Original Article

The Possibility Of Modifying The Computerize Embroidery Machine To Produce Cut Pile Tufting Carpets

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Abstract

The current study aimed to produce cut pile tufting carpets by modifying a computerized embroidery machine in order to produce carpets with multi-colors designs up to 9 colors at the lowest costs, less effort, high performance, in short time , smallest number of carpets, and according to the customer's request, using materials and tools available in a small quantity. It also aimed to test some of the properties of the functional performance of carpets subject of this study, comparing with cut pile tufting carpet done on Normal mechanical tufting machine, both made from same materials and specs. The importance of the study lies in saving a lot of time and effort expended in the carpet industry, as well as improving the carpet industry for small projects and the field of interior design projects. This method will achieve its requirements for carpets and achieve popularity in the markets due to the long consumer life of carpets and the possibility of obtaining them in the shortest possible time with designs and colors required, with the least amount of raw materials and the lowest costs. The carpet samples were subjected to tests to measure the functional performance of the carpets, which are: Pile withdrawal test, the resilience and compressibility performances (the compression recovery & percentage work recovery). The results of the tests achieved that the functional performance of the carpets done on modified computerized machine and what produces on normal tufting mechanical machine nearly same .

Key words: Tufting Machine – Embroidery Machine – Primary Backing – Stitches – Needle – Hook – Knife – Yarn – Design – Pattern - Tufting Creel Machine – Carpet .

1. Introduction

A tufting machine is essentially a huge sewing machine, usually 1or 2 or 3 or 4 or 5 meter wide, with hundreds of needles that insert loops of yarn into the primary backing of the carpet. Yarn is fed from a creel, one tube of yarn for each needle and threaded through the needles. To produce 1or 2 or 3 or 4 or 5 meter width tufting carpet roll need hundreds of yarn cones according gauge of machine (no of needle per inch).
The picture (1) show Normal mechanical tufting machine

Picture (1) Normal tufting mechanical machine

Embroidery machines it is specialized sewing machine to allow you to embroider beautiful designs that are much more complicated than what a sewing machine could produce. They're used for aesthetic purposes, using a repetitive, texture-building technique to outline patterns and fill them in with color. Advanced embroidery machines are even digitized, meaning they can provide elaborate embroidery patterns on a computer. Embroidery computerized machine have 1-25 multiple heads. With each head, you can have up to 15 needles. With each one being able to hold a different color. Picture (2) show computerized Embroidery machine 15 Heads each head have 9 needles (colors).

Picture (2) embroidery machine 15 heads 9 needles colors

Embroidery and tufting are two distinct yet closely related textile techniques that share several technical similarities. Both processes involve the creation of decorative designs or patterns on fabric, but they differ in terms of the tools and materials used. Despite these differences, there are commonalities in the methods employed in embroidery and tufting. One notable technical similarity between embroidery and tufting is the use of a needle or a similar tool for the creation of designs. In both techniques, a needle is used to manipulate the fabric, creating intricate patterns and designs. In embroidery, the needle is typically threaded with various colored threads, which are then stitched onto the fabric to form the desired design. In tufting, tool is used to insert loops of yarn or thread into the fabric, creating a raised pile or texture. Another shared technical aspect between embroidery and tufting is the use of a base fabric or material. Both techniques require a foundation onto which the designs or patterns are created. In embroidery, the base fabric can be any type of textile, such as cotton, silk, or linen. Similarly, tufting also requires a fabric base, which can range from woven fabrics to non-woven materials like felt or even carpet.

The research problem is determined by the fact that the current tufting carpet industry requires skilled and trained manpower and large investments, in addition to the difficulty of producing special orders in small quantities, The current manufacturing method requires a large number of thread cones and large amounts tons of thread .

Table no (1) showing no of needle for each gauge according width of machine.

Table (1) no of needles according gauge in each machine width

Gauge	no of needle inch	Total no of needle according width of machine				
		1 meter width	2 meter width	3 meter width	4 meter width	5 meter width
3/8.	2.66	105	210	314	419	524
3/16.	5.33	210	420	630	840	1050
5/32.	6.4	252	504	756	1009	1261
1/8.	8	315	630	946	1261	1576
1/10.	10	394	788	1182	1576	1970
1/12.	12	473	946	1418	1891	2364

The minimum yarn weight / cone supply from yarn manufacture 2 kg, the minimum yarn weight per creel to run machine showing in table no (2)

Table (2) minimum yarn weight creel for each machine width according gauge

Gauge	**no of needle inch**	**minimum Total yarn weight (kg) according width of machine**				
		1 meter width	**2 meter width**	**3 meter width**	**4 meter width**	**5 meter width**
3/8.	2.66	210	419	629	838	1048
3/16.	5.33	420	840	1260	1680	2100
5/32.	6.4	504	1009	1513	2017	2522
1/8.	8	630	1261	1891	2522	3152
1/10.	10	788	1576	2364	3152	3940
1/12.	12	946	1891	2837	3782	4728

And that is high cost business. Tufting machine usually use plain color only or stripes colors, and some limited geometric pattern by using Needle sliding bar, also by changing pile height to give pattern, in last few years make design by compute with multi colors by using colored yarn picture (3) show tufting carpet structures.

Picture (3) tufting carpet structures

Also tufting done by white color yarn easy to print like Nylon, wool, acrylic, cotton and polyester then dyed soled color or printing by Rotary printing machine or chromo jet printing machine or Digital printing machine, also can't produce small quantity or custom made order , the minimum order must be use full creel yarn weight . This type of carpet manufacture is large, high-investment industries and the difficulty of obtaining skilled and trained labor, in addition to the effort with time expended, to try to overcome this problem, the most important elements of the research problem can be identified in the following:

Lack of studies and research on how to apply tufting carpet embroidery technique. The high cost of selling cut pile carpet products. The limited designs implemented in Mechanical tufting carpets in the market. Limiting the techniques of implementing tufting carpets in the local market to a limited number of techniques does not meet the need for professional development in the furniture sector. The difficulty of achieving the customer's demand for small quantities of production per design in the current tufted carpet manufacturing techniques. As an attempt to overcome this problem in the current research, the following questions can be answered:

What is the possibility of making carpets using a computerize embroidery machine? What is the possibility of using carpet yarn to make carpets on a computerize embroidery machine? What is the possibility to making carpets designs in different colors? What is the possibility of study some of the functional performance characteristics of the carpets under study? Are the implemented products have a long consumer life?

Search terms:

Tufted**:** A method of manufacturing carpet. Tufts of yarn are inserted through a carpet primary backing to create a pile of cut and/or loop ends.

Embroidery: the art or process of forming decorative designs with hand or machine needlework.

