تحسين كل من جودة المنتجات وأداء العاملين فى صناعة الملابس

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الجامعة التكنولوجية بسمنود

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الملخص

تعتبر الحياكات قلب صناعة الملابس الجاهزة ، و يعتبر تقليل عيوب الحياكات هو مفتاح إدارة الجودة وواحدا من التحديات التى تواجه هذه الصناعة ، و التي يمكن تقليلها بتجنب أخطاء المناولة و إستخدام طرق التصنيع السليمة، لذلك تم إستخدم برنامج تصميم التجارب ذو المحاولات التسعة لهذا الغرض.

إشارت الملاحظات المقاسة إلى إمكانية زيادة الإنتاجية والربحية، إذا تحسنت جودة المنتج، وقل زمن إصلاح العيوب، حيث تنخفض تكاليف الإنتاج وتتحسن بإستخدام زمن تشغيل أقل للمنتج.

تناولت الدراسة تحليل أسباب عيوب الحياكات، وإقترح الحلول للتغلب عليها، وجد ان عدد العيوب المسجلة إنخفض من (344000) عيب حياكة في السنة الى (96800) عيب فى السنة، كما تحسن معامل "سيجما" الدال على مستوى العيوب و كفاءة العاملين من (1.9) الى (2.8) بنسبة تحسن (47%) . كان هدف هذه الدراسة هو التحقق من كيفية استخدام منهجية (Six Sigma) لتقليل نسبة الخلل. في قطاع صناعة الملابس الجاهزة.

ولما كان الانتاج بالجمله يفرض حدوث أخطاء مما يزيد من فرص زياده العيوب، فقد بذلت جهود عديده نتج عنها وجود ادوات لتقليل هذه العيوب، إلا انها جميعا تبنى على العمليات الانتاجية (صوت العملية) ، دون ان تضع فى اعتبارها رغبات او اشتراطات العميل(صوت العميل) ، و تقدم هذه الدراسة نظام مراقبة جديد، لتقييم كلا من الأداء والجودة معا يعرف بمستوى سيجما.

بحساب مستوى الأداء و الجودة، ثبت ان الإنتاج (فانلة بحمالات من تريكو اللحمة) غير تنافسى و ضعيف ، واقترحت الدراسة، خريطه طريق ، لتحسين الاداء و الجودة ، تتكون من تتبع العيوب ،وتم رصد كمياتها، ثم استخدامت نظريه "بارتو" فى التعرف على الاسباب الحقيقية لهذه العيوب، و استخدمت خريطة السبب و الأثر فى تحديد مستويات التشغيل واخيرا إستخدم نظام تصميم التجارب فى تحديد شروط الانتاج المثالية .

الدراسة الحالية توفر على الشركة أكثر(283244.157 جينه/ سنة) بفرض ان إصلاح العيوب لم يحتاج الى مواد او مستلزمات جديدة او (1086090.407 جينه/ سنة) فى حالة إحتياج إصلاح عيوب الدرجة الثانية الى مواد وخامات إضافية.

الكلمات المفتاحية:

الملابس – عيوب الحياكات – تكلفة إعادة إصلاح العيوب – منهجيه 6 "سيجما" – مستوى "سيجما"– منحنى السبب والأثر – نظرية "بارتو"– نظام تصميم التجارب

Defects analysis in the apparel industry

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<u>Abstract:</u>

Increasing the production rate along with quality improvement is a major challenge in the (RMG) sector of Egypt. For sustaining in competitive textile business, it is important to minimize the cost of production and cutting wastage reduction. Fabric quality improvement can reduce the sewing defects.

Improvements in the quality of processes lead to cost reductions as well as service enhancements. In the more recent history of the quality development, the quality improvement program Six Sigma has been successful. The case study conducted on a knitting mill near Mansoura. During the production of knit garment many defects are found in the garment. These defects make the garment poor in quality which may leads to the rejection of the garments from the buyer due to poor garment quality.

Application of Pareto chart, fish bone diagram and Process Sigma Level/and or Performance Level tools helps solving those problems on priority basis. Corresponding training has been given to quality control team as to prevent those problems in future. The result came out with significant process sigma level of (4)for knitted garment, which used to be (0.91) in previous production quality.

<u>Keywords:</u>
Garment, Sewing Defects, Cost of Rework, DMAIC, Sigma Level, Cause and Effect diagram, Pareto Analysis, Factorial Design.

