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Defect Analysis and Determination of Cutting Time in the Cutting Department in a Tunisian Clothing Company

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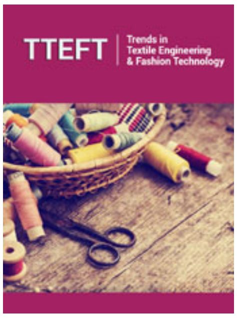

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Abstract

The increase in industrial competition, especially in the clothing sector, pushes companies to take actions towards improving the production system and quality. However, the majority of studies focused on the production department. The objective of this study is to analyze the defects within the cutting department in a Tunisian clothing company. The Failure mode and effects analysis FMEA method was used to analyze the defects. The obtained results showed that the RPN coefficient varied between 108 and 336. Following these results, an improvement plan was carried out for each defect to reduce the risk of defects. In the second part of this study, an analysis of cut time was performed to determine a multiple regression equation as a function the number of fabrics used, number of linings, number of biais of binding, number and size of yoke. The analysis of the regression equation gave a correlation coefficient of 96.8% and an error value of 1.5% (<5%), meaning the model found is statistically representative.

Keywords: Tunisian clothing; Clothing industries; Cutting; Manufacturing knitted; Fabrics

Introduction

In view of the growing competition in the clothing industries, many companies must move improving efficiency in terms of productivity and quality. Indeed, the production phase remains essential for the success of the company while respecting the customer's requirements in terms of time, cost and quality. But, in reality, the problems encountered during production affect deadlines. Therefore, planning and customer satisfaction are affected too. Several studies have been made to find the parameters affecting impact on the management of production. In 1996, Fisher showed that the newly-launched products have a great influence on production management [1]. According to Donolhue [2], fashion products that have a short cycle time have an influence on productivity. Market requirements and product characteristics have an effect on the choice of planning and production control system [3]. Studies in the area of management improvement deviated from simulation and the laws linking action parameters to performance indicators.

This helps managers to lead their production system [4]. Another study proposes calculating action parameters to achieve a value for a performance indicator [5]. Other studies have used tools to improve production efficiency, such as the D.M.A.I.C tool of the six-sigma method which allows analysis at the level of a production system [6]. The MSP (Statistical Process Control) also called SPC (Statistical Process Control) brings together a set of methods to monitor and improve a production process from a statistical point of view [7]. TPM is a methodology for increasing the availability of equipment by reducing investment needs and investing in human resources to lead to better use of equipment with right product quality and reduced labor costs [8]. The Failure mode and effects analysis (FMEA) method has been used in several studies to analyze and resolve problems. The AMDEC method helps achieve quality through preventive action. This tool aims to detect product failures, define the actions to eliminate these failures, reduce their effects and prevent or detect their causes and document the development process [9]. The Failure mode and effects analysis (FMEA) method is a method that reduces defects and the number of failures. It is applicable in all types of manufacturing processes. Researchers have used this method in the clothing industry such as Yücel [10] who has succeeded in reducing the seam defects found in his study [10]. Indeed, most of the research has been directed towards improving productivity in the production phase. Limited research has been concentrated in the cutting department such as Zuo's [11] study which investigated operating parameters and cutting time [11]. Yeung LHW [12] proposed a genetic algorithm approach in the cutting department to solve the problem of the cutting operation in the clothing industry [12]. Mehmet KÜÇÜK [13] used the FMEA method in the cutting department to analyze the defects encountered and reduce them in order to improve the quality of the cutting processes. The objective of this study is to apply the FMEA method in the cutting department in a Tunisian clothing company to look for the defects encountered by finding solutions for each problem. The second objective is to develop a method for measuring cutting time using the linear regression method as a function of the number of fabrics, number of linings, number of biais of binding, size of yoke and number of yokes.

Material and Methods

The study was carried out in the cutting department of a totally exporting clothing company, specializing in manufacturing knitted articles such as swimwear, panties, boxers, underpants and underclothing. The cutting department contains 3 machines equipped with an automatic cutting system and 6 tables for spreading and cutting. The daily production capacity varies between 25,000 to 30,000 pieces per day.

