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The Effect of Mechanical Variables on The Beating-up Force for Different Types of Weaving Machines

Elfowaty, H.[1] & Dorgham, M.[2*]

[1]Faculty of Technology of Industry and Energy, Samannoud Technological University, Gharbia, EGYPT
[2]Spinning, Weaving and Knitting Dept., Faculty of Applied Arts, Helwan University, EGYPT

*Corresponding author: dr.hebaelfowty@gmai.com

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Abstract: This research paper intends to measure the impact of changing some mechanical variables such as the machine speed and the type of beating-up mechanism for the weaving machine on the beating force on the textile during producing variable types of terry fabrics using a measuring system.Examine the impact of mechanical modifications on various weaving machines that affected the quality of the textiles manufactured. Since the reed is responsible for beating, the quality of the fabrics on the textile machine and the fabric pattern must be correlated with the weft density of the cloth and the beat-up force. The beat-up force, responsible for moving the yarns, directly impacts the stress on the yarns and consequently, the produced fabrics' quality. As terry fabrics have various applications, finding the optimal method to manufacture superior terry textiles following study factors (machine speed, beat-up mechanism, weft count, weft density) is essential.

Keywords: Weaving machine, Machine speed, Beating-up mechanism, Terry towel fabrics

1. Introduction

The weaving process is a crucial stage in textile production, where warp and weft yarns interlace to form fabric. Among various woven fabrics, terry fabrics hold a significant place due to their unique looped structure, which provides superior absorbency and softness. However, the production of high-quality terry fabrics is highly dependent on mechanical settings and parameters (Kandzhikova & Germanova ,2016). One of the most critical aspects influencing fabric quality is the beat-up force, which ensures proper weft insertion and fabric structure formation. Several mechanical variables, including machine speed, beating-up mechanism, weft density, and weft count, can significantly impact this force. High-speed weaving machines require precise control over these parameters to prevent excessive thread stress, fabric defects, and energy inefficiency.

Moreover, the type of beating-up mechanism plays a fundamental role in determining the force distribution across the fabric. Different beating mechanisms, exert varying levels of stress on the warp and weft threads, affecting fabric uniformity and strength (Singh & Verma, 2016). Research has shown that adjusting the picks' density and count further modifies the force required during beat-up, influencing the final texture and durability of terry fabrics. Thus, optimizing mechanical variables in weaving machines is vital for improving fabric properties, reducing production costs, and enhancing operational efficiency. This study aims to analyze the impact of these variables on beat-up force using an advanced measuring system, thereby providing valuable insights for the textile industry.

The efficiency of the beat-up process is essential in weaving, as it determines the tightness, strength, and surface properties of the final fabric. The beating-up force directly influences the fabric structure by dictating the degree of weft insertion and compactness. Studies have demonstrated that variations in loom speed and beat-up mechanisms significantly alter the distribution of force applied to the yarns, which, in turn, affects fabric durability and performance (Azzam & Büsgen, 2006). Terry fabrics, widely used in towels and home textiles, require precise control of mechanical variables to ensure high absorbency and resilience. The three-pick terry weaving technique, commonly employed in industrial production, is particularly sensitive to beat-up forces, making it crucial to evaluate the effects of mechanical parameters such as weft density and yarn count. A higher weft density often results in increased fabric weight and better pile stability but also necessitates greater beat-up force, which could lead to higher thread tension and potential defects (Kakde et al., 2017)

Furthermore, different types of beating-up mechanisms, such as fixed and movable beat-up systems, distribute forces differently across the fabric structure. Fixed mechanisms apply a uniform force distribution, while movable beat-up mechanisms may reduce peak stresses, leading to smoother fabric formation and fewer defects.

Given the importance of these mechanical factors, this study seeks to systematically analyze the relationship between beat-up force and mechanical variables using advanced measuring techniques. By understanding these interactions, manufacturers can optimize weaving settings to enhance fabric quality while minimizing energy consumption and mechanical stress on yarns.

1.1 Research Problem

The quality of woven fabrics, particularly terry fabrics, is highly influenced by mechanical variables such as machine speed, beating-up mechanisms, weft density, and weft count. Despite advancements in weaving technology, manufacturers often face challenges in optimizing these factors to ensure consistent fabric quality while maintaining production efficiency.The primary problem lies in the lack of a precise understanding of how different mechanical settings impact beat-up force and, consequently, fabric characteristics. Not-optimized machine settings can result in fabric defects, excessive yarn stress, and increased production costs. While previous studies have explored certain aspects of weaving mechanics, there is still a need for an integrated approach that systematically analyzes the influence of these variables on the beat-up force in different types of weaving machines.

This research seeks to address the gap by investigating the relationship between mechanical variables and beat-up force, using an advanced measuring system to provide accurate data. The study aims to offer practical recommendations for optimizing machine parameters, thereby enhancing textile production quality and efficiency.

