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# A Study and Investigation on the Influence of Static and Dynamic Loading on the Properties of Handmade Persian Carpet (I) – The Effect of Static Loading –

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**Abstract:** The paper reports the physical and mechanical properties of hand-woven carpets, which have been put under static force. Two groups of wool fibres, from two parts of Iran, were prepared to spin pile yarns for the carpets. Each group of the fibres included both conventional and tanned wool. Then two yarn counts, $N_m = 4/2$ and 6/2, were spun for two different knot densities. After weaving the carpets, they were put under static force and their thickness variations were measured and plotted against time, in logarithm scale. The resiliency of the carpets piles after eliminating the static force, were measured and plotted against time, in logarithm scale, too. The results were compared to each other and analysed with respect to parameters such as the type and quality of the wool fibres as well as knot density of the carpets.

**Keywords:** Tanned wool, Physical and mechanical properties, Carpet thickness, Pile recovery, Static and dynamic forces

## Introduction

It can be claimed that the hand woven carpet represents the great history of Iranian arts. The oldest sample of Iranian carpets found in city of SARAB (located in north west of Iran) confirms this fact [1]. During a digging, in 1949, in Siberia Mountains an Iranian hand woven carpets, named Pazyryk, was found. The pile of the carpet was made of wool with 200 knots/in$^2$ [2].

In producing the carpet different materials such as cotton yarns with various counts, twist, and ply are used for warp and weft ends of the carpet. Although, the most obvious fibres observed and touched by people is wool. In carpet industry, the coarse and fine wool fibres are mixed and spun. These fibres can be used for carpet when their resiliency, dyeablity, fibre length, number of crimps, vegetable trash percentages, tenacity, elongation and fineness of the fibres is suitable [3].

Nowadays another type of wool fibre, tanned wool fibre, which is mixed with conventional wool fibre, is used, too. The tanning process can be made in various ways, however it consists of the following [2]:

(1) Soaking (16 hours)

During this process the skins are rinsed in cold water to remove excess salt and dirt from the wool and pelt. Rehydration (soaking) of the pelt takes places in fresh cold water float overnight.

(2) Fleshing

In this treatment, the skins are fleshed using a fleshing machine which removes excess fat and muscle tissue from the back of the skins. This allows for more rapid and complete penetration of chemicals in the later stages of processing, particularly during pickling and tanning.

(3) Scouring (0-45 minutes)

To scour the skins, the surfactants are used at 38 °C to remove dirt and grease (lanolin) from the wool.

(4) Pickling (16 hours)

Prior to tanning, the skins are pickled in a solution containing acid and salt. The salt is added to prevent swelling of the skins by the acid. The tanning agent lowers the internal pH of the skins to approximately 2.8-3.0, thereby preparing the skins for penetration.

(5) Tanning (16 hours)

Tanning is generally achieved by using chromium salts, which form cross-links with the collagen, stabilising the skin structure and preventing putrefaction. The tanning step is conducted at about 25 °C and pH 2.5-3.0 to allow for penetration of the chrome. Once penetrated, the chrome is fixed to the collagen by raising the pH to about 3.6 using sodium bicarbonate, and heating to about 35-40 °C. This step raises the shrinkage temperature of the skin from about 60 °C to around 100 °C.

A lot of research works have been carried out in the field of preparing wool from woolskin. These findings have resulted in new view in connection with tanned wool fibres, so that the value of tanned wool is not only lower than conventional wool fibres, but also in most cases its price is similar to it [4].

Iranian Standard (ISIRAN) [5] has advised the use of wool fibres with length of minimum 5 cm and diameter of at least 20 $\mu$.

The physical properties, such as extensibility and resiliency, of wool fibres used for carpet play a fundamental role in quality of the rug. The extend of resiliency of Iranian wool fibres has been worked out within 83.02-95.4 percent which is so higher compared with non-domestic wool fibres, i.e. the Iranian wool fibres have excellent characteristics for hand woven carpet [5].