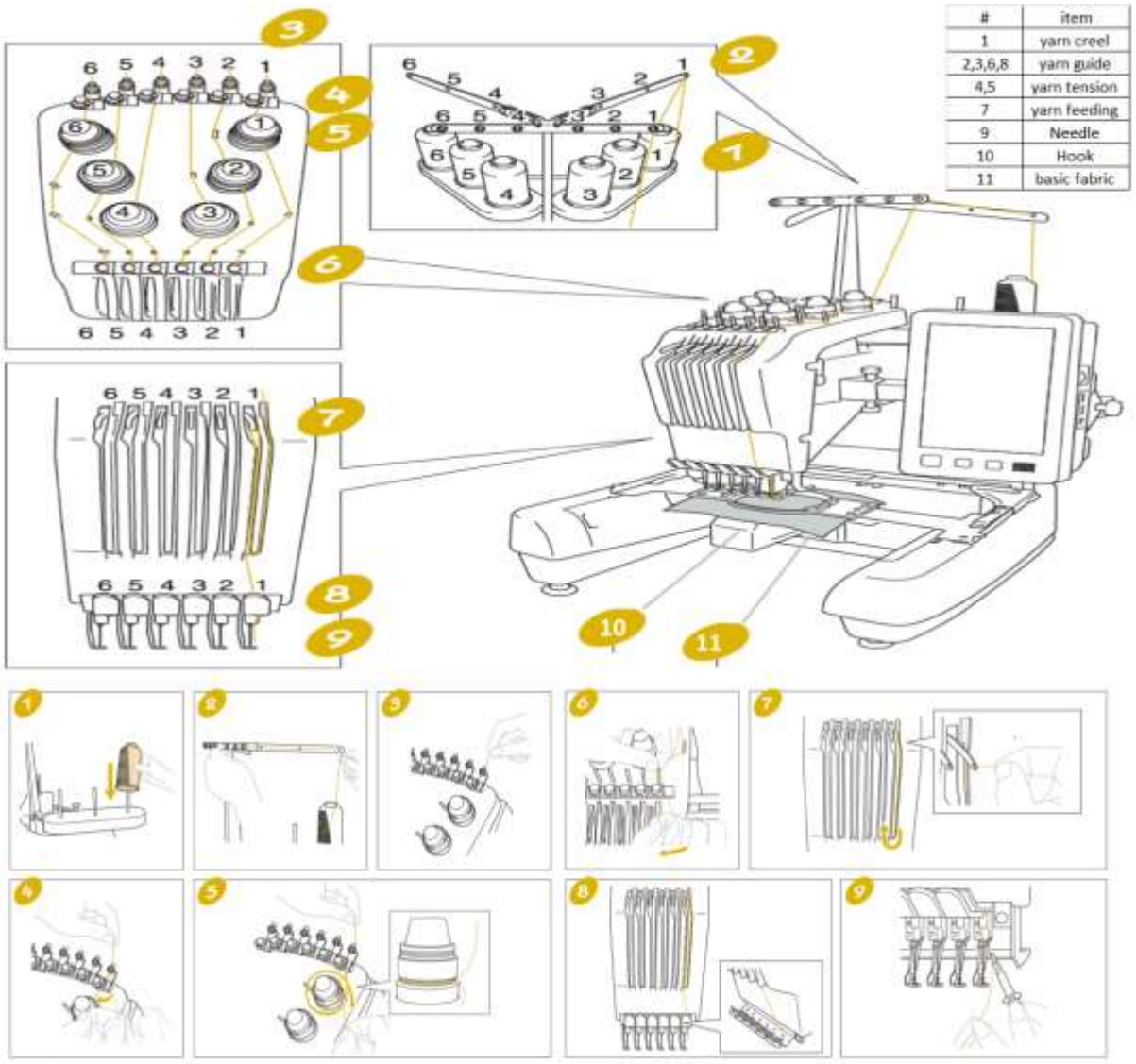
Yarn Creel: The place where yarns are positioned behind of the tufting machine

Microenterprise :It is a type of small business, usually with five employees or less and a founding capital of no more than USD 35,000. Microenterprises are usually family businesses.

Productive families: These are the families that rely on the skills of their members to meet their needs, through the production and sale of products from home, with the aim of increasing the income of families and raising their standard of living.

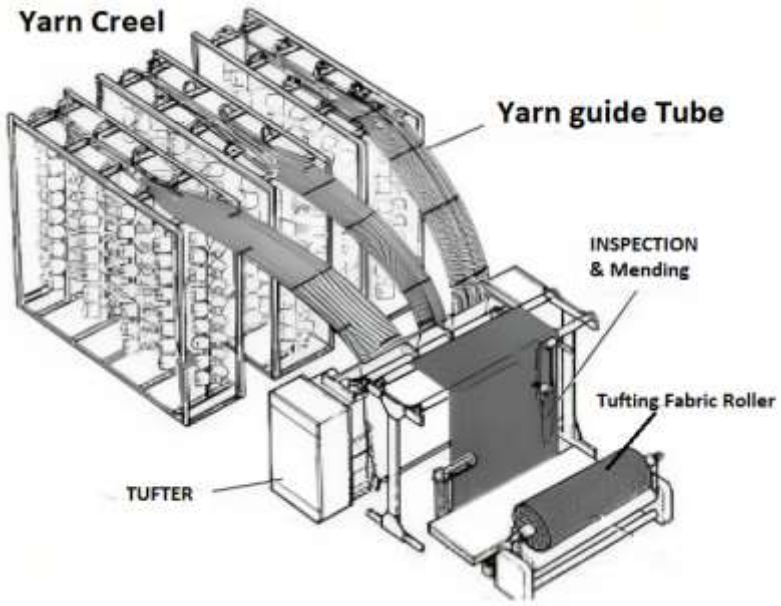
2. Materials and Method

Process in both embroidery machine and tufting machine same but in different gauge part stitch form, we will convert parts of stich form in embroidery to become same gauge parts of tufting pile form , they have Yarn , Yarn creel , Yarn tension , Yarn guide , Yarn feeding , Needle , Hook, and basic fabric .picture (4) showing diagram Embroidery Machine parts Process.