1.2 Research Objectives

a. Understanding how mechanical variables impact beat-up force can help manufacturers produce higher-quality terry fabrics with improved durability, softness, and uniformity.
b. Optimizing machine speed, beat-up mechanisms, and weft density can minimize defects, reduce yarn waste, and lower production expenses.
c. By determining the optimal machine settings, the study can contribute to increased operational efficiency, reducing downtime and maintenance issues.
d. The findings will provide valuable insights to weaving machine manufacturers, fabric producers, and textile engineers, assisting them in selecting appropriate machine settings for different fabric types.
e. The research will contribute to existing knowledge in textile engineering, specifically regarding the mechanics of beat-up force and its effects on fabric properties.

1.3 Research Hypotheses

a. Increasing machine speed significantly affects beat-up force, leading to variations in fabric density and stress distribution.
b. Different beating-up mechanisms exert varying levels of force on yarns, influencing fabric uniformity and strength.
c. Higher weft density increases beat-up force, enhancing fabric compactness but also raising yarn stress.
d. Changes in weft count influence beat-up force requirements, affecting the durability and texture of the fabric.
e. Optimized mechanical parameters result in superior fabric quality with reduced defects and improved production efficiency

2. Research Methodology

This study employs an experimental research approach, combining quantitative analysis with controlled testing to evaluate the impact of mechanical variables on beat-up force. The study follows a systematic experimental design, where different weaving machines, speeds, and beating-up mechanisms will be tested under controlled conditions. The impact of these variables on the beat-up force will be measured using an advanced force measurement system.

3. Literature Review

The production of high-quality terry fabrics relies on several mechanical parameters, including machine speed, beating-up mechanisms, weft density, and weft count. These factors influence the beat-up force, which directly affects the structural integrity and performance of woven textiles. Several studies have explored the impact of these mechanical variables on the weaving process, highlighting their significance in ensuring optimal fabric properties. This section reviews existing research related to beat-up force, weaving machine parameters, and their effects on fabric quality.

3.1 Terms and Definitions

The loops that make Terry textiles have the potential to absorb a lot of water. It may be made by knitting or weaving. Weft (or filler) is supplied horizontally via two linear warp beams on looms used to weave towels. Terry cloth is a popular fabric for towels and washcloths because it is thick, soft, and absorbent. It is also used to make various clothing, including robes and sportswear. Terry cloth is made similarly to other textiles, but during the manufacturing process, the pile is molded into loops that flow out from the base. Terry fabric can be made from linen or cotton. Terry weaving is thought to be a later development in the history of woven materials Turk Fabric', Turkish Toweling' or Turkish Terry' is still used to describe terry toweling (Bozgeyik, 1991). Woven Terry textiles play a significant part in the toweling fabric industry because of their remarkable mechanical and functional qualities, which include softness, compressibility, dimensional stability, and water absorption. The name "terry," which refers to the hand-pulled pile loops that create absorbent ancient Turkish toweling, is derived from the French word "tirer" which means "to pull out."

Towels are made of woven materials that have loops on the surface of the fibers. Typically, a small amount of blending yarns or chemical fiber yarns are added to pure cotton yarns, which are used as raw materials (Humphries, 2004). This was woven on a towel loom. Depending on the weaving technique, there are two kinds of knitted and woven towels: pillow towels, couch towels, towel covers, and face towels, depending on the purpose; and there are terry cloths for manufacturing clothes. The terry surface is warm, weighty, velvety to the touch, absorbs a lot of moisture, and is long-lasting. Popular towel colors include white, color, floral, silk, plain, jacquard, and jacquard printed towels. To be applied when cleaning the human body directly (Terry cloth fabric, n.d.).

3.1.1 Terry Fabric

Terry fabric is a type of woven textile characterized by looped pile yarns, which enhance its absorbency and softness. It is primarily used in towels and bathrobes.

a. Types of Terry Fabric Based on Loop Formation:
   1) Single-Sided Terry Fabric: Loops are formed only on one side of the fabric.
   2) Double-Sided Terry Fabric: Loops appear on both sides of the fabric, increasing absorbency.
b. Terry Fabric Structure
   1) The fabric is woven using a three-pick pile formation process, where the pile loops form at every third pick insertion
   2) The warp sequence consists of pile warp and ground warp (1:1 ratio), meaning that each ground warp yarn corresponds to one pile warp yarn.

3.1.2 Types of Weaving Machines

a) Based on Beating-Up Mechanism:
   A weaving machine (loom) is a mechanical device used to interlace warp and weft threads to create woven fabric.
b) Fixed Beating Mechanism:
   The reed moves along a fixed pivot point to push the weft yarns into place and commonly used in rapier looms and projectile looms.
c) Movable Beating Mechanism:
   The reed moves forward without a fixed pivot, providing more flexibility in beat-up motion, and commonly used in modern air-jet and water-jet looms to enhance precision.