1. INTRODUCTION:

Textiles and clothing account for more than 27% of Egyptian exports. However, the total income from Egyptian exports is US$ 12 BN. One of the reasons for this low share is the manufacturing of less value-added products; another reason is the quality of some product categories which can be greatly improved. Although the country produces some of the world's best quality cotton, the quality of some apparel produced in the country needs to be improved by employing the Six Sigma methodology. The textile sector plays a significant role in Egypt's economy. Making high-quality products is therefore essential for survival in this fiercely competitive global market. Quality is ultimately determined by customer satisfaction. A lot of factors contribute to a garment's perceived quality, which when considered in its entirety helps reach the desired degree of consumer satisfaction. However, we must keep in mind that a 1% defective product for an organization is still a 100% defective product for the customer who buys it. The research clearly demonstrates how time and money can be saved by assuring excellent production in the garment sectors by removing non-productive activities like uncut thread, open seam, skip stitch, oil stain, unclean area, etc. This has a significant impact on the overall economy of the factory.

1.1. **Production Flow Chart of Composite Knitting Industry:**

Egypt's composite knitting industry contributes significantly to the country's foreign currency earnings. It has units for knitting, dyeing, finishing, garment manufacturing, and washing garments. Its production process is time-consuming and complex. Fig.1 depicts the manufacturing process flowchart for a composite knitting facility.

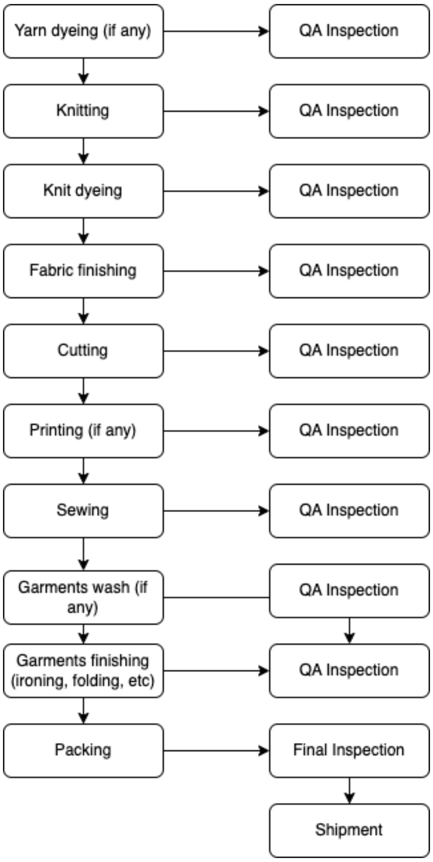

Figure [1] Shows a flow chart for composite knitting industry

One of the most crucial phases of labor-intensive ready-made garment enterprises is the sewing process. Quality issues that arise during this process have an adverse influence on the product's efficiency and quality, and they also increase the cost of production. The purpose of this study is to determine if the knitwear production process is well-controlled in a knitwear production enterprise, to identify the sewing processes in the sewing department that have the greatest rates of sewing faults, and to make recommendations for enhancing quality control. Among the Pareto Chart, Cause and effect diagram, and Factorial design were used in the study. The “Garment fingerprint” was used to determine if the production process is controlled in the enterprise. Additionally, the Sigma level methodologies were

utilized to pinpoint the issues that needed to be fixed in the improvement initiatives as well as to find links between the number of faults and the process groups that were meant to be beneficial in reducing knitwear production faults. As a result, it was determined that the production process in the ready-made garment industry was statistically not under control.
To determine the issues that needs to be resolved and detect

1.2. The problem statement:

However, this amount of rework rate 37781 [8] is there the last 12 months from the section's recorded data. The trial to distinguish between the most influential and least influential defects is not found yet. Their respective root causes are not clearly figured out. This in turn paves the way for the problem to remain inherent and make it difficult to solve them. Therefore, this work incorporates the process of finding the leading defect with its root cause and in turn solving them accordingly.

1.2.1. Goal statement:

To reduce the total defect % to the minimum level and thereby improving quality and reducing waste in turn increasing productivity.

1.3. Stages of Model Development:

a) Identification of various options at the checkpoints to capture defects,
b) Selection of various tools to be used in the model, and
c) Developments of the model.

