Tufted Woven Carpet with Enhanced Machine Mechanism Properties Using Response Surface Design Analysis

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Abstract

This paper indicates the structure of the tufting machine mechanism and got some variables by considered the implement the growth of the Libyan textile in a tufted carpet. By using response surface design analysis we created 2 with adding 4 corner points and 5 center points. Tufted carpet sectors are Needle, Pile yarn, Primary backing, looper, and last Pile cutting knife. Since there was a center point and corner points, the low and high level will previously change the level, Low level for Looper was around 70 and the high level was around 90. Still, Creel's low level was around 30 and a high level was around 70. We collected data between two variables one for Looper which has data of 70, 90,65,86,94.14, and 80 for the second is Creel also has data of 30,70,50,21.72, and 78.28, these two variables explained in a table. Also, we described the response of the contour Plot to see which kind of surface we will get and when it goes out of the focal point. Including what is the plot versus between all the creel, Looper and other responses.

Keywords  
Tufted Woven, Lean, Surface Design, Textile

Structure of textile

Adaptation of sensor and actuator methodology to textile structures has been realized by Bahadir, Senem, ad Kalaoglu. an innovative approach based on the integration of electronics into textiles. Their result shows that the working principle of the system is based on two main functions: sensing the surrounding environment as well as detection of obstacles via sonar sensors and guiding the user by actuators by using a novel control algorithm based on a neuro-fuzzy controller implemented to a processing unit. Ngai, et al. and his team, based on the classification systems considered distributed the textile and apparel supply chain into sectors of textile production, apparel manufacture, and distribution/sales and analyzed the business practices of each sector in terms of operational processes and management/control processes as shown in Figure 1.
There has been a small portion of research over the past years in unindustrialized textile industries; yet, there have been some published works. Hokama published research focused on areas of modeling and simulation of manufacturing operations, whereas strategies and implementation within textile industries were less studied. Over several decades, competition and profitability, from the textile companies, is resulted by having low-cost foreign manufacturers in the marketplace. Furthermore, Hokoma defines the winner of competition and profitability, a company must allocate high-quality products, but at a low cost and at the correct time. The use of overseas manufacturers has been essential to domestic textile manufacturers in order to stay above the competition.

Rudrajeet et al. and his team concluded that many companies have utilized lean manufacturing techniques because they help their organization with shorter delivery times, improvement in quality, and reduced cost. However, as this helps with upstream customers, it has been noticed that it may not be so helpful to downstream customers and competitors who operate with lean principles. The goal of lean manufacturing is to help companies who have an aspiration in finding a way to recover its operations and to be more aggressive with the use of implementing diverse lean manufacturing tools and techniques to eliminate waste and non-value-added activities at every production or service process in order to improve product quality, enhance productivity and reduce costs.

Womack and Jones describe the word “lean” as a system that adapts to operating with a smaller amount, in conditions of all inputs, to produce indistinguishable outputs to those that were produced by a usual mass production systems, all while qualities for the end buyer. The use of lean is to only manufacture what the customer is wanting in a product when it is required and in the quantities arranged.

**Optimization System Throughput Operational Requirements**

For a better understanding of the methodologies applied for the optimization systems planning, it is crucial to define the operational requirements set by the optimization system throughput. Although they may vary significantly among the optimization system throughput, the basic requirements are outlined below:

- Reliability: Any interruptions cause inconvenience to the customers and curtailed revenues for the producers. Even if some devices are out of operation due to outages or scheduled maintenance. Furthermore, restoration of service is always costly.

Figure 1. Classification of textile and apparel supply chain research
• Minimum environmental impact.
• Security: a transmission system is subject to random events (lightning, waste, short-circuits, accidents, etc.), which may cause the loss of transmission lines or cables.
• Transmission services should be provided at lowest cost.

Tufted Woven carpet

Tufting is a process that involves threaded needles punching through the back of a pre-made backing material resulting in loops of yarn on the front or face, of the backing material. A simplified draw showing the structure of a tufting machine mechanism. Some variables we considered that implement at the growth of the Libyan textile in the tufted carpet sector are Needle, Pile yarn, Primary backing, Looper, and Pile cutting knife as showing in figure 1.

![Diagram of Tufting Machine Mechanism](image)

Figure 2. Diagram of Tufting Machine Mechanism

Table 1. illustrates data that required setting up the experimentation of the variables, Looper who grabs the yarn and keeps it below the boking quadratic effect and Creel who feeds into a needle. Data between the two variables showing in table 1.

<table>
<thead>
<tr>
<th>Variables #1</th>
<th>Looper</th>
<th>70</th>
<th>90</th>
<th>70</th>
<th>90</th>
<th>65.86</th>
<th>94.14</th>
<th>80</th>
<th>80</th>
<th>80</th>
<th>80</th>
<th>80</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables #2</td>
<td>Creel</td>
<td>30</td>
<td>30</td>
<td>70</td>
<td>70</td>
<td>50</td>
<td>50</td>
<td>21.72</td>
<td>78.28</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>
By using response surface design analysis we created $2K^2$ with adding 4 corner points and 5 center points. Since there was a center point and corner points, the low and high level will previously change the level, Low level for Looper was around 70 and the high level was around 90. However, Creel's low level was around 30 and a high level was around 70. The analysis of variance showing in table 2.