3.1.3 Measuring System for Beat-Up Force

A measuring system is an advanced electronic setup used to capture, analyze, and record the beat-up force applied during the weaving process.

a. System Components:
b. Sensing Element: Measures the force exerted by the reed.
c. PCB Board Measure Circuit: Records and transmits the force readings.
d. Digital Storage Oscilloscope: Displays the force variations as waveforms.

This system allows precise measurement of the beat-up force, helping to analyze how different machine parameters affect fabric quality.

3.1.4 Beating-Up Mechanism

The beating-up mechanism is the mechanical system in a loom that controls the movement of the reed to push the weft yarns into place.

Types of Beating-Up Mechanisms in This Study:

a. Fixed Beating-Up Mechanism: The reed moves on a fixed axis, maintaining a consistent beat-up motion.
b. Movable Beating-Up Mechanism: The reed moves with greater flexibility, allowing for a more controlled beat-up force application.

c. Different beating mechanisms influence how force is distributed, affecting fabric uniformity and loop formation.
d. This research investigates the differences in beat-up force between these two mechanisms.

3.1.5 Machine Speed

Machine speed refers to the number of revolutions per minute (RPM) performed by the weaving machine.

a. Speeds Used in research: Lower Speed, Higher Speed.
b. Impact of machine speed on Beat-Up Force:
    1) Higher speeds increase productivity but also increase yarn stress, affecting the final fabric's quality.
    2) Lower speeds provide better control over beat-up force but may reduce efficiency.

3.2 Previous Studies

3.2.1 The role of beat-Up force in weaving

The beat-up force is a critical mechanical factor in the weaving process, ensuring the proper placement of weft yarns to form a compact fabric structure. Variations in beat-up force can result in different fabric densities and strengths (Shih et al., 1995). The reed's movement and its interaction with the weft influence the uniformity of the woven fabric. High beat-up force can lead to increased fabric tightness but may also cause excessive stress on the warp yarns, resulting in breakage and defects. Conversely, lower beat-up forces may produce loose fabric structures, reducing overall durability.

3.2.2 The impact of machine speed on fabric properties

The speed of a weaving machine plays a significant role in fabric production efficiency and quality. High-speed looms enable increased productivity, but they require precise control of beat-up force to prevent defects. Demonstrated that as loom speed increases, the impact force exerted on weft yarns also rises, necessitating adjustments in the beating-up mechanism to maintain fabric uniformity (Katunskis, 2004). Studies have shown that excessive loom speed without proper force calibration leads to thread misalignment and uneven fabric density. However, optimized speed settings contribute to improved weaving efficiency without compromising fabric properties.

3.2.3 Beating-up mechanisms in different weaving machines

Different types of weaving machines utilize various beat-up mechanisms, which affect the distribution of force across the fabric. Fixed beat-up mechanisms apply a uniform force, whereas movable systems adjust force dynamically based on fabric type and density requirements. Compared conventional and modern beat-up mechanisms, concluding that advanced movable systems reduce stress concentrations, leading to improved fabric uniformity and reduced defects. The optimizing beat-up mechanisms enhance energy efficiency and reduce mechanical wear on the loom components (Plate & Hepworth, 1973).

3.2.4 The influence of weft density and weft count

Weft density and count significantly impact beat-up force and fabric texture. The higher weft density increases beat-up force requirements, improving fabric compactness but also raising the risk of excessive yarn tension. The effect of varying weft counts, noting that finer weft yarns require higher beat-up forces to achieve the desired fabric tightness, while coarser yarns demand lower forces due to their increased thickness and weight (Cai, Wang, & Xu, 2022) . Managing these factors is crucial for optimizing fabric performance in industrial production.

3.2.5 Terry fabrics and their mechanical considerations

Terry fabrics, widely used in towels and home textiles, require unique weaving techniques to ensure high absorbency and durability (Durur & Öner, 2013). The three-pick terry weaving technique is particularly sensitive to variations in beat-up force. The effect of mechanical parameters on terry fabric properties and found that optimizing beat-up force is essential for maintaining loop stability and fabric softness. Additionally, different terry weaving machines concluded that machine type and beat-up force settings significantly influence final fabric quality.

3.3 Manufacturing of Terry Towels

3.3.1 Terry towel weaving

Terry towel is a form of woven fabric that uses two beams during the weaving process. One beam will be used for ground manufacturing, while the other will be used for loop formation. The beat-up mechanism of the Terry loom is responsible for loop generation on the top beam. 3-pick Terry is the most popular commercially. 3 picks Terry indicates that after each 3-pick insertion, the fabric is fully beaten up and one loop pile is generated. Figure 1 See the graphic below for an example of a beaten-up situation.

