The Influence of Silver Nano-treatment on Sewing Threads

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Abstract: Sewing thread is an integral component of the garment. Although sewing thread can be made from any fiber, most threads are made from polyester, cotton or blend of them. The fiber choice is in large part dependent on the end use. Nanotreatment was used to enhance sewing threads properties. In this study the role and impact of silver nanoparticles on three types of industrial sewing threads (sample no.1: (100% polyester), sample no.2: (75% polyester & 25% cotton) and sample no.3 (25% polyester & 75% cotton) have been investigated. Tests were focused on changes at the structural level and changes in linear density, tensile strength, tenacity, elongation and frictional coefficient properties before and after silver nanotreated sewing threads. The structure and morphology of the silver nanoparticles was observed by scanning electron microscopy (SEM). All results have been statistically analyzed using *statistica* software. The effect of silver nanoparticles on physical and functional properties was highlighted. The difference of the impact of silver nanoparticles on polyester and its blend with cotton sewing threads has been compared. It was found that silver nanotreatment lead to unchanged linear density, an increase in tensile strength and tenacity. The nanotreatment of threads improved its frictional coefficient properties in a highly significant manner. Study of the impact of nanotreatment on the properties of cotton and polyester samples showed a bigger impact on blended cotton samples than polyester samples.
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1. Introduction

Sewing threads are special kinds of yarns that are engineered and designed to pass through a sewing machine rapidly. They form efficient stitches without breaking or becoming distorted during the useful life of the product. The basic function of a thread is to deliver aesthetics and performance in stitches and seams (Bulletin post: coats sewing solutions", Nov. 2014). The most important properties of sewing thread that impact quality, performance and manufacturability are: thread structure, uniformity, strength, fiber type, finish, linear density, elasticity, elongation and friction resistance. Studying properties of threads and changes of mechanical properties after sewing were analyzed in many studies (Mori and Niwa, 1994; Sundaresan et al., 1997&1998; Zˇiliene˙ and Baltrusˇaitis, 2000; Rudolf and Gersˇak, 2001; Ajiki and Postle, 2003).Although sewing thread can be made from any fiber, most threads are made from polyester, cotton or blend of them. Silk and linen are also used but the high cost of these fibers limits them to specialized uses. The fiber choice is in large part dependent on the end use. Polyester provides strength and chemical resistance. The high strength may be too strong for some fabrics. Cotton is not as strong and is more susceptible to abrasion than polyester of the same thickness. Cotton can be mercerized (treated with caustic soda) to increase the strength. Cotton is also less resistant to chemicals. Cotton threads have excellent sewability and are stable at high dry temperatures and therefore less affected by hot needles during sewing. Cotton has higher moisture absorption characteristics than polyester which can lead to rot in hot humid climates (Kim Anderson; 2009). Since the updated research work aim to enhance the mechanical and structural properties of sewing threads, Nanotreatment started to be a corner stone in this effort. Silver nanotechnology utilizes nanoscale silver to bestow antibacterial properties onto a given product. Generally, this involves the application or incorporation of nano-sized silver particles into or on the surface of a product. Nanosilver technologies appear in a variety of manufacturing processes and end products. It can appear imbedded in a coating which is applied to the product by the manufacturer (coating). Some products come in a liquid form and are meant to be applied to form a coating (coating & spray). Nanosilver can be presented in a liquid form such as a homeopathy colloid or contained within a shampoo (liquid). It can also be embedded in a solid such as a polymer master batch or be suspended in a bar of soap (solid). Nanosilver can also be utilized in the textile industry by incorporating it into the fiber (spun) or produced as a powder. (Emma Fauss; 2008). The alteration of materials' surface properties by nano silver particles improves the mechanical properties and durability of materials and also influences material's functionality, activity or can enhance its stability (B. Mahltig, et al.; 2005) & (M. S. Smole, et al.; 2006).

2. Material and Methods

This study aims to investigate the effect of nano-treatment on the physical and mechanical properties of different types of sewing threads.

Three types of raw (untreated) sewing threads have been used; sample no.1: (100% polyester), sample no.2: (75% polyester & 25% cotton) and sample no.3: (25% polyester & 75% cotton). Each type was treated using silver Nano-particles (AgNPs). Treatment has been applied in Nano-particles laboratory, at the National institute of standards (NIS) in Egypt.