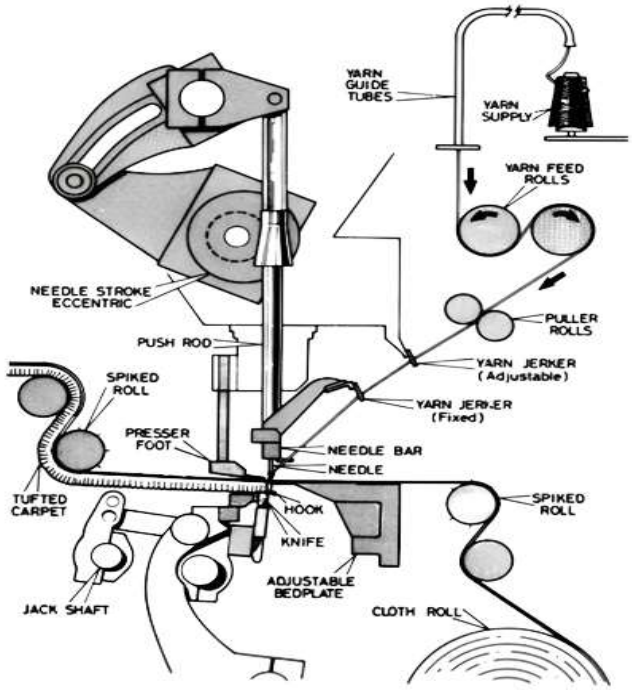


Picture (4) Schematic diagram Embroidery Machine parts Process

Picture (5) shows an overall view of a tufting machine and picture (6) schematically illustrates the main elements controlling the action of a cut-pile tufting machine. Tufts of yarn are inserted into a primary backing fabric by means of vertically reciprocating needles operating rather like sewing needles. There are several hundred threaded needles mounted on a bar across the width of the machine and a corresponding number of hooks on another bar.



Picture (5) an overall view of a tufting machine



Picture (6) Schematic diagram of a cut-pile tufting machine.

Materials and Methods

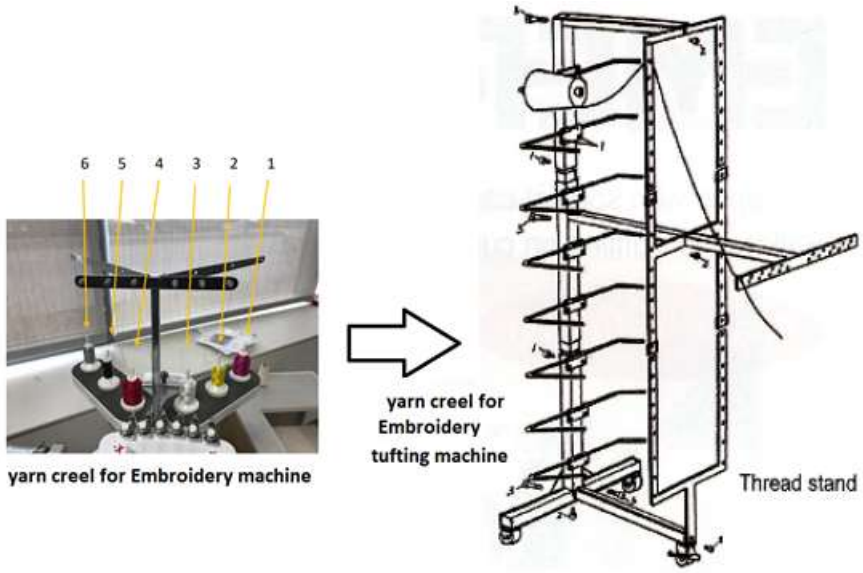
To let Embroidery machine to make carpet we changed the next:

1- The general specifications of embroidery thread are 150D/2, 108D/2, 75D/2 and so on. The most commonly used specifications are: Rayon embroidery yarn is 120D/2, polyester embroidery line is 108D/2.Taking polyester embroidery line 108D/2 as an example, 108D refers to the raw material of embroidered thread - the specification of polyester filament 108 D (Denier) that is, the weight of 9000 meters single strand silk is 108 grams, and the 2 refers to the embroidery thread made from two strands of polyester filament. in carpet use

any type of yarn , in study we used Polyester DTY (Draw Texture Yarn) yarn count 1200D/2 , can use cotton or wool or spun polyester in range 6/2 Ne ,picture (7) show yarn in Embroidery machine and yarn in Tufting Embroidery machine

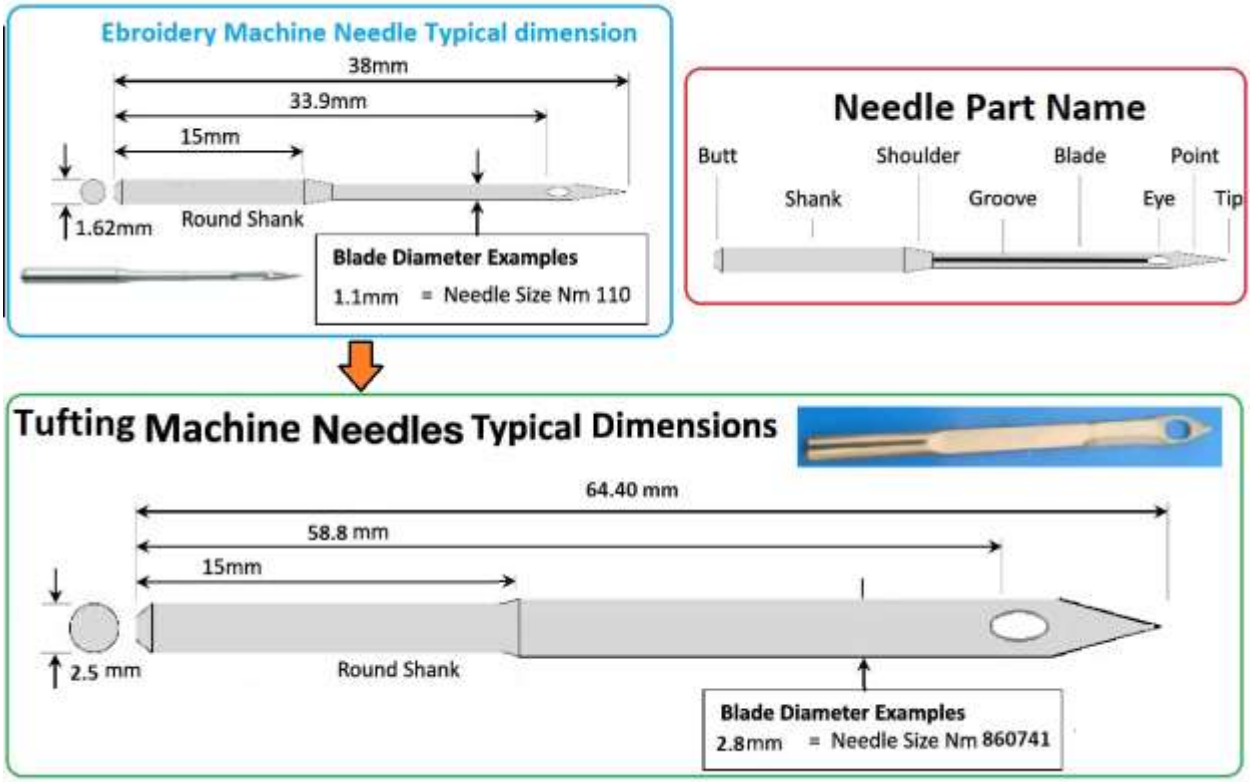
Picture (8) yarn Embroidery machine and yarn Tufting Embroidery machine

2- Yarn creel make in large to become suitable carry big cheese cone for tufting carpet yarn picture (8) showing creel of embroidery tufting machine.