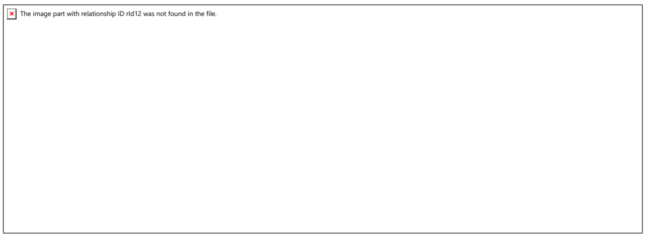


Figure 1. The beat-up position (Badawi, 2008).

The pile of towels has a significant impact on its water-absorbing capacity and other characteristics. The quality, weight, and other necessary criteria define the loop's length. Piling manufacturers utilize zero twisted, hydro, compacted, and combed yarns. Various high-value fibers, including the superior characteristics of cotton Suvan, Giza, Pima, bamboo, modal, and so on, are used to build piles to increase their absorbency and lint properties. OE and 2-ply variants provide enhanced strength and compactness in ground fabric which usually uses comparably coarser counts for ground yarn (Terry Towel, 2013).

3.3.2 Various methods for producing pile textiles

Two loom beams are required for Terry weaving: one for the ground of the cloth and another for the pile. Every beam has a distinct stress. Loops may be made on the surface of the terry cloth using the terry mechanism. The terry mechanism creates a temporary variation in the distance between the necessary picks by reducing the sweep of the slay or shifting the fabric that dropped away from the reed. Drawing-in and denting are two important processes that happen before the actual weaving starts. The terry weave is used to create terry cloth. The various types of terry weave are distinguished by the number of picks used before the quick beat-up. The cloth surface's terry loop is made by fabricating a false fell for a specified number of picks at a distance from the actual cloth fell. The loop length is determined by this space, and the number of wefts determines the terry type: 3-pick, 4-pick, 5-pick, and 6-pick terry. As shown in Figure 2.

Figure 2. Terry structure
(A)3-pick terry, (B)4-pick terry, (C)5-pick terry, (D6-pick terry.

3.3.3 The terry weave slack-tension pile method

A set of warps is introduced to construct the piles, in addition to two sets of threads (warp and weft for the ground). The ground of the fabric is made up of a collection of warps kept in tension. At regular intervals, the tension in the warps that make up the pile is released. At regular intervals, the tension in the warps that make up the pile is released, and the warp threads are pushed forward by the reed's motion. The tension is restored, and the subsequent picks enable the warps to form loops. Using four harnesses, two for slack pile warps and two for tight ground warps, is the simplest method to construct this structure.

Two fillings are inserted through this shed, but the next one is not beaten up by the reed. The pile warps are then lowered, and a pick is placed into the ground warps to interlace them. All three fillings are pushed to the edge of the cloth after the third pick. The pile warps form in loops because the tension on the pile warps is loose when the fillings are beaten up. Because two picks go under the looped pile and one pick comes between two rows of piles, this is known as a three-pick terry cloth. In the production of terry textiles, the threads from both series (pile and ground) are often drawn in pairs. Two warp threads from the same series wind up in the same reed dent since they are also carried through the reed in pairs. It is evident from the design (Figure 3) that the interweaving of successive pile warp threads and succeeding ground warp threads is opposing. Pile warp threads beneath two picks and above one pick makes a pile in the rear of the loom, while those above two picks and under one pick form a pile on the face. It is crucial to adhere to a particular shedding sequence regarding cables while using them, the terry motion, which regulates the reed's activity in the production of terry textiles; if not, the pile loops would be either absent or inadequately formed (Singh &Verma, 2017).

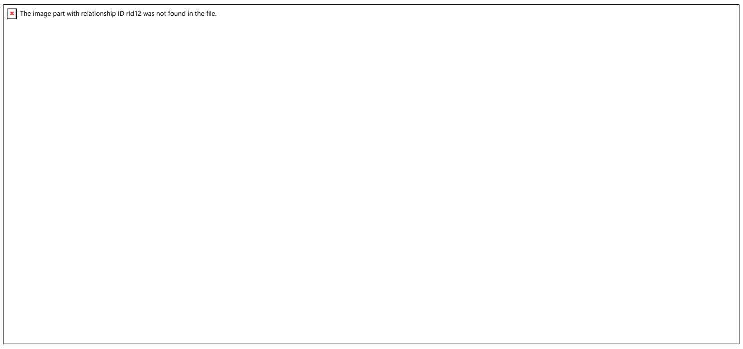


Figure 3. 3-pick Terry's graphic design (Sulzer Pumps,1997).

