Case Report
Open Access
CrossMark

TPM project for remedying weft distortions in a textile mill

Abstract

This document gives formatting instructions for authors preparing papers for publication in the Occurrence of weft distortions in woven fabric is a typical quality problem which seriously impairs the use of the cloth. The consecutive weft yarns are supposed to be placed parallel to each other and also perpendicular to the edges of the fabric. In any cases that this placement is disturbed for some reasons, the appearance of weft yarns as straight lines are deformed. In this paper, a TPM implementation in a large scale worsted fabric mill is conducted with an aim to remedying weft distortions like skewness or bowing. Such quality problems and irregularities become much more apparent in the cases of plaid and plain striped fabrics. A TPM team was organized with a mission of eliminating this quality problem and analyzed the machinery and operations along the whole production cycle within the departments of weaving preparation, weaving and finishing. The most common reason for such defects may be an uneven distribution of tension along the cloth width during dyeing or finishing processes. Irregular treating and handling during scouring, dyeing or finishing might also cause or enhance the occurrence bowing or skewing. Rectifying the tension settings on processing machines along with malfunctioning equipment detected during TPM inspections enabled to rectify these defects. The OEE score of 66% was increased to 79% after the TPM implementation.

Keywords: bowing, selvedge, skewness, TPM, weft distortions, worsted fabric

Volume 11 Issue 1 - 2025

Hikmet Ziya Ozek,[1] Duygu Yavuzkasap Ayakta[2]

[1]Department of Textiles Engineering, Namik Kemal University, Tekirdag, Turkey
[2]R & D Center, Yunsa Yunlu San. ve Tic. A.S. Tekirdag, Turkey

Correspondence: Hikmet Ziya Ozek, Professor, Department of Textiles Engineering, Namik Kemal University Corlu, Tekirdag, Turkey, Email zozek@nku.edu.tr

Received: December 23, 2024 | **Published:** January 09, 2024

Introduction

The introduction should be succinct, with no the production of conventional textiles mostly involves various conversion processes in the material form such as from fiber to yarn and from yarn to fabric. The essence of the fiber remains the same but its arrangement within the new structure is altered. This makes the machinery adjustment and assembly very critical in terms of product specifications and resultant quality. In this respect, the maintenance of the textile machinery has a direct effect on the quality of the product as well as on the efficiency. Total Productive Maintenance (TPM) as a manufacturing strategy focuses primarily on the maintenance of plants and equipment. The objective of the TPM as a lean manufacturing philosophy is to markedly raise quality and productivity while, at the same time, increasing employee morale and job satisfaction. This is achieved by defeating unplanned stops and machine breakdowns, short stops, slow running and accidents so as minimizing potential defects in products manufactured.[1–3] It aims to maximize the performances of machine and equipment by virtue of optimizing the maintenance of machine and equipment.

Several production facilities and organizations, small, medium or large, overall the world implement Total Productive Maintenance to gain potential benefits leading to more profits,[4,5] Especially textile and partly garment industries appear to be one of the leading industries in taking advantage of the TPM tool.[6] The importance and advantage of TPM methodology with the advent of Industry 4.0 has also been emphasized in some researches.[7,8]

An accurate planning and careful implementation are required to establish a successful TPM system and maintain its continuity and sustainability.[4,5] This may be very painstaking with high involvement of employees and demanding procedures. The ides of Total Productive Maintenance forces employees to take over ownership of their machinery and assigning them responsible for the maintenance of machines and equipment while operating those machinery. That means, operators would be responsible to carry out cleaning, inspecting, and lubricating work as well as executing corrective work involving machinery and equipment in addition to typical production job tasks as part of their daily routine. All these additional responsibilities and tasks would necessitate changes in attitudes and attain new capabilities and behavior appropriate for the TPM implementation.[9]

On the other hand, TPM implementations may also met by employee resistance due to cultural incompatibility or failures and disapprovals in establishing new routines.[10,11] There exist critical problems about employee work-related attitudes toward TPM, particularly in labor-intensive industries such as apparel production.

In this paper, the advantages of TPM implementation in a large scale worsted fabric mill is reviewed on the subject of weft distortions like skewness or bowing and selvedge problems in certain fabric qualities. Such quality problems and irregularities become much more apparent in the cases of plaid and plain striped fabrics. An increasing demand for those qualities due to the rising fashion trends, multiplied the extent of the problem, and a detailed examination of this particular quality issue has become inevitable. A TPM team was organized with a mission of eliminating this quality problem.

Total Productive Maintenance (TPM) and survey of literature

Total Productive Maintenance is a holistic approach to equipment maintenance which endeavors a strong framework for impeccable production, with

No Breakdowns

No Small Stops or Slow Running

No Defects

Additionally provides safe working environment: No Accidents

The TPM framework is built on the Eight Pillars of TP, each one focusing on specific aspects of maintenance and production. The layout of pillar structure is illustrated in Figure 1. As it is seen in the figure, a typical TPM includes the 5S Foundation, as well. The aim of the 5S framework is to ensure that the work environment is clean and tidy. It incorporates five key principles for steady and systematic activities; namely Sort, Straighten, Shine, Standardize and Sustain.