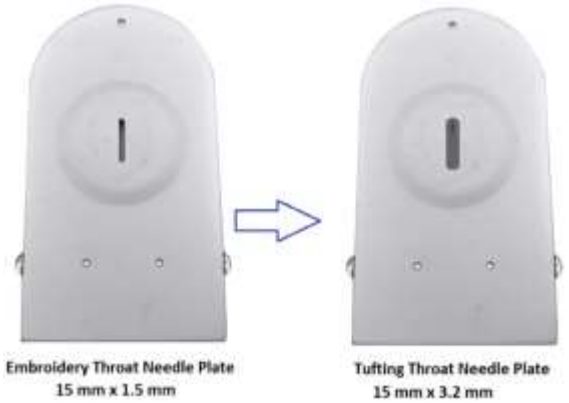
Picture (8) creel of embroidery tufting machine.

3- Change Needle from Embroidery Needle size 75/11 (DBXK5) to Tufting Needle size Groz Beckert No.(860741 HM02 R-W-B-Z) with large Eye to become suitable for Yarn1200Dtex x 2, picture (9) show dimension and specs. Of Embroidery machine Needle and Tufting machine Needle.



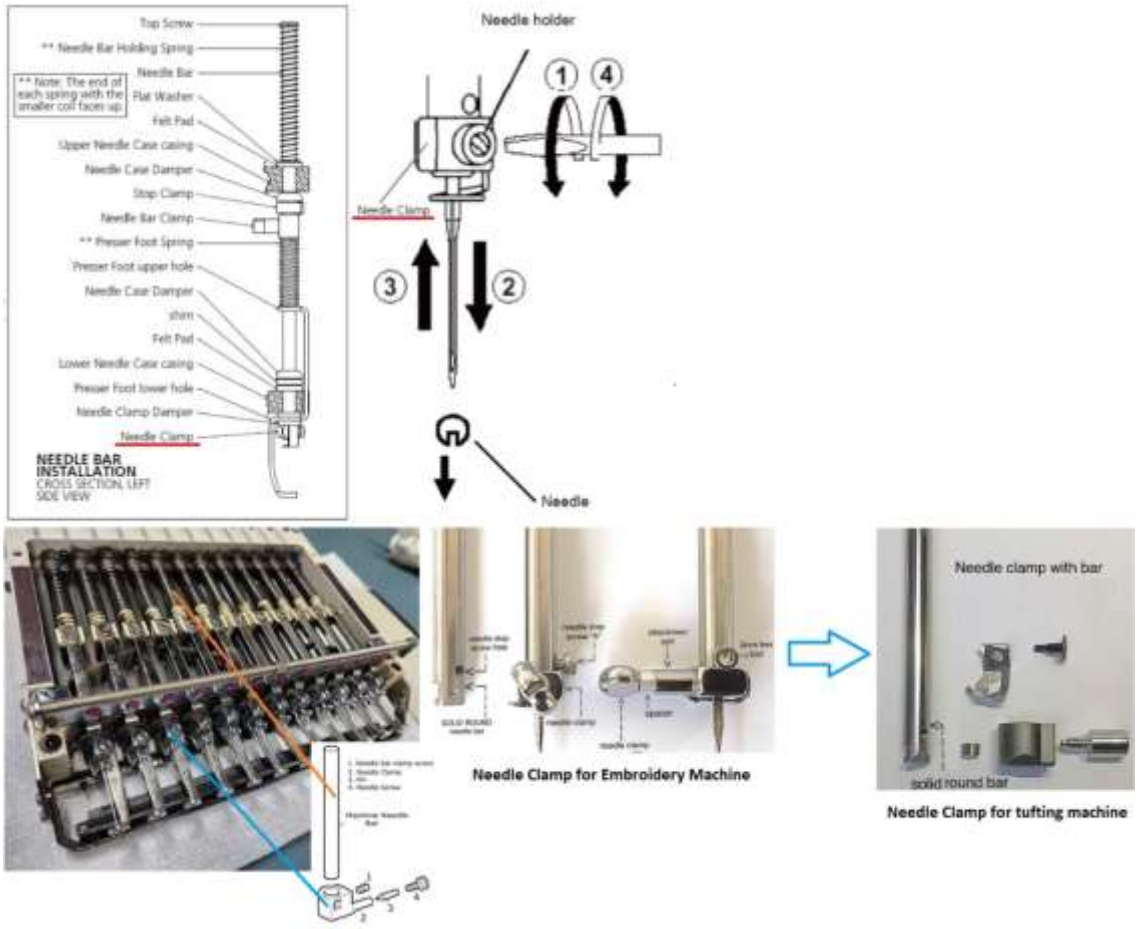
Picture (9) dimension and specs. Of Embroidery and tufting machines Needles

4- Change Embroidery Throat Needle Plate from 15 mm x 1.5 mm to 15 mm x 3.2 mm to become suitable for tufting needle blade diameter, picture (10) show Throat Needle Plate for embroidery and tufting machine.



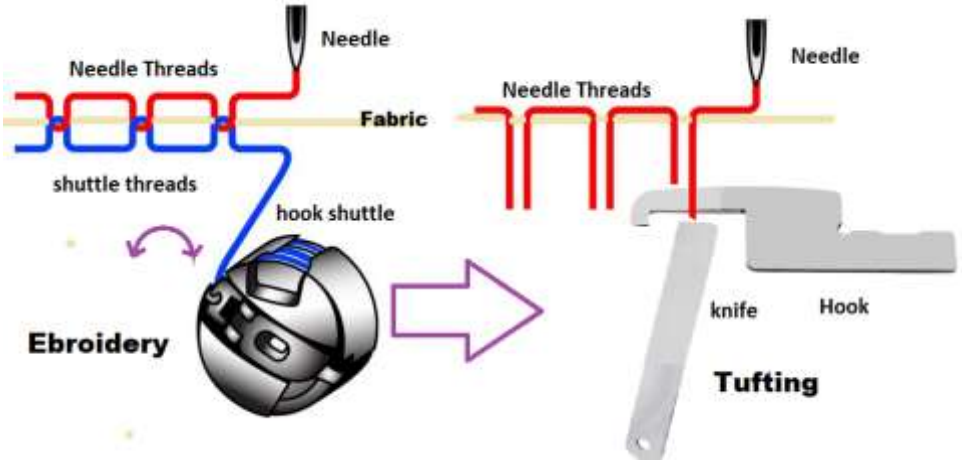
Picture (10) Throat Needle Plate for embroidery and tufting machine.