Sewing threads were treated by spraying (AgNPs) all around the threads while, oven curing all around the threads for a specified period of time. In detail, treatment was done into conditioning atmosphere of 21◦C and 65% RH. First, samples were rinsed and left horizontally to dry into oven at 200◦C for 10 minutes, making sure that samples have no humidity and to accept nano-treatment. Second, silver Nano-particles treatments of (AgNPs) were used to cover all over the samples. Third, treated samples are kept for 15 minutes to absorb all treating substance (AgNPs); then dried into oven at 180◦C for a period of 5 minutes. Finally, samples were kept for 24 hours into the conditioning atmosphere, subsequently rinsed and left to dry horizontally.

Figure (1): Uster Tensorapid Tester

Both treated and untreated threads were tested using a number of test methods; First, Scanning Electron Microscope (SEM) was used for characterization of nano-treated samples. The thread samples treated with the silver Nano-particles were mounted on a specimen stub with a double-sided adhesive tape and coated with gold in a sputter coater and examined with a scanning electron microscope of Hitachi VP-SEM S-3400N model. The scanning electron microscope (SEM) tests were done at a magnification of 1.20-10.00 µm. Second, Linear Density Test was done to all specimens before and after treatment with silver Nano-particles.

Third, Tensile Strength & Elongation Tests were carried out in the National Institute for Standards (NIS), Egypt, according to (ASTM D2256 / D2256M -10e1) by USTER TENSORAPID (figure 1). Forth, Tenacity Test was performed according to ASTM D1578-93 (2011). Finally, Frictional coefficient Test was done according to (ASTM D3412/D3412M – 13).

3. Results

Laboratory tests were performed at standard conditions as mentioned before; results were documented and analyzed statistically by (*STATISTICA* software presented from *STAT-SOFT*) according to equa-tions and correlation coefficient to show the effect of using silver Nano-particles treatments of (AgNPs) on the characteristics and mechanical properties of the studied sewing threads.

1- Scanning Electron Microscopy (SEM) test:

Electron microscope produces images of samples by scanning them with a focused beam of electrons. The electrons interact with atoms in the sample, producing different signals that can be detected; these signals contain information about the sample's surface and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image (www.purdue.edu; 2013).

The following figures (2-7) show SEM examination of both treated and untreated sewing threads.

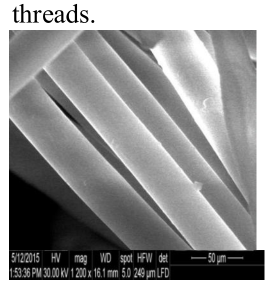
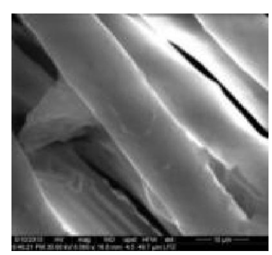
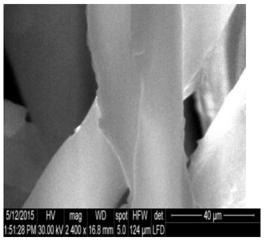


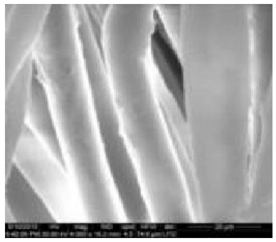
Figure (2): SEM image of untreated sample 1

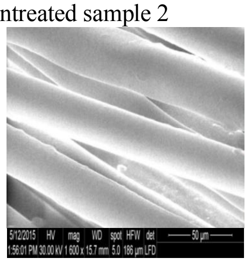


Figure(3): SEM image of nanotreated sample 1

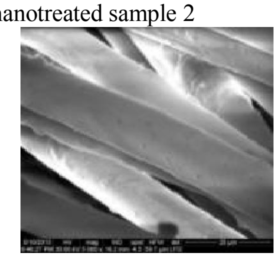


Figure(4): SEM image of untreated sample 2


Figure(5): SEM image of nanotreated sample 2



Figure(6): SEM image of untreated sample 3


Figure(7): SEM image of nano-treated sample 3

The previous figures show the structure and morphology of the silver nano-particles on the threads and were clearly visible in scanning electron microscope (SEM) images. The deposition of silver nano-particles on the sewing threads are coating the fibers and penetrating them, whilst the look and texture of sewing threads remain the same before nanotreatment, the thread has a smooth surface and is uniform, whereas after nanotreatment there is a significant roughness on the surface of the thread samples.

