

Enhancing cocoon processing: Optimization and efficiency of motorized sorting and deflossing machine in silk production

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Abstract

The silk cocoon, a crucial product of the silkworm's larval stage, is characterized by its delicate, loose layer of silk filaments known as floss. Effective silk extraction, or reeling, necessitates the removal of this floss through a process known as deflossing. While most cocoons are uniform in shape and size due to their genetic makeup, some display defects that can impede reeling efficiency and compromise silk quality. To address these challenges, we have engineered a sophisticated motorized machine designed for both sorting and deflossing of silk cocoons. This state-of-the-art machine classifies cocoons into categories such as Good, Double, Uzi pierced, Flimsy or thin-shelled, Melted or stained, and Thin-end, prior to the deflossing process. It features three high-performance rotating metal shafts, driven by a motor, which meticulously remove the floss at a processing rate of up to 65 kg per hour. Performance evaluations demonstrate that at an optimal speed of 680 RPM, the machine achieves a deflossing rate of 68.4 kg per hour, leaving just 1.6 kg of cocoons partially deflossed. This advanced technology significantly enhances silk quality and operational efficiency, reduces manual labor, and accelerates processing times, thus aligning with the increasing global demand for superior silk products.

Keywords: Deflossing, *Bombyx mori*, reeling, motor powered machines

Introduction

Silkworms produce silk cocoons enveloped in a delicate, loose layer of white silk filaments known as floss. The process of removing this floss, called deflossing, is crucial for enhancing cocoon quality. This task can be performed manually or with specialized deflossing machines (Lakshmi, 2016) [4].

Seasonal influence on the performance silkworm breeds/hybrids which may affect the genotypic as well as phenotypic expression including cocoon weight, shell weight, shell ratio etc. of the silkworm (Nacheva et al., 1989) [5].

The genetic diversity of *Bombyx mori* encompasses over 4,000 strains, which are carefully maintained by 46 institutions dedicated to the preservation of silkworm genetic resources. These strains include univoltine, bivoltine, and polyvoltine varieties, each exhibiting significant variations in qualitative and quantitative traits that ultimately influence silk yield (Bindroo & Moorthy, 2014) [1]. Sorting cocoons into categories such as intact, damaged, flimsy, melted, or double is essential for maximizing renditta (silk yield per weight of cocoon) and ensuring the desired shine of the silk yarn (Rao et al., 2011) [7]. Efficient sorting and deflossing directly affect the economic value of the silk, as higher-quality cocoons yield silk of superior market value. With global silk demand rising annually by about 5% (FAO, 2002), advanced and efficient deflossing technologies are increasingly important. Manual deflossing is a labor-intensive process that requires workers to spend long hours removing floss from each cocoon, making it both time-consuming and physically

demanding. As noted by the FAO (2002), removing the floss is essential for subsequent processing stages such as reeling and grainage. To address these challenges, there is a clear need for mechanized solutions.

The development of a motorized cocoon deflossing machine represents a significant advancement in this area. Such a machine enhances deflossing capacity and efficiency, reduces manual labor, and minimizes the time required for the floss removal process. Our newly designed silk cocoon sorting and deflossing machine has been specifically engineered, fabricated, and evaluated to optimize both sorting and deflossing performance, meeting the evolving demands of the silk industry.

Material and Methods

The silkworm cocoon cleaning machine represents an advanced technological innovation designed for the comprehensive processing of cocoons. This includes sorting, deflossing, and cleaning away extraneous dirt prior to their sale to reeling industries. The machine features a straightforward construction and operates with a motorized system. It is constructed from locally sourced materials, including standard steel and a 32 mm steel shaft with diamond knurling. Key components of the machine include a V-belt drive, gears, a ½ hp AC single-phase motor, A-type pulleys, a 600 mm feeding tray, a 30-watt LED lamp, 6303 bearing blocks, and a tray jali. The machine incorporates three 32 mm shafts equipped with diamond knurling and high-pitch threading to facilitate effective deflossing. The feeding tray, measuring 600 mm x 600 mm and 5 mm thick, is fitted with a 30-watt LED lamp to enhance the sorting

process of silk cocoons. For speed reduction during operation, self-aligned SKF 6303 bearing blocks are utilized. The machine has been assembled and rigorously tested for efficiency and stability at Teksons, MIDC Kupwad, Dist- Sangli, Maharashtra.