5- Change the needle bar clamp inner diameter round shank from 1.62 mm to new needle tufting round shank diameter 2.5 mm. picture (11) show needle clamp



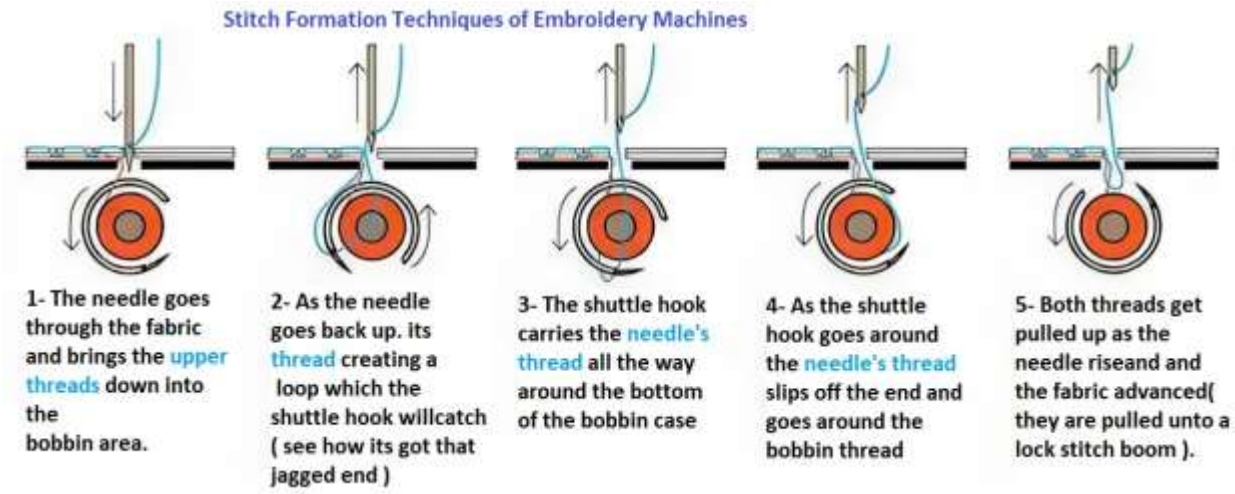
Picture (11) needle clamp for embroidery and tufting machine

6- Change shuttle hook for Embroidery Machine to Gauge Parts for cut pile tufting machine (Hook & Knife) picture (12) show gauge parts for stitch of embroidery and tufting cut pile formation.



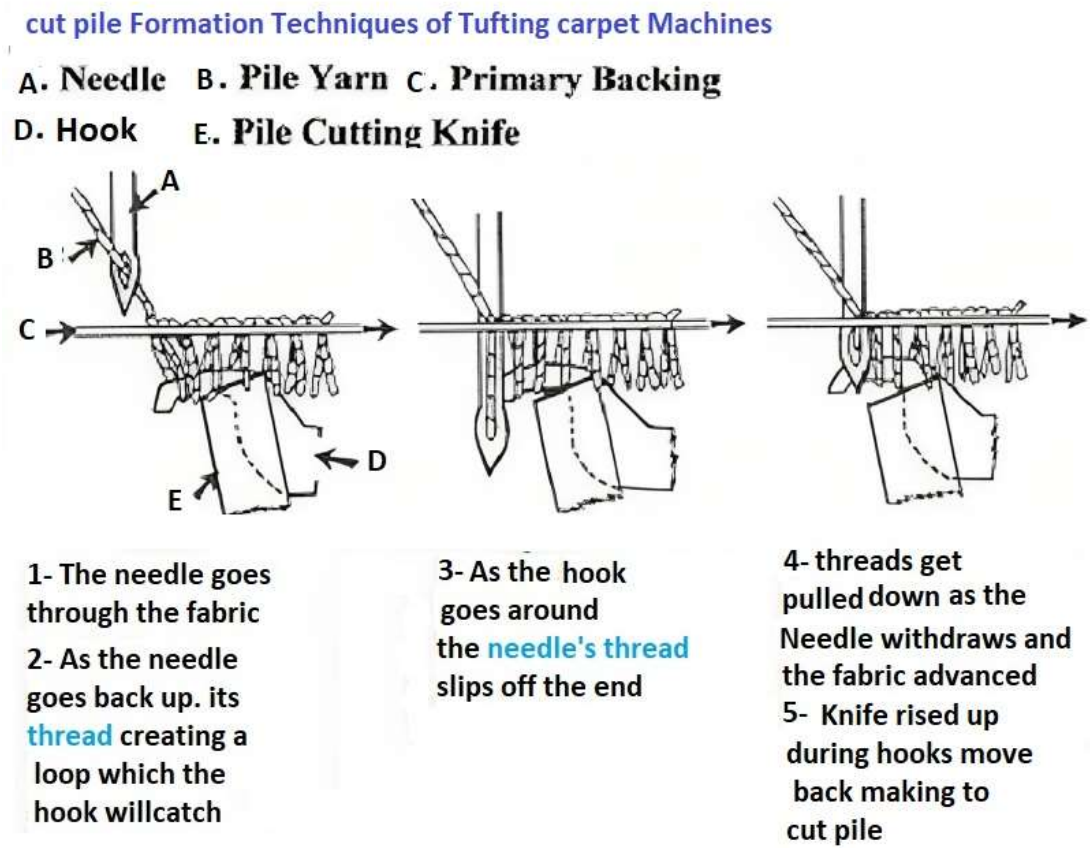
Picture (12) gauge parts for stitch of embroidery and tufting cut pile formation.

Picture (13) show stitch formation techniques of Embroidery Machine



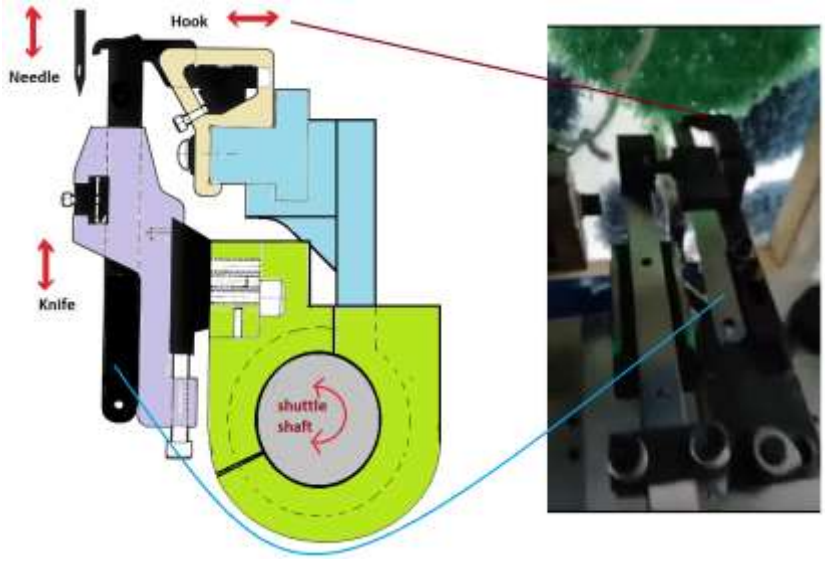
Picture (13) stitch formation techniques of Embroidery Machine

And picture (14) show cut pile formation technique of tufting machine



Picture (14) cut pile formation technique of tufting machine

Picture (15) show tufting gauge parts Mechanism changed in embroidery machine to convert from embroidery stitch to cut pile tufting.



