Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 3, No. 3, March : 2024

DESIGN AND FABRICATION OF NON-WOVEN NEEDLE PUNCHING MACHINE

B. Govinda Reddy, Assistant Professor, Department of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Hyderabad bgrmech@gmail.com
P. Shashidar, Assistant Professor, Department of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Hyderabad psr326@gmail.com
K. Santosh Kumar, Assistant Professor, Department of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Hyderabad santoshmech09@gmail.com
D. Kareemulla, Student of Mechanical (MCT) Engineering Dept., MGIT, Hyd. dkareemulla_mct201408@mgit.ac.in
G. Abhinay, Student of Mechanical (MCT) Engineering Dept., MGIT, Hyd. abhinaysachin@gmail.com
K. Sai Charan, Student of Mechanical (MCT) Engineering Dept., MGIT, Hyd. Saicharaankmb4@gmail.com
M. Srinivas, Student of Mechanical (MCT) Engineering Dept., MGIT, Hyd. Msrinivas_mct201427@mgit.ac.in

Abstract:
Needle-punched Nonwoven fabrics are made from various fibrous webs (usually carded webs) in which fibers are bonded together mechanically through fiber entanglement and frictions after fine needle barbs repeatedly penetrated through the fibrous web. Needle-punched fabrics have characteristic periodicities in their structural architecture that result from the interaction of fibers with the needle barbs. Fiber segments are re-orientated and migrated from the surface of the web towards the interior of the fabric, forming pillars of fiber orientated approximately perpendicular to the plane Non-woven fabrics are used in the creation of a variety of household and medical goods, in the agricultural industry and in land application uses, just to name a few. Non-woven fabrics are popular, not only because they can be made quickly, but also because they are very cost-effective to make. These fabrics can also be reused and recycled, which adds to their appeal.
Key words: Needle punching Machine, Fiber Binding Machine

I. Introduction
1.1 History
The history of nonwoven needle punching machines is closely tied to the development and evolution of nonwoven fabrics. Nonwoven fabrics are engineered textiles that are not woven or knitted but are instead manufactured by bonding or interlocking fibers together. Needle punching is one of the key methods used in the production of nonwoven fabrics.

Fig 1.1 Non-woven needle punching machine layout

1. Early Development of Nonwovens (Pre-20th Century):

- Nonwoven textiles have a long history, with early examples dating back to ancient civilizations where felting processes were used to create nonwoven fabrics.
- Traditional methods such as felting, matting, and other manual techniques were employed to produce nonwoven materials.

2. Modern Era (21st Century):

- In the 21st century, nonwoven needle punching machines continue to evolve with advancements in automation, precision, and efficiency.
- Manufacturers focus on developing machines that can handle a variety of fibers and meet the specific requirements of different applications.

1.2 Felting Needles

Felting needles are specialized needles used in the art and craft of felting, a process that involves matting and condensing fibers together to create a fabric or three-dimensional object. Felting needles have small barbs or notches along their shafts, and these barbs play a crucial role in entangling and interlocking the fibers during the felting process. There are several types of felting needles, each serving a specific purpose in the felting techniques:

1. Barbed Needles: Felting needles are often barbed or have small notches along their length. These barbs catch and entangle the fibers as the needle is pushed through the material.

Fig 1.2 Barbed Needle

2. Single-Pointed Needles: Most felting needles are single-pointed, resembling traditional sewing needles. These needles allow for precision in the felting process, making them suitable for detailed work.

Fig 1.3 Single point Needle

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 3, No. 3, March : 2024

3. Multi-Needle Tools: Some felting projects, especially larger ones, may require the use of multiple needles simultaneously. Multi-needle tools or holders hold several needles together, allowing for faster felting and covering larger areas.
4. Gauges and Sizes: Felting needles come in various gauges and sizes. The gauge refers to the thickness of the needle, and the size relates to the length of the needle. Different gauges and sizes are suitable for various types of fibers and projects.

