impacts the environment by increasing material waste and contributing to a higher carbon footprint.

V. CONCEPT

Thermal Transfer Overprinting (TTO) for food packaging at Narayana Foods PVT. LTD**.** The research targets the Mini MM's Biscuits (33g) SKU, which represents a significant portion of the total printing volume and incurs high operational costs due to excessive ribbon usage and inefficient printing patterns. The study targeted to counter these difficulties with the help of few key actions to optimized the printing cost.

A. Flexibility in Font Type and Letter Height

Adjusting font type and letter height ensures compliance with both legal and FSSAI requirements without increasing ribbon consumption. Letter height adjustments include:2 mm (current) → 1.5 mm (proposed) → 1.75 mm (optimized).



Fig 5.1 Letter height reduction

B. Staggered Printing Strategy

Aligning 2 or 3 prints along the width of the ribbon to maximize ribbon usage. Reduced unused ribbon space, increases the number of prints per ribbon pass, and minimizes ribbon waste.



Fig. 5.2 Letter Height 2mm with Two Stagger Print


Fig.5.3 Letter Height. 1.75mm with Three stagger print

C. Coding Window Size Optimization

Current coding window height is 19 mm which we have increased it by 5 mm allows for an additional staggered print. Expanding the coding window size increased efficiency and reduced material waste.



Fig.5.4 Coding window height optimized by 5mm

TABLE I
QUANTITATIVE PARAMETER

Parameter	Post-Optimization Outcome
Ribbon utilization	Increased from 17 mm to 25 mm of 33 mm width (47 % utilization)
Number of staggered prints	Increased from 2 to 3 prints per ribbon pass
Letter height	Reduced from 2 mm to 1.75 mm
Coding window height	Increased by 5 mm to accommodate 3 staggered prints
Ribbon cost per kg	Reduced from ₹0.25/kg to ₹0.13/kg
Material wastage due to underuse	From 48.5% to 24%
Ribbon consumption per metric ton Nos.	From 0.24 to 0.12 Nos.
Estimated ribbon used per year	514.01 Nos.
Printer downtime due to ribbon change	4 min
Ribbon run time	From 14.93hr to 29.5 hr
Annual cost savings	₹50.4 lakh/year estimated for Mini MM's SKU

VI. CONCLUSION

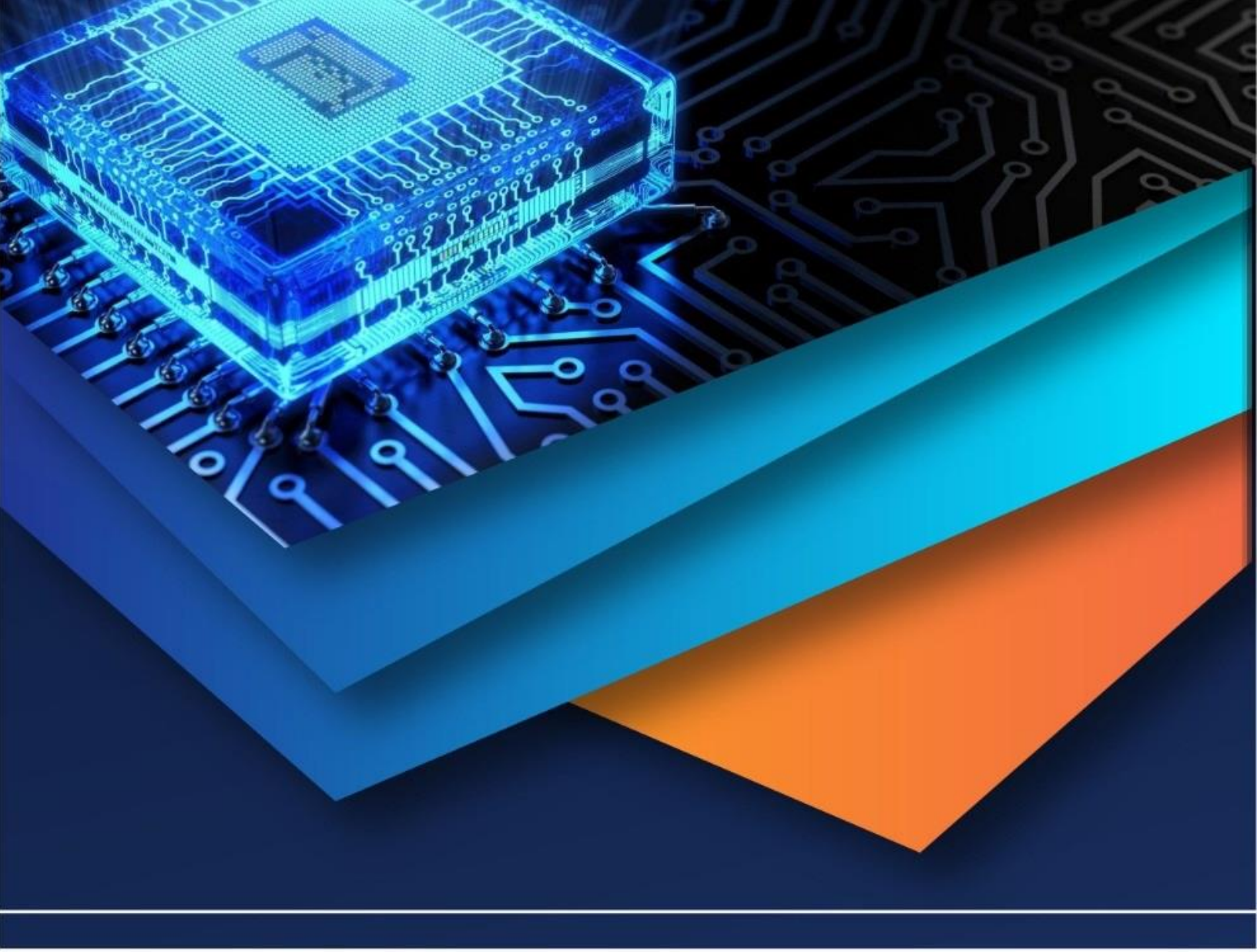
The research conducted at Narayana Foods PVT. LTD. confirms that optimizing ribbon utilization in Thermal Transfer Overprinting (TTO) leads to substantial cost savings and improved efficiency. The key outcomes of the project include:

1) Improved ribbon area utilization by 47%
2) 49% reduction in ribbon usage, resulting in significant material savings.
3) Reduced printing cost from 0.25 Rs/kg to 0.13 Rs/kg.
4) Estimated annual cost savings of ₹50.4 lakhs for the Mini MM's Biscuits (33g) SKU along through staggered printing and coding window adjustments.
5) 46% reduction in carbon footprint due to lower material consumption, contributing to the company's sustainability goals.

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