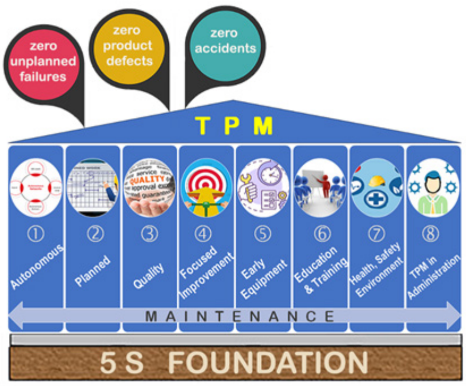


Figure 1 The Components of TPM.

Autonomous maintenance: Placement of responsibility for routine maintenance, such as cleaning, lubricating, and inspection, in the hands of operators.

Planned maintenance: Scheduled maintenance tasks based on predicted and/or measured failure rates.

Quality maintenance:

Designing error detection and prevention into production processes. A Root and Cause Analysis may be applied to dismiss sources of quality faults.

Focused improvement: Organizing small groups of employees work together proactively to achieve regular, incremental improvements in a particular equipment operation.

Early equipment management: Conduction of practical knowledge and understanding of manufacturing equipment gained through TPM towards improving the design of new equipment

Education and training: Provision of necessary knowledge to achieve TPM goals. Applies to operators, maintenance personnel and managers.

Safety, health, environment: Keeping the working environment safe and healthy.

TPM in administration: Application of TPM techniques to administrative functions.

The performance of TPM is measured by a metric called Overall Equipment Effectiveness (OEE). It is used to define the percentage of planned production time which is actually productive. This metric was specifically developed to support TPM operations by accurately tracing progress leading to "perfect production". An OEE score of 100% is perfect production. An OEE score of 85% refers to world class level, while 60% is fairly typical score for distinct manufacturers. The measurement of OEE is highly important to measure OEE in order to disclose and quantify productivity losses, and also to measure and track improvements resulting from TPM activities.

It is known that the TPM is commonly used in manufacturing industry and enables the factory to follow a synergistic relationship among functions, between production and maintenance, for continuous improvements in product quality, operational efficiency, capacity assurance and safety. In the literature, there are various studies describing specific cases of TPM implementations cases from different part of world.

In a study[6] adapted TPM for quality improvement, it was once more confirmed that such a program is capable of achieving positive outcome. It was reported that the TPM can be utilized not only in industrial plants, but also in construction, building maintenance, transportation, and a variety of other fields. The study involved the inspection of fabric faults to eliminate with corrective actions in accordance with the possible source of faults. It was shown that providing the involvement of all individual personnel, a high rate of return in comparison to expenditure may be received.

A TPM implementation[12] aiming at scrutinizing the maintenance system of the textile industry in India, proved that a high rate of unplanned failure reigns in the industry. The condition of equipment, the negligence of operators and shortage of spare parts were reported as the reasons of failures. A deprived preventive maintenance system of the industry is also reported to be responsible for the case. Another finding of the study was the ignorance of minor inspection and restoration of equipment which resulted in escalating the number of failures which challenges to maintain the proactive maintenance plan. They proposed an implementation process devising the implementation steps systematically by breaking down each activities of the pillars of TPM and levelling them in accordance with their priority.

Another TPM study[13] was conducted in a textile company with a high rate of unplanned downtime failure and the loss of the performance in Ethiopia. In addition to overall conditions of equipment due to the ignorance of operator, low skill and lack of spare parts, the overlooked preventive maintenance system of the industry was also reported as primary factors. The systems of TPM and Reliability Centered Maintenance (RCM) were selected and implemented to enhance the n as the appropriate tool for the company to implement to enhance the Overall Equipment Effectiveness. It was clearly shown that the adoption of TPM and RCM achieved to minimize such losses and also to reduce rework to an acceptable level resulting in increased profitability and prestige.

The primary goal of Total Productive Maintenance approach is to change the culture of the company's maintenance policy by involvement of all employees toward the maintenance system of the company. A paper[14] reported the use of TPM to reduce unplanned stoppage and losses obstructing equipment effectiveness. The overall equipment effectiveness of the factory was measured in the beginning of the research and after six months of real time TPM implementation. A considerable improvement was achieved at the end of the work.

Another TPM implementation was carried out in a yarn manufacturing company of India.[15] It was reported that the implementation of Total Productive Maintenance enabled the OEE to increase from 61.14% to 65.68%. TPM implementation was recommended as an effective tool to sustain the world class competition to improve the productivity.

A TPM implementation for Ready Made Garments sector in Bangladesh was reported by Uddin.[16] After examining the current loophole, the study focused on improving OEE factors by adopting a hybridized Total Maintenance (TPM) scheme. The OEE was increased from about 57% to 69% as a result of the execution of the proposed TPM model combined with a proper management strategy. Various attributes of Man, Management, Machinery, Maintenance, Material an Environment were found as the source of low performance through a cause and effect analysis.