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However the above mentioned standard does not allow the use of tanned wool fibres even as combined with conventional wool fibres for hand woven carpet. The reason for such restriction is due to the lower quality of the wool fibres due to the damages caused by chemical treatments during tanning process. These damages reduce the tenacity and dyeablity of the wool fibres, which makes some difficulties in connection with the quality and durability of the carpet [6].

The advantages of a carpet, in addition to decoration features, particularly when it is new, are its comfortablity, suitable temperature and safety when walking. Another aspect of the carpet is its acoustic characteristic, which can absorb the foot fall sound [7]. The isolation characteristic of the carpet also prevents heat transfer, so that the buildings having covered by carpet can save up to 5-13 % the costs of the heating.

The durability of the carpet is other factor which consumers regard, and it is defined the period takes the knots of the carpet are withdrawn from the carpet so that the warp ends of the carpet are seen. This property of the carpet is linked with the quality and the type of the knots used in the carpets. It has been reported that the main abrasion of the carpet occur in turning places of the corridors as well as the edges of the stairs [7].

A lot of works have been carried out to study the effect of the static and dynamic forces on the conventional (non hand woven) carpets, but a little has been done on the hand woven carpets. Ghareaghagi [8] in a research work, spun the woolen yarn from conventional and tanned wool fibres with different combinations portions to weave the rug. He put the rugs under static and dynamic forces according to relevant standards and measured their thickness and the pile recovery of the carpets after removing the loads. He, also, plotted the thickness and the pile recovery of the carpets against time.

In this study we tried to find out how the race of the wool and the tanning treatments will influence the mechanical and physical behaviour of the handwoven carpet under static forces.

## Experiments

### Materials

With respect to this fact that the aim of this research work was to study and investigate the mechanical properties of the hand woven carpet, it was necessary to carry out the experiments on the carpets. The samples with small dimensions should be cut from the carpet. As the hand woven Persian carpets, are expensive in large dimensions, cutting the samples from such carpets are not acceptable and the small carpets should be woven for this purpose. Thus, eight carpets, in dimensions of 60 × 90 cm, were woven. To produce these carpets, two different wool fibres from two parts of Iran were provided. The chosen region were Sirjan (South East of Iran) and Kermanshah (West of Iran). From each region both conventional and tanned wool fibres were prepared. The wool fibres from first region are somewhat finer than the latter region. Then from four groups of the wool fibres two yarns with different counts, $N_m$=2/4 and 2/6, were spun to weave eight rugs. The first yarns group, $N_m$=2/4, were used for rugs having density of 25 knots per 6.5cm, and the second group of the yarns, $N_m$=2/6, were used to weave the rugs with density of 35 knots per 6.5 cm. The woolen yarns were dyed using vegetable dyestuff in traditional method.

In addition to woolen yarns, as the pile of the carpet, the warp and weft yarns were also required. The warp ends used for two groups of the rugs were as following:

(1) Knot density (25): $N_e$=20/20

(2) Knot density (35): $N_e$=20/12

Two different weft ends were used to bind the knots in the carpet firmly. The count of the weft ends were as follows:

(1) Knot density (25)

Thick weft end: $N_e$=10/20 and thin weft yarn: $N_e$=20/5

(2) Knot density (35)

Thick weft end: $N_e$=10/14 and thin weft yarn: $N_e$=20/3

After setting up the frame of the rugs, they were woven on basis of a simple pattern, designed earlier for this purpose.

