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CONSUMPTION OF THE SEWING THREAD OF JEAN PANT USING TAGUCHI DESIGN ANALYSIS

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Abstract:

This work deals with the evaluation of sewing thread consumption in jeans and classic pants clothing. Six different input parameters are chosen and used for investigation. To objectively evaluate their contributions, a Taguchi design analysis was applied. Based on the comparison between each input parameter effect, this experimental analysis helped us to classify the overall tested factors. Indeed, our findings show that the sewing yarn affects widely the thread consumption during stitching of the pant. In spite of their non negligible impact, the number of stitches per cm and the needle type can be considered as influential input factors on thread consumption. In our experimental design the other tested factors were kept constant.

Keywords:

Consumption, pant clothing, sewing thread, Taguchi design

Introduction

Knowing the amount of yarn required for sewing a garment thereby enabling a reliable estimation of the garment cost and raw material required, helps industrial producers to minimize their thread consumption during sewing of cloths. Consumption of sewing thread is a complex textile, especially, clothing research subject. Many studies are conducted to evaluate some clothing problems such as recovery, bagging, physico-mechanical behaviours, etc. [1-3]. However, concerning thread consumption, comparatively little investigative work has taken place on the interrelationship between the sewing machine parameters, the thread insertion inputs and clothing morphology. Relative motion of the fabric plies being stitched affects the prediction of the thread consumption because it is highly complex to fix it as a function of all influential parameters. To measure the thread consumption, accessed by unpicking the seam using such techniques, some input parameters are investigated such as the stitch length, thread tension and its compressive modulus [4]. Dorrity and Olson studied the thread motion and they developed a prototype system for detecting sewing defects. Research results show that the system yields reliable indication of thread consumption-related faults, such as broken top or bobbin threads, misfed fabric, and thread tension imbalance, for several stitch types [6]. Moreover, the effects of check-spring travel and the feed retardation on lockstitch sewing which affects intuitively the thread consumption have been analyzed by Hayes and Kennon [7,8].

Experimental

There are a number of different types of seaming that have been developed to different sewing applications [9]. When we make the assemblage with such machines (Figure 1, a, b and c), e.g., flat felled seam (2 x 401), safety stitch machine (ISO – 516), and lockstitch machine (301), each machine releases a normalized stitch according to the norm ISO 4915:1991 norm [10]. We will study their effect on the thread consumption. All adjustment conditions are regulated to obtain good quality of assembly. Table 1 shows the thread type characteristics.

a
b
c

Figure 1. Different sewing stitchs:
a. Assembly with lockstitch machine (type of stitch: 301)
b. Assembly with felled seam machine (type of stitch: 2x401)
c. Assembly with safety stitch machine (type of stitch: 516)

Table 1. Sewing threads type characteristics.

Characteristics	Thread 1	Thread 2
Composition	100%PES	100%Cotton
Nature	Twisted 2 ends	Twisted 3 ends
Yarn/thread count (tex)	16,5	16,67
Twist direction	Z	Z

Hence, two different threads are used to compare their effects as well as the other input parameters on the sewing thread consumption of pants (Figure 2). In addition, to compare the contribution of the type of sewing machine on the evaluation of thread consumptions of each jean pant, we choose two kinds of machine: within and without automatic thread trimmer.

To objectively evaluate and analyse the overall contributions, a Taguchi experimental design-type was elaborated. Six different inputs, i.e. sewing machine type, S_{MT}, stitch length, S_L, thread count, T_c , needle count, N_c , fabric composition, F_c and mass, M, are investigated. Therefore, a Taguchi experimental design can help us to classify objectively the input parameter contributions on the thread consumption values. Indeed, when the level value is equal to 1, then it is considered the lowest level. However, if the level value is equal to 2 then it is the highest one. This is available when the input factor presents two levels only. Each factor or parameter has levels which define our experimental field of interest limits. Table 2 shows the tested input parameters, their fixed adjustments and their correspondent levels which would help us in preparing our specimens. Juki lockstitch and overlockstitch machine parameters were adjusted to the manufacturer's recommended standard settings.

