

Department of Mechanical Engineering

FINAL DISSERTATION

With a view to obtaining the diploma of:

MASTER

In Mechanical Engineering

Option: Mechanical Construction

Presented By:

DJOUBAR Abdellah & MERZOUGUI Nabil

DEBIH Hamza Chems Edinne

Theme

Study and Creation of a Carding Machine for Natural Fiber

Presented on June 26th, 2024, in front of the jury composed of:

MAKRI Hocine	Professor	Chairperson
LATRACHE Mohamed	MCB	Examiner
MOUSSAOUI Nafissa	MCA	Supervisor
BENHAMADOUCHE Lamia	MCA	Supervisor

Acknowledgements

We would like to extend our heartfelt thanks to everyone who supported us throughout this journey.

Firstly, we express our profound gratitude to our families for their unwavering support and encouragement. Your belief in us has been our driving force.

We also extend our deepest appreciation to our professors and mentors, whose guidance and wisdom have been invaluable. Your dedication to education and your constant support have been crucial to our success.

To our friends and colleagues, thank you for your camaraderie, collaboration, and the many shared experiences.

Your support has made this journey both enjoyable and enriching.

Finally, we thank everyone who contributed to this work, whether directly or indirectly. Your assistance and encouragement have been greatly appreciated.

Dedications

To my father, who was always a source of inspiration and support throughout my life. His values and principles have guided me to achieve this accomplishment. I also dedicate this work to my beloved mother, who has been my pillar of support at every step, always believing in my abilities and encouraging me to persevere and strive.

To my family and friends, and to everyone who contributed to making this dream a reality.

Debih Hamza Chems Edinne

I deeply appreciate my wife's unwavering support and encouragement, guiding me through challenges with patience and love. My children's joy and inspiration have driven me forward, making this achievement possible. I am profoundly grateful to my parents for instilling values that shaped my journey, their wisdom being a constant source of support and inspiration.

Merzougui Nabil

I am deeply grateful to my beloved parents and siblings for their unwavering support and guidance throughout my life. Your love and encouragement have shaped my character and fueled my achievements. From day one, you have stood by me through challenges, offering wise counsel and unwavering belief in my abilities. Your sacrifices and dedication inspire me to strive for excellence and pursue my dreams.

Djoubar Abdellah

table of contents

GENERAL INTRODUCTION..... 1

CHAPTRE I

Art of carding

I. 1 Definition	3
I. 2 Origin and History of Carding Machine	3
I. 3 Objectives of Carding	3
I. 4 Basics of Operating a Carding Machine	4
I. 5 Basic Textile Terms of Spinning	4
I. 5. 1 Fiber.	4
I. 5. 2 Blow Room Lap.	4
I. 5. 3 Chute Feed System.....	4
I. 5. 4 Sliver.	5
I. 5. 5 Yarn.	5
I. 5. 6 Spinning.....	5
I. 5. 7 Yarn Count/Sliver Hank.....	5
I. 5. 8 Yarn Count System.....	5
I. 6 Identification of Needs and Technical Specification of the Machine	6
I. 6. 1 Function of Carding	6
I. 6. 2 Feed-Roller and Licker in Actions	7
I. 6. 3 Worker-Swift Action.....	7
I. 6. 4 Other Carding Action.....	8
I. 7 Study of the key Components of the Machine	10
I. 7. 1 Wire Card Clothing.	10
I. 7. 2 Foundation for Clothing.....	11
I. 7. 3 No Signal Textile Fiber:	11
I. 7. 4 Wire for Teeth.....	12
I. 7. 5 From all that has Been Said so Far.....	13
I. 7. 6 Rip Set and Twill Set.....	14
I. 7. 7 Point per square foot	15

I. 7. 8 English Counts.	16
I. 7. 9 Wire Gauge.	17
I. 7. 10 Flexible Clothing for Cotton Cards.....	18
I. 7. 11 Flexible Clothing for Woolen and Worsted Cards.....	20
I. 7. 12 Fancy Clothing.....	23
I. 8 Differences Between Flexible and Metallic Card Clothing.....	24
I. 9 Design and Requirements of Cylinders in Modern Carding Machines.....	25
I. 9. 1 FEM model of the cylinder.....	26
I. 9. 2 Loads Acting on the Main Cylinder of Carding Machine.....	27
I. 9. 3 Calculation Considerations.....	28
I. 10 Conclusion.....	28

CHAPTER II

Design of the Carding Machine to be produced

II. 1 Introduction.....	29
II. 2 Definition of SolidWorks.....	29
II. 3 Design of the Mechanical Part.....	29
II. 3. 1 Structure.	29
II. 3. 2 Feed Mechanism.....	35
II. 3. 3 Carding Cylinders.	37
II. 3. 4 Card Clothing.....	38
II. 3. 5 Stripping Mechanism.....	38
II. 3. 6 Transmission System:.....	40
II. 3. 7 Gears.	41
II. 3. 8 Bearing Support.	44
II. 3. 9 Control Cabinet Support.....	44
II. 3. 10 Protection System.....	45
II. 4 3D Drawings of the Carding machine.....	45
II. 5 Calculated RDM.....	46
II. 5. 1 Objectives.	46
II. 5. 2 Key Components for RDM Analysis.....	46
II. 5. 3 Material Properties.....	46

II. 5. 4 Calculations.	46
II. 6 Calculated Speed in a Carding Machine.....	47
II. 6. 1 Belt and Chain Speeds	47
II. 6. 2 Perimeter Speed of the Cylinder	48
II. 7 Conclusion.....	49

CHAPTER III

Manufacturing and Maintenance of the Machine

III. 1 Introduction	51
III. 2 Main Source of Rotational Movement of The Machine.....	52
III. 3 Rotational Movement Transmission System.....	52
III. 3. 1 Transmission of Movement by Pulleys and Belts	52
III. 3. 2 Transmission of Movement by Gears.....	53
III. 3. 3 Transmission of Movement by Gears and Chains.....	54
III. 4 Criteria for Material Selection.....	54
III. 5 Materials for Key Components	55
III. 5. 1 Cylinders and Rollers	55
III. 5. 2 Carding Plates.....	55
III. 5. 3 Structure and Frame.....	56
III. 5. 4 Transmission Components.....	56
III. 6 Techniques Used in Assembling Machine Parts.....	57
III. 6. 1 Assembly with Arc Welding	57
III. 6. 2 Assembly with Bolts and Nuts.....	57
III. 6. 3 Assembly with Rivets:	57
III. 7 Machines Used in Manufacturing Mechanical Parts.....	57
III. 8 Surface Treatment and Finishing.....	59
III. 9 Integration and Final Assembly.....	59
III. 10 Carding Maintenance Program.....	60
III. 10. 1 Maintenance Schedule.....	60
III. 10. 2 Importance of Maintaining Machine Reliability	61
III. 10. 3 Classifying Equipment for Maintenance	61
III. 11 Types Of Maintenance.....	62

III. 11. 1 Preventive Maintenance (PM)	62
III. 11. 2 Predictive Maintenance (PdM)	62
III. 11. 3 Corrective Maintenance (CM)	62
III. 11. 4 Reliability-Centered Maintenance (RCM)	62
III. 12 Conclusion.....	63
GENERAL CONCLUSION	64

List Of Figures:

<i>Fig. I. 1. Scheme of the carding machine</i>	6
<i>Fig. I. 2. Action of feed rollers and licker in.</i>	7
<i>Fig. I. 3 Point-to-point action (swift and worker).</i>	8
<i>Fig. I. 4. Point-to-point action (doffer and swift).</i>	9
<i>Fig. I. 5. Shows the stripper (right) removing fibers from the worker (left).</i>	9
<i>Fig. I. 6. Back-to-back action (fancy and swift).</i>	10
<i>Fig. I. 7. Major type of card clothing</i>	10
<i>Fig. I. 8. Angle of wire</i>	12
<i>Fig. I. 9. Rip-Set Clothing</i>	13
<i>Fig. I. 10. Twill-Set Clothing</i>	14
<i>Fig. I. 11. Cylinder Clothing 100s cwc</i>	19
<i>Fig. I. 12. Doffer Clothing 120s cwc</i>	19
<i>Fig. I. 13. Cylinder Clothing, No. 33, cwcc</i>	20
<i>Fig. I. 14. Cylinder Clothing, No. 22-26, 8-Ply</i>	21
<i>Fig. I. 15. Cylinder Clothing, No. 33 Plated, 5-Plyrubber Face</i>	21
<i>Fig. I. 16. Cylinder Clothing, No. 34 Plated, 6-Ply Felt Face</i>	22
<i>Fig. I. 17. Fancy Clothing with Knee</i>	22
<i>Fig. I. 18. Fancy clothing, Straight wire</i>	23
<i>Fig. I. 19. a) cylinder with cast wheel hubs, b) cylinder with welded bottoms:</i>	25
<i>Fig. I. 20. Deflection Line of the Example Cylinder.</i>	26
<i>Fig. I. 21. (a) Tension Forces Acting on The Metallic Card Wire Coils. (b) Load Scheme.</i>	28
<i>Fig. II. 1. Mechanical Design and Frame Dimensions</i>	30
<i>Fig. II. 2. 3D Drawing of The Structure</i>	34
<i>Fig. II. 3. Mechanical Design and Dimensions of The Feeding System Base</i>	35
<i>Fig. II. 4. Mechanical Design and Dimensions of The Drive Cylinder</i>	35
<i>Fig. II. 5. Mechanical Design and Dimensions of The Sprocket</i>	36
<i>Fig. II. 6. Mechanical Design and Dimensions of the driven cylinder</i>	36
<i>Fig. II. 7. 3D Drawing of The Feeding System</i>	36
<i>Fig. II. 8. Feed Cylinder</i>	37
<i>Fig. II. 9. (a) (b) Carding Cylinders</i>	37
<i>Fig. II. 10. Mother Cylinder</i>	37
<i>Fig. II. 11. Output Cylinder</i>	38

<i>Fig. II. 12. Mechanical Design and Dimensions of The Card Clothing.....</i>	<i>38</i>
<i>Fig. II. 13. Mechanical Design and Dimensions of The Fiber Removal Blade.....</i>	<i>38</i>
<i>Fig. II. 14. Mechanical Design and Dimensions of The Crankshaft.....</i>	<i>39</i>
<i>Fig. II. 15. 3D Drawing of The Output System Holder.....</i>	<i>39</i>
<i>Fig. II. 16. 3D Drawing of The Stripping Mechanism.....</i>	<i>40</i>
<i>Fig. II. 17. Mechanical Design and Dimensions of The Pulleys.....</i>	<i>40</i>
<i>Fig. II. 18. Mechanical Design and Dimensions of The Speed Reducer.....</i>	<i>41</i>
<i>Fig. II. 19. Mechanical Design and Dimensions of The Gears.....</i>	<i>41</i>
<i>Fig. II. 20. Mechanical Design and Dimensions of The Reduction Gears.....</i>	<i>42</i>
<i>Fig. II. 21. Mechanical Design and Dimensions of The Gears.....</i>	<i>42</i>
<i>Fig. II. 22. Mechanical Design and Dimensions of The Chain Tensioner.....</i>	<i>43</i>
<i>Fig. II. 23. Bearing.....</i>	<i>43</i>
<i>Fig. II. 24. Mechanical Design and Dimensions of The Bearing Support.....</i>	<i>44</i>
<i>Fig. II. 25. Mechanical Design and Dimensions of The Control Cabinet Support.....</i>	<i>44</i>
<i>Fig. II. 26. Mechanical Design 3D of The Protection System.....</i>	<i>45</i>
<i>Fig. II. 27. 3D drawing for final prototype.....</i>	<i>45</i>
<i>Fig. II. 28. Explanatory Drawing of the Calculated Speed in a Carding Machine.....</i>	<i>49</i>
<i>Fig. III. 1. Transmission of Movement by Pulleys and Belts.....</i>	<i>52</i>
<i>Fig. III. 2. Transmission of Movement by Gears.....</i>	<i>53</i>
<i>Fig. III. 3. Transmission of Movement by Gears and Chains.....</i>	<i>54</i>
<i>Fig. III. 4. Some of the Pieces Chosen in Manufacturing.....</i>	<i>55</i>
<i>Fig. III. 5. Cylinders and Rollers.....</i>	<i>55</i>
<i>Fig. III. 6. Card Clothing.....</i>	<i>56</i>
<i>Fig. III. 7. Structure.....</i>	<i>56</i>
<i>Fig. III. 8. Chain and Belts.....</i>	<i>56</i>
<i>Fig. III. 9. Pictures of the Paint Process.....</i>	<i>59</i>
<i>Fig. III. 10. The Final Assembly of The Initial Model.....</i>	<i>59</i>
<i>Fig. III. 11. Classifying Equipment for maintenance Source [30]......</i>	<i>62</i>

List Of Tables

<i>Table 1: Fillet Clothing for Cotton Cards.....</i>	<i>17</i>
<i>Table 2: Fillet Clothing for Woolen Cards.....</i>	<i>18</i>
<i>Table 3: Differences Between Card Clothing.....</i>	<i>24</i>

Abstract

The textile industry plays a crucial role in the global economy by providing a wide range of products, from clothing to household items. Efficient production of textile fibers is essential to meet the growing market demand while minimizing costs and adhering to environmental standards. This thesis focuses on the design and implementation of an innovative carding machine, aimed at improving the quality of the produced fibers and optimizing the production processes in the textile industry.

Keywords: Textile industry, Carding, Natural fibers, Carding machine, Machine design, Fiber processing, 3D modeling, SolidWorks, Prototype, Experimental testing, Machine maintenance, Machine performance, Material selection.

Résumé

L'industrie textile joue un rôle crucial dans l'économie mondiale en fournissant une large gamme de produits allant des vêtements aux articles ménagers. La production efficace de fibres textiles est essentielle pour répondre à la demande croissante du marché tout en minimisant les coûts et en respectant les normes environnementales. Cette thèse se concentre sur la conception et la réalisation d'une machine cardeuse novatrice, visant à améliorer la qualité des fibres produites et à optimiser les processus de production dans l'industrie textile.

Mots clé : Industrie textile, Cardage, Fibres naturelles, Machine cardeuse, Conception de machines, Transformation des fibres, Modélisation 3D, SolidWorks, Prototype, Tests expérimentaux, Maintenance des machines, Performance des machines, Sélection des matériaux.

ملخص

تلعب صناعة النسيج دورًا حيويًا في الاقتصاد العالمي من خلال توفير مجموعة واسعة من المنتجات التي تتراوح من الملابس إلى الأدوات المنزلية. إن الإنتاج الفعال للألياف النسيجية ضروري لتلبية الطلب المتزايد في السوق مع تقليل التكاليف والامتثال للمعايير البيئية. تركز هذه الأطروحة على تصميم وتنفيذ آلة تمشيط مبتكرة، تهدف إلى تحسين جودة الألياف المنتجة وتحسين عمليات الإنتاج في صناعة النسيج.

الكلمات المفتاحية: صناعة النسيج، تمشيط الألياف، الألياف الطبيعية، آلة التمشيط، تصميم الآلة، معالجة الألياف، النمذجة ثلاثية الأبعاد، سوليد وركس، النموذج الأولي، الاختبارات التجريبية، صيانة الآلة، أداء الآلة، اختيار المواد.

GENERAL INTRODUCTION

The significance of carding in the spinning process is underscored by two popular adages: 'the card is the heart of the spinning mill' and 'well-carded sliver is half spun'. These expressions highlight the pivotal role of carding in achieving desirable outcomes in spinning operations. Research indicates a strong correlation between the operation of the card and both quality and productivity [1, 2]. Indeed, carding stands out as the paramount process in spinning, significantly influencing yarn quality. Various process parameters such as flat speed, taker-in speed, and cylinder speed, along with settings like licker-in and feed plate adjustments, play crucial roles in controlling quality and ensuring efficient production, thereby minimizing costs.

The selection of cylinder wire is contingent upon several factors including cylinder speed, the type of raw material being processed, and the desired production rate. Additionally, the front angle of the wire is primarily influenced by cylinder speed and the coefficient of friction of the raw material. This cylinder speed, in turn, is determined by the production rate. Higher production rates necessitate more room for the fibers to effectively undergo carding. The wire plays a critical role in maintaining control over the fibers during the carding process [3]. Consequently, to accommodate higher production rates, it becomes essential to increase the space within the wire. Furthermore, higher cylinder speeds are required to accommodate the expanded space needed for the fibers during carding operations [4, 5].

As the cylinder speed increases, so does the centrifugal force generated by the cylinder, which aims to expel the fibers and debris. However, when the front angle is too low and the cylinder speed is insufficient, coupled with high frictional forces, it leads to poor quality card sliver due to inadequate transfer of fibers from the cylinder to the doffer [6, 7]. Consequently, fiber recycling occurs, resulting in more neps and entanglements. The fibers moving towards the tooth tip, combined with centrifugal action, necessitate a sharp front angle to retain the fibers in place during the carding process [8].

The primary function of the doffer is to remove fibers from the cylinder. The licker-in plays a crucial role in opening fiber tufts, with better results achieved with a higher number of rows per inch. In cases where the wire pitch is insufficient, increasing the licker-in speed can compensate for this. However, for fine and long cotton, higher licker-in speeds may lead to fiber breakage [8].

The setting between the cylinder and doffer is critical, heavily influenced by cylinder speed, the delivered sliver's hank, and the type of wire. If this setting is too close, the wires may become polished, impacting fiber transfer. Conversely, if it's too wide, fibers won't transfer

General Introduction

properly, leading to cylinder loading, which significantly affects yarn quality, especially when processing synthetic fibers. The closest setting between the cylinder and flat tops is vital, directly impacting nep formation. While a very tight setting increases flat waste, for cotton processing, settings like 0.25, 0.2, 0.2, 0.2, 0.2 mm are recommended [9].

Research indicates that increasing licker-in speed results in higher fiber rupture, yarn imperfection, and hairiness, while decreasing single yarn strength. This higher fiber rupture is attributed to increased opening point density and beating intensity. Consequently, there's a rise in short-fiber content, leading to increased yarn imperfection and reduced single yarn strength [10]. Nonetheless, yarn unevenness and card cleaning efficiency improve with higher licker-in speeds [11, 12].

As the production rate of the carding machine increases, the single yarn strength decreases, mainly because of improved fiber transfer efficiency resulting in reduced fiber opening and alignment within the sliver [13]. Decreasing the nep level in the card sliver is achievable by increasing the point density of top flats, thereby minimizing yarn imperfections through intensified nep opening [14].

An increase in card production rate correlates with higher yarn unevenness due to inferior carding and increased cylinder loading. Moreover, the total yarn imperfections rise with increasing production rates and decreasing cylinder speeds, primarily due to heightened cylinder loading [15].

The purpose of this study is to research the combined effect of cylinder speed, flat speed, taker-in speed, and cylinder to flat setting on yarn properties like yarn strength, yarn imperfection yarn unevenness, and yarn elongation, which has not been studied so far.

Chapter I

Art of Carding

I. 1. Definition

According to the dictionary [16], the term "card" refers to a wire-toothed brush or a machine equipped with rows of wire teeth used for disentangling fibers like wool before spinning. The word "card" originates from the Latin word "Carduus," which means thistle. In the fifteenth century, a pair of hand cards, which were thistles mounted on a wooden frame, were used to comb and clean cotton and wool fibers before spinning [17].

I. 2. Origin and History of Carding Machine

The carding machine evolved from the old carding tool, which consisted of two blocks with toothed comb plates. By the 18th century, manual carding methods began to be replaced by mechanical ones. In 1738, L. Paul from the United Kingdom expanded carding by using a needle-equipped drum and a corresponding arc-faced comb. In the same year, D. Born developed a multi-drum combing machine. These advancements, along with the addition of feed curtains and stripping choppers to the carding machine, effectively addressed the issues of continuous raw material feeding and the thin-layer output of combed fibers.

By 1792, the Englishman Cartwright invented the roller comb. At the end of the 18th century, a fixed cover plate combing machine was introduced, and shortly thereafter, the American Velman created the rotary cover plate combing machine, which improved cotton combing. In 1810, the Frenchman Gelard also developed a roller comb machine. Since the 19th century, carding machines have undergone numerous improvements and developments, resulting in various specialized combing machines.

Carding machines can be categorized into two main types: rotary cover plate carding machines and roller-type combing machines. The former is mainly used for carding cotton and medium-length fibers, while the latter is primarily used for combing wool and other long fibers. All carding machines consist of basic components such as feeding, combing, stripping, and coil forming (winding) mechanisms. In rotary cover plate carding machines, the main carding component is the cover plate, whereas in roller-type carding machines, it is the work roller.

I. 3. Objectives of Carding

The primary objective of the carding process is to open up the raw material (flocks) and separate the fibers until they are mostly individualized. During this process, foreign matter such as seeds and dust is effectively removed, and the quality of the output (sliver) is improved by eliminating neps and short fibers.