1.3.1. Development of Model:

The suggested improvement model is given below:
1. Defect capturing at the End Line through check sheets,
2. Parto Chart,

3-Analysis of defects,
4-Cause & Effect Analysis of highest occurring Defects, and
5-Factorial design

1.3.2. Six Sigma Defect Metrics:

Before describing the approach to the calculation and interpretation of Sigma metrics for process outcome and variation it is important to discuss the issue of so-called short-term and long-term Sigma. The tables (and Six Sigma calculators) used to convert (DPMO) to Sigma levels often contain two sets of conversions, one called short-term Sigma that corresponds to a defect rate that would be observed if the process performance were to shift as much as (1.5) standard deviation (SD), and the other called long-term Sigma that corresponds to the defect rate if the process were properly centered.
In applying Six Sigma to laboratory processes, it is important to remember that the normal convention is to use short-term Sigma in analyzing process outcomes, and long-term Sigma in analyzing process variation.

1.4. Aim of the present work:

Egypt has more than (1,500) apparel factories with an average production capacity of (500) million pieces per day, and it is considered to be the first sector in terms of the labor force, which recorded (1.5) million workers, (50) percent of which are women. Sewing forms an essential part of garment manufacturing. Minimizing sewing defects is the key task for garments quality management and it is one of the challenging jobs. These days One of the most critical factors in the garment manufacturing industry is garment defect because it has a detrimental impact on actual productivity. The term "defect" is frequently used In the garment industry. The classification of flaws and the judgment of an inspector are key factors in the garments industry. These defects can be minimized by avoiding errors during the handling of materials/machines and by following the right working methods. A factorial design with nine replications was performed.

The implementation of this article enhances the process performance of the key operational process, resulting in greater resource utilization, reducing variability, and maintaining the output quality of the process. The result of this observation demonstrated that by reducing reworks activities, an industry may increase productivity and profitability with better product quality. Additionally, it reduces expenses and speeds up internal throughput. This paper provides a general review of this progress.

2. Theoretical Part:

Process performance may be evaluated by:

2.1. Proportion Defective (p):

p = Number of Defective Units / Total Number of Product Units

Yield ($Y_{1st\text{-}pass}$ or Y_{final} or RTY) (2)

Y = 1 – p The Yield proportion can be converted to a sigma value using the Z tables

2.2. Defects per Unit – DPU, or u in SPC

DPU = Number of Defects / Total Number of Product Units The probability of getting ‘r’ defects in a sample having a given "dpu "rate can be predicted with the Poisson distribution.

2.3. Defects per Opportunity – DPO

DPO = no. of defects / (no. of units X no. of defect opportunities per unit) (3)

2.4. Defects per Million Opportunities (DPMO, or PPM)

DPMO = dpo x 1,000,000 Defects Per Million Opportunities *or DPMO* can be then converted to sigma & equivalent C_p values

Given: a proportion defective of 1%

2.5. Converting Yield to sigma & C_p Metrics:

- Yield = 1 – p = .990 (4)
- Z Table value for .990 = 2.32σ (5)

Estimate process capability by adding 1.5 σ to reflect the 'real-world' shift in the process mean 2.32σ + 1.5σ = 3.82σ
(6)

This σ value can be converted to an equivalent C_P by dividing it by 3σ:

C_P = 3.82σ/3σ = 1.27. (7)

Other measures of process performance include:

- Process capability indices such as C_{pk}
- Natural tolerance limit or sigma level
- PPM defective or defective parts per million
- Process performance indices such as P_{pk}
- Quality costs or cost of poor quality (COPQ)

3. Practical Part:

3.1. Study Case:

The rapidly shifting economic conditions, such as increased global competition, shrinking profit margins, and consumer demand for high-quality goods at low prices, force manufacturers to lower production costs without sacrificing quality to remain competitive in the market. The primary prerequisite for lowering production costs and raising quality is defect minimization. By minimizing reworks, it will help shorten the cycle time and ultimately increase production. Considering this, the current study investigates the application of Six Sigma's DMAIC technique to reduce the defect rate in a chosen garment manufacturer. This methodical technique for minimizing faults uses the DMAIC methodology's five phases of Define, Measure, Analyze, Improve, and Control. In each phase, a different Six Sigma tool was applied. The main categories of flaws were determined using Pareto analysis. Cause and effect analysis was used to identify the underlying causes of such flaws. It is crucial to establish and maintain precise, thorough, and up-to-date written records of inspection and test methods for each operation if you want to reduce faults and rejects effectively. These documents need to contain and clarify the standards for approval or rejection.

If any problems are discovered, QC supervisors record the number of defects on the Check Sheet for all production lines.