Picture (15) tufting gauge parts Mechanism changed in embroidery machine

Theoretical framework

The Taft embroidery method will be used, which is done with the following machines and materials:

- Computer with tuft design system Program or any suitable design Program
- Tuft Embroidery machine
- Backing by hand or by latex machine or by TPR (Thermos Plastic rubber backing) Machine.
- Over edge sewing machine or tape sewing machine

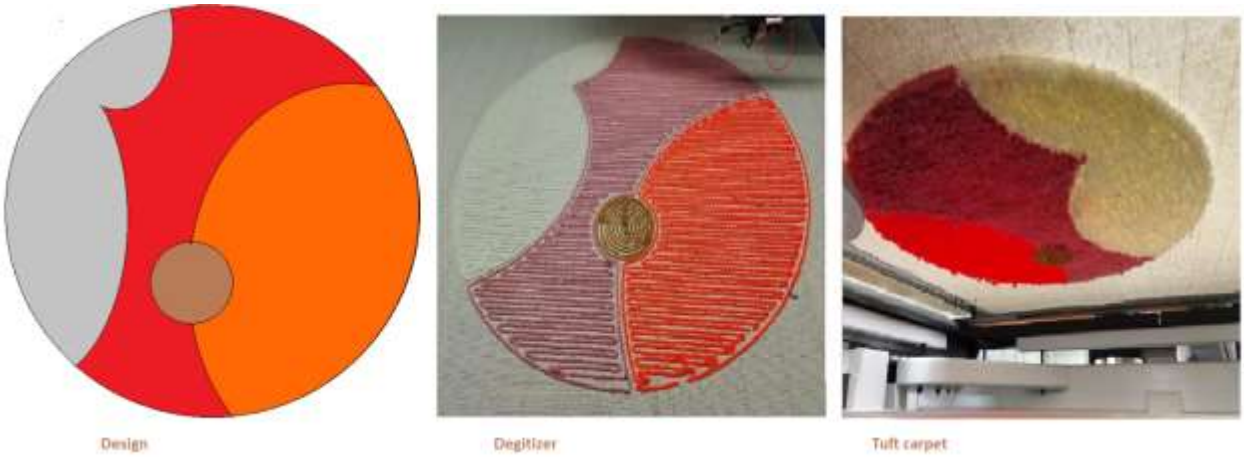
Materials use:

Yarn for pile from cotton or Acrylic or Polyester or Polypropylene or wool.

The picture (16) show production process for tufting Embroidery carpet and Mat

Picture (16) Embroidery tuft carpet process

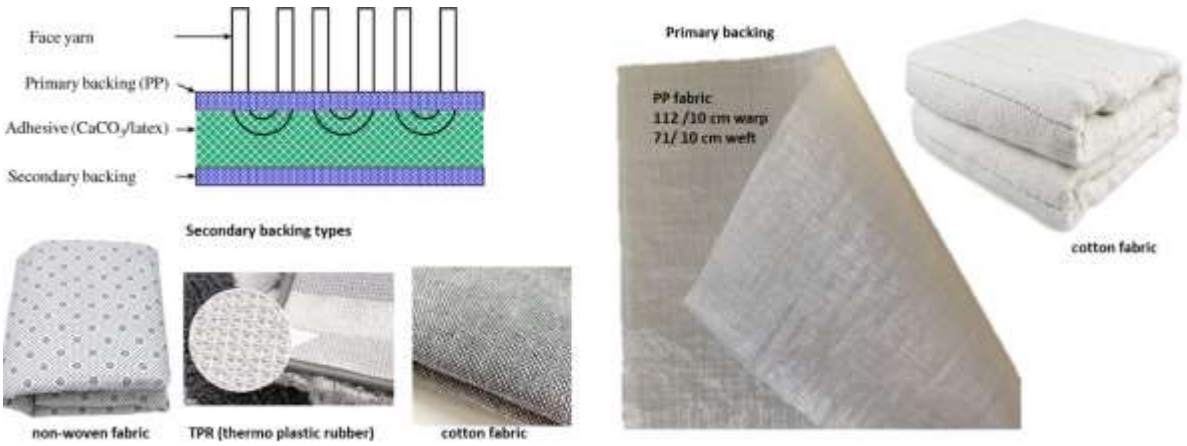
Picture (17) show process design, Digitizing and tufting carpet on machine.



Picture (17) process design, Digitizing and tufting carpet on machine.

The material use for making bath Mat by Embroidery tufting machine are the next:

1- Primary backing: normally use Polypropylene fabric his yarn weft and warp made as fibrillated tape woven by plain construction 1/1 – 112 threads /10 cm warp and 71 threads/10 cm in weft, weight of 1 meter square is 110 gm. You can also use any fabric as primary backing like non-woven or cotton Fabrics.
2- Found different kind of Secondary backing can use like cotton fabric, non-woven anti slip fabric, PVC anti slip and TPR anti slip. In our samples we used non-woven dots anti slip. Picture (18) show Types of primary and secondary backing Fabrics



Picture (18) Type of primary and secondary backing Fabrics

3- Yarn for Pile

All type of yarn can use Polypropylene, Polyester, Viscose, Acrylic, wool, cotton, Bamboo. And nylon. Yarn count in range 1200Dtex x 2 ply, 15/3 Nm x 2 Ply, 4.5/2 x 2 Nm. According type of yarn continues filament or spun.
In our samples we use DTY polyester yarn 1200Dtex /350F x2, 120 TPM.
The picture 19) show Type of yarn use in bath mat sample

Picture (19) Type of yarn used in bath mat

The next 11 designs done from carpet number (CE1) to carpet number (CE10) by amended computerize embroidery tufting machine for this study each one different in number of colors from 1 color to 9 colors and carpet number (CT1) done by Normal Tufting mechanical machine by 1 color.

CE-1 1 color	CE-2 2 color
	
CE-3 3 color	CE-4 4 color
	
CE-15 5 color	CE-6 6 color
	

CE-17 7 color	CE-8 8 color
	
CE- 9 9 color	CE-10 10 color
	
CT- 1 1 color	
	

All carpet samples were produced at the same manufacturing condition such as pile yarn, stitches / 10 cm, pile height, gauge, primary backing and pile density, only the type of tufting methods were changed. The carpet samples properties are given in Table 3, Table 4 and Table 5 respectively. Both samples which done on normal tufting machine and on Modified tufting Embroidery computerize machine making secondary backing in the same type non-woven fabric bonded by latex.

Table 3. Tuft properties.