The tasks of the carding machine can be summarized as follows [17, 18]:

1. Open the raw material into individual fibers.
2. Remove foreign matter like seeds and sand.
3. Disentangle and remove neps.
4. Eliminate dust and some short fibers.
5. Achieve a higher degree of blending.
6. Reassemble the fibers into a form suitable for further processing.
7. Achieve a certain degree of longitudinal order.

The carding process achieves a high degree of foreign matter removal, ranging between 80-95%, and also removes a significant amount of micro-dust from the feed material [18]. In modern carding machines, the degree of nep disentangling can reach up to 85%, depending on the type of cotton used [19].

I. 4. Basics of Operating a Carding Machine

The fundamental operations in yarn manufacturing are carding, drawing, and twisting. Carding separates the fibers and combs them into an ordered, even web. Drawing attenuates a loose rope of carded fibers into a thinner rope until it reaches a thickness suitable for twisting. Twisting then provides the yarn with coherence and structural stability. While the production processes for different yarns share many similarities, the preparation of various textiles for yarn manufacture is highly dependent on the chosen material.

I. 5. Basic Textile Terms of Spinning

I. 5. 1. Fiber:

The fundamental component used in making textile yarns and fabrics is fibers. Fibers are fine substances characterized by a high ratio of length to thickness. They can be either natural, such as cotton, wool, and silk, or synthetic, such as polyester, nylon, and acrylic.

I. 5. 2. Blow Room Lap

The blow room lap is a thick, compressed layer of fibers formed by passing raw material through various machines in the blow room section of a textile mill. It consists of cleaned and opened fibers, ready for further processing in the carding and spinning stages.

I. 5. 3. Chute Feed System

The chute feed system consists of a series of chutes or channels through which fibers are transported from the blow room or opening line to the carding machines. It enables the

controlled and uniform feeding of fibers, optimizing the performance of carding machines and enhancing the quality of the resulting sliver or roving.

I. 5. 4. Sliver

In summary, a sliver is a continuous strand of fibers produced during the carding or combing process in textile manufacturing. It serves as a crucial intermediate product in the production of yarn, contributing to the quality and characteristics of the final textile product.

I. 5. 5. Yarn

Yarn is a long continuous strand of fibers, typically twisted together to form a cohesive thread. It's one of the fundamental elements in textile manufacturing, serving as the building block for fabrics, clothing, and various other textile products.

I. 5. 6. Spinning

Spinning is a vital process in the textile industry, converting raw fibers into yarn, which forms the basis for various textile products. Different spinning methods and techniques cater to different types of fibers and end-use applications, ensuring the production of yarns with specific characteristics tailored to their intended use.

I. 5. 7. Yarn Count/Sliver Hank

Yarn count is a numerical expression that defines the fineness or thickness of yarn. It is an essential parameter in textile manufacturing, affecting the texture, strength, and appearance of the final fabric. Different systems are used to express yarn count, and they can be classified into direct and indirect systems. The term "hank" in this context typically refers to a fixed length of sliver, usually 840 yards.

I. 5. 8. Yarn Count System

Indirect system: In the indirect system, the yarn count indicates the length per unit mass of yarn. Common units include the English count (Ne), metric count (Nm), and worsted count (Nw).

Direct System: In the direct system, the yarn count indicates the mass per unit length of yarn. Common units include tex and denier.

Similarly, the numerical expression of the fineness or coarseness of lap, sliver, and roving is called hank.

Note: English (Ne) count system is commonly followed in India.

English Count: No. of Hanks of length 840 yds. weighing in 1 pound

1yds: 0. 9144mtrs

1lbs: 0. 453 Kgs.

e. g. 40s Ne = 40 hanks of 840 yds weighs 1 lbs.

I. 6. Identification of Needs and Technical Specification of the Machine

I. 6. 1. Function of Carding

The card has three main functions:

- ✓ To open and disentangle the blend to a single fiber state and mix it homogeneously, minimizing the breakage of fibers or formation of neps.
- ✓ To remove impurities such as vegetable matter.
- ✓ To deliver the carded material in an appropriate form for the next stage of processing, such as a web, sliver, or slubbing [20].

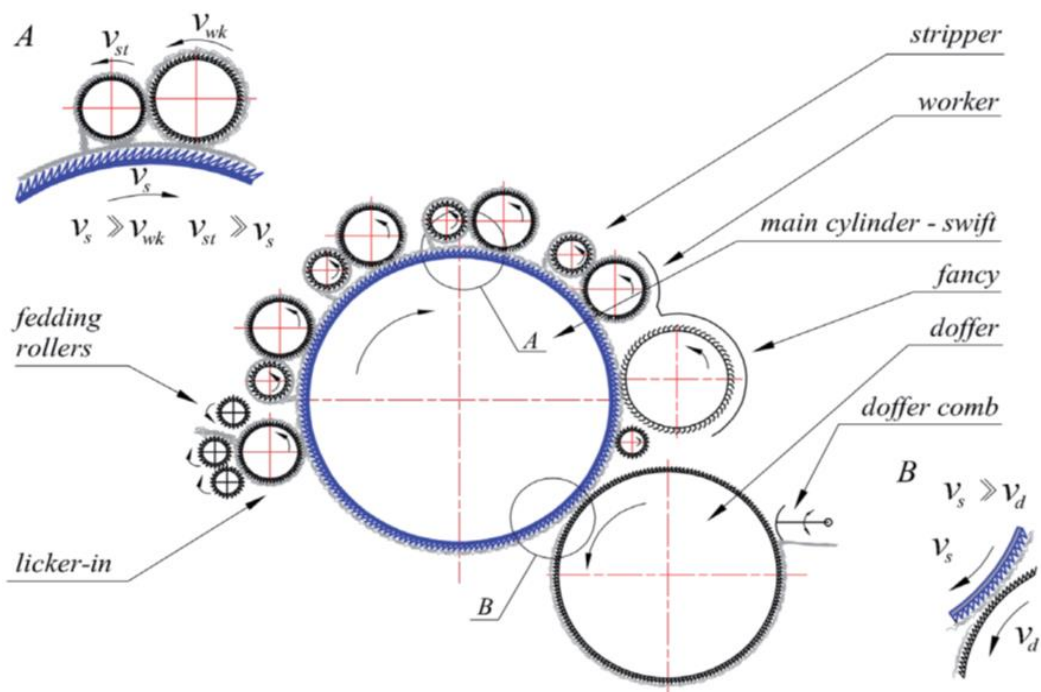


Fig. I. 1: Scheme of the carding machine

In a carding machine within a carding set, fibers are initially picked up by the swift teeth and transported to other pairs of rollers, namely the worker and stripper rollers. Due to the significant difference in tangential velocities between the swift (V_s) and the worker (V_{wk}) (where V_s is much greater than V_{wk}) and the small gap between them, the teeth effectively separate, comb, and straighten the fibers.

The stripper roller, which has a tangential velocity (V_{st}) greater than that of the worker (V_{wk}) (V_{st} is much greater than V_{wk}), redirects a portion of the fibers back for further carding. This process is repeated between the cylinder and subsequent pairs of worker-stripper rollers.

However, the distance between the swift and the subsequent workers decreases. Finally, a roller rotating at high speed—called the fancy ($V_f \gg V_s$) with long bent needles—lifts the fibers above the swift's teeth, carrying them further and condensing them on the teeth of the slowly rotating doffer (V_d) because $V_s \gg V_d$. If the carding machine is the last in the carding set, an oscillating blade (doffer comb) combs and condenses the fibers after carding [21].

I. 6. 2. Feed-Roller and Licker in Actions

The feed sheet is a short, wide conveyor that gradually delivers the fiber to the feed rollers. The licker-in grabs the clumps of fiber from the feed rollers. Its teeth (or pins) begin to open the clumps into smaller tufts by tearing at them while they are held by the slowly rotating feed rollers, causing some fibers to break at this stage (Fig. I. 2). The tufts are then transferred from the licker-in to the main cylinder (or swift) by the transfer roller. By the time the tufts reach the swift, they are partially separated and are further divided when they encounter the worker roller [20].

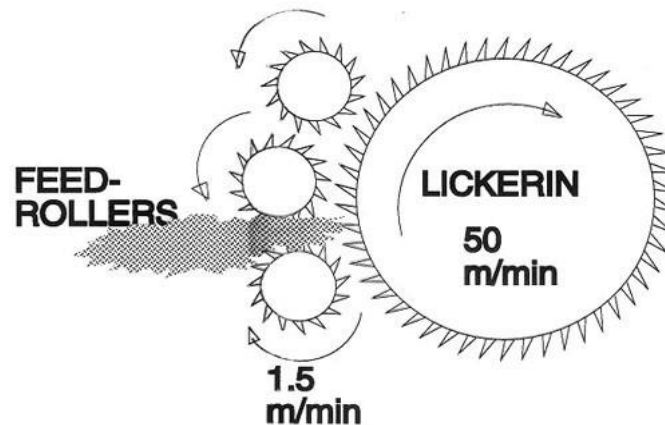


Fig. I. 2. Action of feed rollers and licker in.

I. 6. 3. Worker-Swift Action

The primary function of carding is to separate tufts into individual fibers. Essentially, each tuft is "halved" at a working point, where the worker and swift compete for a tuft (Fig. I. 3). This action is called "point-to-point" due to the directions from which the teeth of the two rollers approach each other.

A single tuft, which may contain approximately 10,000 fibers, needs to be "halved" (n) times to fully individualize the fibers, where $2^n = 10000$. Since $2^{13} \sim 10000$, this simple analysis suggests that around 13-14 working points are needed on the entire card. In practice, most tufts undergo more than one revolution on the swift and are recycled through a working point multiple time.

The working action involves a contest between the worker (A) and the swift (B) for a tuft of wool (C). Fibers caught by the worker's teeth are slowly moved away from the swift and transferred to the accompanying stripper roller, which then re-deposits the fibers back onto the swift [20].

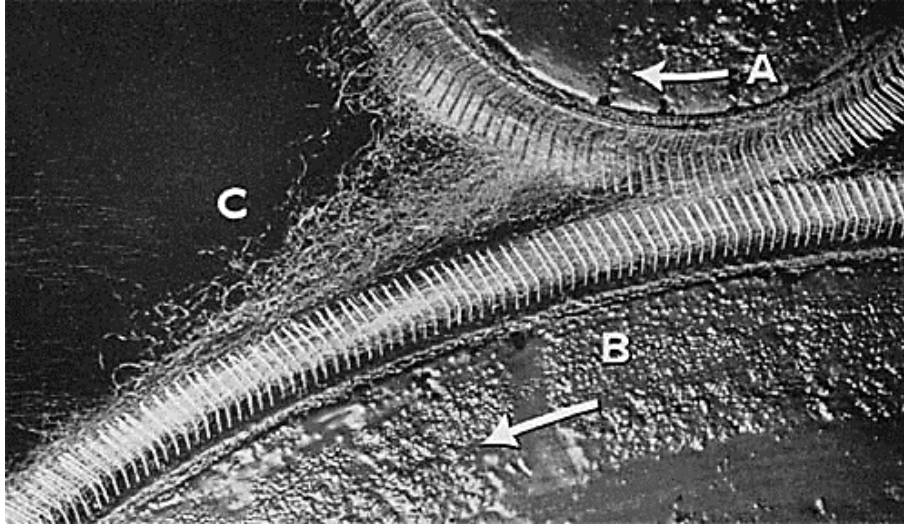


Fig. I. 3. Point-to-point action (swift and worker).

I. 6. 4. Other Carding Action

Fibers or small tufts of fiber are similarly separated by the doffer, which removes a proportion of fibers from the swift in the doffing zone. The fibers retained by the doffer are removed by the doffer comb in the form of a sheet of partially aligned fibers, known as the web, and are not returned to the swift. Fibers not taken by the doffer remain on the swift to be re-worked and mixed with fresh fiber. The variability in the time that a fiber spends on the card (i. e. , the number of workings and swift revolutions it undergoes) primarily drives the mixing action of the card.

Between the worker and the doffer is the fancy, which has much longer and more flexible pins than any other roller. The purpose of these long pins is to lift the fibers to the surface of the teeth of the swift so they can be more easily captured by the doffer.

The various actions of the card rollers fall into three groups:

1. Point to point, which results in some fibers being retained by each surface.

Figure I. 4 shows the doffer (left) removing fibers from the swift (right) [20].

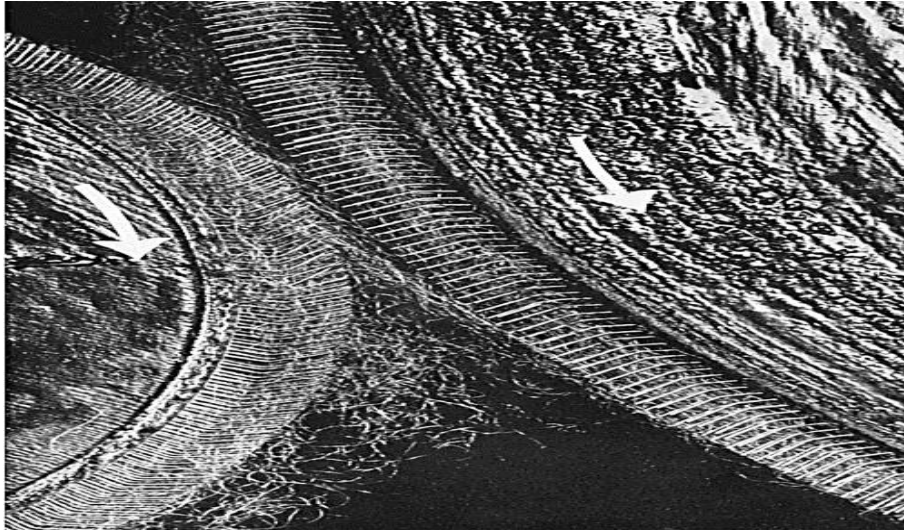


Fig. I. 4. Point-to-point action (doffer and swift).

2. Point-to-back, where all the fibers are transferred from one surface to another (stripping). Because the fibers merely slip off the teeth of the worker onto the stripper, negligible fiber breakage occurs. The transfer of fibers from the stripper back onto the swift is also a point-to-back action (Fig. I. 5).

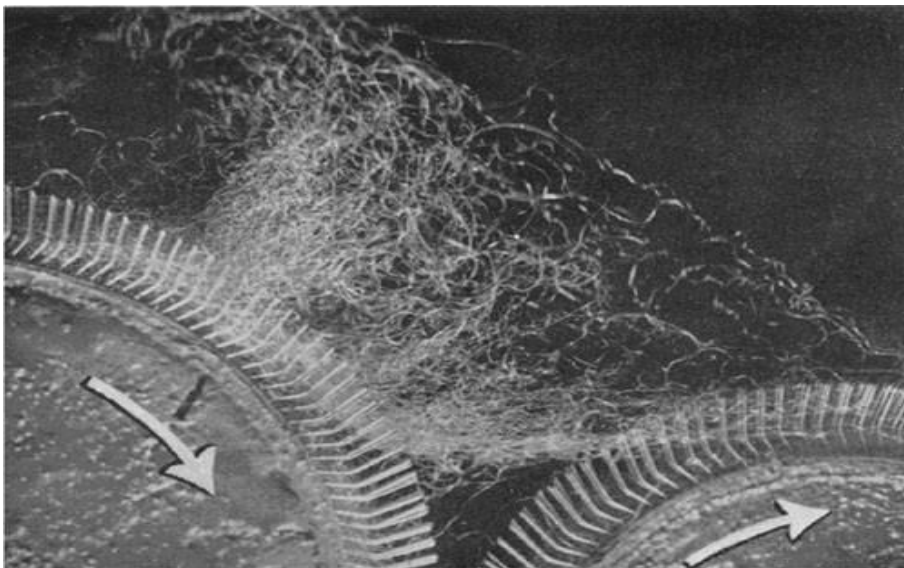


Fig. I. 5. Shows the stripper (right) removing fibers from the worker (left).

3. Back-to-back, which is an action carried out only by the fancy in conjunction with the swift. This action raises embedded fibers above the surface of the swift teeth, making it easier for the doffer to remove them. In Figure 6, the fancy is on the left and the swift is on the right. This is the only interaction on a card where the teeth of two rollers are in contact with each other [20].

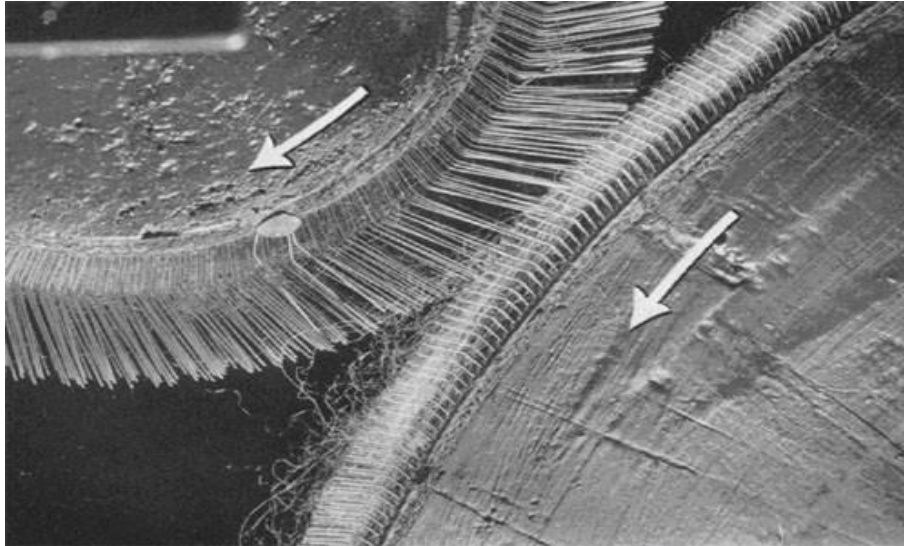


Fig. I. 6. Back-to-back action (fancy and swift).

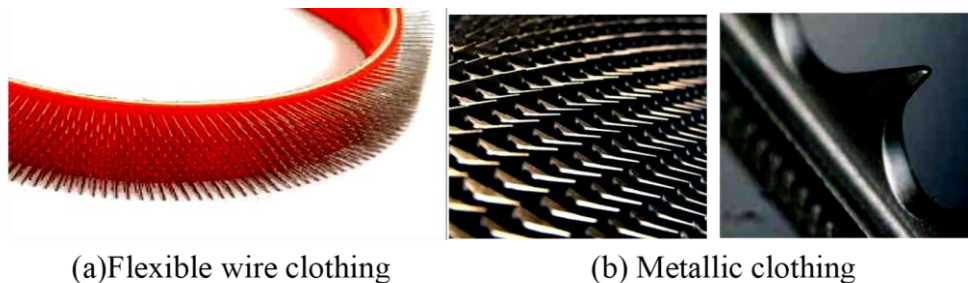
I. 7. Study of the key Components of the Machine

I. 7. 1. Wire Card Clothing

I. 7. 1. 1. Major Type of Clothing

When studying principles, you observed that the most important working parts of all cards are covered with card clothing. Selecting the proper sizes of clothing, ensuring correct installation, and maintaining the clothing carefully are among the most important fundamentals in carding. If you were to attend a meeting of carding overseers, you would find the topic of card clothing is an endless source of technical discussion among the expert [22].

If you could read everything that has been written about card clothing, you would probably come away confused by the variety of opinions you encountered. To introduce you to the study of clothing, we will therefore begin with a clear description of the major types of card clothing (Figure I. 7).



(a) Flexible wire clothing

(b) Metallic clothing

Fig. I. 7. Major type of card clothing.

At first glance, it seems impossible that two entirely different materials can be used for the same purpose. However, as you study carding theory and practice, you will find that this is indeed the case. One point on which all experts agree is that good carding is impossible if the card clothing is not properly maintained. Therefore, for successful carding, it is essential to study the care and maintenance of card clothing. To start with we will look at the type of flexible wire clothing that is commonly used for the card cylinder or to be more specific for the foundation into which the card wires are set [22].

I. 7. 2. Foundation for Clothing

Leather was originally used for card clothing, and although it is still used in some places, it is not very common today. Leather is hard to obtain in a completely uniform quality and can be quite expensive. Various fabric foundations have been developed as alternatives, many of which are more satisfactory than leather. Let's look at the specifications that a satisfactory clothing foundation must meet:

1. The foundation must be strong, fit the cylinder tightly under controlled tension, and endure the strain of carding for many years, typically up to ten years.

2. The foundation must be stretched to prevent the clothing from becoming loose, developing blisters, or raising, which can lead to poor performance and increased maintenance costs due to wire dulling.

3. The foundation must provide flexibility, allowing the wire to move slightly under strain and regain its position, while securely holding the wire during grinding and normal operations.

4. The initial cost of card clothing is minor compared to other carding expenses. Proper maintenance controls this cost, and the price should reflect the clothing's quality.

I. 7. 3. No Signal Textile Fiber

A fabric foundation that meets all the specifications for good card clothing might consist of four layers. A typical foundation for cotton card cylinder clothing includes:

☒ Top Layer: A strong cotton twill fabric.

☒ Second Layer: A heavy fabric with a strong linen warp and woolen filling.