Additionally, as seen in Figure 4, the relative density of pile loops is either higher or lower and is inversely proportional to the number of picks placed for each horizontal row of loops. In the design for a 4-pick terry cloth, the loops of the pile are evenly distributed throughout both sides.

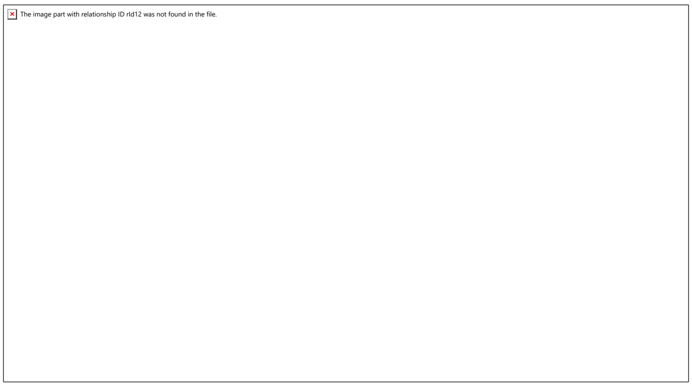


Figure 4. 4-pick Terry's graphic design

4. Experimental Work

In this study's experimental section, twenty-four specimens were manufactured with varying loom speeds, machine beat-up mechanisms, pick densities, and weft counts (Ne). To create terry woven fabric, samples typically have 3 components: pile thread, ground warp thread, and weft thread. The following are the requirements for ground warp yarns: the warp density is 24 Ends/cm, the warp count is 24/2 Ne, the reed number is 12/cm, and the denting is 2 yarn/dent. Weft yarn parameters include weft counts of 12/1 and 16/1 Ne, pick densities of 10, 15, and 20 picks/cm, and yarn type of ring-spun 100% cotton yarn.

Table 1. The samples' specifications for the movable beat-up mechanism

Sample No.	Beating-up mechanism type	Loom speed (rpm)	Weft count (Ne)	Weft density (picks/cm)
1	M	280	12/1	10
2	M	280	12/1	15
3	M	280	12/1	20
4	M	280	16/1	10
5	M	280	16/1	15
6	M	280	16/1	20
7	M	310	12/1	10
8	M	310	12/1	15
9	M	310	12/1	20
10	M	310	16/1	10
11	M	310	16/1	15
12	M	310	16/1	20

Table 2. The samples' specifications for the fixed beat-up mechanism

Sample No.	Beating-up mechanism type	Loom speed (rpm)	Weft count (Ne)	Weft density (picks/cm)
13	F	280	12/1	10
14	F	280	12/1	15
15	F	280	12/1	20
16	F	280	16/1	10
17	F	280	16/1	15
18	F	280	16/1	20
19	F	310	12/1	10
20	F	310	12/1	15
21	F	310	12/1	20
22	F	310	16/1	10
23	F	310	16/1	15
24	F	310	16/1	20

a. M: Movable beat-up mechanism.
b. F: Fixed beat-up mechanism.

The terry textiles were created using the three-pick pile creation process. On both sides of the textile, the pile of the terry textiles utilized in this study was created. To cover the vast variety of terry fabric constructions produced in industry, the count of weft yarns and the weft density of various terry textiles were chosen. The warps are spread out throughout the fabric in a pile and ground pattern (1:1). In warp sequence, a pile of warp yarn joins each ground warp yarn (1:1). The entire weave is composed of 2 warps (loop and ground) and four warp yarns and three picks (Elfowaty,Dorgham,& Fouda,2022a).

Three various pick densities (20,15,10 picks/cm), two various pick counts (16/1, 12/1 Ne), two various machine speeds (280, 310 rpm), and two separate production machine beating mechanisms (Fixed, Movable) were used to weave the terry textiles samples. The manufacturing process of the Terry Textile can indicate that the various samples were manufactured on two various textile machines Vamatex, SP1151es (movable mechanism) and Sulzer, Tps600 (fixed mechanism) Terry Model (Elfowaty,Dorgham,& Fouda, 2022b).

4.1 Measuring the Beat-Up Force Affecting Produced Samples

With advancements in signal capturing and analysis technology, an advanced measurement system was designed and implemented to determine the beat-up force applied during the weaving process. This measurement approach is based on detecting voltage variations within a measuring circuit, which serve as indicators of changes in the beating-up force (Vibe, 2023). These voltage fluctuations result from changes in the electrical resistance of a strain gauge, which directly corresponds to the applied beat-up force. By integrating this system into the weaving process, real-time force measurements were collected and analyzed, providing valuable insights into the influence of mechanical parameters such as machine speed, weft density, and beat-up mechanisms on fabric production.

The measurement system comprises four main components:

- Element of Sensing
- PCB Board Measuring Circuit
- Digital Storage Oscilloscope
- Computer Screen for Data Visualization

Each of these components plays a crucial role in accurately measuring and analyzing the beat-up force applied during weaving.