2- Linear Density Test:

Linear density test was done to all samples before and after treatment. Table 1 show the data obtained in (Tex). It is obvious that the data is statistically insignificant as shown in Figure 8.

Table 1: Linear Density results before and after nanotreatment in (Tex)

	Before treatment	After treatment
Sample No.1	30	30
Sample No.2	16	16
Sample No.3	16	16

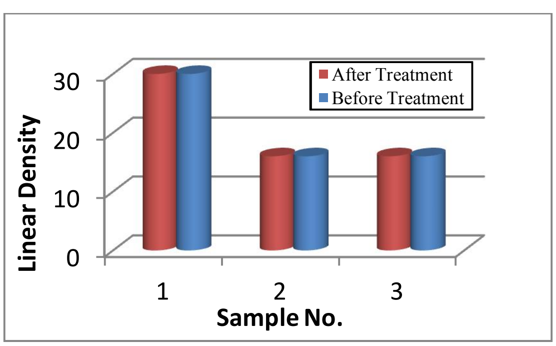


Figure (8): Linear Density before & after nanotreatment

3- Tensile Strength Test:

Experiments to study the tensile strength of samples before and after nanotreatment were conducted. If an external force is applied to a material, it is balanced by internal stresses developed in the molecular structure of the material. In high speed sewing machines the external force applied on the needle thread is as high as 200 gf (Mohanapriya Venkataraman, et al, 2014). In order to withstand this force during sewing, a thread must possess adequate strength and elasticity. Since different materials have different molecular structures, their behavior in response to this force will be different. The tensile strength and elongation of sewing thread must be adequate for good sewing performance and seam strength. The elongation of a thread determines the effectiveness of the tensile force acting on the thread. Table 2 & Figure 9 show the results of the tensile strength before and after nanotreatment

Table 2: Tensile Strength results before and after nanotreatment in (kg)

	Before treatment	After treatment
Sample No.1	5.5	6
Sample No.2	4.5	5
Sample No.3	3	4.5

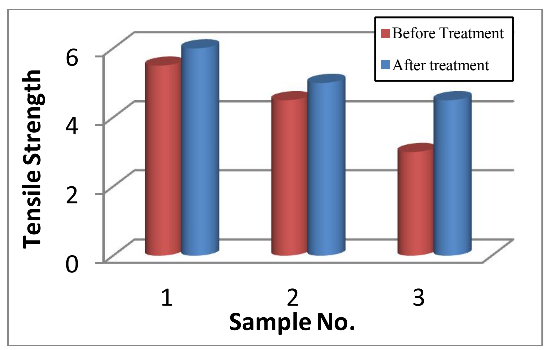


Figure 9: Tensile Strength before & after nanotreatment

By applying the results of Tensile Strength test statistically as shown in table (3), there is insignificant correlation between the results before & after nanotreatment (p-value is 0.129)

Table 3: The correlation of tensile strength results before & after nanotreatment

	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Before	4.333	1.258	3	-0.833	0.577	-2.5	2	0.129
After	5.166	0.763						

4- Tenacity Test:

The data of tenacity test for treated and untreated sewing threads were documented in table 4 and figure 10.

Table 4: Tenacity results before and after nanotreatment in (gm/tex)

	Before treatment	After treatment
Sample No.1	33.11	42.15
Sample No.2	21.11	36.48
Sample No.3	15.11	25.93

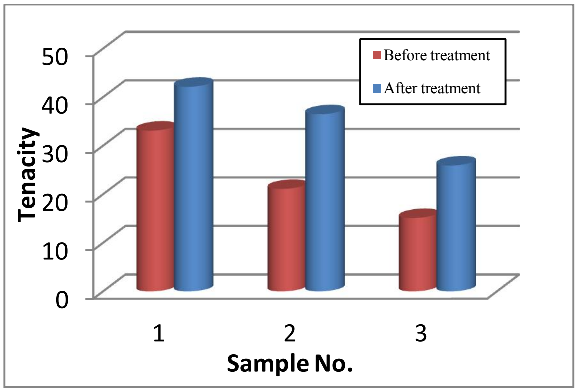


Figure 10: Tenacity test before & after nanotreatment

These data were analyzed statistically in the form of mean value, standard deviation and p-value as shown in table 5. There is statistically significant correlation between the results of tenacity test before & after nanotreatment (p-value is 0.024)

Table 5: The correlation of tenacity results before & after nanotreatment

	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Before	23.11							
After	9.165	8.231	3	-11.743	3.264	-6.230	2	0.024

5- Elongation Test:

Table 6 illustrates that the results of elongation test have increased after nanotreatment (as shown in figure 11).