☒ Third Layer: A somewhat lighter fabric, either all cotton or a strong cotton warp with worsted filling, known as "cordette. "

☒ Back Layer: Another cotton twill, which lends strength to the foundation and is comparatively inexpensive.

The linen, which runs lengthwise in the clothing, provides strength, while the wool, running crosswise, provides flexibility for the wires. These layers are cemented together with a suitable adhesive, forming one thick fabric. After the adhesive dries, it becomes oil-resistant and reasonably moisture-resistant, remaining pliable yet holding the fabric in a firm bond.

There are endless variations in the construction of clothing foundations. For instance, linen warp is sometimes used without any filling as one layer in the foundation, called "flexifort," and clothing containing such linen warp is referred to as flexifort clothing. Another variation might include two layers of cotton cloth at the bottom, a layer of wool, and a top layer of cotton. This type of foundation is often called CWCC clothing. For doffers and flat tops, CWC clothing is used, which has cotton twill on the face and back with heavy woolen cloth between the layers of cotton twill.

A for special purpose the top layer of the foundation may be covered with felt or with rubber or plastic the foundation or the clothing is made in broad width after the adhesive has thoroughly dried the clothing is cut into long narrow strips and the wires are inserted [22].

I. 7. 4. Wire for Teeth

The wire teeth of the card clothing are made from different metals and come in various sizes and shapes. Tempered steel, ranging in diameter from 0. 009 to 0. 017 inches, is most commonly used. The cross-section of the wire is usually round, but it can also be oval, triangular, or diamond-shaped for special purposes.

There are certain terms you'll hear in connection with card wire:

- ✓ **Cut:** A short piece of wire from which each card wire is bent.
- ✓ **Staple:** The formed piece of wire that is inserted into the foundation.
- ✓ **Crown:** The bottom part of the staple that lies flat on the back of the clothing.
- ✓ **Points:** The two ends of the staple that protrude through the foundation.
- ✓ **Knee:** The bend in the staple between the surface of the clothing and the wire.

These components work together to ensure the wire is securely attached to the card clothing and functions effectively in the carding process [22].

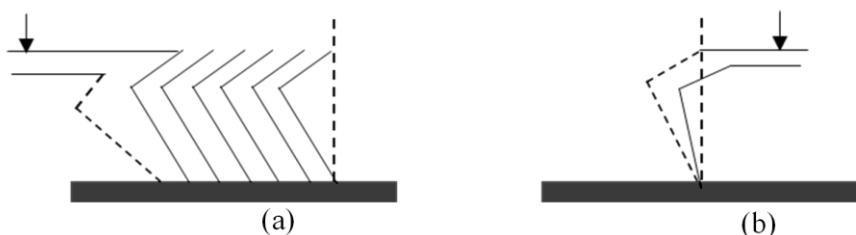


Fig. I. 8. Angle of wire

The wire is not placed perpendicularly through the foundation but at an angle, as shown in Fig. I. 8 (a). The angle at the knee offsets the angle at which the wire passes through the foundation. This is an important point: if the fibers resist the action of the wire, the point is pulled backward and moves down in a curve. When the wire is in this position, the setting between the carding surfaces becomes more open.

Now look at Fig. I. 8 (b) and observe what happens if the knee of the wire is bent past the angle where the point of the wire is above its base. When the wire encounters resistance, it will be raised, as indicated. In a close setting, this may cause the wire to strike the opposite carding surface, potentially causing damage to the wire [22].

I. 7. 5. From all that has Been Said so Far

You will already understand how important it is that card clothing is made just right. The wire teeth are inserted into the foundation by a completely automatic machine. This machine first cuts the wire and bends it into the form of a staple. It then pierces holes in the foundation and pushes the wire ends through. Finally, it bends the knee of the wire at the correct angle.

There are two major forms in which flexible wire card clothing is produced:

1. Fillet Clothing or Filleting
2. Sheet Clothing, Including Tops

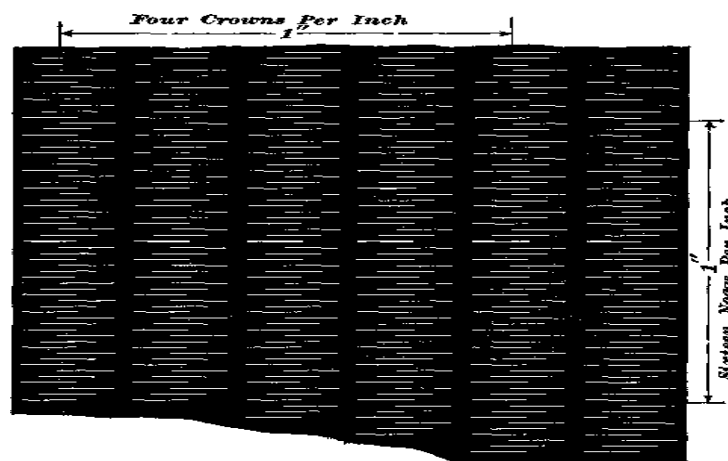


Fig. I. 9. Rip-Set Clothing

Fillet clothing comes in narrow strips, usually 1.5 or 2 inches wide. It is wound around the card cylinders or various card rolls in a spiral. The length of the filleting is several hundred feet, with the exact length depending on the size of the cylinder to be covered.

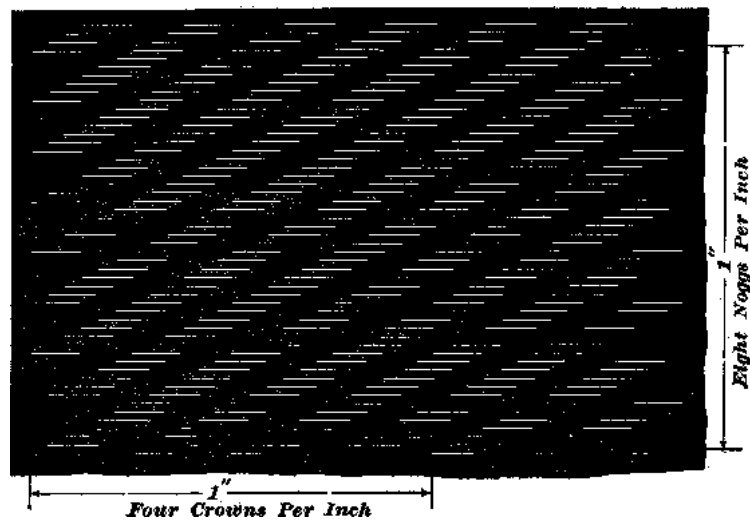


Fig. I. 10. Twill-Set Clothing

Sheet clothing is sometimes used to cover the cylinder of woolen and worsted cards. This sheet clothing is usually 5 inches wide and matches the width of the cylinder. It is filled with wire staples except for a narrow border on all sides used to attach it to the card cylinder. For cotton cards, sheet clothing is used on the flats. These sheets or tops fit the flats and are $1\frac{3}{8}$ inches wide and $42\frac{1}{2}$ inches long. A $\frac{7}{8}$ -inch strip down the center is filled with staples, while $\frac{1}{4}$ inch strips on each side are left blank for attaching the sheet to the flats [22].

I. 7. 6. Rip Set and Twill Set

If you look at the surface of card clothing, the teeth appear to be tightly set without any particular pattern. However, if you examine fillet clothing, you'll notice that the crowns form a rib-like pattern, as shown in Fig. 9. Note how one crown is off to the left, one is in the center, and the third is to the right of the rib. On the surface of the clothing, there are two points for each crown. The three crowns you have just observed form a short diagonal line within the rib. Each group of three crowns is called a nogg.

In the clothing shown in the illustration, there are four crowns per inch and sixteen noggs per inch. This information is used to determine the number of points in card clothing. Most clothing is standardized to four crowns per inch, and only the number of noggs needs to be specified.

If you look at the back of sheet clothing, you'll find the wire set in twill lines, as shown in Fig. I. 10. Each seventh crown will be exactly over the first crown of the next twill line, so the repeat of the twill is six. Since this repeat is called the nogg in twilled clothing, there are six crowns per nogg, not three as in rib-set clothing. However, in any type of clothing, the number

of crowns per inch is generally standardized at four. Now, let's take a look at the various ways of measuring card clothing [22].

I. 7. 7. Point per square foot

When it comes to ordering card clothing, you need to know how to specify the clothing you want. There are two ways of doing this: the American system and the English system. Both are used in the United States, so even though having two systems can be a nuisance, you'll need to become familiar with both.

To start, you must take a ruler and measure the crowns per inch and the noggs per inch. Figs. I. 9 and I. 10 show how to do this. In the American system, it is customary to specify the points per square foot. You can use either a rule or a formula, whichever you prefer. Remember, to understand the figures used, that there are two points for each crown, and that a square foot has 144 square inches.

Here's how you can calculate it:

- ✓ Measure the Crowns per Inch: Determine how many crowns there are in one inch.
- ✓ Measure the Noggs per Inch: Determine how many noggs there are in one inch.
- ✓ Calculate Points per Square Inch: Multiply the crowns per inch by the noggs per inch, and then multiply that result by two (since there are two points per crown).
- ✓ Convert to Points per Square Foot: Multiply the points per square inch by 144 (the number of square inches in a square foot).

This will give you the number of points per square foot, which is the standard measurement in the American system.

$$P = C \times 2 \times N \times F \times 144 \quad (1)$$

In Which

- ✓ P = points per square foot.
- ✓ C = crowns per inch (in width).
- ✓ N = noggs per inch (in length).
- ✓ F = crowns per nogg.

EXAMPLE

Look at the rib-set clothing in (Fig 10). Note that there are 4 crowns per inch in the width, and 16 noggs per inch in the length. Recall that there are 3 crowns per nogg in rib-set clothing. How many points per square foot does this clothing have?

$$P = 4 \times 2 \times 16 \times 3 \times 144$$

$$p = 55,296 \text{ points per square foot. Ans.}$$

As long as you are dealing with regular clothing, the formula in the preceding article can be greatly shortened. For rib-set filleting you can use the formula that follows.

$$P = N \times 3,456 \quad (2)$$

This formula presupposes that the clothing has 4 crowns per inch. If this is not the case, you must use the long formula given in the preceding article. Sometimes you may want to determine the points per square inch, rather than per square foot-some manufacturers list their clothing in this manner. You can use the same formula as above, but use 24 to multiply. the noggs instead of 3,456.

For twilled sheet clothing, where each nogg has twice as many points as in the rib-set clothing, use the formula that follows.

$$P = N \times 6,912 \quad (3)$$

If you want the points per square inch, use 48 instead of 6,912. Again, the short formula works only for standard clothing with 4 crowns per inch.

I. 7. 8. English Counts

To understand the English method of counts in card clothing, let's take a brief look at the history of card clothing:

A century ago, card clothing in England was made in 4-inch-wide strips. The crowns were set like bricks in a wall, or like plain weave, with two crowns per nogg. This plain or open set is seldom used today. The clothing always had 5 crowns per inch, and each count indicated the number of noggs in 4 inches. Each count was equivalent to 720 points per square foot. Even though the clothing on which it is based has become almost extinct, the English counts are used today for all types of card clothing. The noggs and crowns in modern clothing are differently arranged, but one English count still represents 720 points per square foot.

To compare the points per square foot to the English counts, use these simple formulas.

$$P = C / 720 \quad (4)$$

In Which

- ✓ C = English counts;
- ✓ P = points per square foot.

EXAMPLE. You need card clothing with 64,800 points per square foot. The card clothing in the supply room is marked with English counts. Which counts do you need?

Solution $C = 64,800 / 720 = 90$ s counts. Ans.

This formula may also be used in another form to find the points per square foot when the English counts are known.

$$P = C \times 720 \quad (6)$$

EXAMPLE. A doffer is to be covered with 120s clothing. How many points per square foot do you specify?

Solution $P=120 \times 720=86,400$ points per square foot. Ans.

Table. I. 1. Fillet Clothing for Cotton Cards

English counts	Points squar foote	Noggs (Approximately)	Wire Gauge Number
90 s	64. 800	19	31
100 s	72. 000	21	32
110 s	72. 200	23	33
120 s	86. 400	25	34

I. 7. 9. Wire Gauge

Up to now, we've only counted the wire points, but there's another item to consider: the diameter of the wire. This diameter varies depending on whether the clothing is coarse or fine. The wire diameter is numbered by the American standard wire gauge, where the higher the gauge number, the finer the wire. For example:

- ✓ No. 30 wire has a diameter of 0. 014 inches
- ✓ No. 32 wire has a diameter of 0. 0128 inches
- ✓ No. 34 wire has a diameter of 0. 0104 inches, and so on.

You can measure the wire with a simple V-shaped measuring gauge. Slip the wire into the V-shaped slot of the gauge, and read the number on the side when the wire is as far as it will go.

While there are no definite standards to guide you in selecting a wire of a certain diameter for card clothing with a certain number of points per square foot, there are certain diameters generally used with clothing of a particular number of points per square foot. In Table I. 1, some commonly used card fillet clothing for cotton cards is listed.

For woolen-card clothing, the wire gauge number and the noggs are usually given in the specifications instead of the English counts. Consequently, we'll list these first in Table I. 2. It's also better to specify "8-rib, 3-twill" for the 2-inch fillets to avoid any possibility of misunderstanding.

Table I. 2. Fillet Clothing for Woolen Cards

Wire Gauge Number	Noggs	Points Square Foot	English Counts (Approximately)
28	10	34. 560	48 s
30	12	41. 472	58 s
32	14	48. 384	67 s
33	16	55. 296	77 s
34	18	62. 208	86 s
35	20	69. 120	96 s

You'll notice that the range of the woolen-card clothing runs to much lower points per square foot than that of the cotton-card clothing, and that the wire in equivalent clothing is somewhat finer. This difference reflects the different requirements and characteristics of woolen and cotton carding processes. Wool fibers are generally shorter and finer than cotton fibers, requiring a different approach in carding. As a result, woolen-card clothing typically operates at lower point densities and utilizes finer wire compared to cotton-card clothing [22].

I. 7. 10. Flexible Clothing for Cotton Cards

Most cotton cards in America are covered with flexible clothing, and the types of clothing used are fairly standardized. For the cylinder, CWCC clothing is commonly used. Here's a breakdown of the clothing used for different types of cotton carding:

- Carded cotton intended for coarse counts, roughly 4s to 15s, is carded with 90s counts cylinder clothing.
- For medium-carded yarns and coarse-combed yarns ranging from 15s to 30s, 100s counts cylinder clothing is used.
- Fine yarns ranging from 30s to 70s typically use 110s counts cylinder clothing.
- Extremely fine-combed yarns, those above 70s, use 120s counts clothing.

Characteristic cotton-card cylinder clothing is shown in Fig. I. 11. Note the thickness of the CWCC foundation. The clothing, like most cylinder filleting, comes in strips 2 inches wide. If you could inspect the backs of the strips, you would find 8 ribs in the width, meaning 4 crowns per inch. You would count 21 noggs per inch in the length. According to the formula you have learned, this would give you:

$$P = 21 \times 3,456 = 72,576 \text{ points per square foot}$$

Since clothing of 100s English counts would have $(100 \times 720 = 72,000)$ points per square foot, this is the type of clothing that would be used. The difference of 576 points per

square foot is insignificant and would be neglected. This means that although the calculated value based on the observed counts may slightly differ from the ideal value, it falls within an acceptable range and doesn't significantly impact the performance of the carding process.



Fig 11: Cylinder Clothing 100s cwc

The clothing used for the doffer is typically somewhat finer than that used for the cylinder, with a usual difference of 10 counts. For example, 110s counts would be used on the doffer while 100s counts would be used on the cylinder. The foundation of the doffer clothing is thinner, and CWC foundation is commonly used. The tops for the flats are usually selected to match the doffer clothing, meaning the clothing on the flats is also 10 counts finer than that on the cylinder. This consistent difference in counts ensures proper coordination and effectiveness in the carding process across different components of the carding machine.



Fig. I. 12. Doffer Clothing 120s cwc

Characteristic cotton-card doffer clothing, as shown in Fig. I. 12, features finer wire and a thinner foundation compared to that of the cylinder clothing. Despite these differences, the height of the wire remains the same at $\frac{3}{8}$ inch from the crown to the point. The doffer filleting is only 1 inch wide. The clothing shown has 6 ribs in the width, meaning 4 crowns per inch, and there are 25 nogs per inch.

According to our formula, that would be 86,400 points per square foot, which corresponds to 120s counts clothing. This indicates that the clothing on the doffer is of a finer quality compared to that on the cylinder, as expected.

I. 7. 11. Flexible Clothing for Woolen and Worsted Cards

While there's a certain level of standardization in cotton carding processes, the same cannot be said for woolen and worsted carding. Wool fibers exhibit a much wider range in terms of coarseness, fineness, length, and texture compared to cotton fibers. Additionally, the carding machines used for woolen and worsted carding are different from those used for cotton, as you've learned.

In fact, many mills have even abandoned flexible clothing altogether in favor of metallic clothing. We'll delve into the details of metallic clothing later on. This shift underscores the unique requirements and challenges posed by woolen and worsted carding processes, which necessitate different approaches and equipment compared to cotton carding.

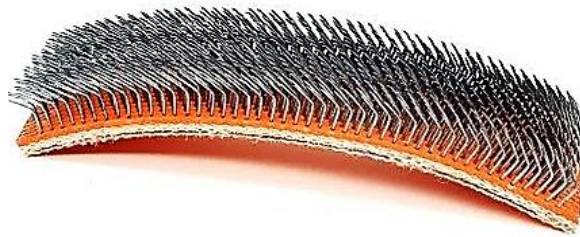


Fig. I. 13: Cylinder Clothing, No. 33, cwcc

With the increasing processing of rayon, synthetic staple, and blends of various fibers, having knowledge of different types of card clothing becomes essential. The more familiar you are with various types of card clothing, the better equipped you'll be to experiment when conventional clothing types prove unsatisfactory for new fibers.

A characteristic cylinder clothing for a woolen card is depicted in Fig. I. 13. With a CWCC foundation, 2-inch width, 4 crowns per inch, and 16 noggs per inch, the clothing bears resemblance to coarse cotton-card cylinder clothing. The wire gauge is No. 33. This clothing might be utilized on the first breaker for very fine, lofty wool; on the second breaker for medium work; and on the finisher when fairly coarse work is being processed. The clothing for the workers resembles the cylinder clothing but is only 1 inch wide. The staple or the overall height of the clothing is $\frac{3}{4}$ inch from the crown to the point of the wire. This is $\frac{1}{4}$ inch higher than the $\frac{1}{2}$ -inch height of the clothing for cotton cards.

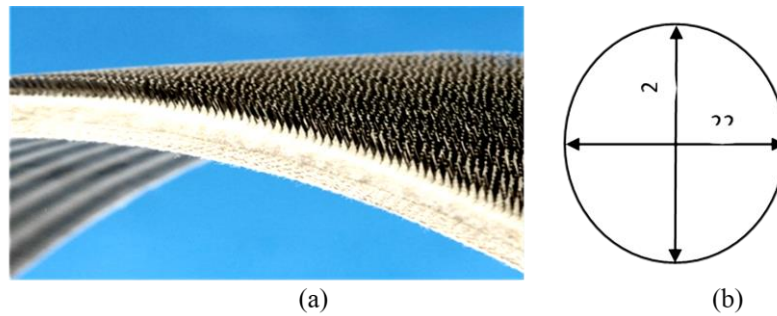


Fig. I. 14. Cylinder Clothing, No. 22-26, 8-Ply

The clothing discussed in the previous article was more or less similar to that on a cotton card. However, the clothing shown in Fig. I. 14 (a) is different. This is a very heavy fillet, typically used for carpet wool and other coarse, matted fibers on the first breaker card. The foundation is 8-ply, with a wool face. The wool face facilitates easier stripping and helps absorb shocks while the wires work on the tangled fibers.

While the wire on all the clothing we've studied so far was round in cross-section, the wire in Fig. I. 14 (a) has a double-convex cross-section, as indicated in the section sketch (b).

The gauge is given as No. 22-26 because the shorter diameter is equivalent to No. 22, and the longer diameter is equivalent to No. 26. This wire shape offers at least two advantages: 1) the long diameter adds strength to the wire; 2) the short diameter provides room for the fancy to lift the stock to the surface. Additionally, as you'll discover when studying card grinding, double-convex wire takes and holds a sharper point.

If you were to examine the lock of the 2-inch strip of clothing, you would notice only 6 ribs, meaning 3 crowns per inch. With 10 noggs per inch, this represents a very open spacing. The purpose of this open spacing is to leave room for the stock between the heavy wires.

Now, let's examine another variety of cylinder wire used in the worsted-type clothing shown in Fig. I. 15. At first glance, this clothing resembles the clothing shown in Fig. I. 12 and Fig. I. 14. With No. 33 wire, 8 crowns per inch, and 20 noggs per inch, it is suitable for fine work. However, it differs from the clothing depicted in the preceding figures in several key aspects [22].