The specifications of the carpets have been tabulated as following:

| Carpet | Wool race | Wool type | Knot/ 6.5 cm | $N_m$ | $\mu$ | T.P.M | Break. strength (g/tex) |
|---|---|---|---|---|---|---|---|
| A | Sirjani | Normal | 25 | 2/4 | 30.5 | 80 | 4.5 |
| B | Kermanshahi | Normal | 25 | 2/4 | 33 | 80 | 4.7 |
| C | Sirjani | Tanned | 25 | 2/4 | 30.5 | 80 | 4 |
| D | Kermanshahi | Tanned | 25 | 2/4 | 33 | 80 | 4.3 |
| E | Sirjani | Normal | 35 | 2/6 | 30.5 | 95 | 5.6 |
| F | Kermanshahi | Normal | 35 | 2/6 | 33 | 95 | 6 |
| G | Sirjani | Tanned | 35 | 2/6 | 30.5 | 95 | 5 |
| H | Kermanshahi | Tanned | 35 | 2/6 | 33 | 95 | 5.2 |

Where:

A: Carpet woven from Sirjani wool (Kerman area), knot density of 25/6.5 cm

B: Carpet woven from Kermanshahi wool, knot density of 25/6.5 cm

C: Carpet woven from tanned wool of Sirjani, knot density of 25/6.5 cm

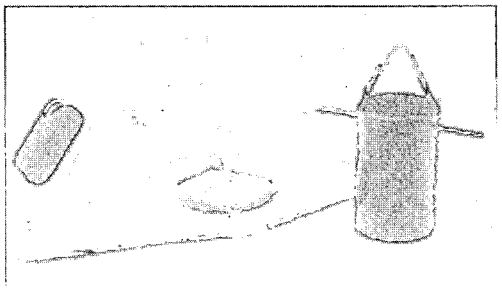
D: Carpet woven from tanned wool of Kermanshahi, knot density of 25/6.5 cm

E: Carpet woven from Sirjani wool, knot density of 35/ 6.5 cm

F: Carpet woven from Kermanshahi wool, knot density of 35/6.5 cm

G: Carpet woven from Sirjani tanned wool, knot density of 35/6.5 cm

H: Carpet woven from tanned wool of Kermanshahi knot density of 35/6.5 cm



**Figrue 1.** The WIRA static load device.

### Test of the Effect of Static Force

The rugs woven with above specifications were put under the static force. This treatment is carried out to study the effect of static loads such as the weight of chair legs, etc. on the physical and mechanical properties of the hand woven carpets.

To study the effect of the static force on the physical and mechanical properties of the hand woven carpets, the four samples, 50 × 50 mm, were cut from them. Then the samples were placed on the special holding plate and under the piston of the static load instrument, which can be observed in Figure 1. After, the weight is hung at the end of the lever, specified by a round groove. This device, which is basis of similar instrument and according to WIRA standards [9], used these days to create static load on the carpet, has a lever with length rate is 5:1. The hung weight of 9.1 kg at the end of the lever, create a pressure of 7 kg/cm$^2$ on the surface of the sample carpet is being tested. In this research work the samples were put under the static load for 0.25, 0.5, 1, 2, 5, 8, 12 and 24 hours and their thickness were measured at these times. Then the variations of the pile thickness were plotted against time in logarithm scale.

The static load was eliminated and the recovery of the carpet piles was measured after 0.25, 0.5, 1, 2, 5, 8, 12 and 24 hours and their thickness were measured at these times. Then the variation of the pile thickness was plotted against time in logarithm scale.

## Results and Discussion

As the instrument we used was similar to WIRA equipment, shown in Figure 1, the static load applied on the samples, as explained earlier. Then their thickness and recovery variations were measured and plotted, as explained in the previous section.

### Influence of Static Load on Properties of Hand Woven Carpets

In this section the properties of the hand woven carpet under static load are dealt with. The relevant graphs should be discussed and analysed with respect to parameters like the race and quality of the wool as well as the carpet density. To make more sensible the findings, the results were compared and analysed using statistical method (ANOVA). Therefore it is essential to plot the mentioned graphs and compare the curves and discuss the findings.