Definition of the problem: weft distortion in woven fabric

The problem of weft distortions in woven fabric is a typical quality problem which seriously impairs the use of the cloth. The form and dimension of distortions are varied, and therefore, named separately. The consecutive weft yarns are supposed to be placed parallel to each other and also perpendicular to the edges of the fabric. In any cases that this placement is disturbed for some reasons, the appearance of weft yarns as straight lines are deformed. The illustration of weft distortions and regular appearance are given in Figure 2.

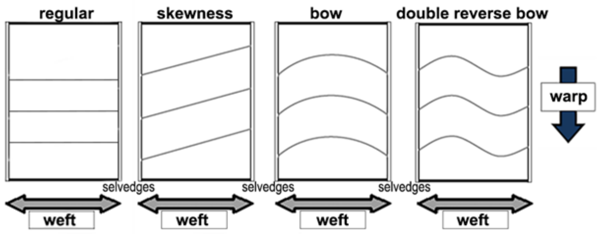


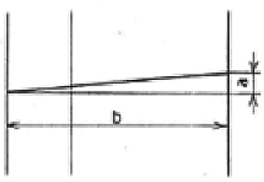
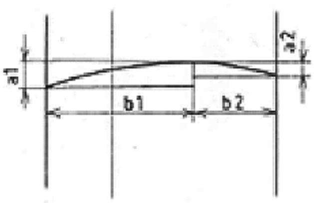
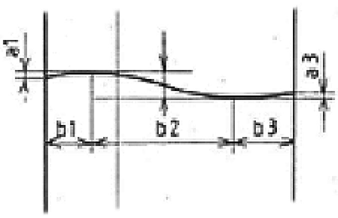
Figure 2 Basic scenes of weft distortions in comparison with regular fabric.

Skew: Weft skewing refers to a condition in which filling (weft) yarns are angularly displaced from a line perpendicular to the edge or side of the woven fabric. Ideally, a weft yarn should be placed perpendicularly to the edges of the cloth as seen in Figure 2. This happens because of excessive tension variation across the fabric width.

Bow: This fault also refers to a distortion of weft yarn around the center of the fabric but more troublesome. In the case of bowing, weft yarns appear even at the two edges but curved across the middle of the fabric. The displacement of weft yarns with reference to a line perpendicular to the selvedges takes place, and the wefts are positioned in the form of an arc with varying arc angles. It looks like rows of yarn stripes forming a bow-shaped curve or curves along the fabric width. The direction and number of bowings may be varied depending on the severity of the distortion as seen in double reverse bow given in Figure 2. Bowing and skewing are not among very frequent fabric faults but may be very annoying in the case of striped fabrics as explained above. It may occur because of several reasons stemmed from the processes in weaving preparations, weaving and finishing.

The measurements of bow and skew are made in accordance with the international standard ISO 13015,[17] named as Woven fabrics — Distortion — Determination of skew and bow. In the standard, skew is defined as fabric condition where the picks, although straight, are not at right angles to the ends, while the curvature of the warp or weft of fabrics is termed as bow. The methods of measurement for the level of distortion as Error Angle is given in Table 1. If there occur more than one bowing, then the value of EA is selected as the highest of all measurements.[18]

Table 1 Measurements methods and formula for weft distortions[18]

Distortion type	Skewness	Bowing	Double bowing
Control Measurement Method			
Error Angle (EA)	EA = a/b.100	a_1/b_1.100 a_2/b_2.100 if $a_2/b_2 > a_1/b_1$ aEA=a_2/b_2 if $a_2/b_2 < a_1/b_1$ aEA=a_1/b_1	a_1/b_1.100 a_2/b_2.100 a_3/b_3.100 EA is the highest one
Actual measurement data*	a=1,5 cm, b= 150 cm	a_1=2,0 cm a_2= 0,8 cm b_2=100 cm b_2=50 cm	a_1 =0,5cm a_2=1,5cm a_3=1 cm b_1=30cm b_2=80 cm b_3=40cm
EA	1,0 %	1,6% 2,0%	1,66% 1 .88% 2,5%

*Actual measurements were made on the samples of Wool/Polyester blend (55/45) woven worsted fabric with a unit weight of 200 g/m²

In practice, a specially designed board is used for measuring the weft skewness. Two straight lines intersecting at the right angle serve as the reference lines. The fabric is carefully torn or cut along the width and the edges (selvedge) of the cloth is placed parallel to short line (as seen in Figure 6). The distance between the long line and the fringe side of the fabric laid down on the board is measured at the widest point.

The TPM framework is built on the Eight Pillars of TP, each one focusing on specific aspects of maintenance and production. The layout of pillar structure is illustrated in Figure 1. As it is seen in the figure, a typical TPM includes the 5S Foundation, as well. The aim of the 5S framework is to ensure that the work environment is clean and tidy. It incorporates five key principles for steady and systematic activities; namely Sort, Straighten, Shine, Standardize and Sustain.