1.3 Basic Mechanism

The basic mechanism of a nonwoven needle punching machine involves the use of barbed needles to mechanically interlock and entangle fibers, creating a cohesive nonwoven fabric. Here is a step-by-step explanation of the basic mechanism:

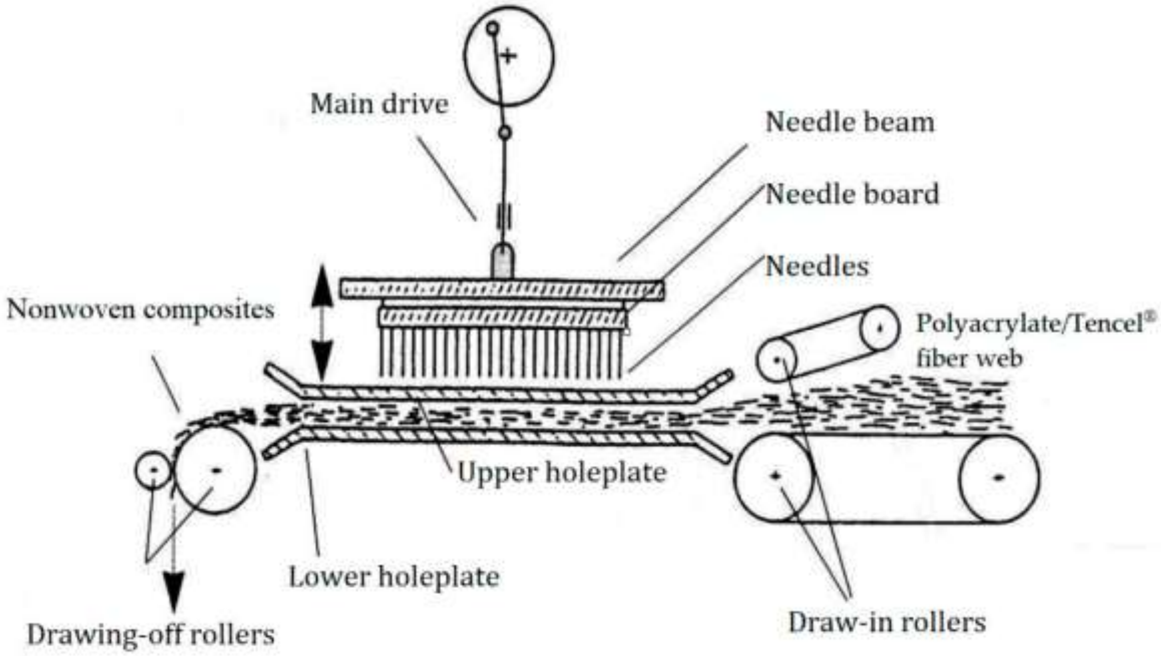

Fig 1.4 Mechanism

1. Web Formation: The process begins with the formation of a fibrous web. This web is typically made up of loose or carded fibers, which may be natural, synthetic, or a combination of both.
2.Feeding the Web: The fibrous web is fed into the needle punching machine. Depending on the specific type of machine, the web may be layered or cross laid to achieve desired characteristics in the final nonwoven fabric.
3. Needle Board: The heart of the needle punching machine is the needle board. This board contains numerous barbed needles arranged in a specific pattern. The number and density of needles can vary based on the machine type and application.
4. Needle Penetration: As the fibrous web passes over the needle board, the barbed needles repeatedly penetrate the web. The needles punch through the layers of fibers, carrying some of the fibers along with them.
5. Entanglement and Interlocking: The barbs on the needles play a crucial role in entangling and interlocking the fibers. As the needles withdraw, the barbs catch and pull fibers from the web, creating a network of entangled fibers. This mechanical entanglement is what gives nonwoven fabrics their strength and stability.
6. Web Consolidation: The repeated action of the needles passing through the web consolidates the fibers and forms a cohesive fabric. The density of the needle punches, as well as the arrangement of needles, influences the properties of the final nonwoven material.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 3, No. 3, March : 2024

II. Current Challenges

The current non-woven needle punching machine faces challenges in terms of efficiency, reliability, and adaptability to varying materials. The existing technology may result in inconsistent product quality, increased downtime due to frequent maintenance issues, and limitations in handling different types of non-woven materials. Additionally, there may be concerns related to energy consumption and environmental impact. This project aims to address these challenges by developing an advanced non-woven needle punching machine that enhances overall performance, minimizes downtime, ensures consistent product quality, and is versatile enough to handle a variety of non-woven materials. The solution should also consider energy efficiency and sustainability aspects to align with industry standards and regulations.