#### *Effect of Wool Fibres Race*

As stated earlier, two different types of wool fibres, with different fineness, were used to spin the woolen yarn and finally weave the carpets. To investigate the effect of the race of wool, i.e. fibre fineness, on the properties of the hand woven carpets, the relevant curves are illustrated with respect to this parameter. Figure 2, Figure 3, Figure 4 and Figure 5 illustrate the results in a comparative way. The difference between the relevant curves is the race of used wool. Comparing the thickness variations of two carpets, A

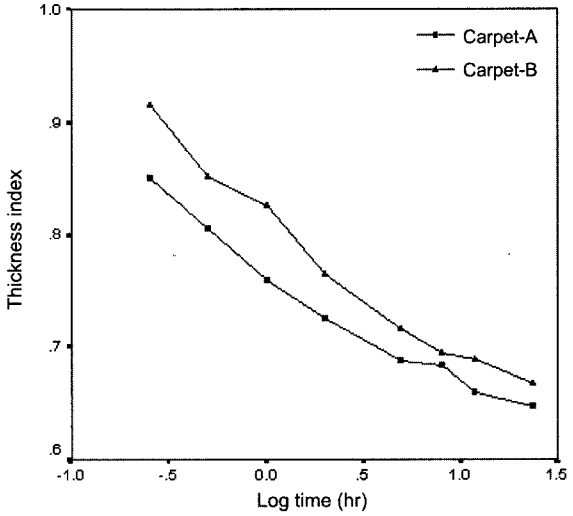



**Figure 2.** The thickness variations of the carpets A and B, under static load.

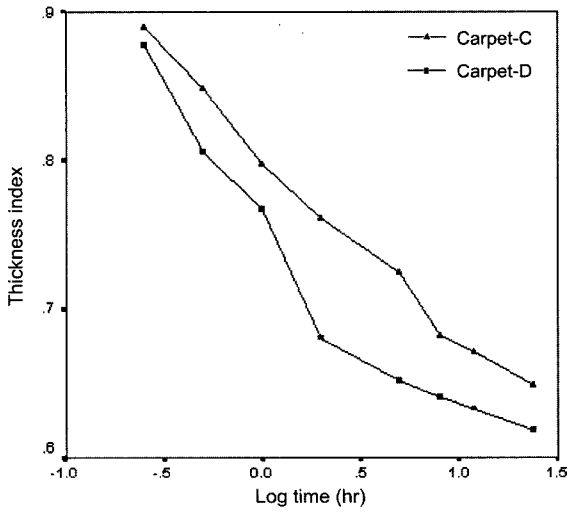



**Figure 3.** The thickness variations of the carpets C and D under static load.

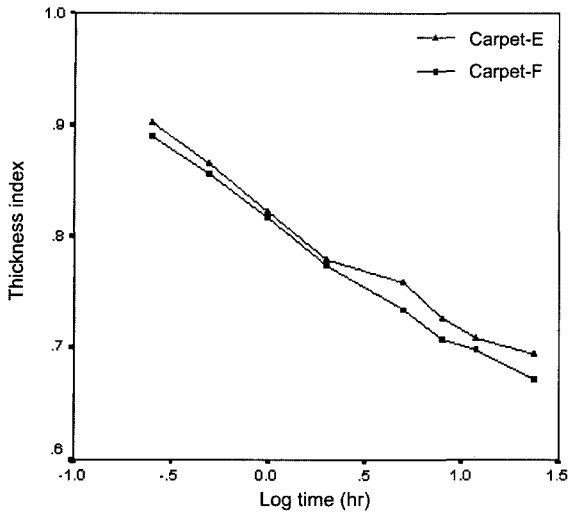



**Figure 4.** The thickness variations of the carpets E and F under static load.

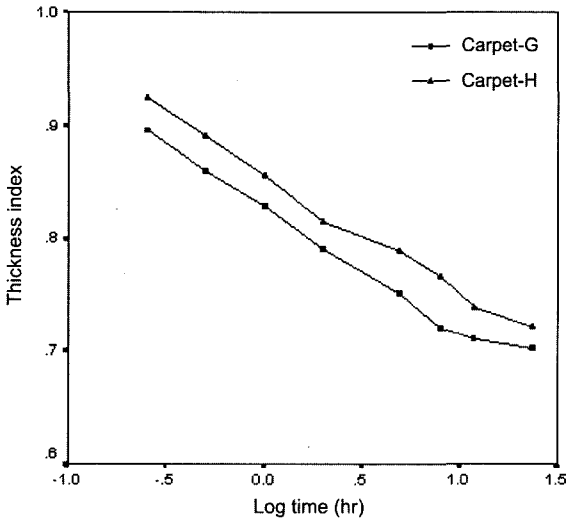



**Figure 5.** The thickness variations of the carpets G and H under static load.

and B, indicates that the thickness of carpet A under static load decreases more than thickness of carpet B. The reason for such behaviour may be due to fineness of two wool fibres. It means the carpet A is softer and more comfortable than carpet B, as the Sirjani wool fibres are finer than Kermanshahi one.

Considering Figure 3, indicates the trend of thickness reduction of the carpets C and D, woven from tanned wool of Sirjani and Kermanshahi, which are almost alike to similar carpets (carpets A and B). However the carpets C and D show more reduction in compared with carpets A and B. It can be explained due to the chemical damages from tanning process. Another difference is larger reduction of the thickness of carpets D compared with carpet C. The reason for this phenomenon may be due to the effect of chemicals and the tanning process on the fibres surface and structure of type D.

In Figure 4, if the behaviour of carpets E and F is considered, it can be observed that both carpets have similar thickness reduction. So as in the beginning both carpets show similar trend, although the thickness reduction of carpet E is less than carpet F, whereas in previous case, it was different. Despite of this similarity between the curves, the analysis made using ANOVA indicated that the reduction of these carpets (E and F) are different.