Studies on the subject of weft distortions are very limited in the literature and most of the studies focus on the problem as a fabric deformation. In the early studies, the relation between shearing and skewness was discussed since the effect of shearing makes the fabric skewed. Cusick[19] paid attention to the existence of skewness during draping of the fabric and in another paper,[20] the effect of skewness on the drape of gore skirts was examined. A high negative correlation between shear hysteresis in the filling direction and skewness levels was found. Nine different weaves including plain, regular twill, zigzag twill and herring bone, were analyzed to identify the effects

Citation: Ozek HZ, Ayakta DY. TPM project for remedying weft distortions in a textile mill. *J Textile Eng Fashion Technol.* 2025;11(1):6–13.
DOI: 10.15406/jteft.2025.11.00397

of weave structure.[21] The measurements were made after 24 hours of relaxation period of gray fabrics. After the period of relaxation, the shape of all the samples were converted into trapezium from the initial rectangular form. The regular 3/3 twill weave samples produced the highest skewness level while the samples of zigzag twill weave had the lowest skewness score. The free space beneath the floating yarns in the fabric structure was claimed to be the fundamental effect on the skewness. Hence, the fabric skewness is reported as the degree of the warp and weft float distortion. The lower the weave factor, the higher the skewness but the configuration of opposite position of floats in zigzag weave generated a balance, due to the equal forces, and reduced the risk of skewness.

The effect of twist level on the weft skewness was also examined in another study.[22] Wool / Polyester (45/55) blend fabrics were produced by using Nm 48/2 blended yarn with 6 different twist values including the "s" and "z" directions. The samples were left for resting for 15 days after the weaving operation. Separate sample combinations were prepared, both in the same direction and in different directions, and analyzes were carried out. A steaming process was applied to the samples two and three times. The study revealed that there is a linear relationship between twist amount and weft curvature and that the number of steaming appear to have a positive effect on weft curvature.

The effect of weft density on the weft skewness was analyzed in another experimental study.[23] Various twill weave fabrics with four different weft densities were examined. This study proved that an increase in the weft density resulted in decrease of weft skewness for all the twill weave samples. It was revealed that any increase in weft density reduces the free spaces between the yarn floats which in turn shortens the free length of float. This reconfiguration causes the fabric shearing rigidity to raise that eventually restricts the ability of the warp floats' in-plane lever to move and the amount of skewness declines.

The effect of fabric weight, width and fabric construction on the weft skewness and shrinkage rates of denim cloth were examined in another study.[24] The weaves of 2/1, 2/2 and 3/1 right hand twill and 5 end satin were selected and measurements were taken before and after washing. The level of weft skewness was the highest for 3/1 twill and the lowest 2/2 twill weave as seen in Table 2. The fabric width and fabric weight were reported to have no effect on the skewness. A relationship between weft skewness and wet shrinkage was not found in this study.

Table 2 Basic fabric parameters and weft skewness values in denim fabrics[24]

Weave structure	Fabric weight (g/m²)	Gr. Fabric widht (cm) (g/m²)	Skew (cm)	Skew (%)	Shrinkage (%)
2/1 Right Twill	302,10	137,20	6.5	5.2	9.26
2/2 Right Twill	303,80	137,70	0	0	0.37
3/1 Right Twill	301,08	137,95	13	10.3	8.48
5 end Satin	303,12	137,20	4	3.4	12.96

Implementation of the TPM for remedying weft distortions

A considerable increase in quality problems and customer complaints on this issue led to the implementation of a TPM project at the mill. The selvedge arrangement of this type of cloths are also included into the content of the project. The TPM work was conducted at seven steps.

Step 1: Announcement of TPM implementation within the factory: To overcome possible resistance to change on the part of operators and other employees and skepticism of the merits of TPM, the project was introduced and also promoted by the top management. It is well known that a successful TPM program can never be achieved without the support of management from the top down. A team of six people were delegated to conduct the work throughout the factory.

Step 2: Identification of working area for the TPM program: elimination of weft distortions: The scope of the project was named as "Elimination of Weft Distortions" which have looked like an alarming issue for the production quality. The project team started to identify the standard procedures along the routine workflow by means of questioning and observations. The fabric suffering from this problems were examined and any unusual data, and similar features were pinpointed and analyzed. In the weaving section, the inspection of weaving loom equipped with leno selvedge apparat revealed that there was a clear difference between the tensions of ground warps and selvedge yarns. The reed dent setting for the selvedge yarn was fixed as twice the ground setting making a rigid and wavy selvedge. It was noticed that this problem continued in the finishing department during the passage of stenter machine. Therefore, the content of the work was extended to cover the departments of weaving preparation, weaving and finishing.

Step 3: Definition of optimal working conditions: This is the step to define the satisfactory settings and working conditions for the selected equipment or processes. In general, the 5S system is widely used tool for handling conducting this step because it makes you to define the improvements you're seeking – sort, set, shine, standardize, sustain. After completing a clear picture of the equipment and machinery and its current state, a draft for an autonomous maintenance plan should be prepared at this stage. Bowing and skewing are fractious defects and therefore maximum care should be taken and handled properly during entire processing to avoid wastage at garment making stage.

In the weaving machine, picks are inserted at a right angle to the warp yarns during weft insertion and pushed into the fabric cloth fell at the same position. So warp and weft are expected to remain always at a perpendicular angle. But this configuration may be disturbed in the following operation as fabric goes through a lot of processes and formation of skew or bowing happens. On the other hand, in the case of twill weave pattern such as 2/2 twill, bowing formation inherently develops in fabric.