Fig. I. 15. Cylinder Clothing, No. 33 Plated, 5-Plyrubber Face

We have considered so far by being constructed specifically for working with moist stock. The wire is plated to resist rust. The foundation is 5-ply, with a top layer of rubber. This rubber face keeps the moisture in the stock from penetrating into the foundation.



Fig. I. 16. Cylinder Clothing, No. 34 Plated, 6-Ply Felt Face

In Fig. I. 17, you'll observe yet another type of card clothing. The notable feature of this clothing is the felt face of the foundation, which encloses the wire all the way up to the knee. Although the soft felt doesn't impede the regular movement of the wire, it aids in restoring it to its normal pitch. However, the primary functions of the felt are to preserve stock, prevent the card from becoming overloaded, and ensure uniformity in the sliver.



Fig. I. 17. Fancy Clothing with Knee

Typically, when a card is initiated after stripping, the resulting sliver will be lightweight for a period. This condition persists until a solid bed of interlocked fibers forms from the clothing's surface to the wire's knee. The light sliver and the fiber base represent stock losses. When carding fine wool or other costly fibers, using felt-base clothing may prove cost-effective. Additionally, felt-base clothing can be beneficial when carding synthetics prone to static electricity buildup and card loading. When combined with plated wire and high humidity, this clothing type can prevent loading. However, it's crucial to note that felt-base clothing demands careful adjustment of the fancy and stripping processes; otherwise, the felt base may be damaged.

I. 7. 12. Fancy Clothing

There's little disparity between the clothing utilized for the cylinder and that for the flats, workers, and strippers. However, you'll notice that the fancy clothing, as depicted in Fig. 18, is quite distinct. Recall that the fancy serves solely as a raising mechanism, and its wire points extend into those of the cylinder clothing.



Fig. I. 18. Fancy clothing, Straight wire

The fancy clothing illustrated is set in a leather foundation, with wires measuring 1. 1 inches from crown to tip. The wire is No. 28, plain set with 12 rows across the 11-inch width of the fillet, featuring 2 nogs per inch. This type of fancy clothing is suitable for short stock due to its gentle action.

Fancy clothing with a straight wire, as depicted in Fig. I. 18, is more prevalent in modern usage. It can be employed on virtually any card and with any type of fiber. The straight wire is set into the leather foundation at a 65-degree pitch, providing a somewhat stronger action than equivalent wire with a knee. In certain types of cards where the fancy roll is not enclosed, the straight-wire fancy may result in more fly compared to a knee-wire fancy. Nevertheless, most woolen carders favor straight-wire fancies because they can set these fancies more easily and run them at slower speeds without risking stock winding around them.

The specific clothing shown in the illustration features No. 28 wire, 1. 5 inches long from crown to point. There are 3 crowns in the 1. 5-inch width of the rib-set clothing, with 3 nogs per inch lengthwise. You'll notice that the fancy wire is spaced more loosely compared to cylinder wire. Typically, a common fancy has about half as many points per square foot as the cylinder wire it is used with. Open-spaced fancy clothing has about half as many points as common fancy clothing [22].

I. 8. Differences Between Flexible and Metallic Card Clothing

Table. I. 3. Differences Between Card Clothing

S/N	Flexible card cloth	Metallic card cloth
01	Foundation material and card cloth of flexible card cloth are separate in formation.	Foundation material and card cloth of metallic card cloth are integral in formation
02	Carding angle alter under strain.	Carding angle do not alter under strain.
03	Fibers chocks onto the bending zone.	Fibers don't chock.
04	Degree of cleaning of flexible card clothing is low.	Degree of cleaning of metallic card clothing is higher
05	Degree of action is comparatively gentle.	Degree of action is comparatively aggressive
06	Replacement frequency is higher.	Replacement frequency is lower.
07	Lower working speed due to flexibility	Faster working speed due to rigidity
08	Teeth have knee or "U" shape.	No knee and "U" shape.
09	Frequency of grinding is high	Frequency of grinding is lower
10	Degree of opening is lower.	Degree of opening is higher.
11	Degree of unneping is low.	Nep is high.
12	Productivity of flexible card cloth is low.	Productivity of metallic card clothing is high.
13	Flexible card cloth has replacement flexibility e. i. only damaged part replaceable.	Complete set to be replaced
14	Cost of flexible card cloth is low.	Cost of metallic card cloth is high.
15	It is used in flat card clothing.	Now-a-days, It is used in the licker-in, main cylinder and doffer without exception.

I. 9. Design and Requirements of Cylinders in Modern Carding Machines

Since the nineties of the last century, thanks to the research described, among others, in [22], carding machines have been equipped with cylinders with internal ring-like reinforcements. These reinforcements serve to guarantee the necessary rigidity of the entire cylinder, both during operation and during its manufacturing processes (such as grinding the surface with disk-type grinding wheels before reeling the metallic card wire). The design of a typical working cylinder, as produced by BEFAMA SA, is depicted in Figure 19a. It comprises a shell made of sheet metal welded along its edges, cast wheel hubs, the shaft, and reinforcement rings. This solution has been effectively utilized in the production of carding units. Presently, primarily for technological reasons, cylinders are enclosed with bottoms welded from sheet metal with ribs, which are simpler to manufacture (Fig. 19b). The solutions provided by leading carding machine manufacturers and specific designs may vary in terms of the construction of the bottom and reinforcement rings.

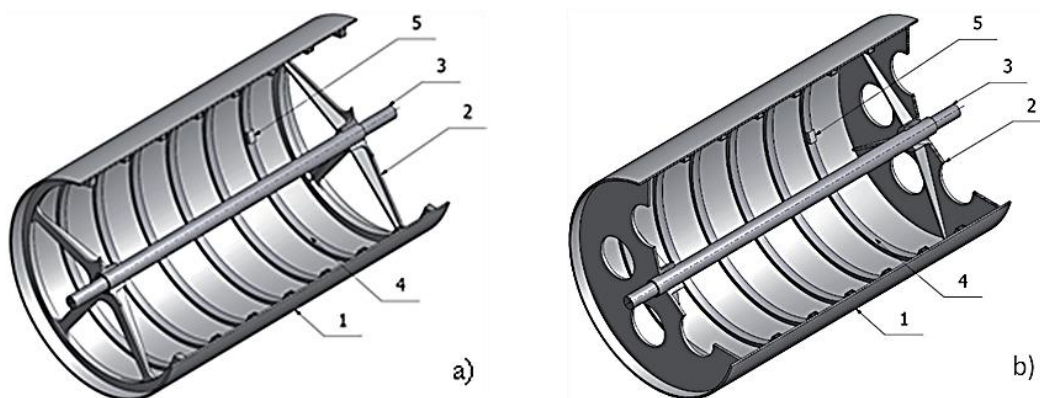


Fig. I. 19. *a) cylinder with cast wheel hubs, b) cylinder with welded bottoms:*

(1) shell, (2) cast wheel hubs/ bottoms, (3) shaft, (4) reinforcement ring, (5) balancing slug.

The quality of carding significantly relies on the height and configuration of the gap between the swift and the worker, as well as between the swift and the doffer. For carding fine fibers, the optimal height of the gap typically ranges between 0.3 and 0.15mm. Additionally, to achieve desirable uniformity in the resulting web, the gap's shape should closely resemble that of a rectangle.

Considering the longevity of the metallic card wire teeth, which tend to decrease in hardness from the top to the base, it's advisable not to grind the cylinder after the wire has been reeled as long as the teeth remain sufficiently sharp. Consequently, the design of the swift should ensure that after reeling the metallic card wire under tension, the deflection amplitude (D) of the shell does not exceed several hundredths of a millimeter (Fig. I. 20).

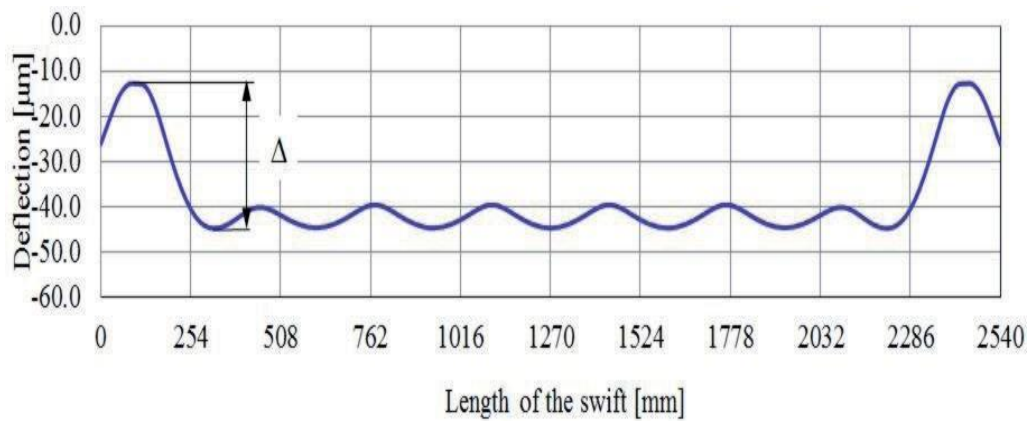


Fig. I. 20. Deflection Line of the Example Cylinder.

Considering the dimensions of the mainline (diameter x length: Ø1500mm x 2500 mm) and the cabinet (Ø1270 mm x 2500 mm), the typical wall thickness falls within the range of 10 to 14mm. Consequently, construction requirements necessitate a considerable height. However, it's essential to recognize that augmenting the structure's height, which directly impacts deflection, results in increased costs and mass of the cylinder. Moreover, efforts to enhance inertia aim to achieve a balance between structural integrity and operational efficiency.

A regulation in a scenario granting the entitlement to employ a designated brake mechanism to halt the cycle at a predetermined time in the event of a holiday is necessary. Efforts should be directed towards refining the design of the handles, particularly advantageous for combing delicate fibers. Consequently, a standard pulley was individually constructed utilizing Finite Element Model (FEM) for enhanced precision.

I. 9. 1. FEM model of the cylinder

The discrete calculation model of a cylinder with a flat side axis (refer to Fig. I. 19b) was constructed using Shell 63 elements for the shell, bottoms, and ribs, and Beam elements 188 for the rings and shaft. The Shell 63 is a four-node shell element with six degrees of freedom at each node—three translations and three rotations—allowing it to account for both membrane state and shell curvature. Beam 188 is a two-node beam element that adheres to Timoshenko beam theory, which considers both bending and shear deformations.

During the shaft splitting process, special care was taken to ensure that nodes were positioned at the locations of the self-aligning roller bearings supporting the roller. Hinge support was applied on the right side (the side where the transmission driving the roller is situated), while the roller support was applied on the left side at the nodes.

Summary of Model Components:

❖ Shell 63 Elements: Used for the shell, bottoms, and ribs; four-node with six degrees of freedom per node.

❖ Beam 188 Elements: Used for the rings and shaft; two-node elements following Timoshenko beam theory.

❖ Shaft Splitting Process: Ensured node positioning at bearing locations.

❖ Supports:

- Right Side: Hinge support.
- Left Side: Roller support.

This approach allows for a detailed and accurate representation of the cylinder's mechanical behavior under various conditions, aiding in the precise design and analysis of the carding machine components.

I. 9. 2. Loads Acting on the Main Cylinder of Carding Machine

The primary loads acting on the cylinder during operation include:

1. Influence of Fibers on the Teeth of Card Wire: During the carding process, fibers exert forces on the teeth of the card wire. However, these forces are relatively small and can be omitted when calculating the deflection of the cylinder shell.

2. Construction Dead Weight and Centrifugal Force: The dead weight of the construction and the centrifugal force generated during operation also influence the cylinder. Nonetheless, these factors can be neglected in deflection calculations due to the significant stiffness of the cylinder shell and the relatively low rotational speed of the cylinder (approximately 100 to 200 rpm).

3. Reeling Tension and Reeling Pitch: The tension S during reeling and the reeling pitch t of the card wire on the cylinder with radius R generate a pressure on the cylinder shell. This pressure is directed radially inward and can be expressed as:

$$P_r = \frac{S}{t.R} \quad (7)$$

where P_r is the radial pressure, S is the reeling tension, t is the reeling pitch, and R is the radius of the cylinder (Fig. I. 21a).

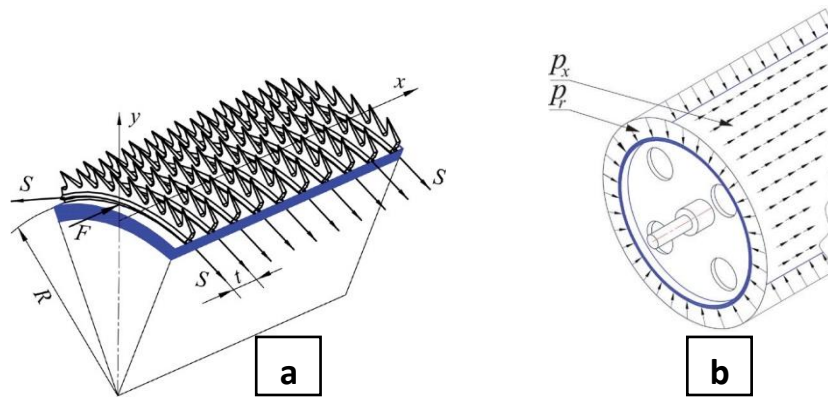


Fig I. 21. (a) Tension Forces Acting on The Metallic Card Wire Coils. (b) Load Scheme.

I. 9. 3. Calculation Considerations

- **Neglected Forces:** Small forces from fiber interaction and the combined effects of construction weight and centrifugal force are not considered in deflection calculations due to their minimal impact.

- **Primary Load:** The main load considered is the radial pressure resulting from the tension and pitch of the card wire during reeling.

- This focused approach simplifies the analysis while ensuring that the significant factors affecting the cylinder's performance are addressed. The pressure calculation provides a critical understanding of the stress distribution within the cylinder shell, aiding in the design and optimization of the carding machine components.

I. 10. Conclusion

In this chapter, we have explored the fundamental aspects of carding, its origins, and its objectives. The primary goal of carding is to disentangle and align fibers to produce a continuous web or sliver, which is essential for subsequent textile processes. We discussed the basic operations involved in carding, including the roles of key components like feed rollers, licker-ins, and worker-swift actions. Additionally, we covered essential textile terms related to spinning, such as fiber, blow room lap, and sliver, to provide a comprehensive understanding of the carding process. The study of key components of the carding machine, including wire card clothing and its various specifications, highlighted the importance of these elements in ensuring efficient and effective carding. This foundational knowledge sets the stage for the detailed design and development processes covered in subsequent chapters.

Chapter II

Design of the Carding

Machine to be produced

II. 1. Introduction

This chapter will be devoted to carding machine design and sizing, and we will present several parts precisely developed using SolidWorks software. Our goal will be to integrate them harmoniously into a single structure, while maintaining the necessary flexibility in the machine's performance.

II. 2. Definition of SolidWorks

SolidWorks is a computer-aided design (CAD) and computer-aided engineering (CAE) software program used for creating 3D models and 2D drawings. Developed by Dassault Systems, SolidWorks is widely used by engineers, designers, and architects for designing and simulating products. Its features include:

- **3D Modeling:** Allows users to create detailed 3D models of parts and assemblies.
- **Simulation:** Provides tools for analyzing the physical behavior of models under various conditions using finite element analysis (FEA).
- **Drafting:** Facilitates the creation of precise 2D drawings from 3D models.
- **Collaboration:** Includes tools for data management and collaboration, allowing multiple users to work on a project simultaneously.
- **Customization:** Offers various plugins and add-ons to extend its functionality for specific industries and applications.

SolidWorks is widely used in industries such as automotive, aerospace, consumer products, and manufacturing due to its comprehensive toolset and user-friendly interface.

II. 3. Design of the Mechanical Part

Designing the mechanical part of a carding machine involves a detailed understanding of its components and their functions. The carding machine's primary objective is to open, clean, and align fibers to prepare them for spinning. Here's an overview of the design considerations and key components involved in the mechanical part of a carding machine.

II. 3. 1. Structure

The structure of a carding machine is designed to support the efficient processing of fibers, ensuring they are opened, cleaned, aligned, and delivered as a continuous sliver. Here's a detailed breakdown of the structural components and their functions.

II. 3. 1. 1. Frame

The robust structure that supports all other components. It is usually made of heavy-duty steel to provide stability and minimize vibrations during operation, provides additional support and houses the motor and other drive mechanisms.

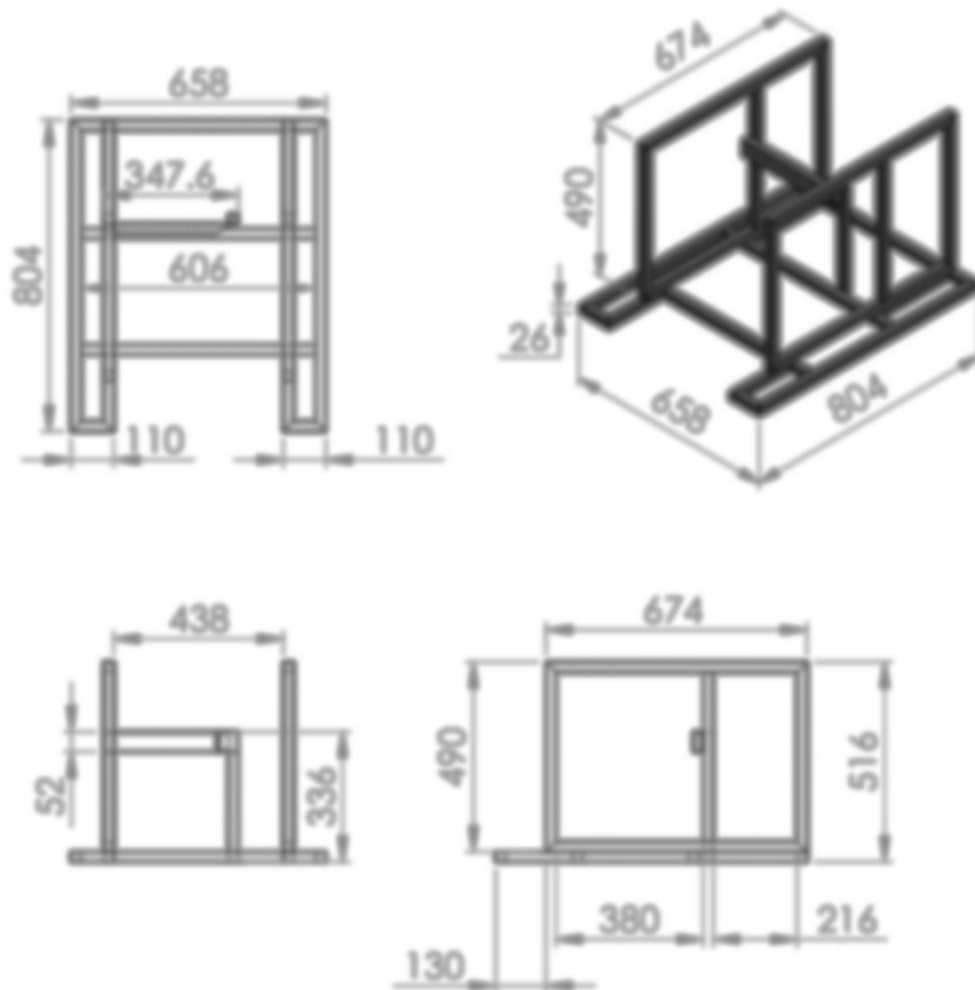
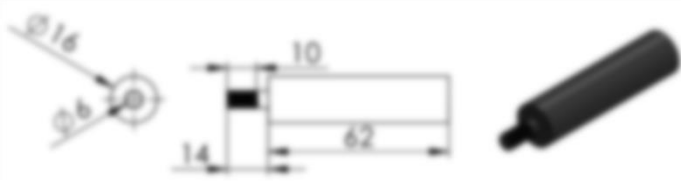
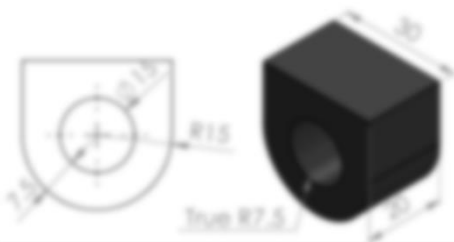
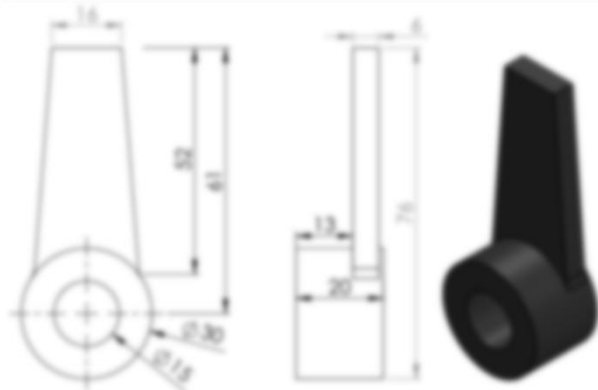
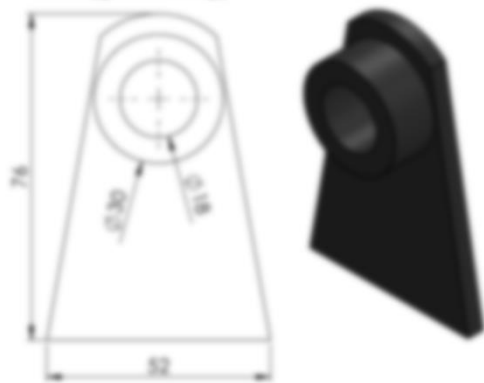
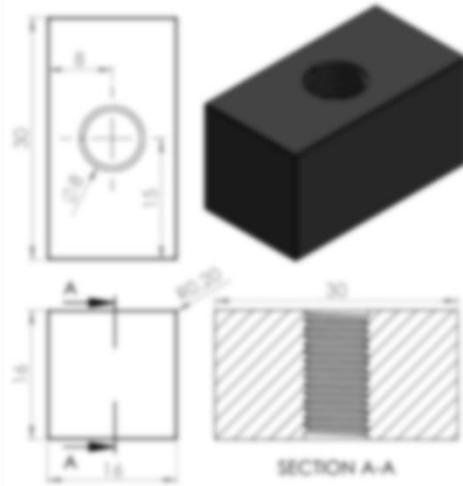
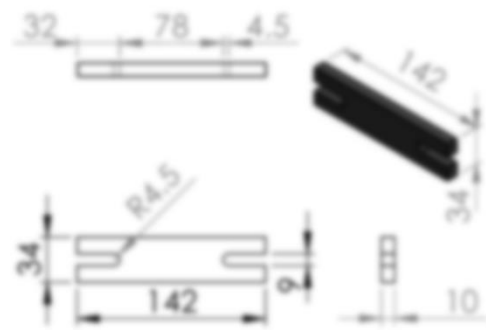
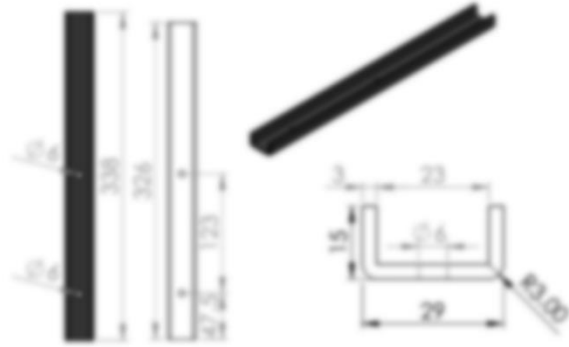