Quality assumes a critical part in all parts of life, whereas decreasing the quantity of defective pieces in the clothing industry is an essential function. Garment industries in Egypt are facing stiff competition from Sri Lanka, Bangladesh, India, and China. Manufacturers must do everything possible to cut down on product flaws and boost their level of competition at this critical moment.

A manufacturing unit producing Men's shorts was facing Oil spots, Sewing defects, and B-grade products. Following an examination of the checklist and rejection data statistics, it was determined that the(DMAIC) approach would be the best way to address the issue.

3.2. Definition:

The garment industries are suffering from a high rate of rejections of their products. There are four sections under the Garment wing of the company such as cutting, sewing, finishing, embroidery, and printing. Among those sections the sewing section highly suffering from rework due to the existence of different defects as shown in Fig (1)

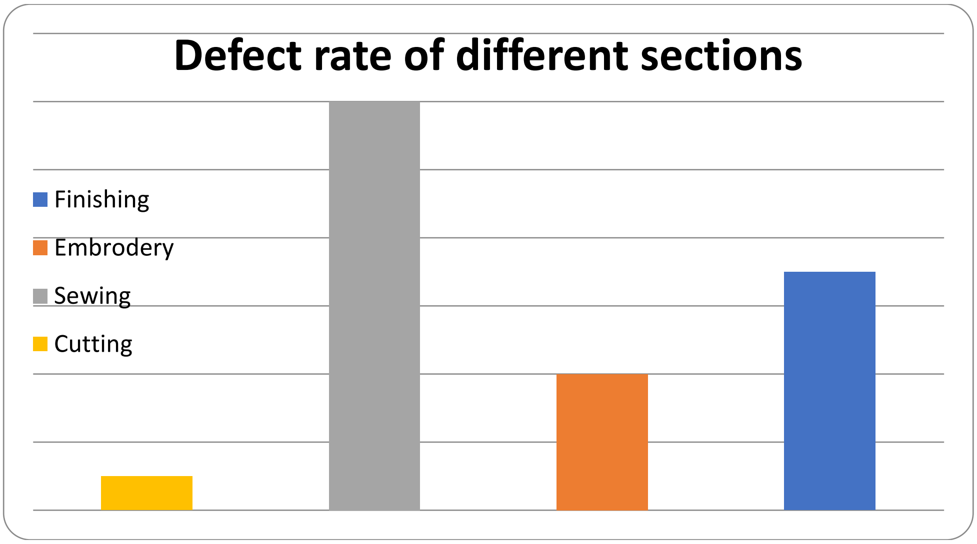

Fig.(2) Shows the Rework Rate [7]

3. 3. Measurement phase:

Table [1] shows the measurement phase.

Month	Total production	Rejected jobs	PPM
December	742	142	191375

3.4. Analysis phase:

Pareto chart for one day of the month of December 2017.

It was found that: the main causes of rejections are:

1-No sewing reasons such as: oil spot and B-grade garments,

2-Sewing reasons, such as: skipped stitch, Broken stitch, Down stitch,…etc.

Hence it was decided to find out the root cause for these defects by plotting a fishbone diagram.

3.5. Analysis of the main cause of no sewing reasons:

a- Application of a scrap paper under the presser feet of sewing machines after the day's work so that the machines which are leaking oil can be tracked.

b. Proper oiling level needs to be maintained to prevent leakage of extra oil
c. Operator to take responsibility for cleaning the machine after lubrication
d. Immediate reporting of oil leakage Ink/ chalk marks:
Usage of good quality markers, the marks of which are easily washable
e. Avoid using pencils for marking.
f- Usage of chalks on white and light-colored fabrics.
Soil and dust:
g- Usage of plastic bags for storing and transportation of pieces.
h- Cleaning of checking tables and machines before the start of the day’s work
i- Avoid keeping garments on the floor and using trolleys for storage.
j- Creating a polyethylene sheet partition between the sewing and finishing departments so that fabric dust doesn’t come over to the finishing unit and settle down on the washed fabric.

3.6. Analysis of the main cause of sewing reasons:

3.6.1. Sewing Defects:

These defects are usually caused by errors arising from the malfunctioning of sewing machines.

3.6.2. Seaming defects:

These defects are typically brought on by mistakes made when an operator and machine interact while handling a garment.

3.6.3. Placement Defects

These defects are typically brought on by mistakes that occur when marking, cutting, stitching, or a combination of these in the sewing room.