Skewness formation at the weaving machine: In the weaving department, a tension optimization study was carried out for selvedge yarns of leno selvedge apparat. The tension extent of selvedge yarns and ground warps were controlled and optimum tension range was determined. This new adjustment was spread throughout the weaving shed by readily applying the same setting to the other machines and controlled production was ensured. The weave configuration at the selvedges were modified to make a strong and stable fabric edges. The number of yarns used in the both selvedges were found to be much more denser than what it should be. In the plain weave type, which is the most frequently used in leno selvedge fabric quality, a considerable savings in raw material were achieved by analyzing the edge wire transitions and reducing the number of wires in the selvedge construction.

Within the scope of the examinations, the selvedge configurations are controlled and some tests were carried out at the leno selvedge structured woven fabrics. The current selvedge structures and occurrence of weft curvatures on these fabrics were regularly followed step by step. It was found that that 4-4 denting arrangement was a

DOI: 10.15406/jteft.2025.11.00397

standard application in selvedge reed arrangements fixed as twice of the ground warp reed denting density.

The total examination of faulty fabric samples confirmed that the standard application was no longer valid since it was creating errors. As a result of the tests carried out on the batches produced as orders in the plant; in 2-2 ground arrangements, it was observed that in the case of using 2-3 arrangement instead of 4-4 in the edge reed, the appropriate edge form could be achieved in the controls performed at each step. As a result, in the finished fabrics, the edge ground tension problem was eliminated, inappropriate % weft curvature value was dismissed and the quality control criteria was successfully achieved. The trial was carried out in Table 3. In the trial productions, progress was made with a total of 35 ends (7 dent x 2 ends/dent = 14 and 7 dent x 3 ends/dent = 21 ends) for one selvedge and a total of 70 warp ends for both edges. Before this trial, it was planned to use 70 ends instead of the standard practice of 112 warp ends.

Table 3 Warp ends arrangement in the design report of M.1 quality

Warp end position	Number of allocated dents	Ends per dent	Total number of ends
Left selvedge	14	4	56
Ground	1862	2	3724
Right selvedge	14	4	56

In the finishing department, it was observed that the operator takes initiative in feeding the fabric batches into the stenter machine. Since this application carried a potential risk in terms of quality, it was ensured that the feedings were made more controlled by checking the synchronization of the feeding brush cylinder speeds in the stenter machine. The awareness of the operators was increased by providing single-point training. Improvements were made in the consumption of electricity and natural by reducing the amount of rework in the business. The gains of the work done in the business were included in the business routine programs. Practical gains and cost savings are explained in the following section (Figure 3).

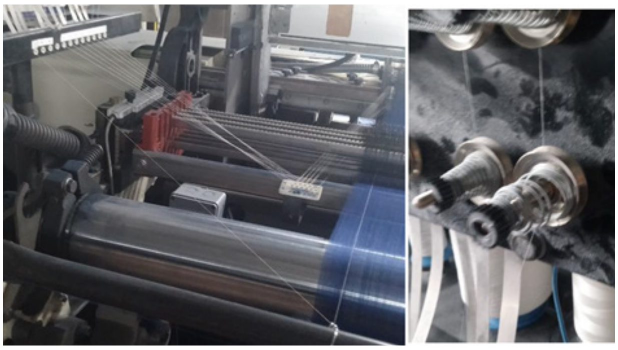


Figure 3 Arrangement of selvedge yarn feeding at the weaving machine and defective spring tensioners which were removed.

In preliminary studies; it was predicted that the finishing processes after the production of leno edge structured woven fabric were based on random preferences and that the front face marking thread used during weaving production would be used in order to prevent confusion. It was observed that a tension difference occurred due to continuous vibration when this marking warp wire was passed through the warp bridge. Therefore, it was thought that passing it through the spare tension peg after the tension peg would eliminate the tension difference and a spare tension peg was added and installed on the machine. The photograph of the arrangement is given in Figure 4. In the tests carried out on leno selvedge yarns where the tensions should be equal on the right and left edges; it was observed that the yarn tension between 15-20 cN may run without any problems. Control was provided with the samples made. The spring tensioner used for regulating the yarn tension were no longer functioning as seen in Fig.3, and they were replaced by new ones.

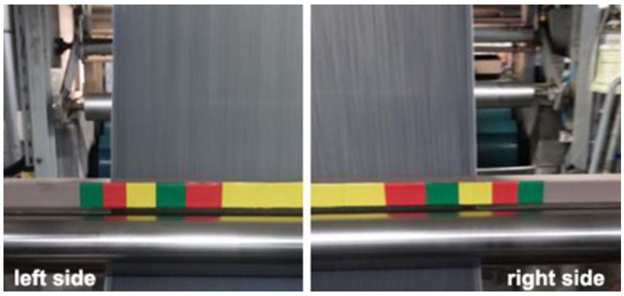


Figure 4 Control of the centering device in the stenter.

The importance of properly adjusting the fabric centering devices located before the Weft Straightener device (Mahlo), in front of the stenter machine in the finishing plant and the ability to perform their controls according to the colors that provide visual convenience, and if there is uncontrolled progress in different colors, the necessary adjustments can be made by the operator and single-point training has been provided. Figure 4 shows the fabric placement and flow of the centering device located in front of the stenter.