Comparison thickness of carpets G and H, in Figure 5, shows that the thickness reduction of carpet G is higher than thickness reduction of carpet H. it can be due to higher bending of the used wool fibres, under the static load applied.

### *Effect of Tanning Process (Wool Quality)*

As mentioned before, the tanning process can cause the quality of wool fibres to lower. To study the extent of this effect, the behaviour of the similar carpets is regarded, too. Therefore, the carpets should be compared in pair, as the following:

(1) Carpets A and C
(2) Carpets B and D
(3) Carpets E and G
(4) Carpets F and H

Considering and comparing the curves of A and C, suggests the thickness reduction of the carpets woven from tanned wool of Sirjani is somewhat higher than the carpet woven from conventional wool of Sirjani. The situation is more obvious in case of density of 25 knots/6.5 cm, but the curves of thickness reduction of the carpets in higher knot density (35 knots/6.5 cm) are coincided on each other. Although the extent of the thickness reduction of the finer carpets are less in comparison with carpet having lower knot density, which is reasonable. The same trend is observed for fine carpets woven from both wool (Tanned and conventional) of Kermanshahi, however, this trend is vice versa in case of carpets with knot density of 25.

This study indicates that the flexibility of the Kermanshahi tanned wool is lower compared with the conventional one. Therefore, for the same reason, the thickness reduction of the carpets, woven from tanned wool fibres, in most cases is less in comparison with the carpet woven from conventional wool fibres.

### *Effect of Knot Density of the Carpet*

To discuss the effect of this parameter, the thickness variations of the carpets woven from similar wool fibres, but with different knot densities should be compared with each other. Thus, in this part, the thickness reduction of carpets under static load are plotted and compared as following:

(1) Carpets A and E
(2) Carpets C and G
(3) Carpets B and F

(4) Carpets D and H

The comparison of the above carpets shows that the thickness reduction of the carpets, having higher knot density, is less compared with carpets having lower knot density, which seems acceptable. Since the increase of knot density causes the carpets pile is not bent easily, i.e. the bending resistance of the piles increases, due to the increase of knot density of the carpets.