Tuft sample	Yarn specifications	gauge	Stitch /10 cm	pile height mm	pile gm/mt²
Embroidery tuft sample 1	PES 1200D / 350F x 2 ply , 120 TPM , HS	1/8.	50	12	1300
Embroidery tuft sample 2					
Embroidery tuft sample 3					
Embroidery tuft sample 4					
Embroidery tuft sample 5					
Embroidery tuft sample 6					
Embroidery tuft sample 7					
Embroidery tuft sample 8					
Embroidery tuft sample 9					
Embroidery tuft sample 10					

Tufting machine sample					

Table 4. Backing Properties.

sample Type and number	primary backing gm/mt²	primary (warp/10 cm x weft /10cm)	latex gm/mt²	secondary Type	secondary gm/mt²
Embroidery tuft sample 1	100	112 x 63	1000	PES non-woven	120
Embroidery tuft sample 2					
Embroidery tuft sample 3					
Embroidery tuft sample 4					
Embroidery tuft sample 5					
Embroidery tuft sample 6					
Embroidery tuft sample 7					
Embroidery tuft sample 8					
Embroidery tuft sample 9					
Embroidery tuft sample 10					
Tufting machine sample					

Table 5. Carpet sample properties.

Carpet samples	weight gm/mt²				
	primary	pile yarn	latex	secondary	Total
CE 1	100	1300	1000	120	2520
CE 2					
CE 3					
CE 4					
CE 5					
CE 6					
CE 7					
CE 8					
CE 9					
CE 10					
CT 1					

Carpet tufting machine and Lap in Al Soraya industrial Group, Jeddah, Saudi Arabia. In order to compare the performance properties of the carpet samples finish backing application, pile withdrawal force and compression-recovery tests in accordance with ISO 4919:2012 and BS 4098:1975 standards respectively were performed. Carpet samples were conditioned at standard atmospheric conditions according to ISO 139:2005 (65±4% relative humidity and 20±2°C temperature) for 24 h before the tests were conducted.

Pile withdrawal test was applied by using a Wira Tuft Withdrawal Tensometer (Fig.1). Carpet specimens were prepared by cutting to size 15 mm × 15 mm. One end of the one tuft was selected and attached with tuft grip. The carpet sample was held down firmly by a steel plate. One end of the pile yarn to be tested was attached to tuft grip and it was placed to the upper jaw. Tensile force was applied to the pile yarn with Constant Rate of Extension (CRE) principle. The tuft grip was raised at steady state. The tension on the pile yarn was increased and the maximum force needed to withdraw the pile yarn and remove from carpet structure was recorded. This procedure was repeated for 10

tufts from each sample. It was assured that there is at least 25 mm distance between the previously drawn tuft and the next one.

Figure 1. Pile withdrawal test device

The compression recovery test was applied to determine the compressibility and recovery capacity of the carpet sample. This test was performed to evaluate the resilience performance of the carpet sample under effect of foot traffic. The tests were performed using an SDL K94 Atlas Digital Thickness Gauge machine according to BS 4098:1975. From different parts of the carpet sample, five specimens with a size of 75 × 75 mm were prepared for each carpet sample. The initial thickness of the carpet sample was measured under 2 kPa pressure. The pressure under presser foot was increased to 200 kPa without removing the carpet sample by sequentially placing extra weights; A: 5kPa, B: 10kPa, C: 20 kPa, D: 50kPa, E: 100 kPa, F: 150 kPa, G: 200 kPa. The carpet thickness was recorded after each weight placed. After the last weight (G: 200kPa) was added, the extra weights were removed one by one at 30 s intervals. The previous process is called as loading and the latter is called as unloading. When all loading and unloading thicknesses were measured, a thickness versus pressure curve was created. By using the measured thickness values four compressibility parameters; compression recovery, work compression, work recovery and the percentage work recovery were calculated by means of corresponding equations given in BS 4098:1975 standard.

The percentage of compression recovery after loading and unloading processes was calculated with following equation (1).

$$\text{Compression recovery (\%)} = \left[\frac{tr - t200}{t2 - t200}\right] \times 100 \quad (1)$$

Where;

t_2: is the thickness under 2 KPa pressure at the beginning of the loading process.

t_r is the thickness at 200 KPa pressure after unloading all weights.

t_{200}: is the thickness at 200 KPa pressure.

The work of compression in j/mt2 was determined by calculating the area under loading curve t_2 and t_{200} thickness values.

$$\text{Work compression (j/m}^2) = 1.5\, t_2 + 4t_{10} + 7.5t_{10} + 20t_{20} + 40t_{50} + 50t_{100} + 150t_{150} + 173t_{200} \quad (2)$$

The work of recovery was calculated in (j/m^2) as an area under unloading curve between t_r thickness values and t_{200} thickness values.

$$\text{Work recovery (j/m}^2) = -173t_{200} + 150t_{150} + 50t_{100} + 40t_{50} + 20t_{20} + 7.5t_{10} + 4t_5 + 1.5\, t_2 \quad (3)$$

The percentage work recovery is calculated with the equation (4) below.

$$\text{Percentage work recovery (\%)} = \left(\frac{\text{work recovery}}{\text{work compression}}\right) \times 100 \quad (4)$$

3. Result and Discussion

The pile withdrawal force results are given in Fig. 2. It can be clearly seen that the pile withdrawal force of the all carpet samples produced by Modified computerized Embroidery tufting machine are same or higher than that of conventional tufting carpet machine sample. From these results, it can be deduced that the modified computerized tufting Embroidery machine plied provides stronger of the pile yarn to the carpet structure. Among the carpet samples tufted with Normal tufting machine, the lowest pile withdrawal forces are obtained with samples are close to each other. So, it can be said that there is no considerable difference between sample done on Normal tufting machine and sample done on modified computerize tufting Embroidery machine. On the other hand, the highest pile withdrawal force is obtained with all samples in both type of machine.

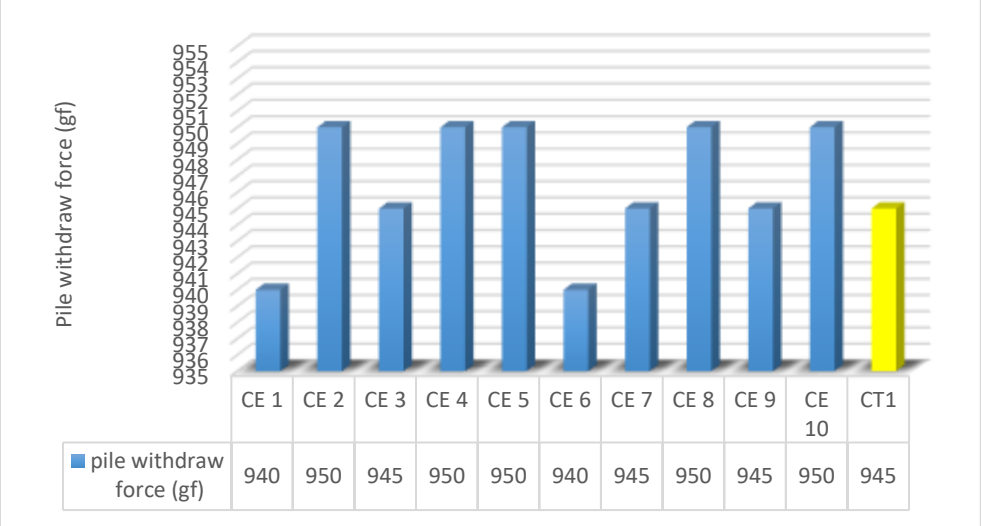


Figure 2. Pile withdrawal force values of the carpet samples.