Bowing formation at the weaving stage: Conventional weaving machines are equipped with temple bars having sharp pins or teethes on their surface, at both sides to stretch the fabric by seizing the fabric selvedges. Which in turn avoid fabric to roll back post beating action due to let off motion force. During take up motion, when the fabric is being pulled by rollers, then reflection of force is more apparent at the center of the fabric, and less at selvedge because of the grip of temple. And eventually, bowing of 2,5 to 3,8 cm is generated at both selvedges of the fabric. This is called as Residual Bowing at Greige fabric. As a result of nature of the fabric structure;

1) Light weight fabrics are prone to expose bowing while heavier fabrics are less likely to expose bowing and skewness.
2) Finer the yarn thickness (metric count) more chances of bowing and coarser the yarn count then fewer chances of bowing will be there.

This bowing can be corrected during fabric processing and doesn't impact fabric geometry and its dimensional stability.

Bowing formation at the processing stage: The key reasons which are found responsible for bowing formation during fabric processing.

a) Fabrics in factor processing go through a lot of processes like singing, desizing, bleaching, mercerizing, dyeing, sanforising and stentering. During all these processes fabric has to pass through set of rollers many times and every time when fabric passes through a nip of rollers there is a chance of bowing formation if there is any speed variation in between 2 sets of rollers. Fabric may go through a stentering frame several times during dyehouse wet treatments.
b) Another important reason for bowing generation is machine operator negligence during fabric stitching. At the time of fabric stitching to make a batch, if proper care and attention is being given by operator then bowing can be minimized. At any given point of time if a roll of greige fabric is being stitched with

another greige roll at an angle then it's a start of bowing and this will increase in further processing.

c) Stenter dryer is a critical machine in the whole fabric processing and plays a significant role in fabric bowing. If the fabric fails to be fed properly into stenter machine then chances of generating bowing in the fabric shall be really high.

Measurement of skewness and bowing: When the filling yarn does not cross each warp yarn at a 90-degree angle, the fabric exhibits *skew*. When the center of the fabric moves at a slower speed than the two edges, the fabric exhibits bow. Most stentering frames have electronic sensors to reduce off-grain problems.

As also included in literature studies, operators were trained on the need to pay attention to the equalization of the stenter feeding brush speeds. In order to eliminate the worker's initiative, 2 inductive sensors PNP NO M8, 2 MP5W-4N type speed indicators were purchased and simultaneous feeding brush movement was provided from a single motor. Right and left photographs of the brush feeding cylinders are given in Figure 5.

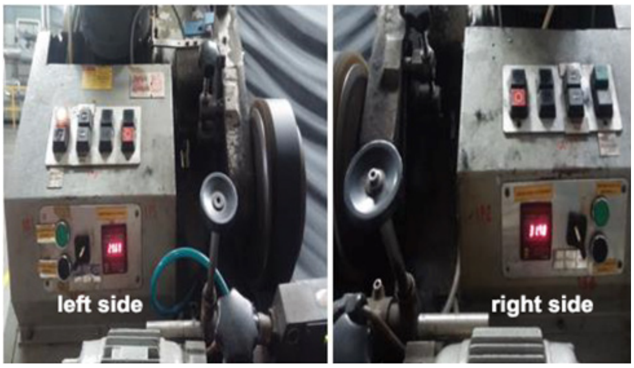


Figure 5 Elimination of speed difference of stenter feeding brush cylinders.

Particularly in striped or plaid patterned worsted fabric qualities, any level of weft skewness or bowing in the middle of the cloth are more prominent and consequently intolerable. The distortions of weft skewness and weft bowing are shown in Figure 6. Bowing and skewing affects striped or patterned fabric qualities more than plain or mono color fabrics, as the greater contrast in patterns makes the distortion more prominent.

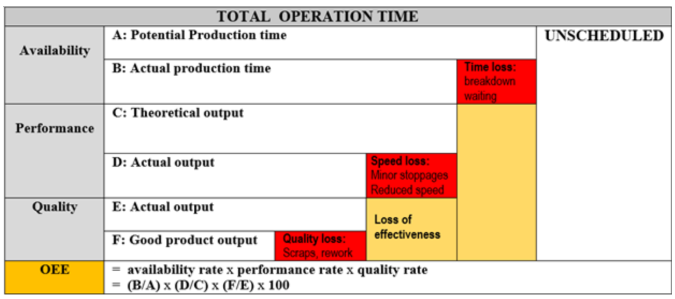


Figure 6 The calculation template for the OEE (Overall Equipment Efficiency).

The most common reason can be caused by an uneven distribution of tension across the fabric width during dyeing or finishing processes. Improper stretching during scouring, dyeing or finishing might also cause bowing or skewing. Correcting the tension settings on processing machines should rectify these defects. You can also ask your supplier to fix bowing and skewing found during fabric inspection by reprocessing the fabric through a compactor or straightening machine.