To determine the input level values, numeric or text values for each level of the factor should be entered. By default, Minitab sets the levels of a factor to the integers 1, 2, 3, 4, 5 ... as a function of the input adjustment regulations. If the input factor has 3 or 4, 5, 6 6 … levels, i.e. adjustment regulations values, then these levels should be indexed by 3, 4, 5, 6, etc.. Hence, by default, Minitab's orthogonal array designs use the integers 1, 2, 3... to represent factor levels. If factor levels were entered, the integers 1, 2, 3, ..., would have been the coded levels for the design. Indeed, a Taguchi design is chosen, because it represents a method of designing experiments that usually requires only a fraction of the full factorial combinations. Besides, an orthogonal array means the design is balanced so that factor levels are weighted equally. Due of this, each input parameter can

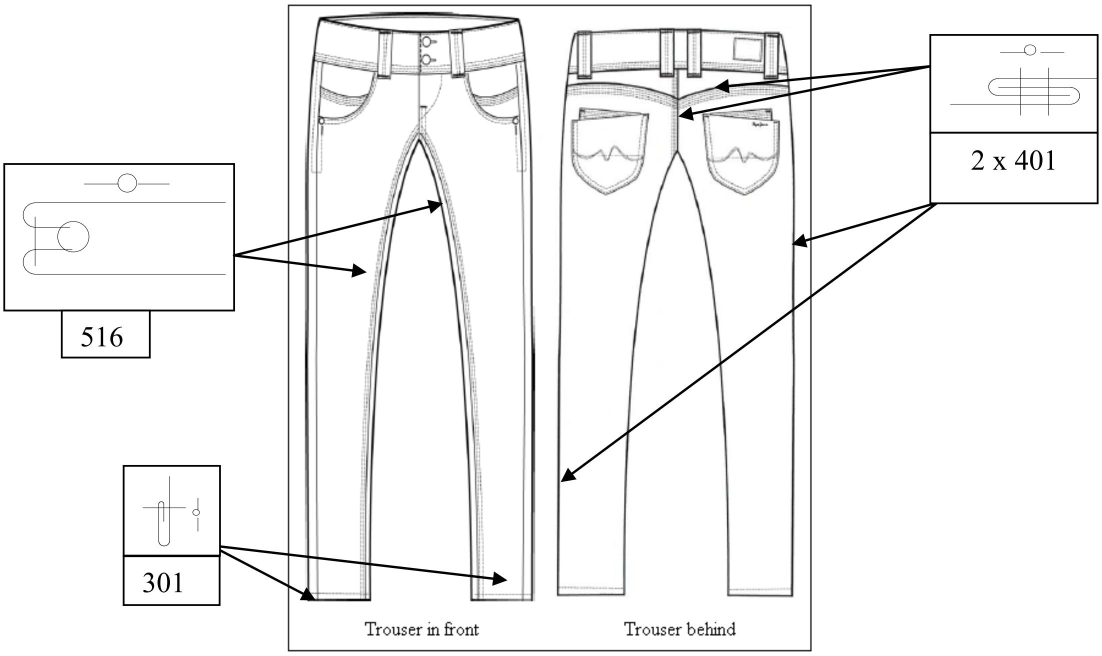

Figure 2. Pant sample.

Table 2. Input parameters and their correspondent levels.

Input level	Sewing machine type, S_{MT}	Stitch length, S_L (mm)	Thread composition, T_c	Needle count, N_c	Fabric composition, F_c	Mass, M (g/mm^2)
1	Without automatic thread trimmer	2,22	100% PES	120	100% Cotton	268
2	Within automatic thread trimmer	2,85	100%Cotton	90	Stretch:98% Cotton + 2% Elastane	417

be evaluated independent of all the other parameters, so the effect of one factor does not influence the estimation of another factor. For these reasons, to analyze objectively the effect of each factor, we applied Minitab 14 software in our work.

Furthermore, to investigate the effect of each input parameter and the all interactions between them, our pant samples (eight specimens) were prepared according to each input combination. An experimental design was fixed to predict the thread consumption as a function of the most influential factors. Moreover, the properties of denim fabrics used to sewing the pant (Figure 1) are illustrated on Table 3.