Table 6: Elongation results before and after nanotreatment (%)

	Before treatment	After treatment
Sample No.1	8.7	8.9
Sample No.2	8.7	8.9
Sample No.3	8.6	8.7

Accordingly, the results of elongation test were analyzed statistically and found to be statistically significant (p-value is 0.037) as shown in table (8).

Table 8: The correlation of elongation results before & after nanotreatment

	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	P
Before	8.666	0.057						
After	8.833	0.115	3	-0.166	0.057	-5	2	0.037

6- Frictional coefficient Test:

The frictional forces developed in the sewing threads are mostly due to the friction with the fabrics and machine parts. The friction occurs mostly in two places, (i) the thread and the needle. (ii) the thread and the fabric being sewn (J. O. Ukponmwan; 2000)& (A. K. Singh, et al.; 1994) & (S. D. Pai, et al.; 1982) & (L. Maleknia, et al.; 2010)

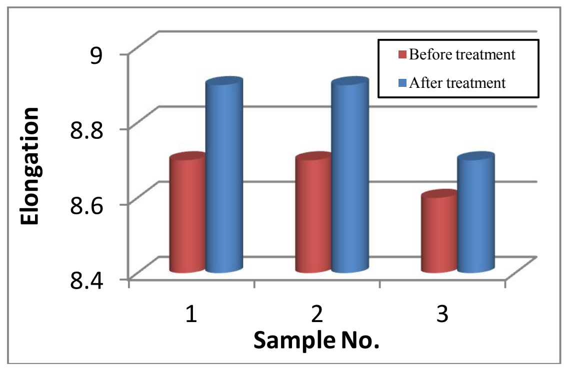


Figure 11: Elongation test before & after nanotreatment

To express the magnitude of the friction under particular conditions it is useful to quote values of frictional coefficient, μ. The coefficient of friction varies with experimental condition, especially on the exact state of the surface. In high speed sewing machine the needle threads rub against the needle or thread eyelet placed at several points in the machine. However, the coefficient of friction between a needle thread and a stainless steel or other guide should be less than 0.2. Thus all the synthetic and natural fiber needle threads require a lubricant finish to reduce this friction to an acceptably low level. It can be observed that the frictional coefficient of the threads has increased significantly after silver nanotreatment as shown in table 9 & figure 12 for sample no. 1, figure 13 for sample no. 2 and figure 14 for sample no. 3. From the results, it is important to note that friction must not be too high, which causes the thread breakage, and not too low, which causes loss of thread control.

Table 9: Frictional coefficient results before and after Nanotreatment

	Sample No.1 before treatment	Sample No.1 after treatment	Sample No.2 before treatment	Sample No.2 after treatment	Sample No.3 after treatment	Sample No.3 after treatment
1	2021	2042	912	925	602	609
2	2054	2056	950	962	608	617
3	2067	2081	982	994	639	642
4	2070	2089	1008	1012	681	689
5	2137	2129	1080	1092	759	762
6	2164	2173	1086	1096	767	771
7	2189	2185	1093	1108	773	776
8	2201	2208	1100	1112	775	778
9	2227	2234	1107	1114	778	780
10	2233	2252	1112	1121	783	789

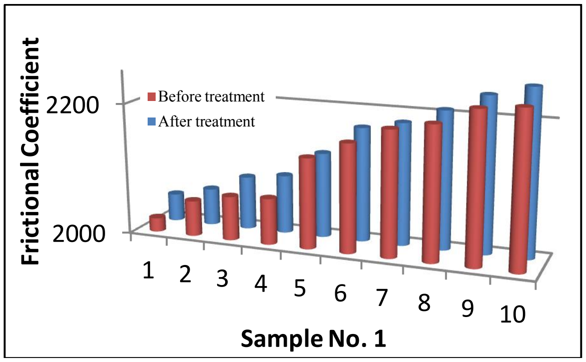


Figure 12: Frictional coefficient test for sample no.1 before & after nanotreatment