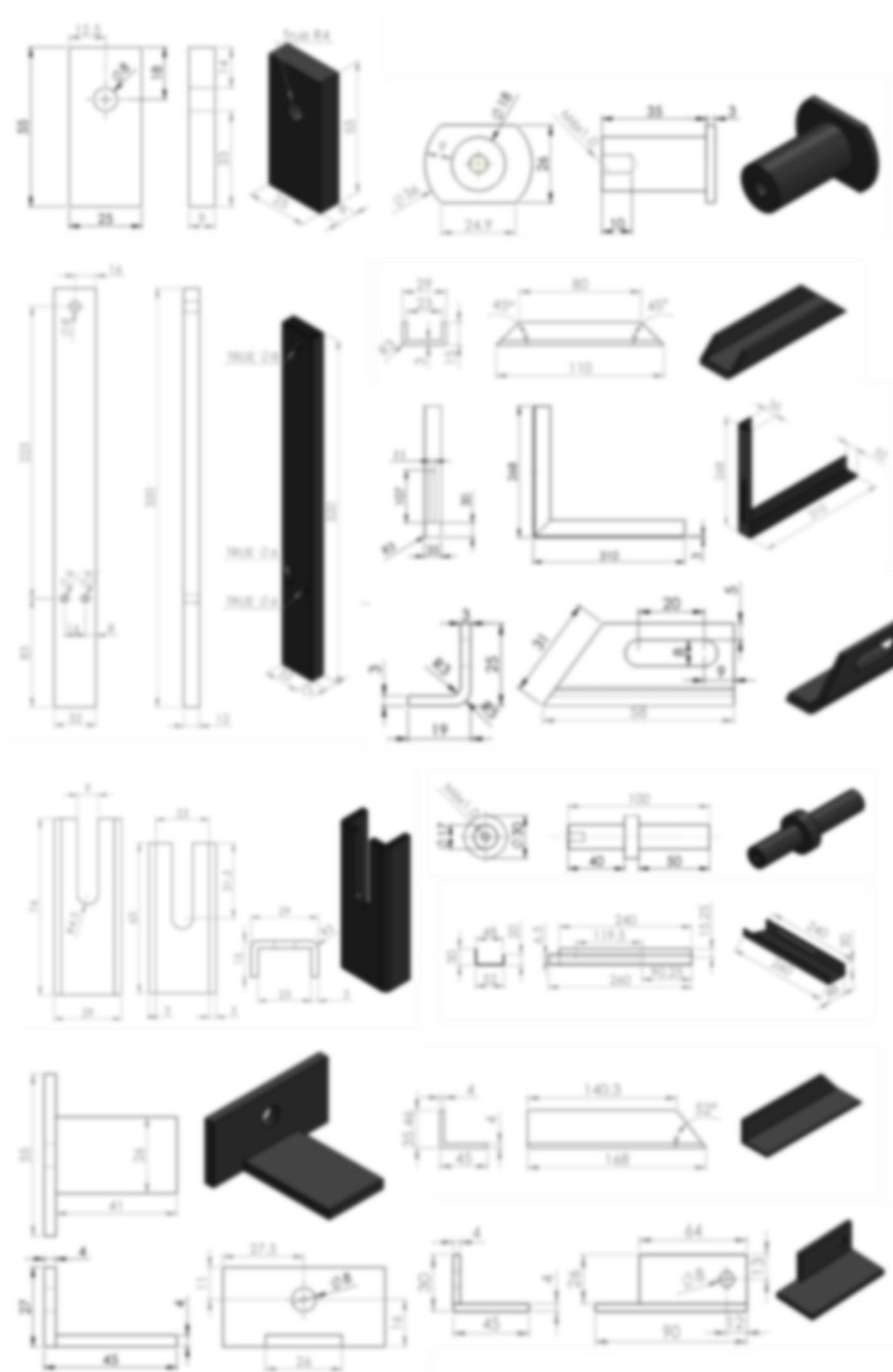
Fig. II. 1. Mechanical Design and Frame Dimensions.

II. 3. 1. 2. Supporting Parts for The Structure

These supporting parts play a critical role in maintaining alignment, reducing friction, and handling loads effectively. Below is an overview of the supporting parts used in this device that are welded to the frame.

Mechanical Design and Dimensions Supporting parts. See the following pictures





II. 3. 1. 3. Structure

The final form of the structure represents a meticulously engineered framework designed to support all components of the device while ensuring optimal performance and durability. By incorporating welded supporting parts such as bearing mounts, guide rails, motor mounts, shaft supports, reinforcements, and control system mounts, the structure provides a stable and reliable foundation for the device's operation. With precise design and expert welding, the structure ensures smooth motion, minimal friction, and efficient handling of loads, contributing to the overall success and functionality of the device.



Fig. II. 2. 3D Drawing of The Structure

II. 3. 2. Feed Mechanism

The feed tray is a vital component of the carding machine, ensuring that fibers are fed smoothly and consistently into the machine for processing. Its design must accommodate the specific requirements of the fibers being processed, with considerations for material, shape, and additional features like vibration mechanisms.

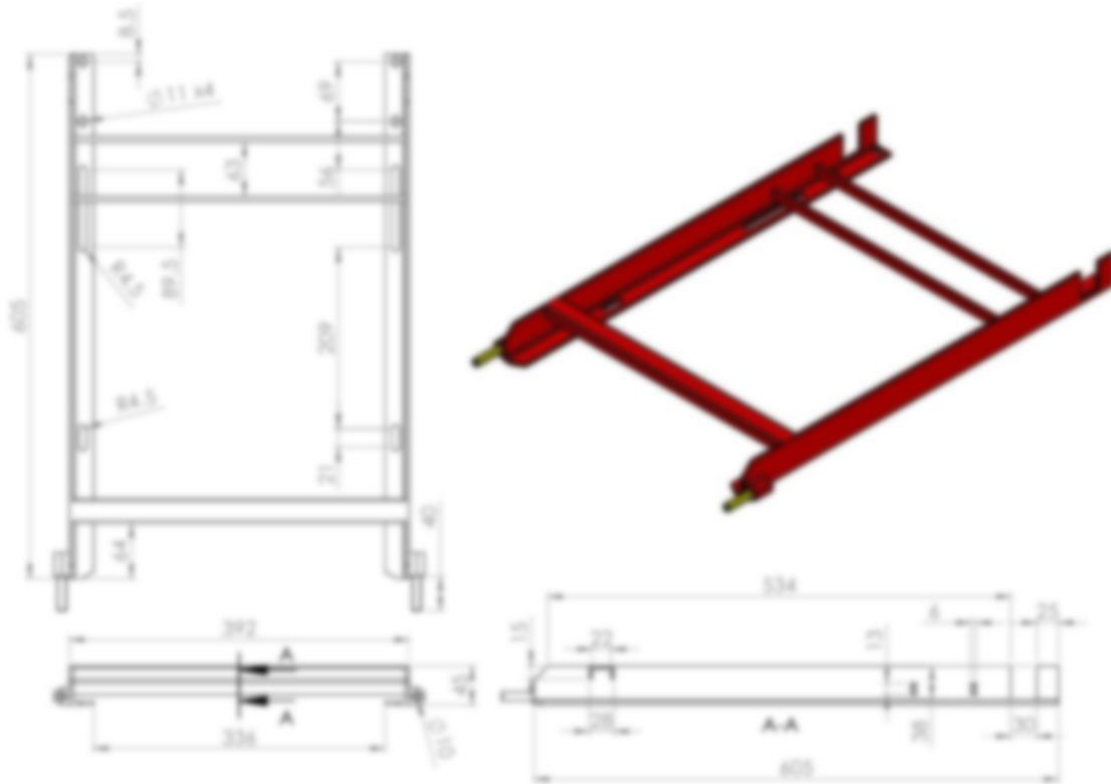


Fig II. 3. Mechanical Design and Dimensions of The Feeding System Base

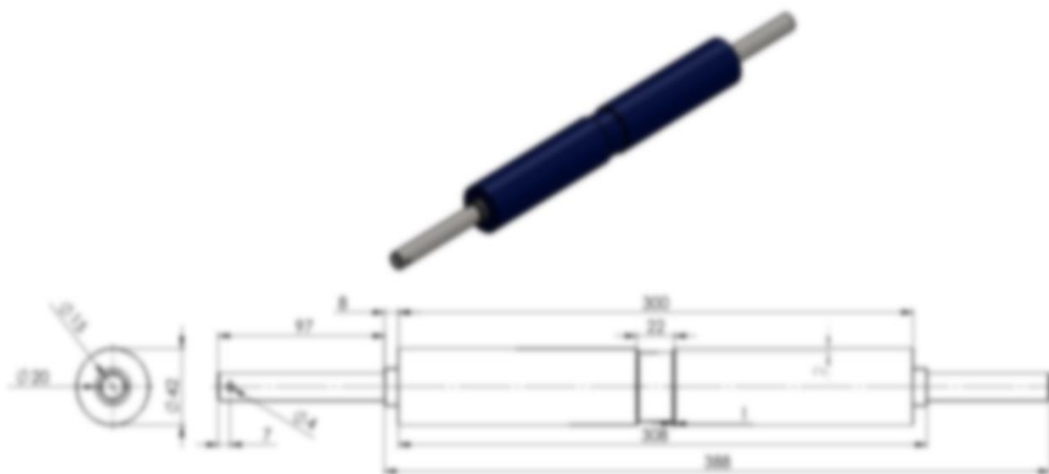


Fig II. 4. Mechanical Design and Dimensions of The Drive Cylinder

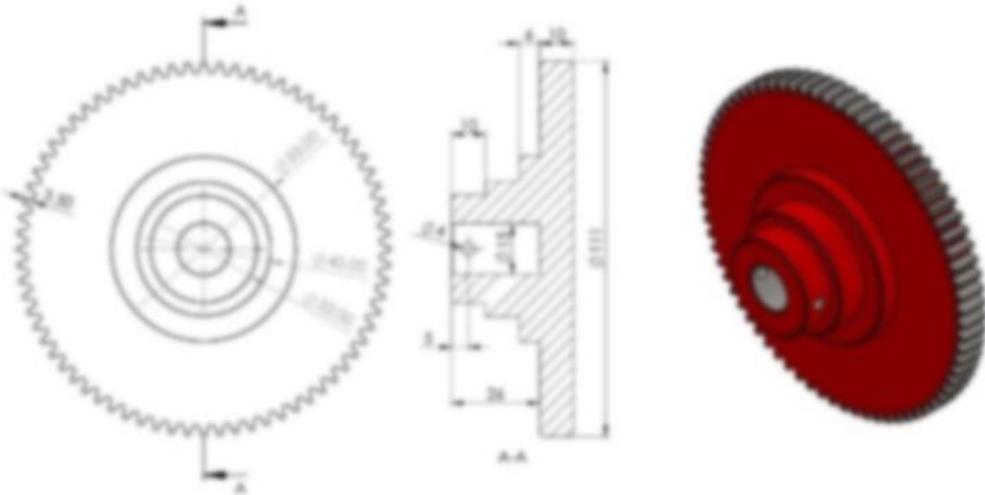


Fig. II. 5. Mechanical Design and Dimensions of The Sprocket

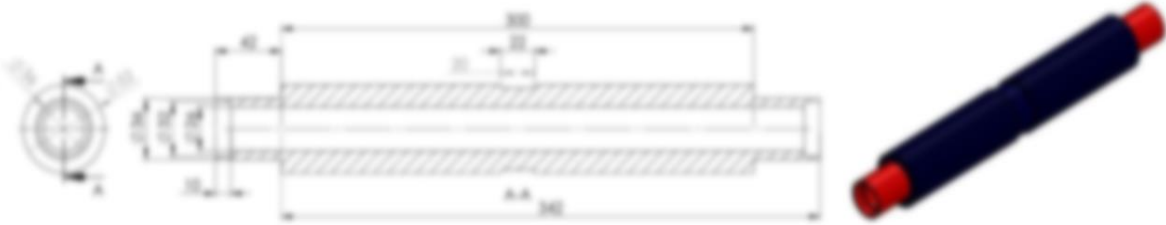


Fig. II. 6. Mechanical Design and Dimensions of the driven cylinder

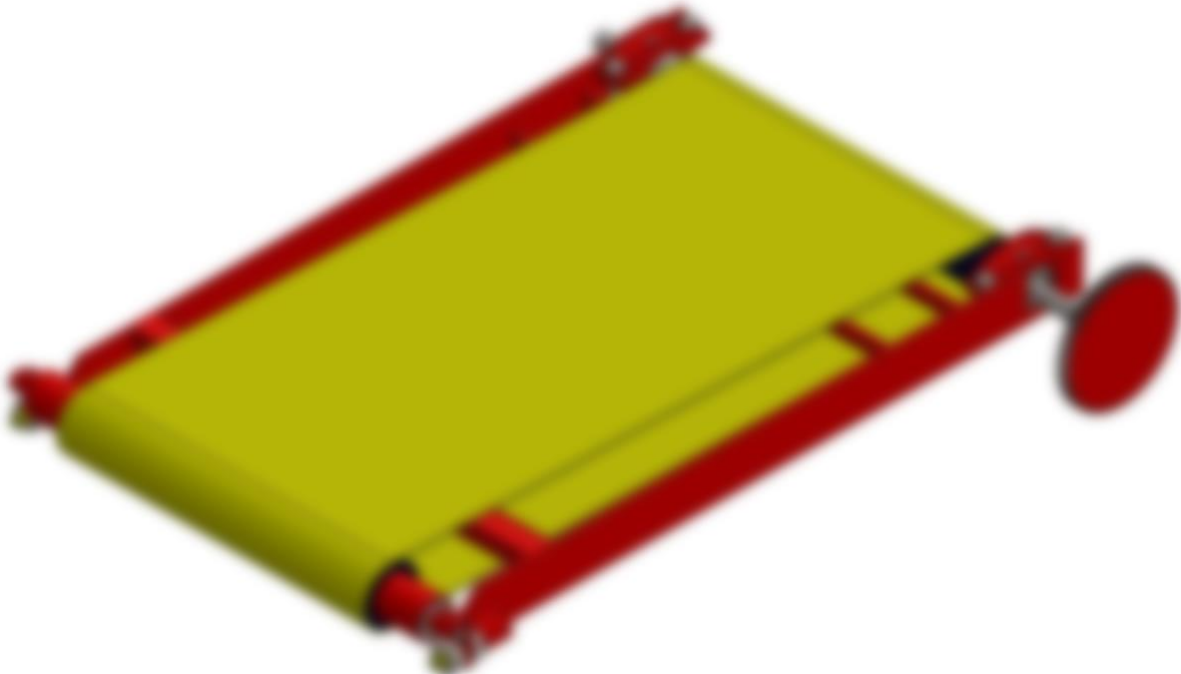


Fig. II. 7. 3D Drawing of The Feeding System.

II. 3. 3. Carding Cylinders

The Carding cylinder is a pivotal part of the Carding machine, responsible for opening, aligning, and cleaning fibers. Its design, including the selection of materials, precision engineering, and integration with other machine components, is crucial for the efficiency and quality of the carding process.

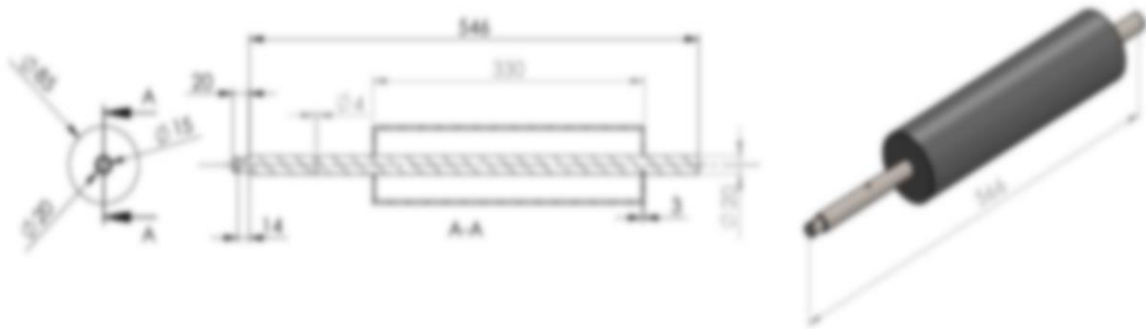


Fig. II. 8. Feed Cylinder

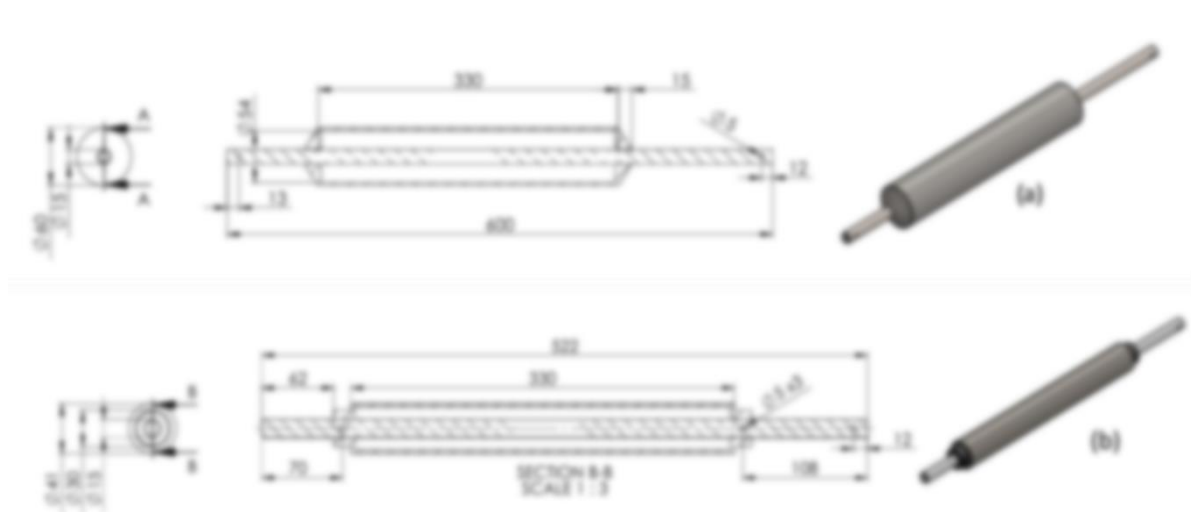


Fig. II. 9. (a) (b) Carding Cylinders

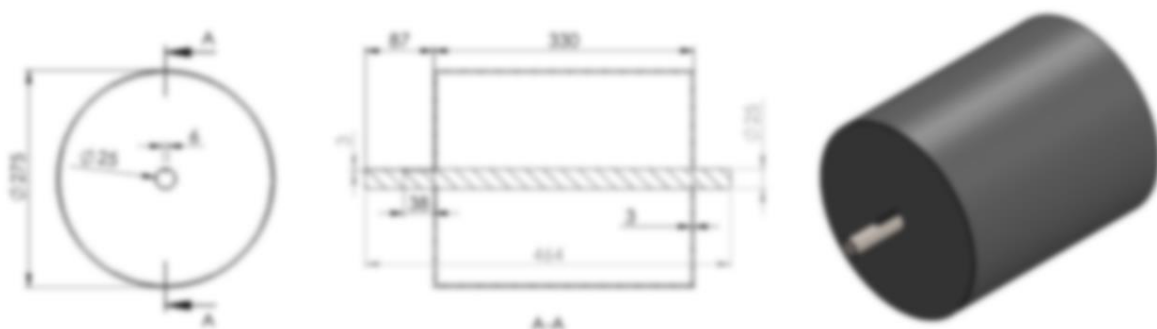


Fig. II. 10. Mother Cylinder

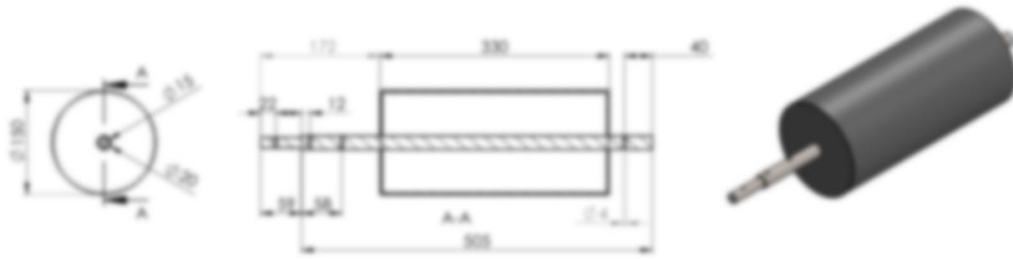


Fig. II. 11. *Output Cylinder*

II. 3. 4. Card Clothing

Card clothing refers to the wire-toothed surfaces used on various components of a carding machine, such as the main cylinder, licker-in, doffer, and flats. Its length depends on the diameter and length of each cylinder.