Table 3 shows the all inputs and their level limits. Each input factor has two levels' limits which are indicated by 1 (the highest and lowest) in our experimental field as shown previously in Table 2. These levels adequately cover the factor space available for each parameter.

Results and discussion

To analyze the variation of the most important parameters, Figure 3 shows the impact of each one: sewing machine type, S_{MT}, stitch length, S_L, thread composition, T_c, needle count, N_c, fabric composition, F_c and mass, M parameters. Table 4 shows the mean consumption of the sewing thread calculated

Table 3. Relevant denim fabric properties.

	Denim Fabric 1	**Denim Fabric 2**
Composition	2% Elastane + 98% Cotton	100% Cotton
Ends/cm)	33	25
Picks/cm)	19	18
Thickness, (mm)	0,60	0,92
Mass, M (g/m²)	268	417

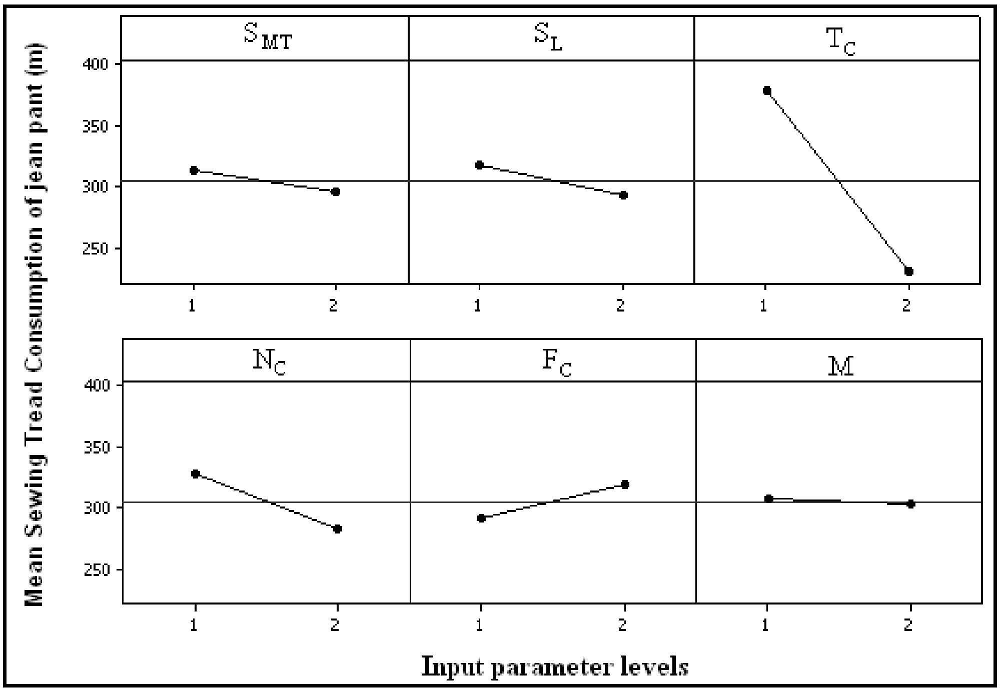

Figure 3. Mean variation of sewing thread consumption as function of studied input parameters given by Minitab software.

Table 4. The Taguchi design used for investigating variation in sewing thread consumption as function of variations in input parameters levels

Test n°	S_{MT}	S_L	T_c	N_c	F_c	M	Mean value of STC (m)
1	1	1	1	1	1	1	451,6
2	1	1	1	2	2	2	347,85
3	1	2	2	1	1	2	192,52
4	1	2	2	2	2	1	261,72
5	2	1	2	1	2	1	231,75
6	2	1	2	2	1	2	236,25
7	2	2	1	1	2	2	432,74
8	2	2	1	2	1	1	281,88

using different levels of variables according to the Taguchi experimental design. To estimate the coefficients in the general relation between the sewing thread consumption STC and different parameters mentioned above, we followed the forward selection regression procedure. For the analysis of regression, with Minitab 14 software, we calculated the sum of squares due to lack of fit called coefficient of regression according to the method given by Droesbeke et al. [13] and Goupy [14].