3.6.4. Defects category:

These defects are typically brought on by mistakes caused by faulty sewing machines and operator-machine interaction.

3.6.5. Fabric defects:

These defects result from mistakes made during the knitting and dyeing of fabrics.

3.6.6. Embroidery defects:

These defects result from mistakes made during the garments' embroidery processing.

3.7. Skipped Stitches Analysis:

A skipped or slipped stitch is created when the stitch-forming tool or needle misses the loop on the lopper. Skips are typically discovered when one seam crosses another, and they frequently happen before or after the substantial thickness. The tables below demonstrate sewing errors caused by one-day skip stitches. Additionally indicated were precise monetary values per day for sewing line skip stitch errors. After gathering the data, we assessed the amount of time needed to fix each error and also looked at the yearly financial losses.

3.7.1. Causes and remedies for Skip stitch:

3.7.1.1. Causes:

+The needle is threaded from the wrong side

+ Machine or bobbin tension is too high.

+ Failure of hook or lopper and needle to enter the loop at the correct time.

+ Needle size and thread weight are mismatched.

+ Worn thread guides, paths, or eyelets (burrs).

3.7.1.2. Remedies

+ Check and re-thread if necessary.
+ Reset the needle, the long groove faces the direction of threading.
+ Tighten presser foot screw.
+ Replace with a new needle.
+ Use thread with a left-hand twist

2.7.1.3. Down Stitch

"When the needle loop could not have forwarded an equivalent direction line this time creates a down stitch. The below graphs represent the one-month down stitch sewing faults. The graphs also show that individual faults value per day in a month. After collecting data, we calculated how many times required to rectify per fault and calculated how many losses per year for rework" [9].

3.7.1.4. Broken Stitch

"Broken stitch appears as equidistant prominent horizontal lines along the width of the fabric tube when a yarn breaks or is exhausted. We see that the below graphs show one month of broken stitch sewing faults in a line. The graphs mentioned individual faults value per day. After collecting the data analyze how many times are required to rectify the specific faults and also observe how much losses per year for this rework" [9].

3.8. Improvement phase:

3.8.1. Implementation plan (Factorial Design):

A full factorial experiment, as used in statistics, is one in which the experimental units are subjected to all conceivable combinations of the levels across all of the components in the design, which may have two or more discrete potential values or "levels" for each factor. Another name for a full factorial design is a fully crossed design. This kind of experiment enables the researcher to investigate how each element affects the response variable and how those effects interact with one another.

Table [2] shows the improvement plan.

Concerned parameters	Current status	Corrective action	Present status
SewingDefects	Factoryplan	UsingAMANN[7]plan	Implemented

3.8.2. Results:

The study explores the use of the DMAIC methodology of six sigma to minimize the defect rate in "Golden Fingers Company”. This is a systematic approach toward defects minimization through five phases of DMAIC methodology named Define, Measure, Analyze, Improve and Control which focuses on the reduction/elimination of eight basic types of defects such as oil stain, skip stitch, broken stitch, uncut thread, uneven stitch, raw edge, Bottom hem, and Placket joint in the sewing section. Different six sigma tools were used in different phases. The define phase rolls out the tools such as SIPOC which clearly show the process map that includes suppliers, inputs, outs, and customers, and based on this the entire quality is judged. The measure phase process capability was done. Continuous sewing process evaluation and extensive brainstorming sessions for the cause-and-effect diagram are done during the analysis phase. Cause-and-effect analysis and Pareto analysis were used to identify the key kinds of defects and the crucial root causes that influence the defects in order to find the fundamental causes of those flaws. The improvement phase is focused on improving the crucial root causes that have an impact on the flaws, together with their factors and levels. In the control phase, a control chart has been used to control the variation within acceptable levels in the process. Finally, some potential solutions are suggested to overcome those causes. The predicted result of the proposed solutions of the defect level in the section may be reduced.

3.8.2. Pareto Analysis:

Use Pareto Chart to identify the most frequent defects, the most common causes of defects, or the most frequent causes of customer complaints. Pareto charts can help to focus improvement efforts on areas where the largest gains can be made. This Pareto Chart is used to graphically summarize and display the contribution of each type of defect. It is a bar graph; the lengths of the bars represent occurrence and they are organized with the longest bars on the left side and the shortest on the right Side. In this way, the chart visually shows which defects are more significant. By using this Pareto Chart major types of defects were identified which is as shown in the Table [3].

Table [3] shows the Parto Calculation Process.