III. Fabrication

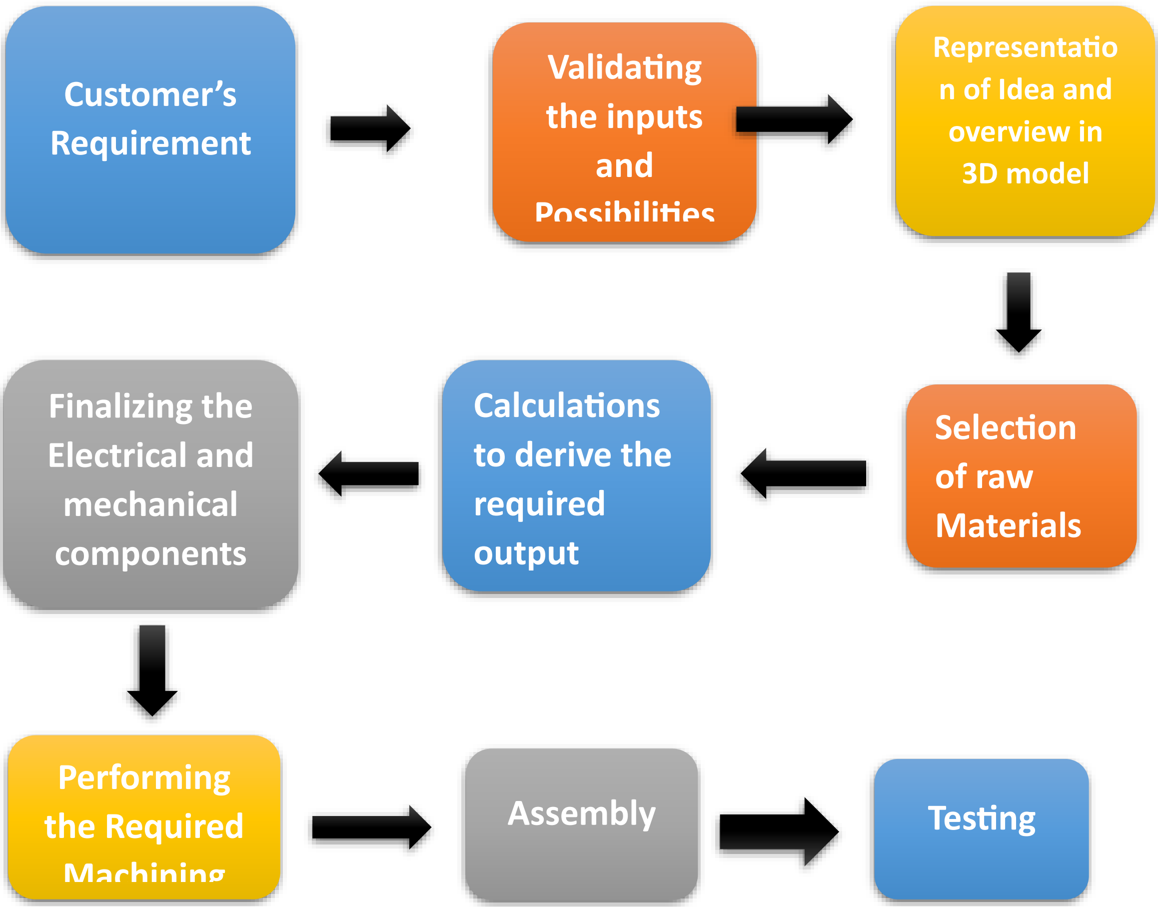

Fig 3.1 Flow Chart of the Design and Development of the Machine

3.1 Requirement

1. Work: The machine should be capable of processing natural Fibers, synthetic Fibers, and specialty Fibers (e.g., Rayan, acrylic, jute, cotton, polyester,)