## The Influence of Static Load on Pile Recovery Behaviour of Hand Woven Carpets

For a further study, the curves of pile recovery of the piles against time, in logarithm scale, should be plotted with regard to the type and quality of the fibres as well as knot density of the carpets.

### *Effect of Wool Fibres Race*

To study the effect of wool fibres race on the behaviour of pile recovery of the carpets after removing static load, the relevant curves are plotted and compared with each other. It is noted all the parameters are the same and just one of the parameter is different. Figure 6, Figure 7, Figure 8 and Figure 9 display the pile recovery of the carpets with respect to the fibre race after removing the static load.

Considering Figure 6, indicates the extent of the pile recovery of carpet B is greater than the pile recovery of similar carpet (A). Viewing the similar carpets having higher knot density, as seen in Figure 7, suggests the trend of pile recovery are quite unlike the carpets having lower knot density. Thus the difference can be related to the effect of the knot densities of the carpets. If the study is extended to the carpets woven from tanned wool, it is observed that the trend of their curves is inverse, particularly with knot density of 25, i.e. the pile recovery of the carpets woven from tanned wool

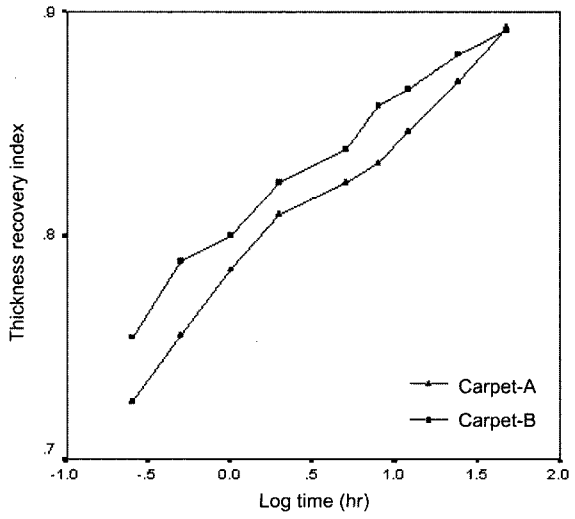



**Figure 6.** The pile recovery variations of carpets A and B after removing static load.

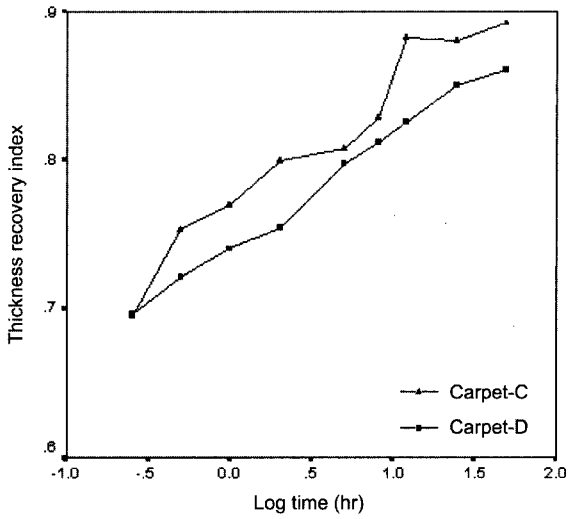



**Figure 7.** The pile recovery variations of carpets E and F after removing static load.

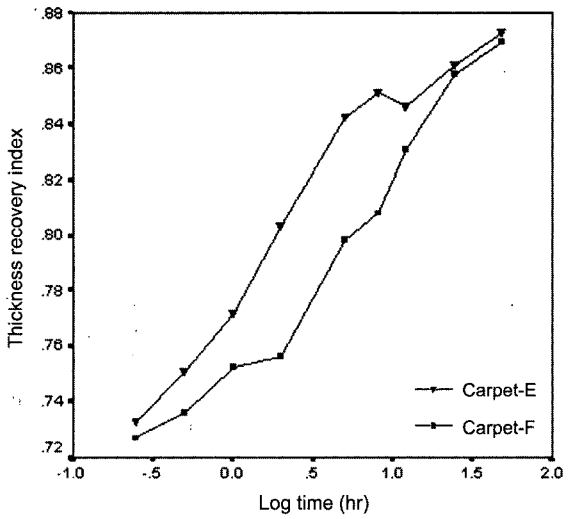



**Figure 8.** The pile recovery variations of carpets C and D after removing static load.

of Sirjani (C) is greater than the kermanshahi's ones (D), which can be observed in Figure 8.