Defect type	fi	Relative fi	Cum. (Fi)	(%)
Oil Spot	50	50	5.3	5.3
Skipped Stitch	20	70	7.4	12.7
Down Stitch	15	85	8.9	21.6
Broken Stitch	14	99	10.4	32
B-grade defect	12	111	11.7	43.7
Embroidery Def.	12	123	12.9	56.6
Seaming def.	10	133	13.9	70.5
Placement Def.	5	138	14.5	85
Fabric defects	4	142	14.9	100
		951		

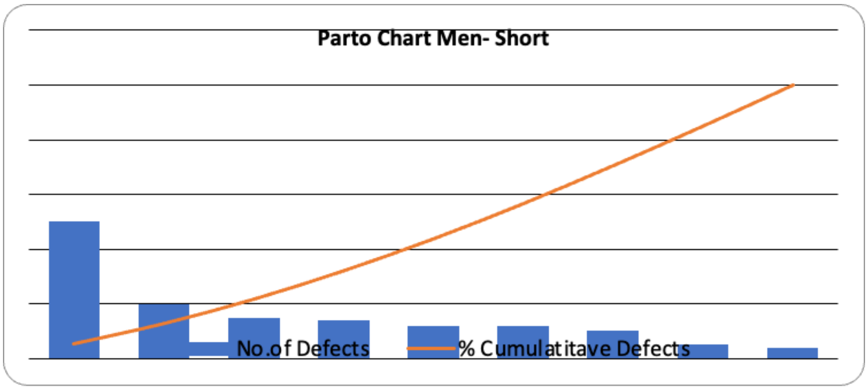

Fig.(3) A Parto chart showing the most recurring defects

For summarized data, each observation summarizes a category. Summarized data can be a count or a calculated value, such as a mean. For raw data, each observation is an occurrence or a defect. All the raw data are in one column of the worksheet, with each observation in a separate row (as shown in Fig.4 a-b).The Check sheet was used to capture the defects encountered in the finishing section. Then Pareto Analysis was performed to identify the top 9 defect types. Those identified 9 top defects are categorized and the main causes for the defects are shown using the Cause-Effect Diagram. Lastly, Factorial design was used to optimize the sewing conditions. Then we have given suggestions for those causes so that they can be applied to them minimize the frequency of those defects encountered. Thus, we can effectively minimize reworks, rejection rate, and waste of time which will ultimately improve productivity.

Table[4] Showing the most common defects in a 2-day period

Category	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Total
Open stitch	II	IIIIII					8
Un even top stitch	I	IIII					5
Loop slanted	IIIIIIII	IIIII					13
Un cut thread	III	IIII					7
Over stitch	II	IIIIII					8
Down stitch	I	IIIII					6
Skip stitch	II	III					5
Uneven lob	III	IIII					7
Broken stitch	II	IIII					6
short stitch	I	III					4
Puckering	III	II					5
label displace	II	IIIIII					8
Raw edge out	I	IIII					5
Up-Down position	II	IIIIII					8
Rejected	II	IIIII					7
	35	67					102

We have performed our Pareto Analysis based on one day of combined defect data of one production line from the finishing section for knitted shorts. From this analysis, we can identify the "Vital few" areas where maximum defects occur. The analysis is shown in Table 1. The cumulative percentage and 80% line are represented respectively by a horizontal line.

3.8.3. Observations from the Analysis

i. Oil spot is the most frequent defect with as much as 35.2 % of the total defects of men's short.
ii. Skipped stitch is the second most frequent defect with 14.1% of the total.
iii. Among other defects contribution of the Down stitch is 10.6%, the Broken stitch is 9.9%, the Embroidery defects are 8.5%, and B-grade effects are 8.5%, respectively.
iv. These five major defects are the “vital few” where 78.3% of total defects occur.

3.9. Cause and Effect Diagram:

Use a cause-and-effect diagram to organize brainstorming ideas about the potential causes of a problem. The diagram can help you visualize relationships between a problem (effect) and potential. Fig.5 shows the "6M" effecting on sewing defects.