4.1.1 Element of Sensing

The sensing element is strategically positioned just before the reed to capture accurate beat-up force data. It consists of a stainless-steel channel with the following dimensions: Length: 15 cm, Width: 3.5 cm, Thickness: 2 cm.

To ensure stability and precision, a metallic spiral zipper is firmly attached to the steel channel using screws. This configuration allows the sensing element to capture the force exerted by the reed while maintaining structural integrity and durability throughout the weaving process. The sensing element converts the mechanical impact into an electrical signal that is further processed by the measuring circuit, as shown in Figure 5.

4.1.2 PCB Board Measuring Circuit

The PCB board's measuring circuit serves as the intermediary between the sensing element and the digital storage oscilloscope. It records data captured by the strain gauge and transmits it to the oscilloscope for further processing. The PCB board ensures that the signal remains stable, accurate, and free from external interference that might affect the readings.

4.1.3 Digital Storage Oscilloscope (HX711 Model)

A digital storage oscilloscope (DSO) was used to display, analyze, and store the measured beat-up force waveforms. The HX711 digital storage oscilloscope was selected due to its high precision and ability to digitize analog signals in real-time.

Key features of the HX711 oscilloscope include:

a. Four available channels to simultaneously capture multiple signals.
b. Digital waveform visualization for easy interpretation of beat-up force fluctuations.
c. Data acquisition capabilities, converting analog signals into a digital format.
d. Windows system compatibility, allowing online data processing via a computer.

Unlike traditional oscilloscopes, which rely solely on built-in screens, this advanced oscilloscope enables real-time monitoring and storage of beat-up force data for detailed post-processing analysis (Arora, 2020).

4.2 Data Processing and Analysis

After capturing beat-up force waveforms, the oscilloscope transfers the data to a computer for further processing. The recorded signals undergo noise reduction and signal filtering to ensure precise force readings.

a. Voltage fluctuation analysis: The measured voltage changes are converted into force values using calibration formulas specific to the strain gauge used.
b. Comparison of different weaving conditions: By analyzing the beat-up force under varying machine speeds, pick densities, and beating mechanisms, the study identifies optimal settings for high-quality terry fabric production.

This advanced beat-up force measurement system allows for high-accuracy data collection, helping researchers and industry professionals optimize mechanical variables to enhance fabric quality and reduce defects.

4.3 Measuring System and Data Collection

To measure the beat-up force, an advanced force measurement system as shown in Figure 5 was integrated into the weaving machines. The system included:

a. High-speed force sensors to detect beat-up force fluctuations.
b. Data acquisition software for real-time monitoring.
c. Optical and mechanical testing tools for fabric structure analysis.
d. The experimental setup provided precise readings of the beat-up force applied under different weaving conditions.

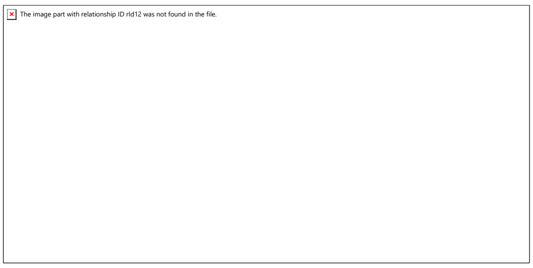


Figure 5. The system components

5. Results and Discussion

After implementing the previous system of measurement on SULZER and VAMATEX machines with two various machine speeds (280, 310 RPM) to produce towel textiles at 3 various weft densities (20,15,10 picks/cm) and two pick's counts (12/1, 16/1 Ne), along with 2 various beat-up mechanisms (Movable, Fixed), The purpose of the experiments was to develop a measure system for assessing the beating-up force on textile machines.

5.1 Signal analysis for beating-up forces measured by electronic sensor

Table 3. The signal analysis for Movable beating-up forces.

M/C Type	Movable beating mechanism											
Loom speed	280rpm						310rpm					
Weft Ne	12/1			16/1			12/1			16/1		
Picks/cm	10	15	20	10	15	20	10	15	20	10	15	20
1 2 3 4 5 6 7 8 9 700	2.4	5.1	7.9	6.2	6.6	7.3	7.7	7.2	7.4	6.6	7.0	4.5
	1.7	2.6	2.6	2.1	2.0	1.7	2.5	2.4	2.9	2.2	1.6	2.0
	1.6	1.7	2.2	1.5	1.6	1.5	2.1	1.9	2.1	1.9	1.4	1.1
	1.5	1.5	1.5	0.8	1.2	0.6	1.4	1.3	1.8	1.2	0.7	1.1
	1.1	1.9	2.3	1.8	2.0	1.7	2.1	2.1	2.5	2.2	1.7	1.5
	3.3	6.0	4.3	3.2	3.7	2.5	4.3	4.8	6.2	3.3	2.4	5.0
	16.1	17.6	18.4	15.1	16.1	16.3	18.1	19.4	21.3	14.8	17.1	18.0
	1.2	3.9	6.2	4.7	5.0	3.4	5.9	5.6	5.7	5.0	5.6	3.4
	1.6	2.8	2.5	2.1	2.0	2.1	2.6	2.7	3.0	2.4	1.6	2.1

Table 4. The signal analysis for Fixed beating-up forces.