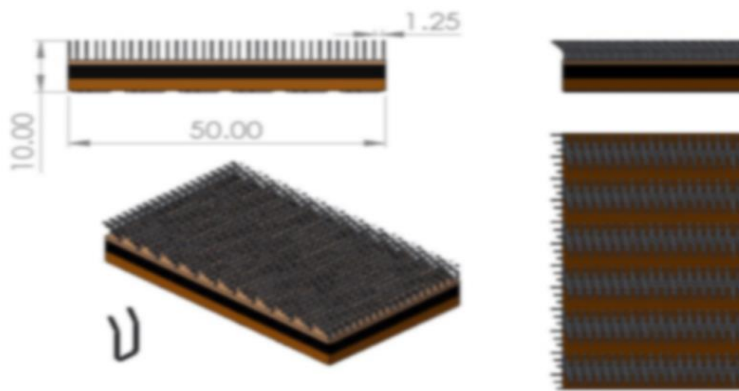


Fig. II. 12. *Mechanical Design and Dimensions of The Card Clothing*

II. 3. 5. Stripping Mechanism

The stripping mechanism is an essential part of the carding machine, ensuring that carded fibers are efficiently and uniformly removed from the doffer roller. Its design, including the selection of materials, precision engineering, and integration with other machine components, is crucial for maintaining the quality and consistency of the carded web or sliver.

II. 3. 5. 1. Fiber Removal Blade

Is a specialized cutting tool designed to separate, align, and clean natural fibers during the carding process in textile manufacturing. This blade is integral to carding machines and plays a crucial role in preparing fibers for subsequent spinning and weaving operations.

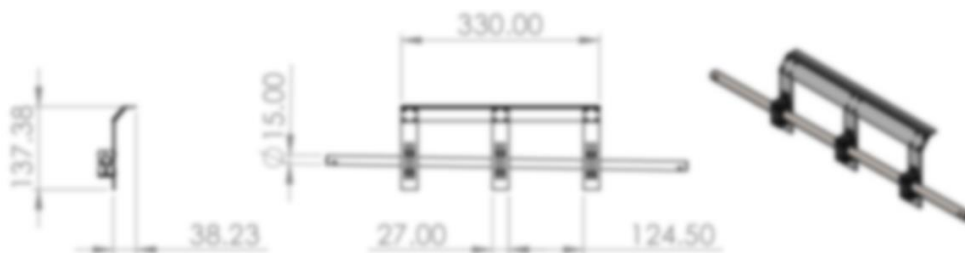


Fig. II. 13. *Mechanical Design and Dimensions of The Fiber Removal Blade*

II. 3. 5. 2. Crankshaft

A crankshaft is a mechanical component that plays a crucial role in converting rotational motion into linear motion or vice versa. In textile machinery, particularly in carding machines, the crankshaft is integral in ensuring the precise and efficient movement of various parts of the machine, which directly affects the quality and consistency of the fibers produced.

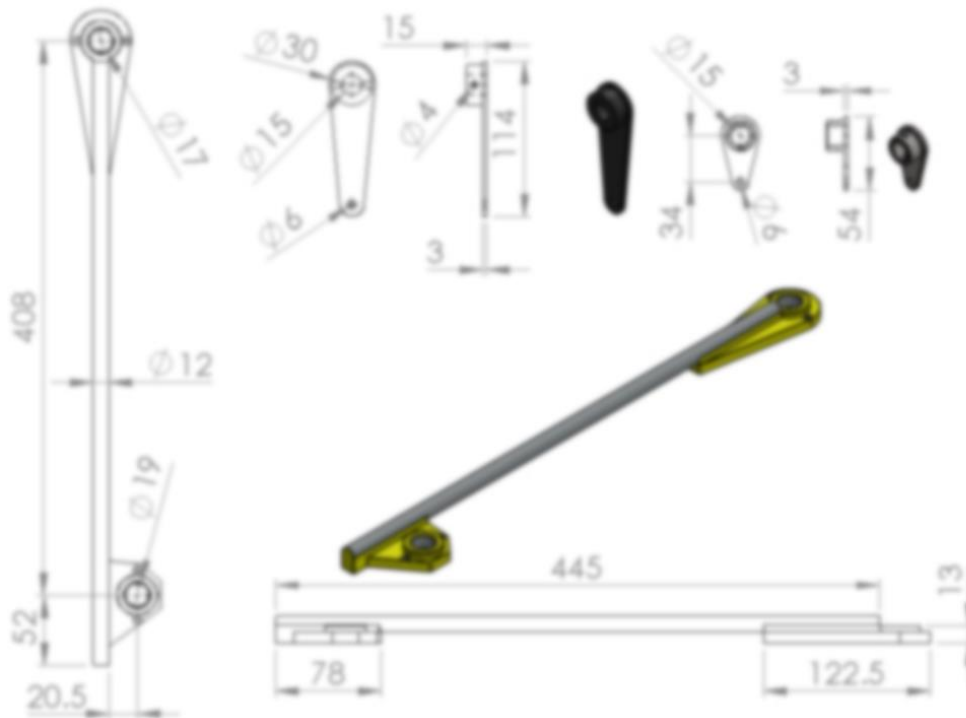


Fig. II. 14. Mechanical Design and Dimensions of The Crankshaft

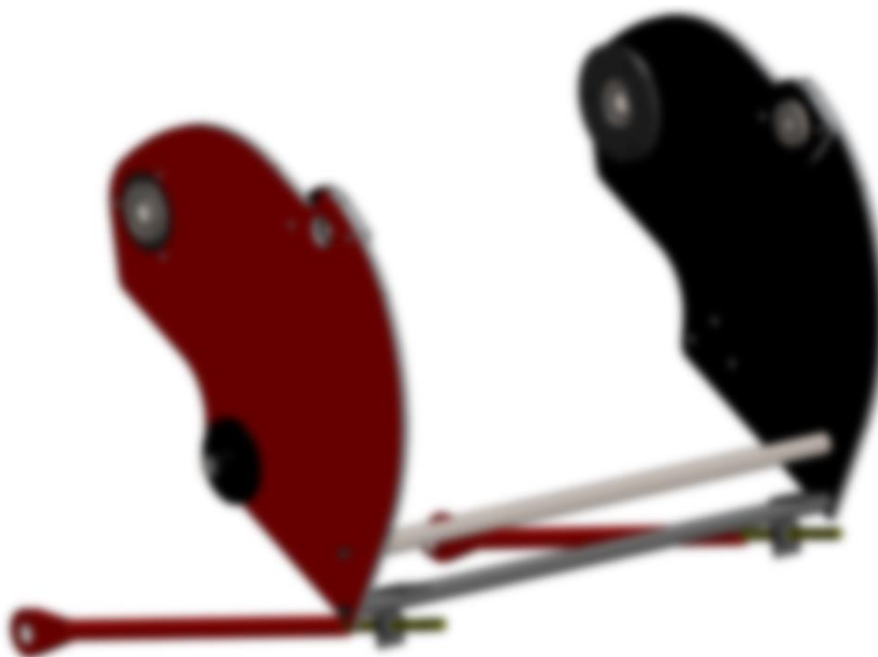


Fig. II. 15. 3D Drawing of The Output System Holder

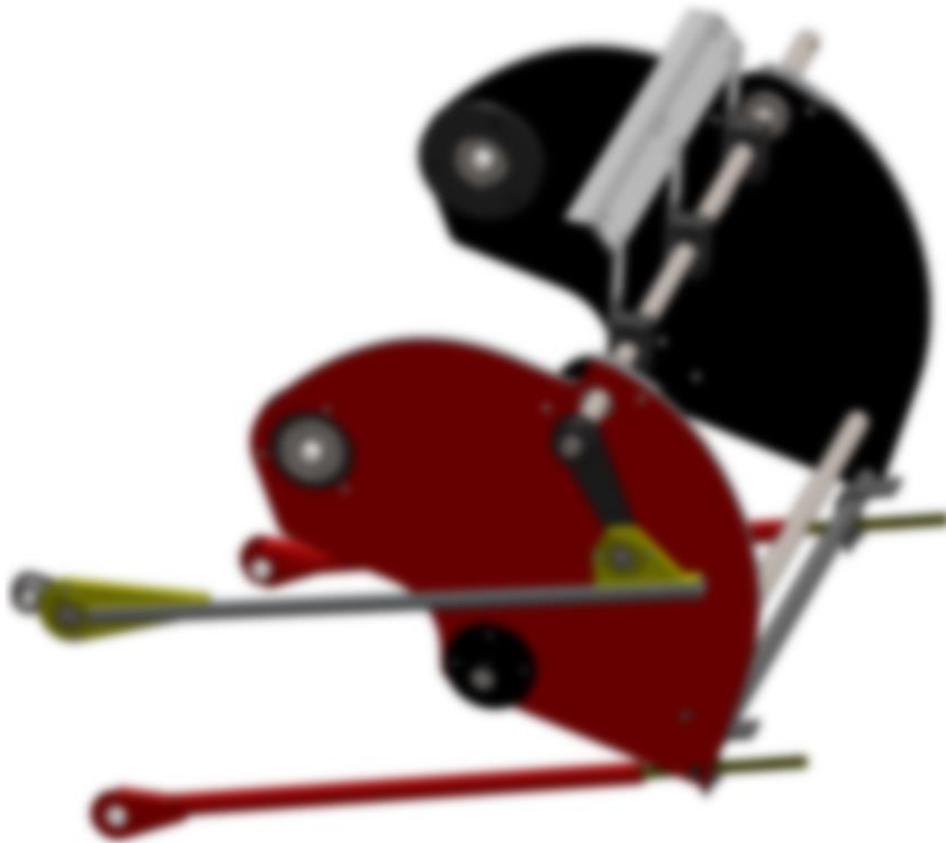


Fig. II. 16. 3D Drawing of The Stripping Mechanism

II. 3. 6. Transmission System

II. 3. 6. 1. Pulleys and Belt

Drive Pulleys: Connected to the motor shaft, transmitting rotational power to other components.

Driven Pulleys: Connected to the shafts of various machine components, receiving power from the drive pulleys.

Belts: Flexible loops that connect the drive and driven pulleys, transmitting rotational motion.

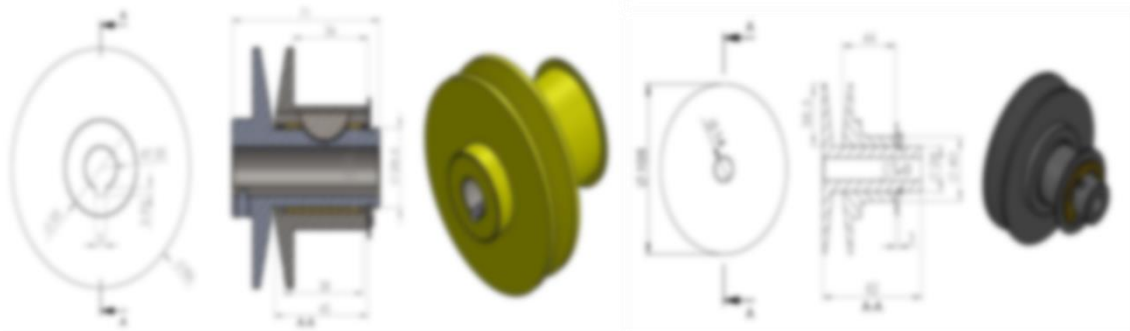


Fig. II. 17. Mechanical Design and Dimensions of The Pulleys

II. 3. 6. 2. Speed Reducer

The speed reducer is a crucial component in the transmission system of a carding machine, responsible for reducing motor speed, increasing torque, and ensuring precise control over machine operations. Its design, including the choice of gears, load capacity, and efficiency, plays a significant role in the overall performance and reliability of the carding process.

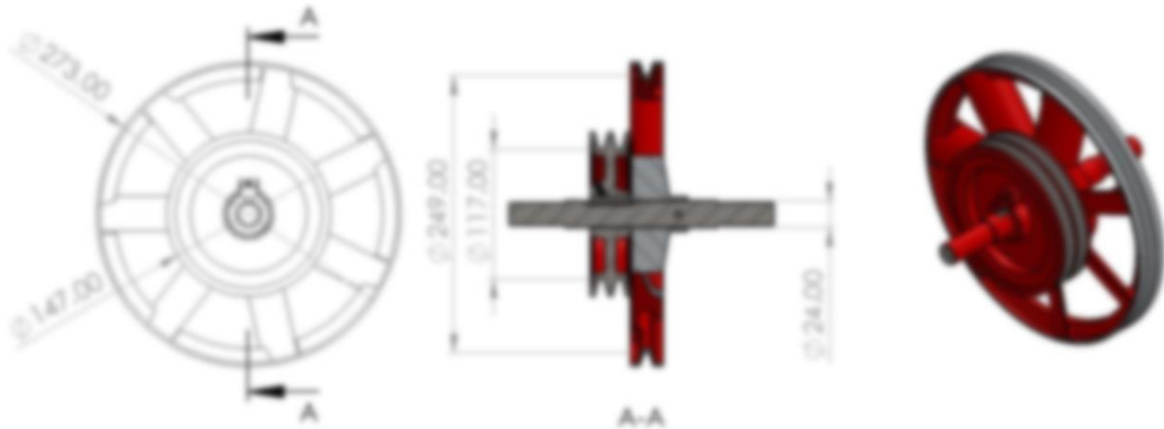


Fig. II. 18. Mechanical Design and Dimensions of The Speed Reducer

II. 3. 7. Gears

Gears are mechanical components that transmit torque and rotational motion between machine parts. They consist of toothed wheels that mesh with each other to transfer power efficiently and accurately. Gears are fundamental in many mechanical devices and systems, from simple machines to complex industrial machinery.

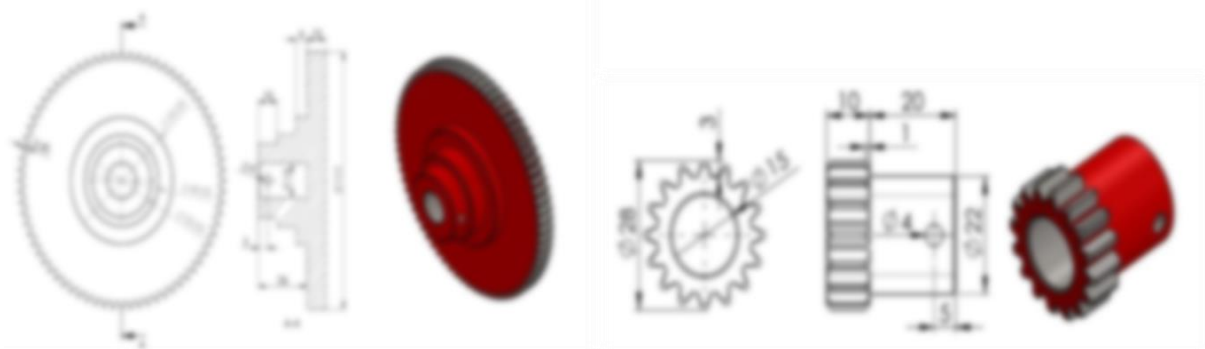


Fig. II. 19. Mechanical Design and Dimensions of The Gears

II. 3. 7. 1. Reduction Gears

Converts high-speed rotation from the motor to slower rotational speeds required by certain components.

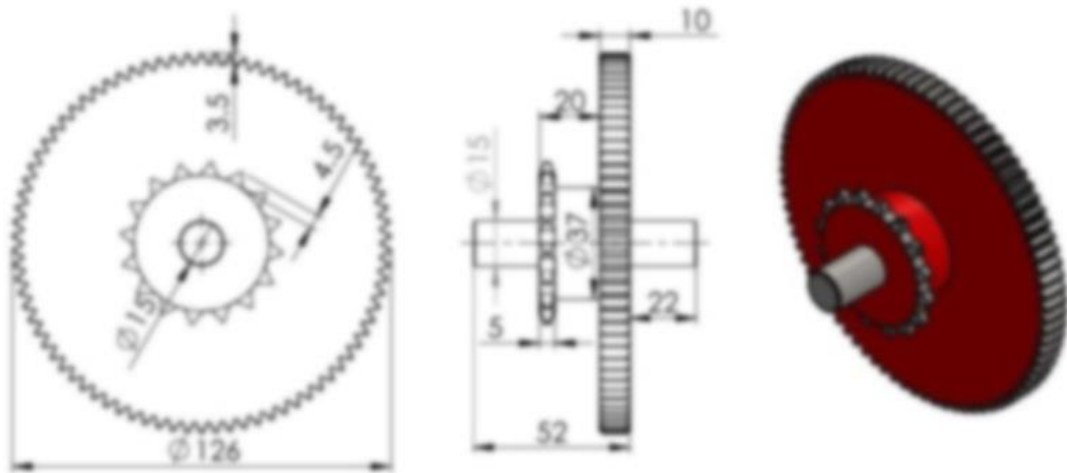


Fig. II. 20. Mechanical Design and Dimensions of The Reduction Gears

II. 3. 7. 2. Chain and Gears

In a mechanical setup, chains and gears are often used together to transmit power and motion between different parts of a machine. This combination leverages the strengths of both components to achieve efficient and reliable operation.

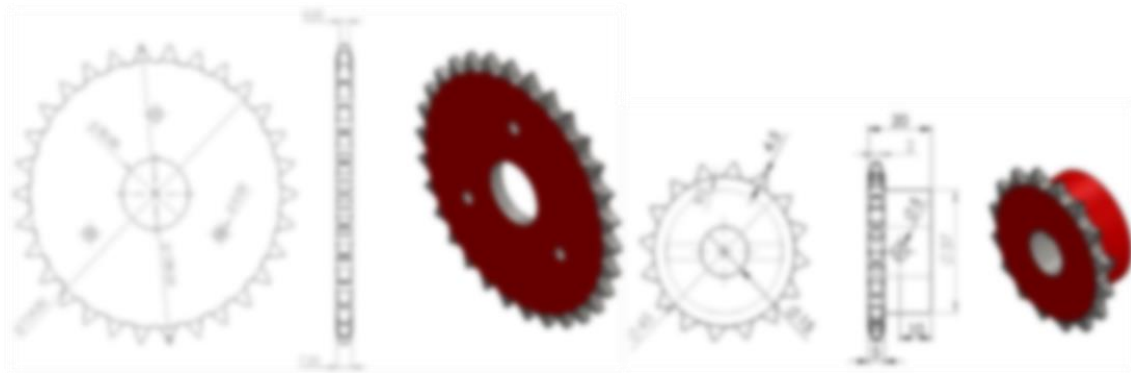


Fig. II. 21. Mechanical Design and Dimensions of The Gears

II. 3. 7. 3. Chain Tensioner

Chain tensioners are crucial components in the transmission system of a carding machine. They ensure that the chains driving various machine parts maintain proper tension, which is essential for efficient and reliable operation. Proper tension prevents slippage, reduces wear, and minimizes the risk of chain failure.