2. Fiber thickness range:

Thickness of fiber = 0.1-1mm
Material thickness = 1-10mm
Number of fiber cloth layers: 10-100 layers
Stitching multiple fibers: 10mm (gap between the needles)
Cloth/mat size: 300mm x 300mm

3. Variable strokes: strokes 1 – 100~200/ per minute

4. Control system: PLC – Programable Logic System, VFD – Variable Frequency Drive,HMI – Human-Machine Interface

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 3, No. 3, March : 2024
In order to meet the needs of the customer demands Needle punching machines can process a wide range of fibrous webs. They can be used with nearly all existing fibers, Including natural, man-made, and Filaments. Some needle-punching machines can adapt to use high-performance fibers like synthetic, silica, carbon, etc.
Needle Punching machines can also process different blends of fibers, for example, jute can be blended with recycled polyesters and low melt melt bi- component fibers to produce needle punched non-woven fabrics for thermal insulation. Size and Gauge sizes of the needle and type of the needle will play a major role in meeting the above requirements.
By selecting the crank mechanism, we can covert the rotary motion of a motor in a linear motion, which we call it strokes in the needle punching machine. Based the Motor selection we can achieve various strokes in the machine. So finally, it depends on the selection of mechanical components.
Integration of all PLC, VFD, HMI is possible, as these provide a automation of the work and helps the User a lot in controlling the whole machine through just handling HMI (human-machine interface). PLC command the motor and controls the required operation .

Fig 3.2 3D model

Components:
1. Base
2. Pillar rods
3. Industrial Lead screw
4. Mounting plate of needles
5. Adjustable plate
6. Connecting rod and crank
7. Housing plates
8. Gear box mounting plate
9. Motor mounting plate
10. VFD
11. PLC

3.2 Theoretical calculations
Assumed data:
No of strokes (vertical motion of needles) per minute =10-1000
Selection of body parts thickness – based on the market availability thickness of MS plates are = 10 to 50(mm)
>Selected thickness of aluminum plate = 35mm
>Required thickness = 32mm
Total weight – 40kgs (weight of aluminum plate – 30kgs + weight of crank mechanism)

1. Required DC motor:
Havells: KW(HP): 3.7(5)
Rpm:2920
Volts:415

Torque: 12 N-m
Power factor :0.8pfc
Required torque to lift the 50kgs weight
Torque(T)=1/2(D x W)
D=Drum diameter
W=Load in Newtons
T= Force x radius = mass x acceleration due to gravity x radius of crank = 50 x 10 x 0.05 = 25 N-m

2. Required Gear box:
5:1 type-worm wheel (gear)
Rpm = motor rpm/5
= 2920/5
=584(gearbox rpm)
Output torque – 12x5 – 60 Nm
Worm gears can be used to increase torque or reduce speed. They can achieve ratios of more than 300:1
Through this gear box rpm is reduced and torque increased as per the gear ratio

3. Transmission system:
Pully system
Driver wheel > Driven pully (2:1)
The rpm from gear box is multiplied by 2 to that is
584 X 2 = 1168 rpm
Due to change in ratio, torque is halved to 30 N-m which is more than our required torque and Final rpm = 1168