The pile recovery of the carpets with knot density of 35, woven from tanned wool, is quite different. So as, considering Figure 9 indicates the extent of pile recovery of carpet H is more than the pile recovery of carpet G for first 12 hours, but this trend becomes reverse after this period.

### *Effect of Tanning Process (Wool Quality)*

One of parameters affecting on pile recovery of the carpets, is the quality of the wool, which may have been damaged due to tanning process. As both races of fibres from Sirjan and Kermanshah regions, were used as normal and tanned fibres, to weave carpets with two different knot densities, thus it is

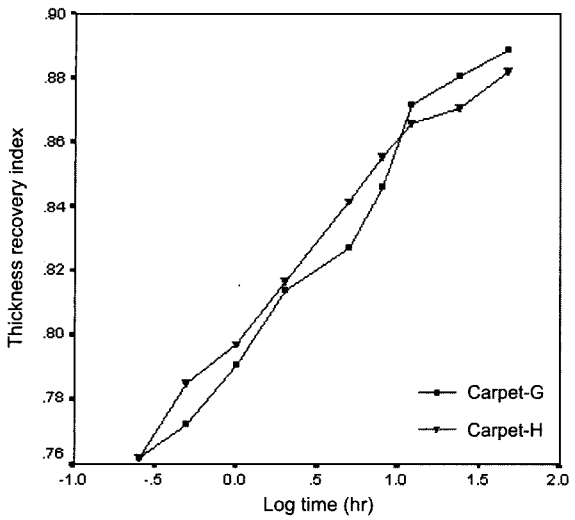



**Figure 9.** The pile recovery variations of carpets G and H after removing static load.

essential to deal with the effect of this parameter. Therefore, the pile recovery of the similar carpets should be compared and analysed, as pairs of carpets having similar knot densities. Considering pile recovery of the carpets A and C, suggests the carpet woven from normal wool of Sirjani has greater recovery in comparison with the carpet woven from similar wool of Kermanshahi, although there are some differences at some times. The reason for the difference can be due to the quality of the fibres as well as the error of measuring, during the measurements. To investigate the recovery behaviour of the carpets regarding the race of fibres and higher knot density, the relevant curves should be considered. The study shows within first two hours, the pile recovery of the carpets woven from tanned wool of Sirjani with knot density of 35, is greater than the recovery of similar carpet woven from tanned wool of Kermanshahi, although after this period the trend becomes inverse. In connection with the carpets woven from Kermanshahi, the trend is interestingly inverse, since its behaviour is unlike properties of the carpets with lower knot density.

### *Effect of Knot Density of the Carpet*

The knot density of the carpet is another factors affecting on the pile recovery of them, after eliminating the static load. Viewing the relevant curves with respect to their knot density, indicates that pile recovery of the carpets woven from normal wool of Sirjani, carpet A, mainly is greater than the similar carpet having knot density of 35 (carpet E), although after a long time the extent of pile recovery of carpet A, is greater, compared with carpet E. In connection with carpets woven from normal wool of Kermanshahi wool, it can be observed that the pile recovery of the carpet with lower knot density is higher than the similar carpet having knot density of 35.

If the investigation is extended to carpets woven from tanned wool of Sirjani, it can be seen that the amount of the pile recovery of the carpets having higher knot density is often greater than the carpets having lower knot density. The same trend is reported for the carpets woven from tanned wool of Kermanshahi.

## Conclusion

In this research work the effects of wool race (fibres fineness), effect of tanning process (wool quality) and effect of knot density of the carpet on the physical and mechanical properties of the carpet under static load were investigated.