The study was started with the defect analysis for 6 months. The FMEA was applied in the different manufacturing processes [14]. The FMEA method allows to implement the zero defect policy for the manufacturing sector. This method is useful for quickly determining defects, the causes of failures and reducing the frequency of breakdowns [15].

To apply the FMEA method in the cutting process, the following steps were followed:

a. Collecting defects during the study period

b. Determining the severity «S» of each defect

c. Determining the occurrence « O » for each defect

d. Calculating the Detection « D» for each defect

e. Calculating the risk priority number according to the following formula [16]:

$$RPN = S \times O \times D \qquad (1)$$

f. Analysis of defects and search for solutions

For the analysis of cutting process times, the study was started by determining the timing of all phases: laying, spreading, cutting, numbering, strapping.

a) The laying phase: this is the preparation of the layout where the diagram of the cut must be presented according to the cut order. The route must be prepared before the start of the cut at least 1 day. The cut order of each order must be done according to the cut order planning.

b) The spreading phase: in this phase and according to the spreading plan, the fabric must be spread. A lay is a superposition of a certain number of fabrics of well-defined length and placed in a fixed order.

c) The cutting phase: in this phase and after placing the pattern on the lay, the yokes must be cut using an automatic cutting system.

d) The numbering phase: in this phase, after cutting, part identification must be made by numbering. The conformity check with respect to the technical file must be carried out at this stage to avoid any defects resulting from the cut.

e) The strapping phase: this is the packing phase of each size. The control of the number of pieces compared to the quantity of the tracking sheet is done at this phase.

The timing was carried out on a number of orders for 23 different items. Then the unit cutting time was obtained according to the following formula [17]:

The standard time of cutting operation =

the laying time+The spreading time+The cutting time+

The numbering time+The strapping time (2)

The linear regression method was used to develop a method which allows the cutting time to be directly measured as a function of the following parameters: the number of fabrics per model, the number of linings, the number of biais of binding, the size of yokes, the number of yokes. Linear regression is one of the multivariate analysis methods that deal with quantitative data. It is a method of investigation on data from observations, or experiments, where the main objective is to search for a linear link between a quantitative Y variable and one or more also quantitative X variables [18].

Result

Analysis of defects in the cutting service

After collecting faults, we applied the FMEA method to calculate RPN for each fault. Table 1 summarizes the faults collected with the level of severity, occurrence and detection as well as the RPN for each fault. From the obtained result, RPN for the whole defect is greater than 100. Indeed, according to the FMEA method, the improvement in the process must start with the defect which has an RPN coefficient more than 100 [13]. For each defect, a defect plan must be carried out to improve the quality level and reduce the risk of defects.

Table 1: The different types of faults collected with the level of severity, occurrence, detection and RPN calculation.

N°	Defects	Severity S	Occurrence O	Detection D	RPN
1	Shade in the fabric rolls or between yokes	7	5	5	175
2	Removal of yokes	8	6	3	144
3	Pleats at the yokes due to poor padding	8	7	6	336
4	Too much waste and leftover rolls	6	5	5	150
5	Roller parts with oil stains and / or damaged	8	5	4	160
6	Asymmetrical pieces for the fabric with stripes or with a pattern	8	6	4	192
7	Fabric damaged during spreading (for the coated fabric)	8	5	4	160
8	Incorrectly shaped parts	8	5	4	160
9	Cutting problems due to crushed paper and / or lost paper markers	8	5	4	160
10	Pieces with wrong shape and size due to poor cutting	10	5	3	150
11	Notches too long or badly cut	8	6	4	192
12	Poorly cut of binding roll	8	5	5	200
13	Mixture of pieces	8	6	4	192
14	No traceability for pieces with the marker	6	6	3	108
15	Color migration after cutting and storage	7	6	5	210

Cutting time analysis

In this part, a cutting time analysis was performed after collecting the cutting time by the timing method for some models. For each model, we collected the number of fabrics used, the number of linings used, the number of yokes, the size of yoke and the number of biais binding. Table 2 summarizes the time in minutes found for each model. Following the results obtained in Table 3, we analyzed the effect of each parameter on the variation of the cutting time. Figure 1 summarizes the effect of each parameter on cutting time.