3.3 Control box Circuitry with PLC integration

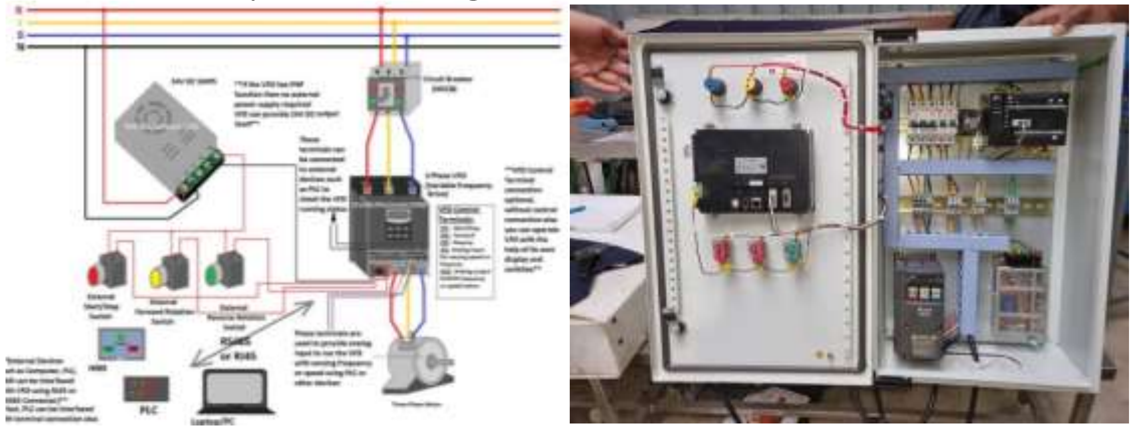

Fig. 3.3 Internal circuitary diagram and control box

IV. Machine future developments, advantages and disadvantages

As industries continue to evolve, the needle punching machine stands as a testament to the ingenuity and adaptability of manufacturing technologies. Its impact resonates not only in the products it creates but also in the efficiency, versatility, and innovation it brings to the ever-expanding landscape of industrial production.

4.1 Advantages

1. Versatility:
These machines are versatile and can process a variety of fibers, including polyester, polypropylene, and other synthetic materials, as well as natural fibers like cotton and wool.

2. High Production Speed: Needle punching machines can operate at high speeds, leading to efficient and rapid production of non-woven fabrics.

3. Uniform Fabric Properties: The needle punching process ensures uniform distribution of fibers, resulting in consistent fabric properties such as thickness, density, and strength.

4. Customizable Fabric Characteristics: By adjusting parameters such as needle density, punching depth, and feed rates, manufacturers can tailor the characteristics of the non-woven fabric to meet specific requirements.
5. Cost-Effectiveness: Needle punching is a cost-effective method for producing non-woven fabrics, making it economically viable for a range of applications.
6. Durability and Strength: The entanglement of fibers during the needle punching process enhances the fabric's durability and tensile strength, making it suitable for various end uses.
4.2 Disadvantages
1. Complexity: PLC integration can add complexity to the machine's operation, making it more challenging for operators who are not familiar with PLC programming and troubleshooting.
2. Initial Cost: The upfront cost of integrating a PLC into the machine may be higher compared to non-PLC counterparts, potentially making it less cost-effective for smaller-scale operations.
3. Maintenance and Repairs: PLCs require specialized knowledge for maintenance and repairs. In the event of a PLC malfunction, it may take longer to diagnose and fix the issue, leading to downtime.
4. Dependency on Skilled Personnel: Effective utilization of a PLC requires skilled personnel who understand the programming language and operation. Dependency on a limited pool of skilled workers can be a disadvantage.
4.3 Applications
1. Textiles and Apparel: Production of non-woven fabrics for clothing and fashion accessories. Manufacturing of interlinings, padding, and insulating materials for garments.
2. Automotive Industry: Making automotive interior components such as carpets, headliners, and seat padding. Producing filters for air, fuel, and oil applications in vehicles.
3. Geotextiles: Creating geotextiles for use in civil engineering projects like road construction, erosion control, and drainage systems.
4. Filtration: Manufacturing filter media for air and liquid filtration applications, including HVAC systems, water purification, and industrial filtration.
5. Construction: Production of non-woven materials used in construction applications, such as roofing underlayment, insulation, and soundproofing.
6. Medical and Hygiene Products: Manufacturing of non-woven materials for medical gowns, masks, surgical drapes, and wound dressings. Producing hygiene products like diapers, sanitary napkins, and wipes.