The mean sewing thread consumption value, STC expressed in meter, is the amount of thread sewed on pants to assembly plies and different zones of trouser. After having sewed all specimens, we measure the length of thread consumed to join different components of pant. By unstitching experimentally all pant samples after sewing their parts we can measure the length of thread used which is represented by the STC (m). Each tested combination in our experimental design was repeated 12 times in order to obtain objectively a mean representative experimental sewing thread consumption value. We prepared Table 4 by taking the entire main, quadratic, and interaction effects into account. According to Minitab 14 software analysis results, the overall statistical effects on the mean sewing thread consumption values of jean pants are illustrated on Figure 3.

To classify the overall input contributions on the consumption of thread, the mean variations between all parameters levels were investigated. This classification can provide a rapid and accurate method to select the influential parameters on thread consumption which helps to predict the amount of sewing thread required to make up a pant garment. We Consequently we obtained different significant input parameters for each parameter. We found the parameters, i.e. thread composition T_c and needle count, N_c, to be significant, while the parameters, i.e. sewing machine type, S_{MT}, stitch length, S_L, fabric composition, F_c and mass, M parameters had little influence influence on thread consumption.

The results of the Taguchi analysis an accurate classification of input parameters shown in Table 5. By changing the level of each input factor, the mean thread consumption varies as mentioned in Table 4. Furthermore, as the corresponding parameter is important and has been classified as the most significant one the mean thread consumption is observed to be high when we modify the input level.

As a result, the thread composition seems the most important parameter. In fact, the increase of both thread composition and needle count (expressed as Nm) parameter values distinctly decreases the thread consumption of denim pants garment. However, when the fabric composition level increases, we obtain more and more consumed thread during the sewing of pants. Besides, our findings show that, among the all input parameters, only two factor levels decrease the thread consumption of pants when their levels increase. However, their contributions on the thread consumption seem lower than the thread composition and the needle count parameters, respectively. According to Figure 3, it may also be concluded that the other input parameters are less influential factors on the thread consumption of pant garment samples. However, these inputs separately have little effect on our results, but it remains interesting to investigate their interactions which can affect together the thread consumption.

Effect of the sewing machine type, S_{MT}

Figure 3 3 also shows that the consumption of sewing thread is high when sewing machine without automatic thread trimmer is used. It is obvious because, due the operator draws himself out for approximately 5 to 6 cm after the sewing operation to cut manually the thread; the consumption becomes higher than when the machine within automatic thread trimmer is used. The excessive thread used is considered as waste which increases the thread consumption. However, our findings show that when the automatic thread trimmer is adjusted to cut the excessive use of thread; the consumption can be widely decreased.

Effect of the number of stitch length, S_L (or number of stitch by cm)

The number of stitches called the stitch length has a notable influence on the variation of the consumption of sewing thread. Moreover, our results show that higher the length of the stitch, higher is the consumption of thread. Indeed this is due to the increase in number of bent thicknesses and of the formed lockstitch number. This result is in agreement with Kennon and Hayes [7,8] and confirms our finding that with the fabric feed in motion the thread is required to form the upper and lower lengths during stitch length modification. During the fabric progression, the take-up lever approaches the top of its vertical travel and this upward excursion also creates a demand for thread. Consequently, the needle-thread which is required to form increasingly large loop to form the stitch length affects the geometric profile of the lockstitch and as a result, the thread consumption modified. By analogy with Hayes and Kennon

Table 5. Classification of the input parameters given by Minitab analysis.

Level	S_{MT}	S_L	T_c	N_c	F_c	M
1	313,4	316,9	378,5	327,2	290,6	306,7
2	295,7	292,2	230,6	281,9	318,5	302,3
Delta♣	17,8	24,6	148,0	45,2	28,0	4,4
Rank♦	5	4	1	2	3	6

Delta♣: The tables include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor.