Step 4: Measurement of OEE: The Overall equipment effectiveness (OEE) is calculated in accordance with the template given below:

Availability = 340 / 415 = 0,819

Performance = 74 / 100 = 0,74

Quality = 74.391,30/6.740.590 = 0,011

OEE = 0,66

The OEE is calculated as 0,66 before the TPM implementations.

Step 5: calculation of losses: Calculations were made to determine the annual gains resulting from the yarn savings obtained. The steps for the calculation are listed as follows.

1) The total meters unwound in December were taken on a warp basis.
2) The total number of wires unwound x the total meters unwound were used to obtain the total meters unwound information.
3) The total meters unwound were converted to kilograms using the average Nm data,
4) The average Nm was found by using the weighted average according to the meter from the Nm data of the warps unwound in December.
5) Number of wasted ends x total meters / average Nm x 1000) =40x1000000/34000 = 1.176,470 kg
6) Wasted yarn weight x Cost per kg = 1176.471 x 103 = 121176,513 TL/month
7) Total Cost x 0.6 (percentage share of plain fabric) = 121176.513 x 0.6 = **72.705,91 TL/month**
8) The average count of false selvedge ends thrown away was also checked and calculated as Nm 40 among the running looms.

As a result of the calculations, with the dissemination made, an annual raw material profit of 72705.91 TL/month x 12 months = 872.470,9 TL/year was achieved.

By embedding this setting into regular production routines, the amount of finishing for reprocessing was cut down and approximately 2-3% (approx. 20,000-30,000 mt/month) production increase was achieved in finishing department. By reducing weft distortions defects caused by reprocessing in the finishing stage, possible savings in the cost of natural gas and electric energy were obtained. On the basis of data covering the last 6 months, the percentage weft distortion rates within the entire plant were examined and calculated. The data reflecting the decrease in weft distortion defects are summarized in Table 4.

Table 4 The share of distorted faulty fabric Production within the total finished fabric quantity

Period	Total amount of finished fabric [m]	Weft distortion meterage [m]	Percentage rate [%]
Month 1	990.888	22.525,0	2,27
Month 2	1.094.556	20.864,5	1,91
Month 3	1.057.946	9.103,0	0,86
Month 4	1.176.173	10.860,6	0,92
Month 5	1.224.740	7.185,5	0,59
Month 6	1.196.287	3.852,7	0,32

Citation: Ozek HZ, Ayakta DY. TPM project for remedying weft distortions in a textile mill. *J Textile Eng Fashion Technol.* 2025;11(1):6–13.
DOI: 10.15406/jteft.2025.11.00397

The electricity and natural gas savings achieved as a result of TPM implementation were calculated based on the unit consumption costs as 0.4319 TL/kwh and 0.1544 TL/m^3, respectively. The monthly average and total annual values obtained as a result of the relevant savings, are listed in Table 5. The total financial outcome of this operation, due to the energy savings was found as 95.155,40 TL per year in average.

Table 5 Record of monthly and annual electricity and natural gas saving after TPM implementation

Period	Finished fabric quantity [m]	Weft distortion rate [%]	Total electricity cost (TL)	Loss of electricity cost (TL)	Total natural gas cost (TL)	Loss of N.G. cost (TL)
Month 1	990.888	0,023	156.359,3	3.549,4	406.002,2	9.216,2
Month 2	1.094.556	0,019	192.653,5	3.679,7	538.242,5	10.280,4
Month 3	1.057.946	0,009	192.858,6	1.658,6	562.910,8	4.841,0
Month 4	1.176.173	0,009	199.872,1	1.838,8	587.288,9	5.403,1
Month 5	1.224.740	0,006	189.331,9	1.117,1	619.377,7	3.654,3
Month 6	1.196.287	0,003	186.648,1	597,3	544.314,9	1.741,8
		Monthly average loss		**2.073,5**		**5.856,2**
		Total annual loss		**24.881,6**		**70.273,8**

Step 6: Introduction of a proactive maintenance program: Warp yarn tension variation at the warp beam and also during weaving and fabric feeder setting at the entrance of stenter were standardized and issued throughout the relevant departments.

Step 7: Embedding TPM procedure : In the final stages, the new procedures for the set up in weaving and stenter machines were reviewed and embedded into factory standard operating procedures after being confirmed bu the management. It is hoped that this new system shall provide the technical staff with a benchmark and concrete data to evaluate its efficiency and performance levels in the future.

Conclusion

It was determined that the occurrence of bowing and skewness was mostly dependent on the finishing operations more than weaving A typical quality problems in textile factory may be arisen because of inadequate material, defective machinery and equipment and negligence of workers and management. The frequent occurrence of weft distortions in the woven worsted fabrics was almost a similar case. Defective machinery, malfunctioning equipment and negligent maintenance and outdated procedures were inefficient to remove these problems.

The specific OEE score for the selected departments measured after the TPM implementation was found as 0,88 which is a decent score by the factory standards. Implementation of TPM for this specific problem has been a quick and reliable solution to eradicate the problem with pinpointing the reasons and malfunctioning devices.

It has been once more proved that maximizing equipment effectiveness through optimization of equipment availability and performance are key issues for consistent product quality and satisfactory level of efficiency.

Acknowledgments

This study was collaborated with an integrated textile factory, Yunsa Yunlu San. Tic. company as part of a PhD study.