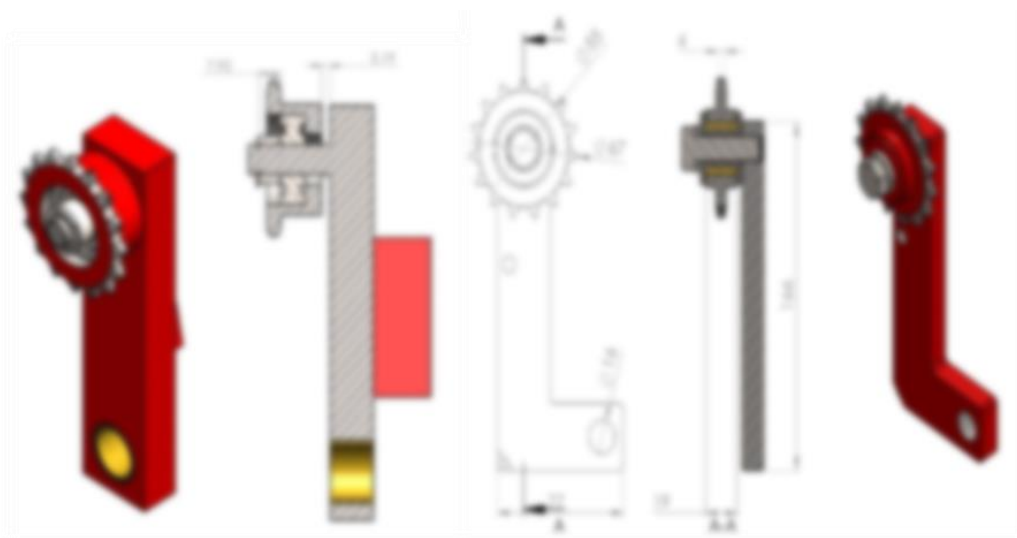


Fig. II. 22. Mechanical Design and Dimensions of The Chain Tensioner

II. 3. 7. 4. Bearing

Bearings are mechanical components that reduce friction between moving parts and support radial and axial loads. They are essential in various applications, from household appliances to industrial machinery, ensuring smooth and efficient operation.



Fig. II. 23. Bearing

II. 3. 8. Bearing Support

In the context of a carding machine, the bearing frame is a structural component that supports and houses the bearings responsible for reducing friction and facilitating smooth rotation of shafts or moving parts. It plays a crucial role in maintaining the alignment and stability of rotating elements, ensuring the efficient operation of the machine.



Fig. II. 24. Mechanical Design and Dimensions of The Bearing Support

II. 3. 9. Control Cabinet Support

A controller holder is a device or accessory designed to support and secure controllers, whether for gaming, industrial, or other electronic devices. It ensures that the controllers are easily accessible, organized, and protected from damage when not in use.

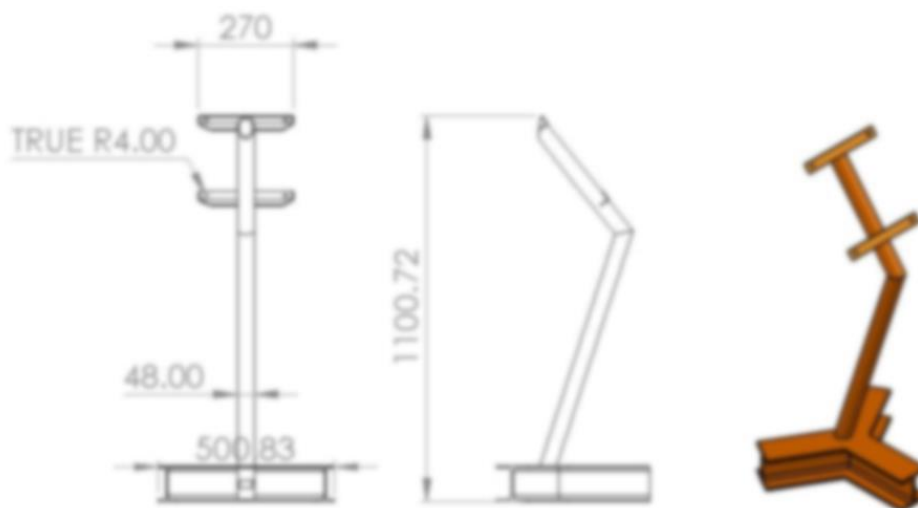


Fig. II. 25. Mechanical Design and Dimensions of The Control Cabinet Support

II. 3. 10. Protection System

In a carding machine, the protection system is essential for ensuring the safety of both the machine and its operators. This system encompasses various safety features and mechanisms designed to prevent accidents, machine malfunctions, and damage to components. A well-designed protection system helps in maintaining a safe working environment, prolonging the lifespan of the machine, and ensuring efficient operation.

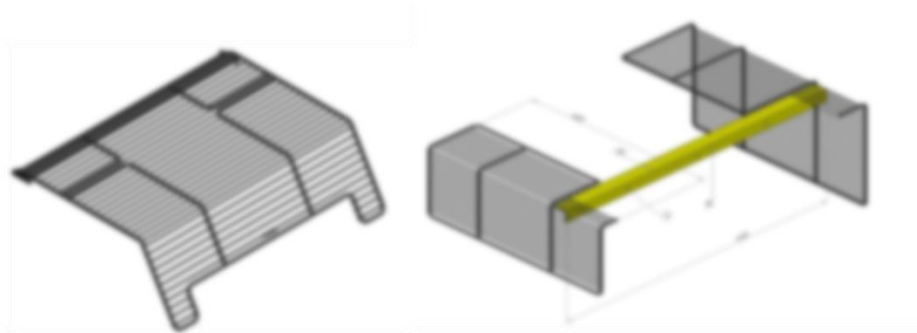


Fig. II. 26. Mechanical Design 3D of The Protection System

II. 4. 3D Drawings of the Carding machine

A 3D drawing of the carding machine represents a detailed and precise visual representation of the machine's components and their spatial relationships. These drawings provide a comprehensive view of the machine's design, including the structure, feeding system, output system, and stripping mechanism.

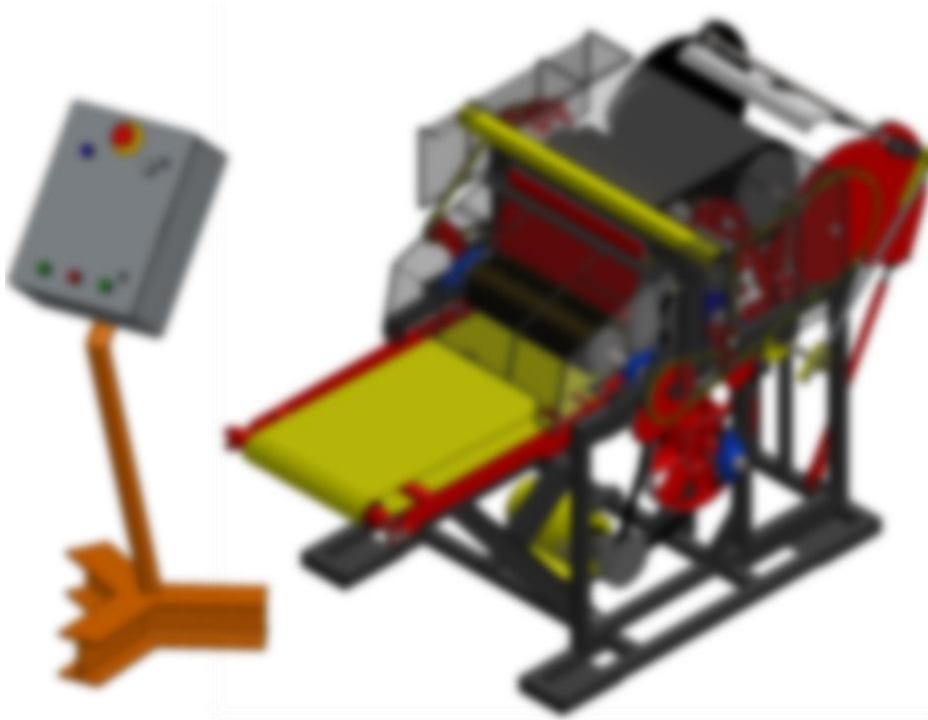


Fig. II. 27. 3D drawing for final prototype

II. 5. Calculated SoM

Resistance of Materials, also known as Strength of Materials (SoM), is a fundamental area of engineering that focuses on analyzing the behavior of materials under various loads and stresses. In the context of a carding machine, SoM calculations are crucial for ensuring the structural integrity and reliability of the machine components. This section provides a detailed approach to calculating the SoM for key parts of a carding machine, including the frame, shafts, and bearings.

II. 5. 1. Objectives

- ✓ To determine the stress and strain experienced by critical components of the carding machine.
- ✓ To ensure that all components can withstand the operational loads without failure.
- ✓ To optimize the material usage and design for durability and efficiency.

II. 5. 2. Key Components for SoM Analysis

1. **Frame:** The structural backbone of the carding machine, supporting all other components.
2. **Shafts:** Transmit rotary motion and power between various parts of the machine.
3. **Bearings:** Facilitate smooth rotation of shafts and reduce friction.
4. **Crankshaft:** Converts rotary motion into reciprocating motion, or vice versa, in certain parts of the machine.

II. 5. 3. Material Properties

Before performing SoM calculations, it's essential to gather the material properties for the components in question. Common properties include:

- ✓ Young's Modulus (E): Measures the stiffness of a material.
- ✓ Yield Strength (σ_y): The maximum stress a material can withstand without permanent deformation.
- ✓ Ultimate Tensile Strength (σ_{uts}): The maximum stress a material can withstand before failure.
- ✓ Poisson's Ratio (ν): Describes the ratio of lateral strain to axial strain.

II. 5. 4. Calculations

II. 5. 4. 1. Stress and Strain Analysis

Axial Stress (σ):

$$\sigma = \frac{F}{A}$$

where F is the applied force and A is the cross-sectional area.

Strain (ϵ):

$$\epsilon = \frac{\Delta L}{L_0}$$

Where (ΔL) is the change in length and (L_0) is the original length.

Young's Modulus (E):

$$E = \frac{\sigma}{\epsilon}$$

II. 5. 4. 2. Bending Stress

For a beam or shaft subjected to a bending moment **M**:

$$\sigma_b = \frac{M \cdot c}{I}$$

where **c** is the distance from the neutral axis to the outermost fiber, and **I** is the moment of inertia.

II. 5. 4. 3. Shear Stress

For a circular shaft subjected to a torque **T**:

$$\tau = \frac{T \cdot r}{J}$$

where **r** is the radius and **J** is the polar moment of inertia.

II. 5. 4. 4. Combined Stresses

When components are subjected to both axial and bending stresses, the combined stress can be determined using:

$$\sigma_{\text{combined}} = \sigma_{\text{axial}} + \sigma_{\text{bending}}$$

II. 6. Calculated Speed in a Carding Machine

The speed at which various components of a carding machine operate is crucial for optimizing the carding process and ensuring the quality of the fibers produced. Proper speed calculation helps in balancing the machine's performance, efficiency, and the quality of the output. This section outlines the methods for calculating the operational speeds of different components within the carding machine, such as cylinders, rollers, and belts.

II. 6. 1. Belt and Chain Speeds

Understanding the rotational speeds of belts and chains in a carding machine is crucial for ensuring efficient power transmission and optimal performance. The rotational speed affects the overall functionality and coordination between different components of the machine. This section explains how to calculate the speeds of belts and chains.

Formula for Rotational Speed

The rotational speed of belts and chains can be calculated using the relationship between the driving pulley (or sprocket) and the driven pulley (or sprocket). The key formulas involve the diameters (or number of teeth in the case of chains) and rotational speeds of these components.

- For belts, the relationship between the driving and driven pulleys is given by:

$$N_2 = \frac{D_1}{D_2} \times N_1$$

- For chains, the relationship is similar but uses the number of teeth on the sprockets:

$$N_2 = \frac{T_1}{T_2} \times N_1$$

where:

- ✓ N_2 = Rotational speed of the driven pulley (Tr/min)
- ✓ D_1 = Diameter of the driving pulley (mm)
- ✓ D_2 = Diameter of the driven pulley (mm)
- ✓ T_1 = Number of teeth on the driving sprocket
- ✓ T_2 = Number of teeth on the driven sprocket
- ✓ N_1 = Rotational speed of the driving pulley (Tr/min)

II. 6. 1. Perimeter Speed of the Cylinder

The perimeter speed (or peripheral speed) of the cylinder in a carding machine is a crucial factor affecting the efficiency of the carding process and the quality of the fibers produced. It refers to the linear velocity at the outer edge of the cylinder as it rotates. This section explains how to calculate the perimeter speed of the cylinder.

Formula for Perimeter Speed

The perimeter speed P of a cylinder can be calculated using the following formula:

$$P = \pi \times D \times N$$

where:

- ✓ P = Perimeter speed of the cylinder (meters per minute, m/min)
- ✓ π = Pi (approximately 3. 1416)
- ✓ D = Diameter of the cylinder (m)
- ✓ N = Rotational speed of the cylinder (revolutions per minute, Tr/min)

By applying previous equations, we get the following results:

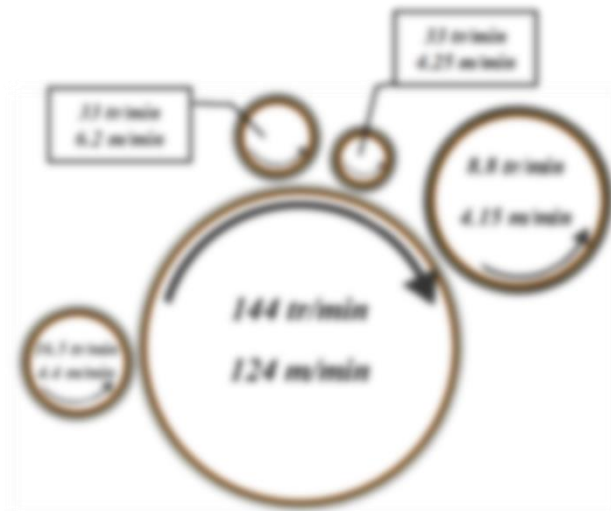


Fig. II. 28. Explanatory Drawing of the Calculated Speed in a Carding Machine

II. 7. Conclusion

In this chapter, we have detailed the design and sizing of the carding machine. Using SolidWorks software, we meticulously developed various components and integrated them harmoniously into a single structure while ensuring the machine's performance flexibility. The design process considered key elements such as structure, feed mechanism, carding cylinders, card clothing, stripping mechanism, transmission system, gears, bearing support, control cabinet support, protection system, and 3D drawings. We also performed necessary calculations and material property analyses to ensure robustness and efficiency. The successful completion of this design phase sets the foundation for the subsequent manufacturing and maintenance processes, which are critical for the development of a reliable and high-performing carding machine.

Chapter III

Manufacturing and

Maintenance of the Machine

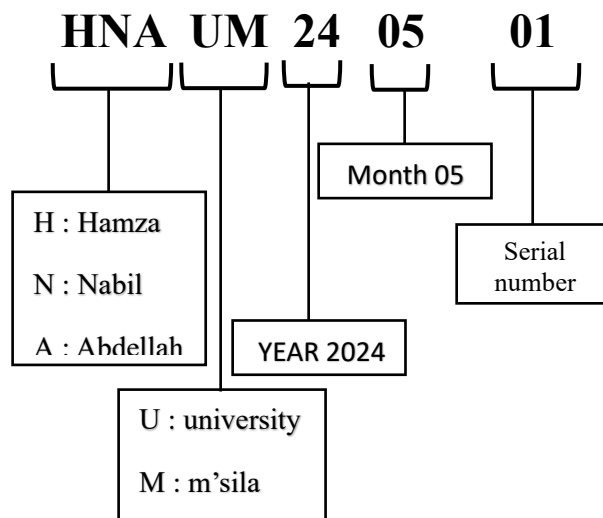
III. 1. Introduction

Manufacturing and experimental testing are critical phases in the development of a carding machine. The success of a carding machine hinges not only on its design but also on the execution of its production and the thorough testing it undergoes. These phases ensure that the machine meets the desired specifications, performs reliably under operating conditions, and maintains quality and efficiency throughout its lifecycle.

The manufacturing process involves selecting appropriate materials, employing precise manufacturing techniques, and assembling components into a fully functional machine. Each step must be carefully planned and executed to ensure that the final product is robust, reliable, and capable of meeting the demands of the textile industry.

Experimental testing, on the other hand, serves to validate the design and manufacturing processes. Through rigorous testing, potential issues can be identified and addressed before the machine is deployed in a production environment. This phase includes performance evaluation, reliability testing, and fine-tuning of the machine to ensure it operates at peak efficiency.

The first thing we started with was choosing the name of the machine, which is **HNA-UM-24-05-01**



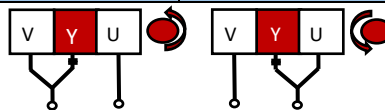
MANUFACTURER LOGO



III. 2. Main Source of Rotational Movement of The Machine

In this machine, the rotational movement is obtained from an electric motor that has the following technical characteristics.

200 W	4 POLE	TYPE	SL- KS
HERTZ	50 60	RAME	A71
VOLT	230 230	JIS C	4004
AMP	1.6 1.5	RATING	CONT
RPM	1440 1740	INS CLASS	B
TERMALY PROTECTION		CAPACITOR	30 μ F
JP	20	BEARING	6202ZZ 6201ZZ
JC	0	SERAL	AK 76030045



III. 3. Rotational Movement Transmission System

After obtaining the rotational movement of the machine, we need equipment to transmit the rotational movement with devices for raising and lowering the rotational movement upon request. After the study we conducted, we chose the following devices.

III. 3. 1. Transmission of Movement by Pulleys and Belts

Gear and pulley drive systems are common methods of transmitting motion from a source to an end load. Almost everyone can recognize belt and pulley drive systems, even without an engineering background.

They are commonly used in everyday devices, but they are also present in industrial machines.

Understanding the differences between the two systems can help design the correct repair and maintenance methods to ensure that they remain in service as long as possible.



Fig III. 1. Transmission of Movement by Pulleys and Belts

Advantages of transmission by pulleys and belts

- ❖ Cost-effective.
- ❖ Simple to use.
- ❖ No need for parallel shaft.
- ❖ Come with jam protection.
- ❖ Load fluctuations are shock absorbed.
- ❖ Reduce noise and vibrations.

III. 3. 2. Transmission of Movement by Gears

Gears are integral to numerous mechanical devices, primarily because they enable gear reduction in motorized equipment. This is essential because a small, fast-spinning motor can generate sufficient power but often lacks the necessary torque—the force that causes an object to rotate or twist. For example, an electric screwdriver requires a significant gear reduction to generate the high torque needed to turn screws, despite the motor itself producing low torque at high speed. Gear reduction decreases the output speed while increasing the torque. Additionally, gears can change the direction of rotation. In a car's differential, for instance, power is transmitted via a shaft running down the car's center. The differential then turns this power 90 degrees to apply it to the wheels.

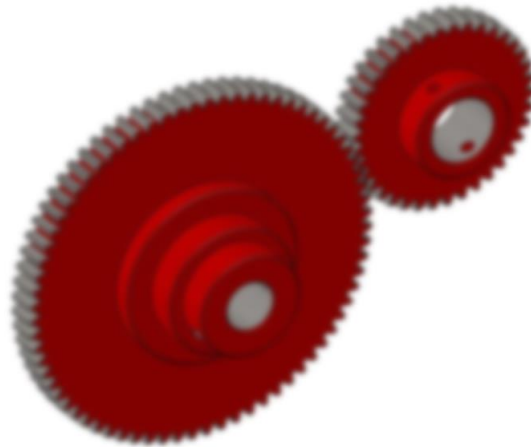


Fig III. 2. Transmission of Movement by Gears.

Advantages of transmission by gears

- ❖ Non-slip drives.
- ❖ High mechanical strength.
- ❖ High transmission efficiency.
- ❖ Suitable for low, medium, and high-power transmission.
- ❖ More compact than belt and chain systems

III. 3. 2. Transmission of Movement by Gears and Chains

Gears and chains are fundamental components in mechanical systems for transmitting motion and power. Gears are ideal for precise adjustments of speed and torque, while chains excel in transferring motion over distances. Together, they enable efficient and versatile designs in various applications, from bicycles to industrial machinery. Regular maintenance and proper design are key to ensuring their longevity and performance.

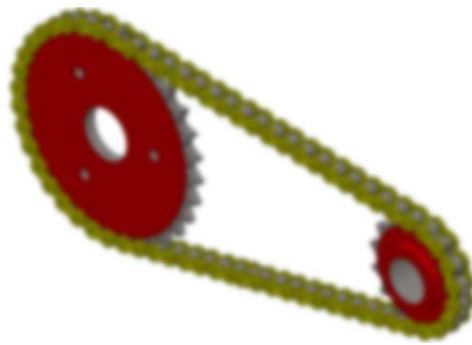


Fig. III. 3. Transmission of Movement by Gears and Chains.