Table 2: The cutting times obtained by model by the timing method.

Model	Nbre of Fabrics	Nbre of Linings	Nbre of Biais of Binding	Nbre of Yokes	Size of Yoke	Cutting Time (min)
Base layer top Fresh warm boy	2	0	0	8	2	1,38
Shorty lou	3	1	1	21	1	3,726
Longh tight calçon 117138	1	0	0	6	2	0,805
Basey layer Top fresh warm Women	2	0	0	8	2	1,438
Basey layer bottom Fresh warm Women	2	0	0	13	1	1,668
Men boy Boxer 500	1	1	0	3	1	1,15
Clea bandeau all over	2	2	0	10	1	2,53
Basey layer bottom Fresh warm Men	2	0	0	14	2	1,725
Culotte 110	1	1	1	4	1	1,254
Tight Run Warm	2	0	0	9	2	1,438
Jamer Boxer	1	1	0	4	1	1,15
Suit WP weter Polo	1	1	0	10	1	1,553
Suit WP 500 Boy print	1	1	0	4	1	1,15
LS TS RUN WARM	1	0	0	10	2	1,035
Boxer 100 Plus	1	1	0	6	1	1,369
Suit Cloé	2	1	1	6	1	1,88
Trunk	1	1	0	4	1	1,61
Running 3/4	1	0	0	7	2	0,863
GLISSE BIKINI WOMEN POINT	1	1	1	8	1	1,484
1P Anna	3	2	0	13	1	3,048
NORA High waist bottom	2	1	0	5	1	1,783
New Vaiana	1	1	0	7	1	1,38

2P Bottom Meg	1	1	0	7	1	1,323
Boxer Stab Boy	3	1	0	15	1	2,703
Boxer Stab Men	3	1	0	15	1	2,703
Boxer 500 Yoke	3	1	0	12	1	2,76
Boxer 100 Pool	2	1	0	6	1	1,725

Table 3: Statistical analysis of various parameters.

Predictor	Coefficients	Erreur-Type	Statistique t	Probabilité P
Constante	0,053368548	0,20135776	0,265043412	0,79356024
Variable X 1	0,451601412	0,057429453	786,358,541	1.08E-03
Variable X 2	0,471601634	0,085021977	5,546,820,358	1.67E-01
Variable X 3	0,17220758	0,080327062	2,143,830,171	0,04390867
Variable X 4	0,067603653	0,010145584	6,663,357,265	1.35E-02
Variable X 5	-0,060615844	0,109087728	-0,555661439	0,00584