Funding

None.

Conflicts of interest

The authors declare that there exists no conflict of interests.

References

1. José CMV, Carlos RCL. Total productive maintenance and the impact of each implemented pillar in the overall equipment effectiveness. *Int J Eng Manag Res*. 2022;10:142–150.
2. Setiawan HHP. A systematic literature review of total productive maintenance on industries. *Performa Media Ilm Tek Ind*. 2021;20:97–108.
3. Wickramasinghe GLD, Perera MPA. Total productive maintenance, affective commitment and employee retention in apparel production. *Merits.* 2022;2:304–313.
4. Wolska M, Gorewoda T, Roszak M, et al. Implementation and improvement of the total productive maintenance concept in an organization. *Encyclopedia.* 2023;3:1537–1564.
5. Zhang TX, Chin JF. Implementing total productive maintenance in a manufacturing small or medium-sized enterprise. *J Ind Eng Manag*. 2021;14:152–175.
6. Gautama RP, Kushwah N, Yada A, et al. Quality improvement in textile industry by progressive quality pillar of TPM. *VSRD International Journal of Mechanical, Civil, Automobile and Production Engineering.* 2014;4(10).
7. Syed IS, Cesar S, Edward S. Decisional DNA (DDNA) based machine monitoring and total productive maintenance in industry 4.0 framework. *Cybern Syst*. 2022;53(5):6510–6519.
8. Guilherme LT, Tarcísio AS, Flavio S, et al. Digitalization of maintenance: Exploratory study on the adoption of Industry 4.0 technologies and total productive maintenance practices. *Prod Plan Control*. 2022:1–21.
9. Seleem SN, Attia E, EI-Assal A. Identification of critical success factors for total productive maintenance. Proceedings of the 18th international Conference on Applied Mechanics and Mechanical Engineering, Cairo, Egypt, 2018.
10. Crawford KM, Blackstone JH, Cox JF. A study of JIT implementation and operating problems. *Int J Prod Res*. 1998;26(9):1561–1568.
11. Sharma R, Singh J, Rastogi V. Importance and effectiveness of human related issues in implementing total productive maintenance: A study of Indian manufacturing organisations. *Int J Ind Syst Eng*. 2016;23:420–434.
12. Kadri M, Kumar A, Bhuneriya AK. Performance improvement through TPM Implementation in Textile industry. *Asian Journal of Convergence in Technology*. 2015;1(6).
13. Achamu G, Melese A, Haile B, et al. TPM and RCM implementation in textile company for improvement of overall equipment effectiveness. *International Journal of Advances in Scientific Research and Engineering (IJASRE).* 2018;4(10):129.

Citation: Ozek HZ, Ayakta DY. TPM project for remedying weft distortions in a textile mill. *J Textile Eng Fashion Technol.* 2025;11(1):6–13.
DOI: 10.15406/jteft.2025.11.00397

14. Kumar V, Geetika S. Analysis of TPM implementation to improve production in a selected section of textile industry. *Elixir Mech. Engineering*. 2016;98:42541–42544.

15. Arun AP, Krishnamoorthi K, Karthikeyan S, et al. Application of TPM to enhance overall equipment effectiveness in yarn manufacturing. International *Journal of Engineering and Advanced Technology (IJEAT)*. 2019;9(1S4):629–632.

16. Uddin Md M, Sakaline G, Aziz Khan MM. Enhancing OEE as a key metric of TPM approach -a practical analysis in garments industries. *EJERS European Journal of Engineering and Technology Research.* 2021;6(2).

17. ISO 13015:2013. Woven fabrics — Distortion — Determination of skew and bow. International Standard Office.

18. Ayakta DY. A study of effect of skewness and fabric constuction on the warp tension and worsted fabric sturcture of worsted fabrics. PhD Thesis, Tekirdağ Namık Kemal University, Graduate School of Natural and Applied Sciences, Department of Textile Engineering. 2020.

19. Cusick GE. The resistance of fabrics to shearing forces. *Journal of the Textile Institute*. 1961;52:T395-T406.

20. Moore CL, Gurel LM, Lentner M. Effects of fabric skewness on the drape of four-gore skirts. *Clothing and Textiles Research Journal.* 1995;13(2) :131–138.

21. Yazdi AA. Weave structure and the skewness of woven fabric. *RJTA.* 2004;8(2).

22. Yazdi AA, Khojasteh MR. The effect of twist liveliness on the woven fabric Distortion. *Fibers and Polymers*. 2006;7(1):79–84.

23. Yazdi AA. The effect of weft density on the skewness of the twill weave woven fabric. *Fibers and Polymers*. 2008;9(6):776–781.

24. Khatun S, Bhuiyan MSA, Hossain AM, et al. Analysis the effect of weave structure, fabric width and fabric weight on skewness and shrinkage of denim fabric, *IOSR Journal Of Polymer And Textile Engineering*. 2018;5(5):31–36.

Citation: Ozek HZ, Ayakta DY. TPM project for remedying weft distortions in a textile mill. *J Textile Eng Fashion Technol.* 2025;11(1):6–13.
DOI: 10.15406/jteft.2025.11.00397