M/C Type	Fixed beating mechanism											
Loom speed	280rpm						310rpm					
Weft Ne	12/1			16/1			12/1			16/1		
Picks/cm	10	15	20	10	15	20	10	15	20	10	15	20
1 2 3 4 5 6 7 8 9 700	12.5	13.7	13.4	9.8	15.2	8.6	18.1	4.2	13.2	5.2	17.9	9.9
	3.9	4.0	4.9	2.3	4.0	5.0	3.5	5.7	5.2	1.8	3.7	4.9
	5.3	3.9	3.8	2.3	5.0	3.0	4.5	2.1	4.2	1.6	4.5	3.3
	2.0	2.4	3.2	1.6	2.2	3.4	1.9	5.5	3.4	1.5	2.1	3.3
	5.6	4.9	5.2	2.9	5.8	4.4	5.3	3.7	5.9	2.0	5.3	4.8
	4.4	6.0	8.9	4.1	4.8	10.5	4.1	20.9	8.8	3.2	4.5	9.7
	31.1	33.1	37.4	22.2	30.9	35.1	33.9	34.9	38.7	21.1	34.1	36.1
	12.4	13.7	13.2	10.0	15.2	8.8	19.0	4.2	13.2	5.2	18.7	10.2
	3.7	4.0	4.92	2.4	4.0	4.8	3.4	5.7	5.4	1.8	3.9	4.9

5.2 Maximum Value of Beating Force for the Produced Samples

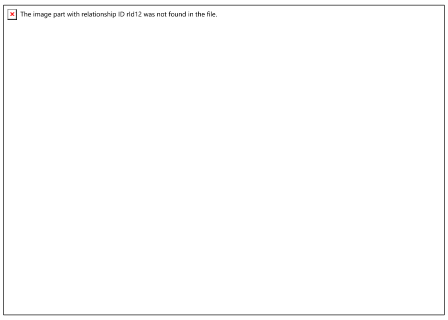
Table 5. Maximum value of beat-up force

Sample no.	Max Force (N/beat)	Sample no.	Max Force (N/beat)
1	**158.56**	**13**	**304.5**
2	**172.88**	**14**	**324.8**
3	**180.45**	**15**	**366.9**
4	**148.26**	**16**	**217.4**
5	**158.63**	**17**	**303.7**
6	**160.15**	**18**	**343.66**
7	**177.38**	**19**	**332.95**
8	**190.28**	**20**	**342.78**
9	**208.43**	**21**	**379.27**

10	**145.54**	**22**	**206.33**
11	**168.09**	**23**	**342.82**
12	**176.87**	**24**	**353.33**

The higher force values in the moveable mechanism, which indicate the point of pile creation at the reed's maximum force in the third beat, fluctuates up and down at a steady rate in response to changes in the warp device's let-off. This demonstrates a noticeable variation in the reed's force from the earlier tables, as shown in Table 5, which is represented depending on the type of beating mechanism (Kim,et al., 2013). The greatest force levels are thought to be quite consistent throughout the number of sensor readings during a fixed mechanism (Kinari, 2007).

5.3 The Relation Between the Factors and the Effect of the Force of Beating



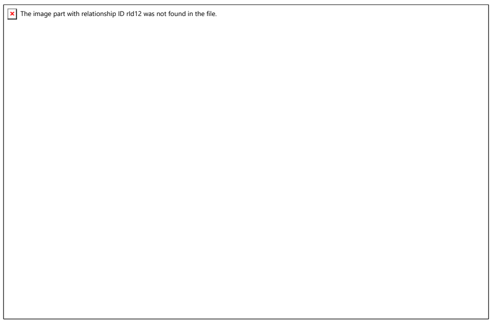
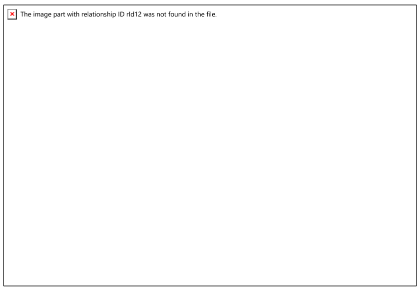