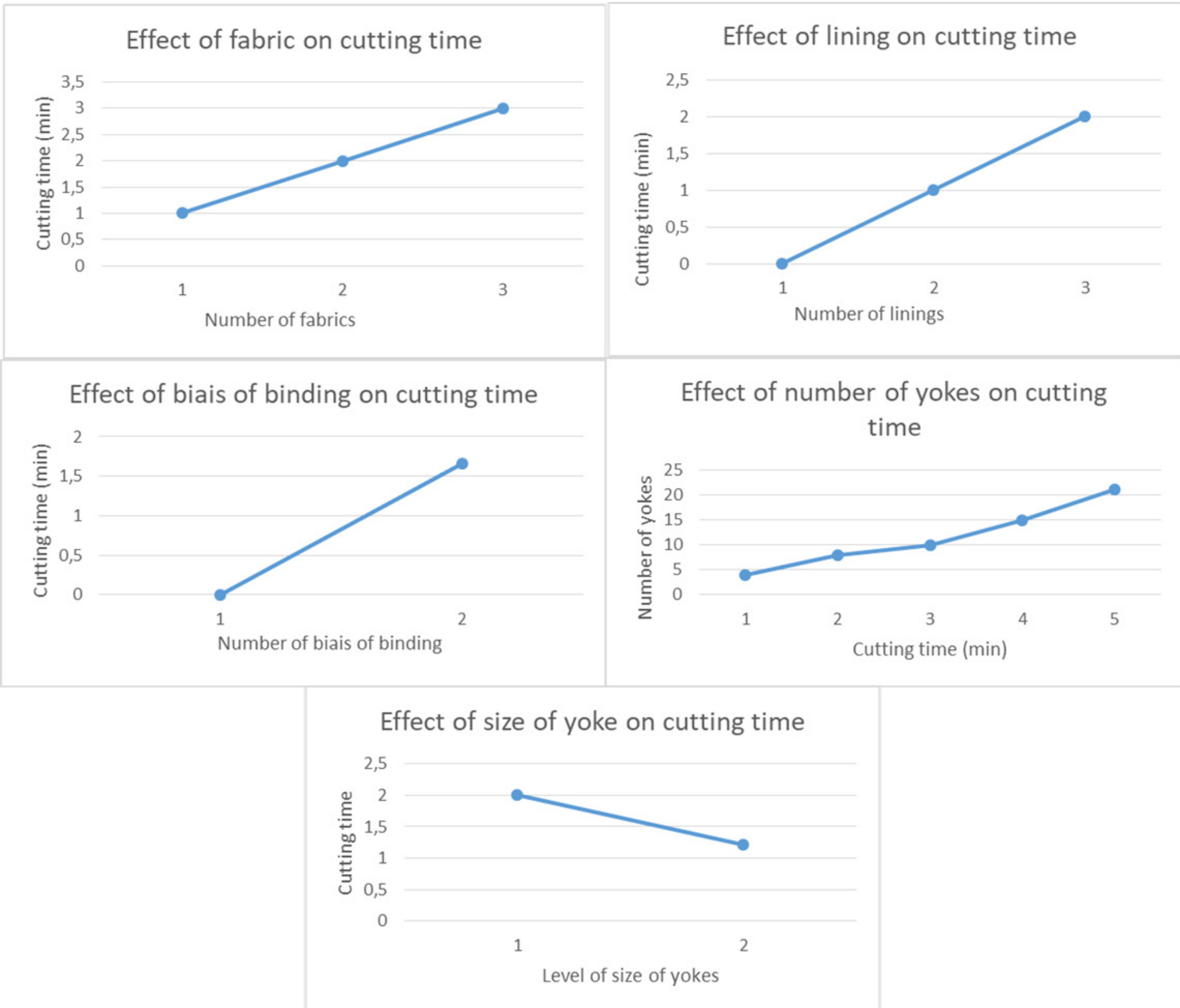

Figure 1: Effect of different parameters on cutting time.

According to Figure 1, the parameters studied have an effect on the cutting time. Indeed, the number of yokes has a positive effect, changing the number of yokes from 3 to 21 increased cutting time by 223%. The number of fabrics in the model has a positive impact on response time. Indeed, the model which contains 3 types of fabrics has an increase in cutting time of 39% compared to a model which contains only one type of fabric. Likewise, the increase in the number of linings in the model led to 47% increase in cutting time when there are 2 types of lining in the model. For the model which requires a binding, the cutting time increased by 25% compared to another model which does not have this type of yoke. Yoke size has a negative effect on the cutting time. The cutting time of a model that contains small panels is longer than one that has large panels. To conclude, the chosen parameters have an effect on the cutting time, so it is possible to have a multiple linear regression according to these factors. By applying the multiple regression method between the chosen factors and the response (cutting time), we obtained the following multiple regression equation:

$$Y(x)=0.053+0.451X_1+0.471X_2+0.172X_3+0.067X_4-0.06X_5 \quad (3)$$

X_1: Number of fabrics used

X_2: Number of lining

X_3: Number of biais of binding

X_4: Number of yoke per model

X_5: Size of yoke

This is a multiple linear regression model [19,20]. That is to say a summation of linearity of different parameters with a constant equal to 0.053. Table 3 summarizes the statistical results of different parameters.