Rank♦: Assigned by Minitab and based on Delta values. Indeed, rank 1 accorded to the highest Delta value, rank 2 to the second highest, and so on. Use the level averages in the response tables to determine which level of each factor provides the best result.

study result [7,8] the increase of the number of stitches per centimeter means the decrease of stitch length geometry which allows a reduction in needle thread consumption as shown in Figure 3. This result is in ultimate agreement with the findings of the Lauriol study [11] which proves that if the sewing length decreases from 2,5mm to 2mm (4 stitches/cm to 5 stitches/cm), then thread consumption increases, approximately, by 10%. Furthermore, in our case, from 2,85mm to 2,22mm (4,5 stitch/cm to 3,5 stitch/cm) the thread consumption increases by 7,8%.

Effect of the sewing thread count, T_c.

As seen earlier and based on the evolutions shown in Figure 3, the sewing thread composition, T_c is the most influential element on thread consumption. Hence, it is clear that that if 100% PES thread composition is used instead of 100% cotton yarn, the thread consumption becomes much less significant. Therefore, compared to cotton thread during sewing pant samples, a thread consumption increase (more than 39%) is saved. Indeed, the thread consumption of pant specimens is equal to 378,51m when the cotton sewing thread is used, but it is equals to 230,56m only when pant samples were sewed using PES thread. This may be due to the physical properties of each thread. Besides, this explanation in agreement with Lauriol [11] confirmed that the sewing thread consumption can decrease by 5% when a continuous polyester yarn is used instead of a cotton thread.

Effect of the size of needle (fineness or needle count, N_c)

To sew our pant samples, two different sizes of needle were used in order to quantify their contribution on the thread consumption. Taguchi analysis shows that when we change the needle parameter from the lowest level (level 1, N_c = 120) to the highest level (level 2, N_c = 90) thread consumption decreases from 327,15m to 281,92m which means a reduction average equals to 13,8%. Indeed, for the needle size of 120 Nm the sewing thread can cause a surplus of lengthening and large loop of the thread which we can avoid. Thus, it is suitable to use, according to the literature, an appropriate thread for the correct size of the needle, D according to the Equation 1:

$$D = k\sqrt{Y_c} \qquad \text{Eq.1}$$

Where:
D is the diameter of the eye of the needle expressed in (mm) which determines the needle fineness.
k is the constant, and
Y_c is the yarn count or linear density of thread expressed in (tex).

Effect of the Fabric composition, F_c.

Regarding the consumption of sewing thread evolution when level of fabric composition changes, we note a highest consumption value, STC_{th}, for pant garment using 100% cotton fabric than for the stretch fabric. Because stretch fabric samples contain elastane filament inside the weft yarns, the fabric structure becomes more extensible which lengthens more and demands more thread during sewing. Compared to stretch denim fabric, the cotton fabric structure encourages a higher consumption of thread. In contrast to this finding, the elastic fabric pant though consumes more sewing thread provides the lowest amount of sewing thread required to make up a garment.

Effect of the fabric mass parameter, M

The mass or the weight (g/mm^2) has a light influence (1.43%) on the thread consumption of sewing pants. It was noticed that a heavy fabric consumes more sewing thread than an average fabric. This consumption is estimated of heavy fabrics that are thicker than the average fabrics.

To improve our results, the regression equation (Equation 2) was carried out out using Minitab 14 software. To predict the amount of sewing thread required to make up a pant garment, we used Taguchi analysis. Our thread consumption as a function of the all input parameters is given in Equation 2 within an estimated error of 0.11. According to our earlier work [15], we calculated the values of R^2 (R = overall correlation coefficient) by dividing the sum of squares due to regression by the sum of squares. An R^2 value of STC is equal to 0.79 indicates that these models can explain 79% of the total variation in the response. Our thread consumption as a function of the all input parameters is given in Equation 2:

$$STC_{th} = 623 - 17,8\, S_{MT} - 24,6\, S_L - 148\, T_c - 45,2\, N_c + 28,0\, F_c - 4,4\, M \qquad \text{Eq.2}$$

After analyzing the results given by the regression analysis model obtained using Minitab 14 software, we concluded that the predicted values of STC_{th} seem acceptable (*R* from the regression model is 0.89 for. Moreover, high values of R^2 prove that good correlations between experimental results and the elaborated models are obtained.