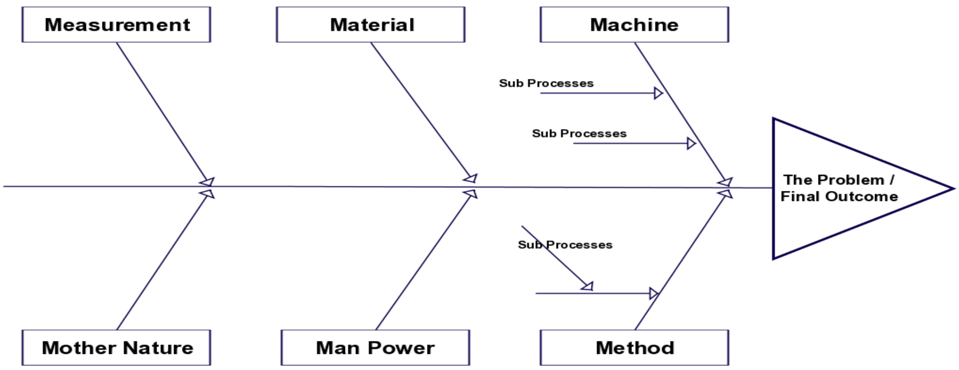

Fig. (4) The 6 "Ms", (used in manufacturing) [10-11].

M1=Materials (includes raw material, consumables, and information, such as: Fabric, i.e., fabric size –Sewing Thread, i.e. thread size),
M2=Machine (equipment, technology, as: Hook, Lopper is not able to hold the thread loop in proper time, Needle deflection or

bending, Tension variation in lopper thread over bobbin and needle),

Man/mind - power = (physical or knowledge work, includes: Kaizens, suggestions: Operator inefficiency, less training, behavior),

M4=Method (process: Loop size or needle is small, improper handling of cut pieces

M5=Measurements (inspection, environment), and

M6=Management.

The last type of Fishbone diagram allows structured brainstorming about potential factors for a response variable to help you design an experiment. You can use this diagram to organize information about potential factors of response variables into Controllable, Uncontrollable, Held-Constant, and Block able Nuisance categories.

Table [5] Shows, suggested solutions for Sewing Defects:

Cause type	Causes	Suggested solutions
Man-power	Operator inefficiency	Provide adequate training to the operator
Machine	Hook, lopper, or needle is not able to hold the thread loop in proper time.	1-Timing of hook or lopper with needle should be adjusted properly. 2- Use needle which design to facilitate loop formation 3- Repair damage in m/c parts
	Needle deflection or bending	1- Adjust the needle 2-Check needle position
	Tension variation	Choice of sewing thread

Method	Loop size or needle is small Improper handling of cut pieces	Adjust needle and thread size Reduce the gap between the presser foot and the hole of the needle plate

3.9.1. Result of Pareto Chart:
There are 9 types of defects where oil spots and skipped stitches can occur at 70 positions. The rest 7 types of defects can occur at 56 positions.

So, the number of total concerning area is 142 which is responsible for the total amount of defects.

Total Number of Defects in Major Concerning Area = 111.
Percentage of defects in major concerning area, = 111/142 = 0.782 X 100% = 78.2%. (8)

Percentage of major concerning area, 78.2%. So, by concentrating only on 21.8 % areas of total defects can be reduced.

3.10. Cost of Rework Example:
Rework of 1 line/day = 142 pieces from the daily output of 742 pieces, and from this let me categorize the rework into different operations like Oil Stain 50 pieces, skipped stitches 20, down stitch 15 pieces, Brocken stitch 14 pieces, B-grade 12 pieces, etc. The estimated time per operation is for instance as per above, in garment industries reworking a piece of garment takes 3 times more than making the first time a good piece [7]. Having these 142 pieces of daily rework at one operation is equivalent to stitching 436 pieces at exactly that specific operation. So, let's take an average operation time is 25 seconds. Total time on rework is 25 sec*436 pieces= 10900 seconds=3.028 hours
Garment minute value is 0.03 USD/ minute
=3.028*60*.03 USD. (9)

=5, 45 USD will be the cost of one operation/ garments, i.e., (80878 EL/day) equivalent to make a rework of 742 pieces/day, and 23263400 EL/year.

3.11. Sigma level calculation:

No. of units = 742

Total number of defects observed = 142

Number of defects opportunities per unit =1 (10)

Then:

Defect per unit "DPU" = (142/742) =0.191 (11)

Defect per opportunity "DPO" = 142/742 x 1 =0.1913746 (12)

Defect per Million Opportunities "DPMO" =191375 (13)

Defects per opportunity "DPO%" =1%

Yield % = 99%

Yield = 1 – DPO = 1 – 0.191375= 0.808625 (14)

Short-Term Process sigma = Ϭn-1 = 2.4 (15)

Long-Term Process sigma = Ϭ n = is 0.9 (16)

Ϭ n includes the 1.5 Ϭ shift.