Advantages of transmission by gears and chains

- ❖ No creep in the drive.
- ❖ Consistent angular velocity.
- ❖ Low maintenance costs.
- ❖ High transmission efficiency.
- ❖ Effective operation in wet conditions.

III. 4. Criteria for Material Selection

To ensure the performance, durability, and efficiency of the carding machine, the selection of materials is crucial. The main criteria to consider include:

1. **Mechanical Strength:** Materials must withstand the forces and mechanical stresses exerted during the machine's operation.
2. **Durability:** Materials must resist wear, corrosion, and other forms of degradation to ensure a long machine life.
3. **Weight:** Optimal weight is necessary to maintain machine stability while facilitating transport and installation.
4. **Cost:** Materials must be economically viable to ensure the overall production cost remains competitive.
5. **Environmental Impact:** Selection should consider environmental impact, favoring recyclable and eco-friendly materials.



Fig. III. 4. Some of the Pieces Chosen in Manufacturing

III. 5. Materials for Key Components

III. 5. 1. Cylinders and Rollers

- Materials: Alloy steel, aluminum.
- Justification: Alloy steel offers excellent mechanical strength and high durability. Aluminum, though less strong, is lighter and can be used for parts under less mechanical stress.



Fig. III. 5. Cylinders and Rollers

III. 5. 2. Carding Plates

- Materials: Stainless steel.
- Justification: Stainless steel is chosen for its resistance to corrosion and wear, essential for the carding plates in direct contact with fibers.



Fig. III. 6. Card Clothing

III. 5. 3. Structure and Frame

- Materials: Structural steel, aluminum.
- Justification: Structural steel is robust and offers excellent stability. Aluminum can be used for some parts of the frame to reduce the overall weight of the machine.



Fig. III. 7. Structure

III. 5. 4. Transmission Components

- Materials: Hardened steel, engineering polymers (for certain parts).
- Justification: Hardened steel is used for gears and shafts due to its high wear resistance. Engineering polymers can be used for parts requiring less mechanical strength but good resilience.



Fig. III. 8. Chain and Belts

III. 6. Techniques Used in Assembling Machine Parts

Among the things that must be taken into consideration in designing the machine is how to choose the appropriate technology for assembling the various parts that make up the machine. In this machine, we used several assembly methods:

III. 6. 1. Assembly with Arc Welding

Arc welding is a fusion welding process used to join metals by creating intense heat through an electric arc, which melts and joins the metals. A power source generates an electric arc between a consumable or non-consumable electrode and the base metal. Arc welders can operate using either direct current (DC) or alternating current (AC).

III. 6. 2. Assembly with Bolts and Nuts

A bolt is a mechanical fastener typically used with a nut to connect two or more parts. A bolted joint can be easily disassembled and reassembled, making bolts and screw fasteners more widely used than any other type of mechanical fastener. They have been crucial in the development of mass-produced items and steel structures.

III. 6. 3. Assembly with Rivets:

Rivets are popular mechanical fasteners used to join two or more materials. A rivet consists of a head at one end and a cylindrical body at the other end, known as the shaft, with the tapered end called the tail. Rivets are used to join both large structural pieces and small electronic assemblies. The shafts are hollow and contain an internal piece called a mandrel, which allows the riveter to deform the tail of the rivet without striking it directly.

III. 7. Machines Used in Manufacturing Mechanical Parts

The manufacture of mechanical parts includes a variety of machines, each of which is designed to perform specific tasks. Below is a look at the most important machines used in the machine manufacturing:

1. Lathe Machine:

- **Usage:** The lathe machine is used in manufacturing cylindrical parts such as rollers and shafts. It can shape metals with high precision and produce smooth and uniform surfaces.
- **Advantages:** High precision, capability to manufacture complex parts, production efficiency.

2. Milling Machine:

- **Usage:** The milling machine is used to manufacture flat and contoured parts and to create various shapes and grooves on the metal surface.
- **Advantages:** Versatility, high precision, capable of performing diverse operations on metal parts.

3. Drilling Machine:

- **Usage:** The drilling machine is used to create holes in metal or non-metal materials. Holes can be used in assembling and fitting different parts of the carding machine.
- **Advantages:** Simple and effective, capability to create holes of various sizes, ideal for preparing parts for assembly.

4. Hacksaw Machine:

- **Usage:** Hacksaw machines are used to cut metal parts into required lengths and shapes. They can be used in cutting metal rods and sheets.
- **Advantages:** Effective in cutting large parts, high precision in determining lengths, ability to cut various materials.

5. Computer Numerical Control (CNC) Machine:

- **Usage:** CNC machine is used to manufacture complex parts with high precision through computer numerical control. It can be used in manufacturing most components of the carding machine.
- **Advantages:** High precision, repeatability, flexibility in manufacturing complex parts, reducing human errors.

6. Welding Machine:

- **Usage:** The welding machine is used to assemble various parts of the metal structure and frame of the carding machine. It ensures strong and stable welds.
- **Advantages:** High load-bearing capacity of welds, ability to unify parts of different sizes and shapes, improving structural stability.

By utilizing these diverse machines, precise and efficient manufacturing and assembly of the carding machine can be achieved, ensuring high performance and durability necessary to meet industry requirements.

III. 8. Surface Treatment and Finishing

- **Surface Preparation:** Cleaning, deburring, and preparing surfaces for coating or painting.
- **Coating:** Applying protective coatings, such as powder coating, anodizing, or plating, to prevent corrosion and wear.
- **Painting:** Painting components to meet aesthetic and protective requirements.



Fig. III. 9. Pictures of the Paint Process

III. 9. Integration and Final Assembly

- **Component Integration:** Integrating bearings, motors, sensors, and other critical components into the main assembly.
- **Alignment and Calibration:** Aligning and calibrating moving parts to ensure smooth operation and optimal performance.
- **System Testing:** Performing comprehensive testing of the entire system, including load tests, operational tests, and safety checks.

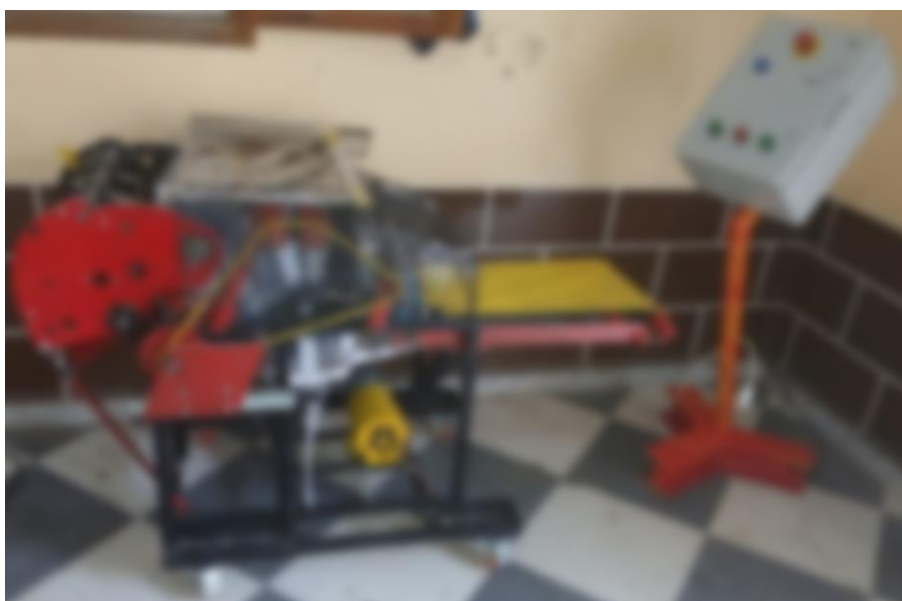


Fig. III. 10. The Final Assembly of The Initial Model

III. 10. Carding Maintenance Program

A well-structured maintenance program is essential for ensuring the continuous, efficient, and reliable operation of carding machines. Such a program will help in minimizing downtime, reducing repair costs, and extending the lifespan of the equipment. Here is a detailed outline of a comprehensive maintenance program for carding machines.

III. 10. 1. Maintenance Schedule

1. Daily Maintenance

- ❖ Inspect the machine for any visible signs of wear or damage.
- ❖ Check and refill lubrication points.
- ❖ Clean accessible areas to remove fiber buildup and debris.

2. Weekly Maintenance

- ❖ Conduct a more thorough inspection of the machine, including hard-to-reach areas.
- ❖ Check the tension and condition of belts and chains.
- ❖ Inspect bearings and other moving parts for signs of wear.
- ❖ Clean or replace filters.

3. Monthly Maintenance

- ❖ Inspect and adjust alignment and calibration of cylinders and rollers.
- ❖ Perform a detailed inspection of the electrical system, checking for loose connections or damaged wiring.
- ❖ Test the functionality of safety mechanisms and emergency stops.
- ❖ Review condition monitoring data and address any anomalies.

4. Quarterly Maintenance

- ❖ Conduct a comprehensive inspection and maintenance of all components.
- ❖ Replace worn parts, such as belts, chains, and bearings.
- ❖ Calibrate and test the entire machine to ensure optimal performance.
- ❖ Update maintenance logs and records.

5. Annual Maintenance

- ❖ Overhaul the machine by disassembling key components for deep cleaning and inspection.
- ❖ Replace major components if necessary.
- ❖ Perform extensive testing to ensure the machine meets all operational standards.
- ❖ Review and update the maintenance program based on the year's performance data and findings.

III. 10. 2. Importance of Maintaining Machine Reliability

According to [23], maintaining machine reliability is essential for minimizing downtime and production losses, enhancing operational efficiency, ensuring workplace safety, and extending equipment lifespan. Regular maintenance activities such as cleaning, lubrication, and calibration contribute to smooth operations and consistent performance [24]. This proactive approach prevents major breakdowns, reduces emergency repairs, and ultimately improves the bottom line [25]. Reliable machines lead to consistent product quality and on-time delivery, which satisfies customer expectations. Regular maintenance also helps companies comply with regulatory standards, avoiding legal and financial consequences [26]. Additionally, it enhances predictability and planning, allowing businesses to better schedule production, allocate resources, and manage inventory [27]. Neglecting machine reliability maintenance increases the risk of catastrophic failures, resulting in extensive damage, loss of production, and potential harm to personnel [28]. Regular maintenance aids in identifying and addressing potential issues before they escalate into major problems. Another advantage of maintaining machine reliability is gaining a competitive edge in the marketplace [29]. Companies with reliable machines can offer consistent product quality, shorter lead times, and superior customer service, setting themselves apart from competitors and attracting more customers.

III. 10. 3. Classifying Equipment for Maintenance

All equipment must first be categorized in order to choose the proper maintenance method for the situation. There are four components of RCM program which are:

1. Reactive Maintenance
2. Preventive Maintenance
3. Predictive Maintenance
4. Proactive Maintenance

Figure (III. 11) below explains the type of maintenance strategy needed for different type of equipment depending on how such equipment is classified in the manufacturing environment.

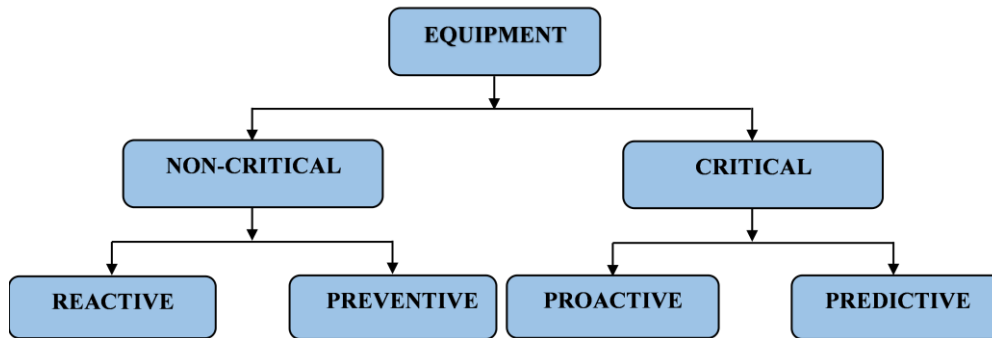


Fig. III. 11. Classifying Equipment for maintenance Source [30].

III. 11. Types Of Maintenance

III. 11. 1. Preventive Maintenance (PM)

Routine Inspections: Conduct regular visual and functional inspections to identify potential issues early.

Scheduled Maintenance: Perform maintenance tasks at scheduled intervals based on manufacturer recommendations and machine usage.

Lubrication: Regularly lubricate moving parts to reduce friction and prevent wear.

Cleaning: Keep the machine clean to prevent the buildup of fibers, dust, and debris.

III. 11. 2. Predictive Maintenance (PdM)

Condition Monitoring: Use sensors and diagnostic tools to monitor machine conditions in real-time (e. g., vibration analysis, thermal imaging).

Data Analysis: Analyze collected data to predict potential failures and schedule maintenance before breakdowns occur.

III. 11. 3. Corrective Maintenance (CM)

Timely Repairs: Address any detected issues promptly to prevent further damage and minimize downtime.

Root Cause Analysis: Investigate the causes of failures to implement corrective actions and prevent recurrence.

III. 11. 4. Reliability-Centered Maintenance (RCM)

Criticality Analysis: Identify and prioritize maintenance activities based on the criticality of machine components and their impact on overall performance.

Optimization: Continuously improve maintenance strategies based on operational feedback and performance data.

III. 12. Conclusion

In this chapter, we have emphasized the importance of manufacturing and maintenance processes in ensuring the reliability and efficiency of the carding machine. The selection of appropriate materials, precise manufacturing techniques, and thorough testing are crucial to meet the desired specifications and maintain quality throughout the machine's lifecycle. We discussed the criteria for material selection, the techniques used in assembling machine parts, and the different types of maintenance strategies, including preventive, predictive, corrective, and reliability-centered maintenance. These strategies help in identifying potential issues early, scheduling timely repairs, and optimizing maintenance activities based on criticality analysis. Implementing a comprehensive maintenance program not only enhances machine performance and extends its lifespan but also ensures consistent product quality and operational efficiency, ultimately providing a competitive edge in the marketplace.

General Conclusion

In conclusion, this study has successfully addressed the design, manufacturing, and maintenance aspects of the carding machine, highlighting the critical components and processes involved in ensuring its optimal performance. The detailed analysis and practical implementations provided throughout the chapters demonstrate the importance of selecting appropriate materials, employing precise manufacturing techniques, and implementing effective maintenance strategies.

The design phase focused on the structural and mechanical aspects of the carding machine, utilizing advanced tools such as SolidWorks for accurate modeling and simulations. The manufacturing phase emphasized the selection of suitable materials and the application of precise assembly techniques to ensure robustness and reliability. The maintenance phase highlighted the significance of various maintenance strategies, including preventive, predictive, corrective, and reliability-centered maintenance, to enhance machine performance and extend its lifespan.

Overall, the comprehensive approach adopted in this study provides valuable insights into the development and maintenance of a high-performance carding machine, contributing to the advancement of the textile industry and setting a foundation for future research and improvements in this field.

REFERENCE

- [1]. LAWRENCE, C. A. Fundamentals of spun yarn technology. Boca Raton: CRC Press, 2003.
- [2]. LEE, M. E. Mathematical models of the carding process: a thesis submitted for the degree of Doctor of Philosophy. Oxford: Trinity College, University of Oxford, 2001.
- [3]. BAGWAN, A. S. , JADHAV, K. Card setting: a factor for controlling sliver quality and yarn. Journal of Textile Science & Engineering, 2016, 6(2), 1–3, doi: 10. 4172/2165-8064. 1000246.
- [4]. Textile Technology Spinning. Process parameters in carding [online]. Fibre2Fashion [accessed 14. 12. 2021]. Available on World Wide Web: <<https://www.fibre2fashion.com/industry-article/3007/process-parameters-in-carding>>.
- [5]. CHELLAMANI, K. P. , CHATTOPADHYAY, D. THANABAL, V. Influence of wire point density in cards and combers on neps in sliver and yarn quality. Indian Journal of Fibre & Textile Research (IJFTR), 2003, 28(1), 9–15, <http://hdl.handle.net/123456789/24736>.
- [6]. SENGUPTA, A. K. , Vijayaraghavan, N. , SINGH, A. Studies on carding force between cylinder and flats in a card. Part I-effect of machine variables on carding force. Indian Journal of Fibre & Textile Research (IJFTR), 1983, 8(3), 59–63.
- [7]. PENGZI, S. Discussion of cylinder speed of carding machine [J]. Cotton Textile Technology, 2001, 4, 32–35.
- [8]. KLEIN, Werner. The Rieter manual of spinning. Vol. 1: technology of short-staple spinning. Wintherthur : Rieter Machine Works, 2014.
- [9]. USTER® STATISTICS: application handbook. Uster : Uster Technologies, 2013, <https://pdfcoffee.com/application-handbook-uster-statistics-2013-pdf-free.html>.
- [10]. KOTB, N. A. Predicting yarn quality performance based on fibers types and yarn structure. Life Science Journal, 2012, 9(3), 1009–1015.
- [11]. Advances in yarn spinning technology. Edited by C. A. Lawrence. Oxford : Woodhead Publishing, 2010.
- [12]. WANG X, Huang W, HUANG XB. A study on the formation of yarn hairiness. The Journal of the Textile Institute, 1999, 90(4), 555–569, doi: 10. 1080/00405000. 1999. 10750053.
- [13]. LORD, E. Manual of cotton spinning. Vol. 2. Part 1. The characteristics of raw cotton. Manchester: Textile Institute, 1961.
- [14]. CHAUDHARI, V. D. , KOLTE, P. P. , DABERAO, A. M. , CHANDURKAR, P. W. Effect of licker in speed on yarn quality. Melliand International, 2017, 4, 193–195.
- [15]. CHAUDHARI, V. D. , Kolte, P. P. , CHAUDHARI, A. D. Effect of card delivery speed on ring yarn quality. International Journal on Textile Engineering and Process, 2017, 3, 13–18.
- [16]. The American Heritage Dictionary of the English Language, Fourth Edition. 2000: Houghton Mifflin Company.
- [17]. Szaloki, Z. S. High-speed carding and continuous card feeding. Institute series on textile processing; vol. 2. 1977, Charlottesville, Virginia: Institute of Textile Technology.
- [18]. Klein, W. A practical guide to the blow-room and carding. Short-staple spinning series; v. 2, 2nd. ed. 2000, Manchester: Textile Institute.
- [19]. Chellamani, K. P. , Chattopadhyay, D. , and Thanabal, V. Influence of wire point density in cards and combers on neps in sliver and yarn quality. Indian Journal of Fibre and Textile Research, 2003. 28(March): p. 9-15.

- [20]. WOOL 482/582 Wool Processing © 2012 The Australian Wool Education Trust licensee for educational activities University of New England.
- [21]. Design of a Carding Machine Modern Main Cylinder Piotr Danielczyk , Jacek Stadnicki University of Bielsko Biala, Departament of Engineering Fundamentals, ul. Willowa 2, 43-309 Bielsko-Biala.
- [22]. Stadnicki, J. , 1997, Optimal Design of the Cylindrical Shell of a Card Machine. Textile Research Journal, 67(1): 6-10
- [23]. T. K. Agustiady, & E. A. Cudney, (2018). Total productive maintenance. Total Quality Management & Business Excellence, 18.
- [24]. P. H. Tsarouhas, (2020). Overall equipment effectiveness (OEE) evaluation for an automated ice cream production line: A case study. International Journal of Productivity and Performance Management, 69(5), 1009-1032.
- [25]. O. Bataineh, T. Al-Hawari, H. Alshraideh, & D. Dalalah, (2019). A sequential TPM- based scheme for improving production effectiveness presented with a case study. Journal of Quality in Maintenance Engineering, 25(1), 144-161.
- [26]. C. Tikkinen-Piri, A. Rohunen, & J. Markkula, (2018). EU General Data Protection Regulation: Changes and implications for personal data collecting companies. Computer Law & Security Review, 34(1), 134-153.
- [27]. M. A. Cohen, & P. Kouvelis, (2021). Revisit of AAA excellence of global value chains: Robustness, resilience, and realignment. Production and Operations Management, 30(3), 633-643.
- [28]. P. Poór, J. Basl, & D. Zenisek, (2019, March). Predictive Maintenance 4.0 as next evolution step in industrial maintenance development. In 2019 international research conference on smart computing and systems engineering (SCSE) (pp. 245-253). IEEE.
- [29]. G. Dess, A. Eisner, G. T. Lumpkin, & G. McNamara, (2019). Strategic Management: Creating Competitive Advantages, 9e.
- [30]. M. A. Tarar (2014, March). Study reliability centered maintenance (RCM) of rotating equipment through predictive maintenance. In Proceedings of the 2nd International Conference on Research in Science, Engineering and Technology (ICRSET'2014), Dubai, UAE (pp. 21-22).