According to Table 3, the test statistics indicate that these are too large values validating the statistical test hypothesis as in linear regression where we must test the significance of the parameters [21]. For each of the variables Xj included in a multiple regression model, the null hypothesis indicates that the coefficients βj are equal to 0, the alternative hypothesis can be one-sided or two-sided, indicating that βj is either less than 0, greater than 0, or just not equal to 0 [22]. So, we reject the null hypothesis. In fact, we can take the decision from the value of p which must be less than a level of precision (in our case 0.05) for the parameters to be statistically significant. For the coefficient p equal to 0.005 less than 0.05 this means that the value of this coefficient is statistically significant. The p-value for the parameters included in the model is equal to 0 i.e., all the coefficients play an important role in the regression model and are statistically significant [23]. The standard deviation of the model (S) equal to 0.14 and the correlation coefficient R^2 equal to 96.8% which makes the error equal to 3.2% less than 5%. According to the values of the coefficient R2, which gives an idea on the quality of the model, the greater this coefficient, the better the model will be. That is to say that the calculated responses will be strongly correlated with the experimental responses. In our case R2 is equal to 96.8% which is a value very close to 1 so the quality of our model is better. Thus, the values of the correlation coefficient and of the adjustment coefficient R^2a 96.1% are important values, which shows that the model provides information and that there is a relationship between the factors and the response [24]. In a hypothesis test, decision making can be based on the probability value (p-value) for the test in question:

A. If the value of p is less than or equal to a predetermined level of significance (alpha = 0.05), the model is statistically significant.

B. If the value of p is greater than alpha, we must reject the model which is not significant.

According to our model P= 0.015, the model is statistically significant. And the statistic F is equal to 130, which corresponds to an important value greater than critical F (4.10-15), which corresponds to the law of FISHER corresponding to the test report. Here the hypothesis H0 of the Ficher-Snedecor test is as follows: the model does not allow to describe the variation of the test results. The law of F gives an idea on the probability of prob F for rejecting the null hypothesis. Below 5% we are not right to reject the gold model in this case we have prob F equal to 3.1%. So, the model is representable [24].

Discussion

In this study, the FMEA method was used for the analysis of defects in the cutting process. The results showed that the equipment has an RPN coefficient that is greater than 100. This requires intervention and improvement of all faults. In 2016 MEHMET carried out another research in the cutting service. He found that 7 defects have an RPN coefficient> 100. These defects are notch errors, waste (length), incorrect packing on the shelves, adhesion of tissue edges, writing of an incorrect batch number to report, propagation error on the wall, wrong spreading plan [13]. Following the defects found in our study, the improvement plan for each defect was carried out:

Defect 1: Shade in the fabric rolls or between yokes

Solution: Make sure that all rolls of fabric are stored in a building protected from the sun and bad weather. The rolls must be protected, wrapped and stored on the sides and on a suitable support. It ensures that the rolls are stored by part number, color number, lot number and by width.

Defect 2: Removal of yokes

Solution: the fabric must be relaxed before the spreading phase according to the rules of the relaxation test carried out by the development department. Each type of fabric has its relaxation conditions before the cutting phase. Make sure that each fabric is identified by indicating the date, time of onset and duration of relaxation. It is important to prevent the fabric from being stored on the ground.

Defect 3: Pleats at the yokes due to poor padding

Solution: it is necessary to check that the spreading tables are flat, regular, without spaces between them. The layers must be spread out when spreading. All the layers should be aligned on one side, in order to optimize the useful width of each layer. Thus, the start and end of the layer should be perpendicular to the selvedge. Move the mattress to the same table. It is forbidden to move the mattress from one table to another. Grab the mattress by the paper at all four corners, move it slowly and carefully, and hold it flat.

Defect 4: Too much waste and leftover rolls

Solution: Use rollers that are the same width for each lay. Optimize the efficiency of the paper markers as a function of the width to reduce waste and consumption of fabric during cutting (Table 4).