Design consideration

In the design conceptualization of the silkworm cocoon cleaning machine, several key factors were taken into account to ensure optimal performance and practicality:

1. Material Selection

Local Sourcing: The choice of materials focused on those that are locally available to reduce procurement costs and simplify maintenance. This includes using routine steel for structural components and standard steel shafts for rotating elements.

Durability: Materials were selected for their durability and resistance to wear, ensuring the machine's longevity and reducing the need for frequent replacements.

2. Ease of Operation

User-Friendly Interface: The machine's controls and functions are designed to be intuitive, allowing operators with minimal training to operate the machine efficiently.

Maintenance Accessibility: Components are designed to be easily accessible for routine maintenance and repairs, minimizing downtime and operational disruptions.

3. Safety Features

Protective Covers: The machine is equipped with safety covers and guards around moving parts to prevent accidental contact and ensure operator safety.

Emergency Stop: An emergency stop mechanism is incorporated to quickly halt the machine in case of an emergency, enhancing overall safety during operation.

Stability: The machine's design includes a stable base and vibration dampening features to ensure safe and steady operation.

4. Operational Efficiency

Minimized Labor Requirements: Designed to operate efficiently with just one or two operators, the machine reduces labor costs and operational expenses.

Energy Efficiency: The motor and other components are selected for their energy efficiency to reduce power consumption and operating costs.

High Throughput: The machine is engineered to handle a high volume of cocoons, improving throughput and productivity while maintaining consistent quality in sorting and deflossing. Ergonomics:

5. Operator Comfort: The design considers ergonomics to reduce strain on operators, including adjustable components

and an accessible working height to enhance comfort during operation.

Efficiency in Workflow: The machine layout is designed to streamline workflow, making it easier for operators to perform tasks efficiently and effectively.

By integrating these design considerations, the machine aims to provide a reliable, efficient, and user-friendly solution for silkworm cocoon processing, ultimately enhancing productivity and ensuring high-quality silk production.

Principle of Operation

The machine operates through a two-stage process: sorting and deflossing.

1. Sorting Process

Input Feed: Silk cocoons are initially placed on a glass plate, which is illuminated by a 30-watt LED lamp mounted above the tray.

Manual Sorting: The operator manually inspects the cocoons using the light from the LED lamp. Good-quality cocoons allow light to pass through clearly, while defective cocoons—such as those that are double, Uzi pierced, flimsy, melted or stained, and thin-end—block or partially obscure the light.

Defective Cocoon Removal: Defective cocoons are identified and manually removed from the glass plate. Only the good-quality cocoons proceed to the deflossing stage.

2. Deflossing Process

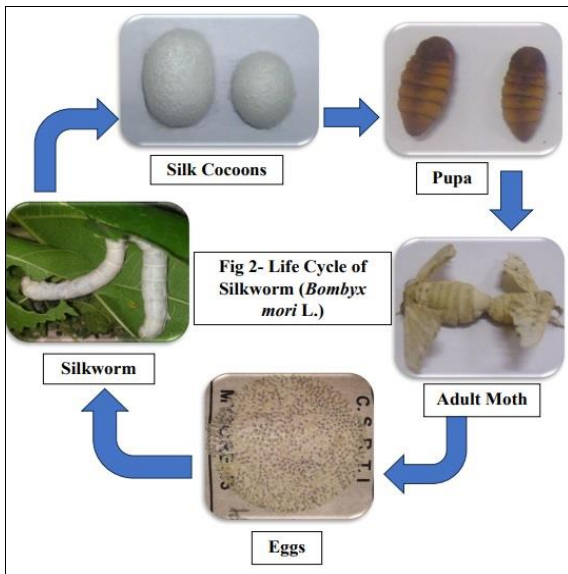
Rotation Mechanism: The remaining good cocoons undergo deflossing through three cylindrical stainless-steel shafts. Power is delivered to these shafts from a ½ hp AC single-phase motor, transmitted through a V-belt drive and pulleys.

Floss Removal: The shafts are designed with diamond knurling and high-pitch threading to effectively grip and remove the floss from the cocoons. The initial two shafts perform approximately 90% of the deflossing work, while the third shaft addresses any remaining floss.

Collection: After deflossing, the cleaned cocoons fall into an outlet tray, ready for further processing.

Measurement and Evaluation

Weight of Deflossed Cocoons: The cocoons collected from the outlet tray are weighed to ensure they are free of the floss layer. Properly deflossed cocoons are assessed for the absence of tangled fibers and unreelable layers. The total floss collected from the three rotating shafts during the operation is measured. This quantifies the efficiency of the deflossing process and the effectiveness of the machine. This systematic approach ensures that only high-quality cocoons, free of extraneous floss, advance to subsequent processing stages, thereby optimizing silk production.