Table 2. The Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>5</td>
<td>111.975</td>
<td>22.3951</td>
<td>11.83</td>
<td>0.003</td>
</tr>
<tr>
<td>Linear</td>
<td>2</td>
<td>11.580</td>
<td>5.7898</td>
<td>3.06</td>
<td>0.111</td>
</tr>
<tr>
<td>Looper</td>
<td>1</td>
<td>0.500</td>
<td>0.5001</td>
<td>0.26</td>
<td>0.623</td>
</tr>
<tr>
<td>Creel</td>
<td>1</td>
<td>11.080</td>
<td>11.0796</td>
<td>5.85</td>
<td>0.046</td>
</tr>
<tr>
<td>Square</td>
<td>2</td>
<td>100.396</td>
<td>50.1978</td>
<td>26.51</td>
<td>0.001</td>
</tr>
<tr>
<td>Looper*Looper</td>
<td>1</td>
<td>98.468</td>
<td>98.4683</td>
<td>52.00</td>
<td>0.000</td>
</tr>
<tr>
<td>Creel*Creel</td>
<td>1</td>
<td>7.125</td>
<td>7.1252</td>
<td>3.76</td>
<td>0.094</td>
</tr>
<tr>
<td>2-Way Interaction</td>
<td>1</td>
<td>0.000</td>
<td>0.0000</td>
<td>0.00</td>
<td>1.000</td>
</tr>
<tr>
<td>Looper*Creel</td>
<td>1</td>
<td>0.000</td>
<td>0.0000</td>
<td>0.00</td>
<td>1.000</td>
</tr>
<tr>
<td>Error</td>
<td>7</td>
<td>13.255</td>
<td>1.8936</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack-of-Fit</td>
<td>3</td>
<td>12.055</td>
<td>4.0185</td>
<td>13.39</td>
<td>0.015</td>
</tr>
<tr>
<td>Pure Error</td>
<td>4</td>
<td>1.200</td>
<td>0.3000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>125.231</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The lack of fit indicates if the model suffers from lack of feet, which is means if there is any higher-order term would feed the model better than this analysis. Figure 2.

Figure 3. Pareto chart of the standardized effects
Suffers
R-Sq value is showing the model is almost 90 percent and more or less regression is coefficient

\[ S \quad R\text{-sq} \quad R\text{-sq(adj)} \quad R\text{-sq(pred)} \]
\[ 1.37609 \quad 89.42\% \quad 81.85\% \quad 30.05\% \]

Table 3. Coded Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T-Value</th>
<th>P-Value</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>10.40</td>
<td>0.615</td>
<td>16.90</td>
<td>0.000</td>
<td>1.00</td>
</tr>
<tr>
<td>Looper</td>
<td>-0.354</td>
<td>0.688</td>
<td>-0.51</td>
<td>0.623</td>
<td>1.00</td>
</tr>
<tr>
<td>Creel</td>
<td>1.664</td>
<td>0.688</td>
<td>2.42</td>
<td>0.046</td>
<td>1.00</td>
</tr>
<tr>
<td>Looper*Looper</td>
<td>-7.52</td>
<td>1.04</td>
<td>-7.21</td>
<td>0.000</td>
<td>1.02</td>
</tr>
<tr>
<td>Creel*Creel</td>
<td>-2.02</td>
<td>1.04</td>
<td>-1.94</td>
<td>0.094</td>
<td>1.02</td>
</tr>
<tr>
<td>Looper*Creel</td>
<td>0.00</td>
<td>1.38</td>
<td>0.00</td>
<td>1.000</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Response \[= -237.7 + 5.996 \text{ Looper} + 0.312 \text{ Creel} - 0.03763 \text{ Looper*Looper} - 0.00253 \text{ Creel*Creel} + 0.00000 \text{ Looper*Creel} \]

Table 4. Fits and Diagnostics for Unusual Observations

<table>
<thead>
<tr>
<th>Obs</th>
<th>Response</th>
<th>Fit</th>
<th>Resid</th>
<th>Std Resid</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>9.000</td>
<td>7.051</td>
<td>1.949</td>
<td>2.31</td>
<td>R</td>
</tr>
<tr>
<td>8</td>
<td>8.000</td>
<td>10.040</td>
<td>-2.040</td>
<td>-2.42</td>
<td>R</td>
</tr>
</tbody>
</table>

Results Results Sections

Regression Equation in Uncoded Units
Contour Plot of Response is to see what kind of surface we have, the most comfortable reason inside the contour plot of response, and decrease when it goes out of focal point Fig 3.