Table 4: Variation in height and maximum length of the lay according to the type of fabric.

Fabric Type	Height Maximum of Lay	Length Maximum of Lay
Heavy knit (polar fleece...)	20cm	8m
Light knit (jersey...)	15cm	8m
Spandex (> 15%)	4cm	5m
Woven	15cm	10m
Sensitive lining:	3cm	2m

Defects 5: Roller parts with oil stains and / or damaged

Solution: Before padding and cutting, check that the tables are clean, and the cart is not leaking oil and is not damaged. Look for flaws in the spreading and reject the layer that contains stains or large defaults. For small defects, it's necessary to put a piece of fabric string across the width of the lay.

Defect 6: Asymmetrical pieces for the fabric with stripes or with a pattern

Solution: Spread each layer of fabric and attach the spreading table needles. Make sure that the stripes or fabric patterns are properly positioned. It's necessary to use manual cutting instead of automatic cutting and ensure that the layers are properly maintained.

Defect 7: Fabric damaged during spreading (for the coated fabric)

Solution: the coated side must be facing downwards in spreading mode. Light color and dark color should be separated to avoid color bleeding.

Defect 8: Incorrectly shaped parts

The line should not be longer than the length of the lay. The very high lay height must be avoided by applying the rules according to the type of fabric (Table 2):

For the height, if the measurements recommended are outside the requested values, it's necessary to check randomly the 1st panel, the middle and the last of 3 stacked cut pieces.

For the length, if the measurements recommended are out of the requested values, it's necessary to check if the lay is correctly aligned with the paper sheet or the edge of the table first layer. And for the soft fabric, the pinch should not be used.

For manual cutting, the paper makers must be glued on the 1st layer of the lay: by tape, by sticky paper (a temperature suitable for the fabric) or the glue of the first layer. And for the soft fabric, the pinch should not be used.

Defect 9: Cutting problems due to crushed paper and / or lost paper markers

Solution: The tracks should be stored in good condition. The beginnings or ends of markers have to be identified with the presence of the following information: Conception Code, Marker Name, Printing Date, Marker Length, Marker Width, Sizes on the marker and Quantity and Efficiency.

Defect 10: Pieces with wrong shape and size due to poor cutting

Solution: The pieces are cut according to the drawing line. After cutting, check the cut pieces with the cutting pattern (acceptable allowances are 0.1cm inside and 0.3cm outside). The cut pieces dimensions must be the same for each layers. The maximum deviation is 1% of the piece total length or a maximum of 0.5 cm. To check the pieces after printing, make sure that the shape is respected and the shrinkage of the pieces due to heat is the same as the shrinkage added in the original pattern. Example: the cutting pattern has a 2% shrinkage; the cut piece after printing must not shrink by more than 2%.

Defect 11: Notches too long or badly cut

Solution: If seam allowances are >0.7cm, the notches have to be done into the piece.

The depth should be between 0.2 and 0.3cm

The position must respect the marker, tolerance: +/- 0.2cm.

If seam allowances are <0.7cm, the notches must be done out of the piece.

They have to be done accurately (position and/or shape). The notches out of the piece are compulsory for the flatloch assembly if the flat seam is equipped with an upper blade.

The notches must be the same for all layers. The layers must therefore be perfectly aligned, and the cutting machine must be perfectly upright. The notches should follow the orientation printed on the marker. For delicate components that may be torn unknitted, the notches should be marked with a pen or with chalk before moving the bundle. All blades should be sharp and clean.

Defect 12: Poorly cut of binding roll

Solution: For roll of fabric: it's necessary to put a plastic film all around the roll to avoid the opening of the roll after cutting. Make sure tension is continuous in all the roll. Binding should be cut with a machine and not by hand. The roll of fabric should not be larger than the roll rest of machine. The roll of fabric should be cut regularly and the blade should be sharp.