It is clear that the process is out of control.

3.12. Factorial Design:

The following 2^4 factorial was used to investigate the effects of seven factors on the sewing variables. The factors are *A* = fabric size, *B* = thread size, *C* = needle size, and D = stitch size. This experiment was performed in a pilot plant. Here is the dataset for this sewing Plant experiment. You will notice that all of these factors are quantitative.

Table [6] Data of experiments showing effects of 2^4 factorial on sewing variables

Variables	-1	0	+1	Interval	Fabric Type
X1=Fabric size(k tex)	140+	150*	160	10	100%
X2=Thread size(tex)	20/2+	40/2	60/2*	20	Cotton
X3=Needle size(Nm)	65	70*+	75	5	Single
X4=Stitch size(spc)	4+	5	6*	1	Jersey

Where:
*Is AMANN Standard [1], + is factory Standard,

3.12.1. Fabric sewability [5-8]:

Fabric sewability means sewing without troubles (skipped stitch, open stitch, down stitch, broken stitch, etc.). Fabric sew ability may be evaluated (response) by the number of sewing defects per shift –seam length – the time between successive defects.

Table [7] Shows multiple sewing runs to identify fabric sewability

Run	Fabric size	Thread size	Needle size	Stitch size
1	140	20/2	65	4
2	140	40/2	70	5
3	140	60/2	75	6
4	150	20/2	70	6
5	150	40/2	75	4
6	150	60/2	65	5
7	160	20/2	75	5
8	160	40/2	65	6
9	160	60/2	70	4

It was found that the best conditions for garment process ability index are achieved at 160 g/m2, 60/3 sewing thread count,75 needle count, and 6 s.p.c. It looks like AMANN standard [1].

The research methodology adopted for this study is a case study. The case study was conducted in a garment factory near Mansoura. It is found the sewing section is highly suffered from defect and rework problems. The work aims to minimize the defect percentage by using the (DMAIC) approach of the Six Sigma methodology.
It was found that the defects, existing

(DPMO) (Defect per Million Opportunity) and Sigma Level of the selected factory was calculated which is indicated in table 7. The frequency of defects (skipped stitch, drop stitch, seam pucker, broken stitch, fly yarn, size, and oil spot) of the inspected: Men's shorts, Men shirt, Women's trousers, and Complete was also.
Table [7]

Total Checked Pieces	131499
No of Defective’s	37781
% of Defective’s	2.873%
DPO	0.126
DPMO	2873.082
Sigma Level	1.91
Cost of Rework	101.100

3.13. Existing Process:

It was found that results of DPMO and Sigma Level of Existing Total Checked pieces 1314999 No. of Defectives 37781(2.873%), Defectives 0.028 DPO 0.126 DPMO 2873.082 sigma level 1.91.

3.14. Modified Process:

At first preliminary investigation was carried out on a men’s shirt, men’s shorts, women’s trousers, and women’s complete items, to identify the area where most of the defects occurred. It was found that men's shorts highly suffered from defects and rework problems. It was found that results of DPMO and Sigma Level of Existing Total Checked pieces 2300 No. of Defectives(B-grade) 231(10.043%), DPO 0. 100, DPMO 100434,783 sigma level 2.81.

3.15. Cost of rework:

It means the rework cost moved from 101.100 Dollars to 6.329 Dollars (91.9% reduction)

CONCLUSIONS:

The purpose of this study is to give more insight into the six sigma methodology. The suggestive, tools developed in the article cover a comprehensive series of aspects in minimizing reworks in the finishing section of apparel industries by ensuring quality. A product or service's value is increased by excellent quality, and it also helps build brand recognition and a positive reputation for garment exporters, all of which translates into satisfied customers, healthy sales, and foreign exchange for the nation that produces the product. Remember that a product that is 1% defective for an organization is 100% defective for the customer who purchases it. The findings of this study indicate that maintaining quality manufacturing reduces nonproductive activities like reworks in the garment industry, which saves time and money and has a significant effect on the economy of the factory. The case study demonstrates that a manufacturing unit's sigma level climbed from 0.9 to 2.4, prompting a stronger focus on improving production quality

Recommendation:

This field study recommends the optimal use of the methodology of I Sigma to overcome the problems of the ready-made garments industry, especially reducing defects and evaluating the performance of employees.

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