As can be seen from the results the time is a major parameter in thickness reduction of the carpets under static load. In most cases the thickness reduction of the carpets follows a linear trend when it is plotted against log time. Comparing the thickness variations of two carpets, A and B, indicates that the thickness of carpet A under static load decreases more than thickness of carpet B. The thickness reduction of the carpets C and D are almost alike to similar carpets (carpets A and B). However the carpets C and D show more reduction in compared with carpets A and B. If the thickness reduction of carpets E and F under static load is considered, it can be observed that both carpets have similar thickness reduction. So as in the beginning both carpets show similar trend, although the thickness reduction of carpet E is less than carpet F, whereas in previous case, it was different. The analysis of the results using ANOVA shows that the behaviour of carpets E and F are not quite similar. Comparison thickness of carpets G and H shows that the thickness reduction of carpet G is higher than thickness reduction of carpet H.

The thickness reduction of the carpets woven from tanned wool of Sirjani, curves of A and C, is somewhat higher than the carpet woven from conventional wool of Sirjani. The situation is more obvious in case of density of 25 knots/ 6.5 cm, but the curves of thickness reduction of the carpets in higher knot density (35 knots/6.5 cm). The same trend is observed for fine carpets woven from both wool(Tanned and conventional) of Kermanshahi, however, this trend is vice versa in case of carpets with knot density of 25.

Results also show that the thickness reduction of the carpets, having higher knot density, is less compared with carpets having lower knot density, which seems acceptable. Since the increase of knot density causes the carpets pile is not bent easily.

The extent of the pile recovery of carpet B is greater than the pile recovery of similar carpet (A) when the load is removed from the carpets. Viewing the similar carpets having higher knot density, suggests the trend of pile recovery are quite unlike the carpets having lower knot density. This parameter is inverse for carpets woven from tanned wool, particularly with knot density of 25, i.e. the pile recovery of the carpets woven from tanned wool of Sirjani (C) is greater

than the kermanshahi's ones (D). The pile recovery of the carpets with knot density of 35, woven from tanned wool, is quite different. So as the extent of pile recovery of carpet H is more than the pile recovery of carpet G for first 12 hours, but this trend becomes inverse after this period.

Considering pile recovery of the carpets A and C, suggests the carpet woven from normal wool of Sirjani has greater recovery in comparison with the carpet woven from similar wool of Kermanshahi, although there are some differences at some times. To investigate the recovery behaviour of the carpets regarding the race of fibres and higher knot density, the relevant curves should be considered. The study shows within first two hours, the pile recovery of the carpets woven from tanned wool of Sirjani with knot density of 35, is greater than the recovery of similar carpet woven from tanned wool of Kermanshahi, although after this period the trend becomes inverse.

The knot density of the carpet is another factors affecting on the pile recovery of them, after eliminating the static load. Viewing the relevant curves with respect to their knot density, indicates that pile recovery of the carpets woven from normal wool of Sirjani, carpet A, mainly is greater than the similar carpet having knot density of 35 (carpet E), although after a long time the extent of pile recovery of carpet A, is greater, compared with carpet E. In connection with carpets woven from normal wool of Kermanshahi wool, it can be observed that the pile recovery of the carpet with lower knot density is higher than the similar carpet having knot density of 35.

If the investigation is extended to carpets woven from tanned wool of Sirjani, it can be seen that the amount of the pile recovery of the carpets having higher knot density is often greater than the carpets having lower knot density. The same trend is reported for the carpets woven from tanned wool of Kermanshahi.

Considering the results reported in this paper indicates unlike the public point of view, the quality of the carpets woven from tanned wool in comparison with the carpets woven from normal wool, are not only lower but also is the same in some cases. This view has been confirmed in New Zealand, too. The only problem is the difficulties in process of spinning, which is necessary to take account all the measures to prevent the damages to tanned wool.

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