V. Conclusion

In the manufacturing of a needle punching machine represents a significant stride in advancing industrial capabilities across various sectors. This versatile machine, designed for precision and efficiency, caters to the growing demand for non-woven fabrics in applications ranging from textiles and automotive to construction and healthcare. The needle punching machine's ability to intricately interlace fibers, creating robust and uniform non-woven fabrics, underscores its pivotal role in modern manufacturing. This technology addresses diverse needs, from enhancing the durability and strength of automotive components to providing essential materials for medical and hygiene products.

5.1 Credit authorship contribution statement

Gottiparthi Abhinay: Team leader, research coordination, project conceptualization, designing, fabrication writing and editing. **Dudekula Kareemulla:** Data collection, literature review, documentation integrity, fabrication. **Konda Sai Charan:** Intermediate fabrication, process optimization, quality control. **Mitta Srinivas:** Materials sourcing and procurement, inventory management, documentation assistance. **B. Govinda Reddy** Guidance, mentorship, Automation. **P.Shashidar:** Guidance, mentorship, research methodology expertise. **K. Santosh Kumar:** Guidance, mentorship, documentation and drafting. **K. Rajshekhar Reddy:** Workshop owner, mentor, and sponsor.

5.2 Declaration of competing interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
5.3 Acknowledgements
We are glad to acknowledge **Mr. K RAJASHEKAR REDDY**, to provide guidance and resources to complete the project and research at **HITANSHI INNOVATIONS.**

References
[1]R. N. Merchant, “Surgical face masks in the operating theatre.,” J. Hosp. Infect., vol. 50, no. 3, pp. 251–256, 2002, doi: 10.1053/jhin.2001.1167.
[2]S. J. Rusell, “Handbook of Nonwovens,” Woodhead Publ. Ltd., 2006.
[3]Sanjoy Debnath and Madhusoothanan, “Thermal insulation , compression and air permeability of polyester needle-punched nonwoven,” Indian J. Fibre Text. Res., vol. 35, no. March, pp.38–44, 2010.
[4]Patanaik and R. Anandjiwala, “Some Studies on Water Permeability of Nonwoven Fabrics,” Text. Res. J., 2009, doi: 10.1177/0040517508091313.
[5]K. Rakshit, A. N. Desai, and N. Balasubramanian, “Engineering needlepunched nonwovens to achieve desired physical properties,” Indian J. Fibre Text. Res., vol. 15, no. 2, pp. 41–48, 1990.
[6]M. Tascan and E. A. Vaughn, “Effects of Total Surface Area and Fabric Density on the Acoustical Behavior of Needlepunched Nonwoven Fabrics,” Text. Res. J., vol. 78, no. 4, pp. 289–296, 2008, doi: 10.1177/0040517507084283.
[7]V. K. Midha and A Mukhopadyay, “Bulk and physical properties of needle-punched nonwoven fabrics,” Dep. Text. Techonology, vol. 30, no. June, pp. 218–229, 2005, [Online].
[8]K. N. Chatterjee, A. Mukhopadhyay, S. C. Jhalani, and B. P. Mani, “Performance characteristics of filter fabrics in cement dust control : Part III-Influence of fibre fineness and scrim on the performance of nonwoven filter fabrics,” Indian J. Fibre Text. Res., vol. 22, no. 1, pp. 13–20, 1997.
[9]Y. Xiao, N. Sakib, Z. Yue, Y. Wang, J. You, and J. Militky, “Study on the relationship between structure parameters and filtration performance of polypropylene meltblown nonwovens,” AUTEX Res. J., vol. 20, no. 4, pp. 1–6, 2020, doi: 10.2478/aut-2019-0029.
[10]V. K. Kothari, A. Das, and A. Sarkar, “Effect of processing parameters on properties of layered composite needle-punched nonwoven air filters,” Indian J. Fibre Text. Res., vol. 32, no. June, pp. 196–201, 2007.