Defect 13: Mixture of pieces

Solution : Cut parts must be clearly identified to be differentiated from wastages. The parts must be checked before assembly. The check should be carried out after the cut. Pick some bundles at the beginning, the middle and the end of the lay for each lay. Check the upper layer, the middle layer and the under layer for each bundle with the reference pattern including allowance. Put the piece on the validated pattern with allowance, and check if it is acceptable, including the notches. The tolerance is +/- 1% with a minimum of 1mm for bra and swim wear. The tolerance is -1 / + 3mm for the finished product. The control must be done with a pattern including shrinkage or not depending on the type of fabric.

Defect 14: No traceability for pieces with the marker

When a panel of garment needs to be embroidered or printed, all the layers of this panel must be identified. The identification must contain: number of lay, Size, number of layer.

The other parts of the garment are stored by lay and size in store until the part printed or embroidered is approved by quality control. Then the bundles can be made. Use the plot to identify stacked cut pieces. Put the numbering on one piece, on all the layers. If there is a marking on one panel of the finished product, write the numbering on that panel and on another, on all folds.

On the stickers, there should be: the number of the layer, the size, the direction of the cut, the identification of the garment, the number of layer. Make the bundles and put them in a basket. Write on the basket which size is inside. When the 1st worker takes the basket, all the stacked cut pieces must be put correctly to avoid mixing all the layers. When the workers are doing their operation, they must respect the order of the pieces. They should start with the panels last number, stitch it, put it aside, same thing for the next. Finally, the workers turn the packet over, fold it, and put it in the basket, exactly with the same position and in the order, it was when taken.

Defect 15: color migration after cutting and storage

After the cutting operation, the fabric can be either spread with coating side down on clean table or rolled up with the membrane/ coated side inside. Rolls of different colors must be separated.

All panels of the same size, same direction must be gathered in the same bundle: On the marker, each size is identified by a letter with a number. Once the lay is cut, all pieces with the same size, letters and numbers should be gathered on the table. The marker paper can be removed when the bundling is in progress for all this size for lay cut. Each bundle must be correctly identified at least with bundle number, Conception Code, Size, Color, and linked with the purchase order number.

Improving the quality within the cutting process following the defects observed, a cutting time analysis was made to find an equation which allows to determine the cutting time of each model depending on the following parameters: the number of fabrics used, the number of linings used, the number of biais of binding, the number of yokes and the size of yokes. These parameters are directly related to the model and not to the external elements such as the materials used, the method of cut or spreading applied. Some researchers investigated the cutting time and the parameters that influence the final time. Indeed, the conditions, the equipment, the interactive mode between the manpower and the machine, the spreading plan and the cutting influence the cutting time [11]. Thus, the type of fabric has an influence on the padding speed and therefore on the yield [11]. The effect of these factors is called floating rate, which is well studied in calculating sewing time, but it is not included for cutting time. This rate was set at 25% for the cutting time [11]. Therefore, the cut time found must be increased by this floating rate. The cutting time measurement allows to give reliable measurements for the calculation of the time of each article in the quotation phase. In addition, the measurement of cutting time per item allows planning within the cutting department to be organized according to the capacity of the labor force and the materials used.

Conclusion

This study allows us to analyze the level of quality within the cutting process and the analysis of cutting times. The FMEA method was used to detect defects by calculating the RPN coefficient varying between 108 and 336. These results allow an improvement plan for each type of defect to reduce the risk of defects in the cutting process. The linear regression method was used in the second part of this study to determine an equation to calculate the cutting time for each model according to the following factors: the number of fabrics, the number of linings, the number of yokes, the number of biais of binding and the yoke size. Linear regression analysis shows that the model found is statistically significant (p-value less than 5%). Thus, the correlation coefficient equals 96.8%, which shows that our model is representative and that there is a strong correlation between the factors and stitching time.

This study focused on possible defects in the cutting department of a clothing company, as well as the analysis of cutting times for each model. A study of personal and material performance is necessary to improve the cutting service process. Thus, the application of lean tools is important to analyze, measure and improve performance indicators within this service.

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