Regarding the interactions given by statistical analysis as shown in Figure 4, it is clear that the overall input parameters are investigated. In fact, it seems that the interactions between S_{MT} and the other parameters are significant. However, the most important one is between S_{MT} and S_L. In addition, when there is a change in fabric composition and the mass, the thread consumption of pant also changes which means that interaction between these parameters is higher. On the contrary, there are some negligible interactions between inputs such as between the needle fineness and the sewing length factor or between fabric and thread composition. Indeed, the variation of one of them can not affect the other and as a consequence, their contributions on the thread consumption are low.

Therefore, according to the results shown in Figure 4, it is clear that there is a good interaction between the mass, M, and sewing machine type (S_{MT}) or stitch length (S_L). However, the interaction decreases between the mass parameter and thread composition. This illustrates the relationship between these parameters [13-15]. Both the highest and lowest levels of the majority of input parameters contribute to the interactions between these parameters.

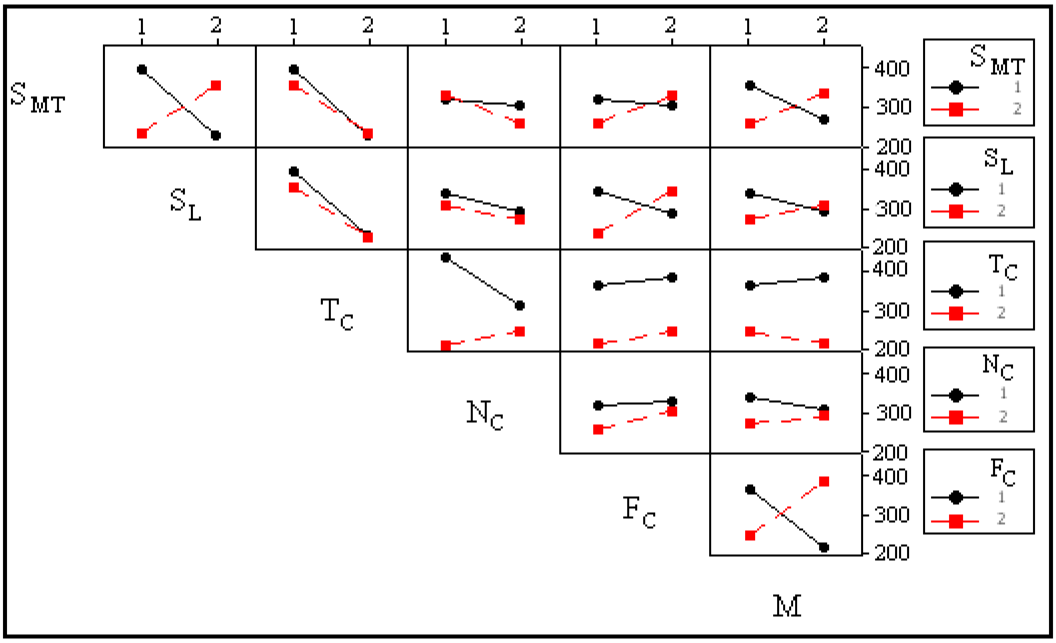

Figure 4. Interaction plot of the studied input parameters STC_{th}.

Conclusion

The contribution of the overall controllable input factors to the thread consumption of sewed pants was established. The current findings showed that the most important parameters are the thread composition and needle composition. In fact, this influential parameter remains the factor which affects sewed denim garments. Although all individual factors effect the thread consumption of sewed pant, these factors present a low interaction which can not affect the sewing thread consumption. In contrast, our results show that the interaction between the mass parameter and the fabric composition is high in spite of the low contribution of each factor on STCth. Furthermore, our results prove that it is possible to affect thread consumption using two different variations of two inputs in addition to changing one factor only. According to our results, it can be concluded that only the two influential parameters should be taken into account to predict and minimize the amount of sewing thread required to make up a pant garment on our experimental design. Further detailed studies using theoretical techniques will follow.

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