Figure 4. Contour Plot of Response vs Creel, Looper
Response Optimization:

Parameters

<table>
<thead>
<tr>
<th>Response</th>
<th>Goal</th>
<th>Lower</th>
<th>Target</th>
<th>Upper</th>
<th>Weight</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response</td>
<td>Maximum</td>
<td>2</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Solution

<table>
<thead>
<tr>
<th>Solution</th>
<th>Looper</th>
<th>Creel</th>
<th>Response</th>
<th>Composite</th>
<th>Desirability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79.5715</td>
<td>61.7119</td>
<td>10.7457</td>
<td>0.971741</td>
<td></td>
</tr>
</tbody>
</table>

Multiple Response Prediction

<table>
<thead>
<tr>
<th>Variable</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looper</td>
<td>79.5715</td>
</tr>
<tr>
<td>Creel</td>
<td>61.7119</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response</th>
<th>Fit</th>
<th>SE Fit</th>
<th>95% CI</th>
<th>95% PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response</td>
<td>10.746</td>
<td>0.602</td>
<td>(9.323, 12.169)</td>
<td>(7.194, 14.297)</td>
</tr>
</tbody>
</table>

Figure 5. Optimization Plot
Surface Plot of Response vs Creel, Looper

Figure 6. Surface Plot of Response vs Creel, Looper

Factorial Plots for Response

Figure 7. Interaction Plot for Response
The investigation presented in Tufted Carpet Factory has shown various significant on Looper. However, Creel and interaction were not significant in Libyan Textile Company. Response as showing in fig 4,5,6,7. We calm data between two variables one for Looper which has data of 70, 90,65,86,94.14, and 80 for the second is Creel also has data of 30,70,50,21.72, and 78.28, these two variables explained in a table. Also, we described the response of the contour Plot to see which kind of surface we will get and when it goes out of the focal point. Including what is the plot versus between all the creel, Looper and other responses.

**A Classification Framework for Textile and Lean Strategies**

Waste sources are all related to each other and getting rid of one source of waste will lead to cost reduction. Perhaps the most significant source of waste is inventory. Work-in-process and finished parts inventory do not add value to a product and they should be eliminated or reduced. When inventory is reduced, hidden problems can appear and corrective action can be taken immediately. There are many ways to reduce the amount of inventory, one of which is reducing production lot sizes.

Hines and Taylor, there’s no need to decrease quality with lean, the cuts are the outcome of finding better, more efficient methods of completing the same tasks. Hiness and his partner identified several wastes such as; Overproduction, Defects, Unnecessary inventories, Inappropriate processing time, Temporary waiting, Unnecessary motion, Excessive transportation, Workforce underutilization, Improper utilization of technology, and Working to the wrong metrics. The lean approach has been applied more frequently in discrete manufacturing than in the continuous/process sector, mainly because of several perceived barriers in the work environment that have caused managers to be reluctant to make the required commitment.

Fawas et al. present a case based approach to demonstrate how lean manufacturing tools when used appropriately, can help the process industry eliminate waste, maintain better inventory control, improve product quality, and better overall financial and operational control. They focused on three lean manufacturing techniques such as pull-type production system, setup reduction, and Total Productive Maintenance (TPM) that can be quantified and modeled objectively.
Mahapatra and Mohanty highlighted the knowledge and understanding levels of Indian managers about the concept of lean manufacturing, its adaptability, the driving factors that lead to its adoption, benefits derived thereon and application of lean tools looking into operating environments (whether continuous or discrete). Their study finally concluded with a broad implementation framework for the application of lean manufacturing in continuous process industries by emphasizing its key areas of application. The similarities and differences in applying lean techniques to continuous and discrete part manufacturing are summarized below.

**Similarities to discrete manufacturing:**

- As a final output, the products produced are only discrete.
- JIT and external setup concepts can be implemented.
- 5S implementation vis-à-vis tooling, cleaning, arrangement of accessories is possible.
- Standardizing work procedures can be done.
- Fool-proofing methods can be implemented.
- The layout is similar to a line process.

**Differences from discrete manufacturing:**

- High volume, low variety products.
- Long setup times.
- Fixed routing and product flow paths.
- Bulk of the work is flowing through different production machines whereas it is at the assembly-line in case of discrete manufacturing.
- Lot size reduction is difficult.
- It is very costly to shut down the process, once it is started.

**The advantages of implementing lean techniques in continuous industries are listed below:**

- Reduce variation in the processes and improve output.
- Inventory and lead time reduction.
- Decrease wastage of raw materials.
- Improve setup time of the machines by external setups.
- Increased use of equipment/improve capacity utilization

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Biography

Dr. Ahmad Yame earned his Bachelor degree in Engineering Technology from the Lawrence Technological University in 2010. Mr. Yame has three master degree, the latest was in 2015 in Industrial Engineering from Lawrence Technological University, second MSc was in Engineering Management 2011 from the Lawrence Technological University and his first MSc was in Mechanical Engineering back in 2007 from the National University of Malaysia. He earned his Associate's degree in Mechanical Engineering 2004 from the Libyan Higher Professional Center for Comprehensive Professions. He primarily develops engineers but also has experience with software and testing. Dr. Yame has tested many enterprise applications for automotive MAHLE Laboratories in 2013, he working with Panasonic automotive in North America since 2016 to test vehicles for AHU/Sync and diagnostic functionalities of engine control systems. He has organized several simulations, in order to test the engine control software and the diagnostic functionality on a CANlog, respectively, through non-regression and diagnostic tests.