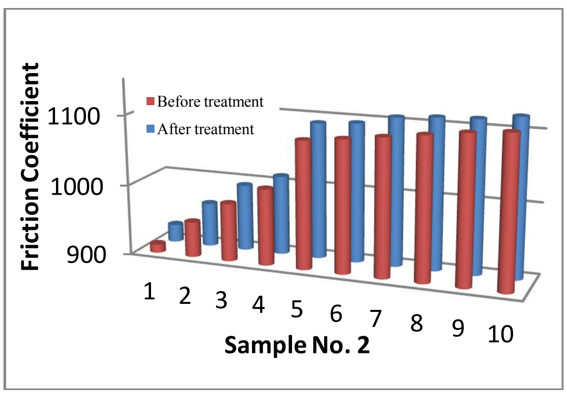


Figure 13: Frictional coefficient test for sample no.2 before & after nanotreatment

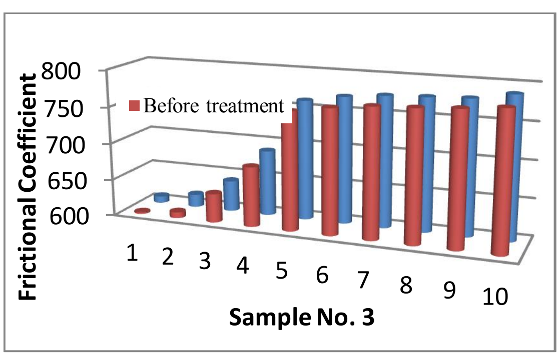


Figure 14: Frictional coefficient test for sample no.3 before & after nanotreatment

All the results of Frictional coefficients test were analyzed statistically before and after nanotreatment to detect the correlation between them.

For the test sample no. 1 (polyester 100%) there is statistically significant correlation between the before nanotreatment results and the after nanotreatment results (p-value is 0.022). This means that the friction coefficient has increased significantly after silver nano deposition as shown in table 10.

Table 10: The correlation of frictional coefficient results for sample no.1 before & after nanotreatment

	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Before	2136.3	77.870	10	-8.6	9.901	-2.746	9	0.022
After	2144.9	75.822						

For test sample no. 2 (polyester 75% & cotton 25%) there is statistically highly significant correlation between the before nanotreatment results and the after nanotreatment results (p-value is 2.46E-06). This means that the friction coefficient has markedly increased after silver nano treatment as shown in table 11.

Table 11: The correlation of frictional coefficient results for sample no.2 before & after nanotreatment

	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Before	1043	73.469	10	-10.6	3.204	-10.461	9	2.46E-06
After	1053.6	73.063						

For test sample no. 3 (polyester 25% & cotton 75%) there is statistically highly significant correlation between the before nanotreatment results and the after nanotreatment results (p-value is 0.00017). This means that the friction coefficient has dramatically increased after silver nano treatment as shown in table 12.

Table 12: The correlation of frictional coefficient results for sample no.3 before & after nanotreatment

	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Before	716.5	75.516	10	-4.8	2.485	-6.106	9	0.00017
After	721.3	73.924						

4. Discussion

The study involved using three types of sewing threads: 100% polyester as sample no.1, 75% polyester&25% cotton as sample no.2, 25% polyester&75% cotton as sample no.3. These sewing threads are commonly used in sewing fabrics. They have different characteristics that impact quality, performance and manufacturability.

The treatment with silver Nano-particles (AgNPs) led to significant enhancement in the behavior of the treated sewing threads.

Study the SEM images before and after silver nanotreatment of sewing threads illustrated that the morphological changes of sewing threads caused by deposition of silver nanoparticles doesn't affect the appearance and texture of sewing threads.

Furthermore, linear density test of sewing threads proved that treatment with nanoparticles doesn't affect the count of the studied yarns.

Whilst, results of the effect of nanotreatment on tensile strength showed increase in tensile strength of the treated threads in sample 1&2 and marked increase in sample 3, this is could be attributed to the percentage of cotton (75%) in sample 3 and due to binding of silver nanoperticles with -O- in cellulose macromolecule in cotton.

As regard tenacity and elongation tests, nanotreatment improved these characteristics significantly, and this is could be attributed to adding power to the sewing threads by silver nanotreatment.

Moreover, study the effect of nanotratment on frictional coefficient of the sewing threads revealed highly significant increase after nanotreatment especially for sample no.3 (25%polyester&75% cotton). This may be attributed to the diffusion of the silver nanoparticles in the sewing threads, which creates surface roughness, resulting in higher level of friction. From the results, it is important to note that friction must not be too high (as in cotton threads), which causes the thread breakage, and not too low (as in polyester threads), which causes loss of thread control.

Finally, the nano treatment enhances the characteristics of sewing threads in the form of tensile strength, tenacity, elongation and frictional coefficient.

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