Figure 6. The beat-up force of the Movable Mechanism
at (280,310) rpm



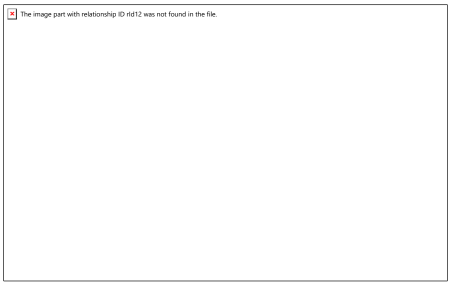


Figure 7. The beat-up force of Fixed Mechanism
at (280,310) rpm

a. The impact of picks density:
The above graph, as shown in fig (6,7) makes it evident that, while all other factors remain constant, the beating force rises as the pick density used to make terry towel samples does.
b. The impact of weft count (Ne):
We can notice that the greater the beating force when using a lower weft count (Ne) (thicker thread)

5.4 The Difference between the Two Mechanisms

Figure 8. The beat-up force of Both Mechanisms at (280) rpm.

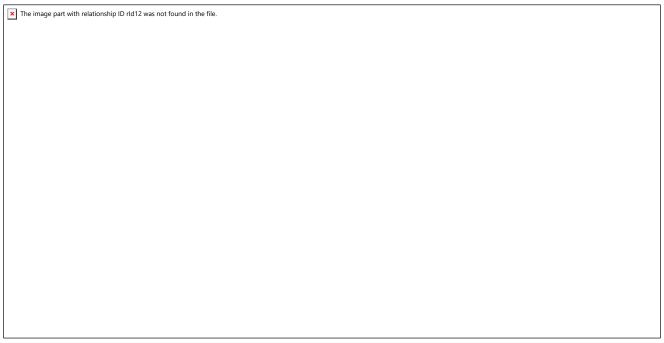


Figure 9. The beat-up force of Both Mechanisms at (310) rpm.

a. The impact of altering the kind of beating mechanism:
   As shown in Fig (8,9), it is evident that, for the same machine operating speed and other variable stability, using a fixed mechanism necessitates a higher beating force than using a moveable mechanism.
b. The impact of changing machine speed:
   From the previous results, the change in machine speed has a little, almost non-existent, effect on the beating force required for terry fabric production, and does not affect the performance of the produced samples.

5.5 The Force Used to Beat Each Manufactured Sample

Figure 10. The beat-up force of 24 manufactured samples.

All of the samples generated during this investigation are displayed in the above graph as shown in Figure (10), which also examines the variation in the beating force values. We see that sample No. 4,10, which employs the thinnest thread [the maximum weft count (16Ne)], The lowest beating force is produced by the movable mechanism and the lowest pick density (10picks/cm). The thinnest thread [smallest weft count (12Ne)], the greatest pick density (20 picks/cm), and the fixed mechanism are used to produce examples No. (15,21), which have the maximum beating force.

6. Conclusion

The findings of this investigation have led to the following deductions:

a. The successful installation of an integral digital measurement system to gauge the terry towel weaving machine's beat-up force, which is fixed opposite the reed.
b. The beating-up force (N/beat) is greatly influenced by the study factors, such as pick densities (picks/cm), pick counts (Ne), and loom speeds(rpm).
c. To determine the desired values of the chosen beating force on the examined woven terry textiles, the weft densities, weft counts, and loom speeds that influence the beating-up force were graphically depicted.
d. To get the best-woven terry towel textiles, the client can choose the characteristics that will make the highest usage of terry towels and modern construction requirements.
e. Quality examination revealed that the best samples are No. (4,10), while the worst samples are No. (15,21), based on less stress and less beating force.

f. In this work, we create twenty-four distinct woven terry textile samples with a range of constructional characteristics, although the present methodology may be applied to any kind of fabric.
g. Because the moving beating-up mechanism uses less beating force and puts less strain on the threads, we can also conclude that it is preferable.
h. From the previous results, we can note that the change in machine speed has little effect on the beating force needed for terry fabric manufacturing when producing the same samples, but we find that changing the machine speed has a noticeable effect on the beating force when producing samples with different specifications.

7. Recommendations

After completing this study, several recommendations can be proposed to enhance future research and improve the quality of textile production. First, it is important to evaluate the quality of the produced fabrics by measuring key properties such as water absorption and abrasion resistance, while also examining how variations in beating force influence these characteristics. In addition, future studies should consider incorporating other variables, including pile yarn density per unit length and pile yarn count, as these factors may significantly affect fabric performance. Furthermore, it is recommended to investigate additional mechanical stresses acting on the threads during the weaving process, such as friction resulting from heddle movement against warp threads and tension stresses on the warping yarns. Finally, producing different types of fabrics and comparing them with terry towel fabrics, particularly in relation to beating force, would provide a broader understanding of textile behavior and contribute to more comprehensive conclusions.

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Conflict of Interest

The authors declare no conflict of interest.

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