Results and Discussion

As shown in the above fig 2- Life cycle of silkworm has four distinct stages i.e. Eggs, Silkworm, Pupa inside the silk cocoons and adult moth. Among which silk cocoons are used for reeling process to get the silk yarn. Sorting and deflossing process of silk cocoons are necessary to get good quality of silk yarn. This motorized machine is designed for both sorting and deflossing of silk cocoons.

Machine Description

The motorized cocoon sorting and deflossing machine is designed to enhance the efficiency of silk production by streamlining the processes of sorting and deflossing. This machine provides significant improvements over manual methods, optimizing both the quality and yield of silk. Key features of the machine include:

Glass Plate: Provides a clear, transparent surface for the initial sorting of cocoons.

LED Lamp: Illuminates the cocoons to aid in accurate manual sorting.

0.5 HP Motor: Powers the system with sufficient force to drive the mechanical components effectively.

Three Diamond-Knurled Shafts: Feature diamond knurling and high-pitch threading to grip and remove the floss efficiently.

V-Belt Drive and Pulleys: Transmit power from the motor to the shafts, ensuring smooth and reliable operation.

Tray Jally: Collects deflossed cocoons and any debris.

Discharging Plate: Directs cleaned cocoons to the outlet for further processing.



Fig 1: Front View of Cocoon Sorting and Deflossing Machine.

Deflossing Capacity

The machine’s capacity is assessed by measuring the weight of the properly deflossed cocoons and dividing it by the operational time. This metric provides an indication of the machine’s efficiency and throughput:

Operational Efficiency: Evaluated by comparing the time required to process cocoons manually versus using the

machine, demonstrating substantial time savings and labor reduction.

Processing Rate: The rate at which the machine processes and deflosses cocoons is calculated, reflecting its ability to meet production demands and improve overall efficiency. The motorized cocoon sorting and deflossing machine marks a substantial leap forward in silk production

technology. By integrating advanced mechanical components and precision engineering, this machine significantly boosts processing efficiency and quality control. Its innovative design streamlines the sorting and deflossing processes, reducing manual labor and operational time while ensuring superior silk quality. This technological advancement not only optimizes production workflows but also meets the growing demand for high-quality silk in the global market, setting a new standard for efficiency and effectiveness in the industry.

Table 1: Deflossing Rates of Silk Cocoons at Different Rotational Speeds (RPM) Over a One-Hour Period by Two Expert Operators.

Sr. No	RPM	Deflossing Rate in Kg	Undeflossed in Kg
1.	640	62.3	7.8
2.	660	65.7	4.3
3.	680	68.4	1.6
4.	700	75.2	5.8
5.	720	78.6	9.2

Table 2: Deflossing Rates of Silk Cocoons at Various RPM Settings by a Single Expert Operator Over a One-Hour Period

Sr No	RPM	Deflossing Rate in Kg	Remain as Undeflossed in Kg
1.	640	49.8	5.2
2.	660	52.9	3.2
3.	680	54.3	1.2
4.	700	57.6	3.7
5.	720	60.7	6.8

Machine performance

The motorized cocoon sorting and deflossing machine reached its highest operational efficiency at a shaft rotational speed of 680 RPM. At this setting, the machine effectively processed silk cocoons at a rate of 65 to 70 kg per hour. This performance is in line with guidelines from the Philippine Fiber Development Agency (PhilFIDA), which emphasizes that achieving high deflossing efficiency is crucial for optimal silk production. Efficient deflossing ensures that cocoons are thoroughly prepared for the subsequent reeling process, thereby enhancing the quality of the final silk product and meeting the rigorous standards of the silk industry.

Conclusions

The analysis of the deflossing machine's performance reveals that the system's maximum deflossing capacity was 55 kg per hour with a single operator, while the capacity increased to 70 kg per hour with the utilization of two operators. This demonstrates a significant enhancement in deflossing efficiency with additional labor. The motorized cocoon sorting and deflossing machine consistently delivered high performance, optimizing both the rate of deflossing and overall operational efficiency.

Recommendations

For optimal performance, it is recommended that the machine be operated with two operators to maximize sorting and deflossing efficiency. To sustain peak operational efficiency and prevent potential bottlenecks, it is crucial to remove accumulated floss from the three shafts every 30 minutes. This preventive maintenance step is essential to avoid any reduction in deflossing effectiveness and ensure comprehensive processing of all cocoons.

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