The resilience and compressibility performances of the carpet samples are evaluated in accordance with the compression recovery (Fig. 3) and work recovery (Fig. 4) percentage values respectively. As it can be followed from Fig.3, the carpet samples tufted with modified computerized tufting Embroidery machine (CE1to CE 10) have better resilience performance same or near from applied on normal tufting machine carpet sample (CT 1).

The compression recovery values of the carpet samples produced with modified computerized tufting Embroidery machine from CE 1 to CE 10 compare with sample done on Normal tufting machine CT 1 are very close to each other. So, it can be concluded that type of tufted technique has not considerable effect on carpet resilience performance.

The compressibility performance of the carpet samples can be evaluated from percentage work recovery values of the samples (Fig. 4). The work recovery is obtained with samples that is produced with modified machine and Normal tuft machine are nearly same.

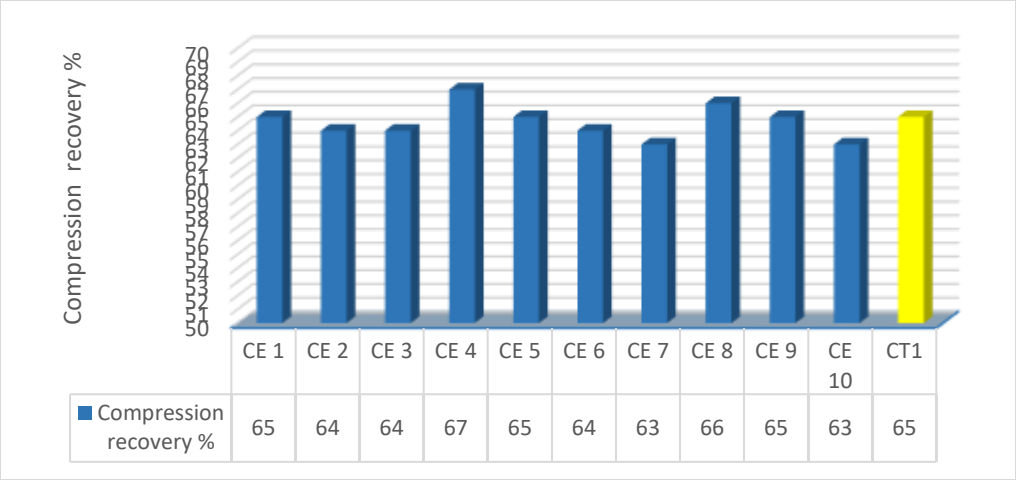


Figure 3. Compression recovery values of the carpet samples.

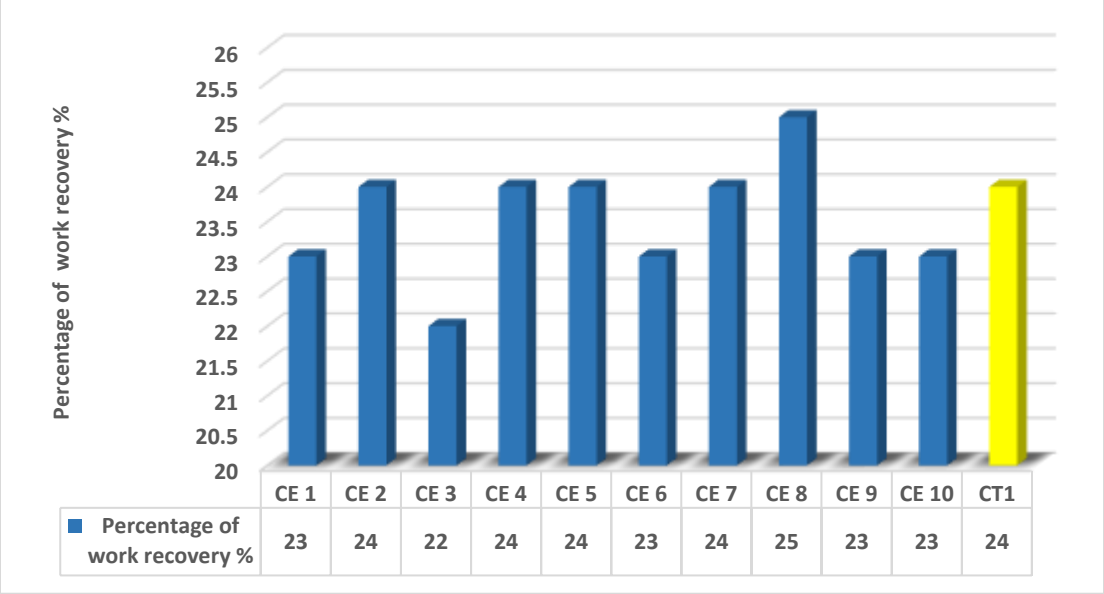


Figure 4. Percentage of work recovery values of the carpet samples.

4. Conclusion

In the content of this study, an alternative approach was developed to produce cut pile tufting carpets with designs have up to 9 colors with very low amount of material, minimum quantity, in small place, short time production, low effort and high performance . In the traditional tufting carpet manufacturing method, the carpet can produce only mono colors or as stripes and need large amount of materials, need large area for machines and high quantity to produce minimum order. The performance of the carpet samples produced with the proposed new approach that is based on the modified computerized embroidery machine usage and normal mechanical tufting machine were compared in terms of pile withdrawal force and compression-recovery. As a result of the applied test method, it was determined that the pile withdrawal force of the carpet samples with modified computerized embroidery machine were nearly same that of Normal mechanical tufting machine applied carpet. So, it was decided that the developed new approach can be applied as a solution to manufacture cut pile carpet. On the other hand, the resilience performance of the carpet samples that is one of the most important performance properties of the carpets was compared by analyzing the compression recovery and work recovery values. It was obtained that the resilience performance of the carpet

samples with modified computerized embroidery machine were nearly same that of produced on normal mechanical tufting machine carpet sample. As a conclusion, it can be evinced that the modified computerized embroidery machine can be used as an alternative to produce cut pile carpet with multi colors up to 9 colors with custom made.

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