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Technology, Pathology and Scientific Analysis of a Piece of Safavid Curtain in the Moghadam Museum

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ABSTRACT

The curtain under study with the inventory number 3421 is one of the exquisite brocade fabrics belonging to Iran's Safavid period (dated 16th century) housed in Moghadam museum. This research aims to identify the stitching techniques, texture, pigments, and deterioration factors and examining the different causes of damages through historical and artistic review. Data and information collected in this study were found through library and field studies, laboratory tests, instrument approaches, analysis, survey, and direct observation of the object. Fibers and pigments were detected by using polarizing light microscopy, chemical tests, and affordable analysis devices. Results showed fibers such as silk, Indigo, and Madder were identified as main colorants used in dying the fibers. Also, according to the SEM results, metal thread was identified as pure silver, which is covered with a layer of black sulfur. According to postural warp and weft, and braid string, the weaving technique was a combination method with a split-woven technique. A series of internal and external destructive factors, as well as improper past repairs, caused several damages to the fabric. Based on the current condition of the object and the damages it contains, this research aims to identify the deterioration factors and assess them.

Keywords: Technology, pathology, Safavid textile, Brocade fabric, Moghadam Museum

1. Introduction

The sixteenth and seventeenth century (AD) can be called the Golden Age of textile art in Iran. Many factors affected textiles technology development in this era, such as expert usage of complex stitching, combinations of different colors, innovation in design, and using silver and gold strings in cloth texture. These practices gave way to producing rare textiles, such as brocade fabrics [1]. Skilled use of complex texture, color combinations, and innovation in the fabric design led to the production of unique textiles in the Safavid period. Among these textiles, brocade fabrics can be noted. Brocade fabric is the most precious and most legendary of Iranian weaves which has a universal reputation in its flourished period, and now examples of it decorate museums and art centers in Iran and other countries around the world.

Brocade fabric that is woven with a combination of natural and metal fibers undergoes chemical and physical reactions causing damages to its structure due to destructive environmental factors over time. Hence, the fabric loses strength, quality of the structure, and original appearance. Any fluctuations in environmental conditions, temperature, humidity, light, and air pollution cause more chemical and physical changes. However, the weft yarn's characteristics could be from natural silk that is used in fabric without gum-making process.

Dryness, friability of fibers, disruption of warp and weft, destruction, and shortage of metal thread are some examples of damages to the fabrics. The colored yarns used in textile design, in addition to paleness, are completely destroyed in some parts, and shortage of the silk fibers and metal threads can be seen in many places. This research intends to identify the fabric’s structure in terms of technique, weaving, design, yarn colors and techniques in metal decorating; and to identify of damages and destructive factors for technological and pathology. It is important to note that in the current situation, the valuable Safavid fabric will be endangered if deterioration factors are not under control.

2. Technological studies

Having enough knowledge about identification of materials and specific characteristics of each component of historical objects is important and necessary in identifying damages and their causes. For this type of composite objects, many studies have already focused on investigating the technology and types of materials used for the metal threads [2].

Figure 1. Safavid brocade fabric in Moghadam museum

2.1 Examination and identification of the components of Safavid brocade

To identify the fibers, first warp and weft yarns and metal threads are carefully separated under the loop. Then, for the diagnosis of vegetable or animal fiber, a burn test was done. According to the smell, the method of burning, and the look of the ashes, animal fibers were identified. For accurate identification and microscopic observation of the structure of the fibers, all yarns of fabric were placed separately between lam and plates, and a polarized microscope was used to observe the structure of the fibers. Microscopic observation of fibers and threads inside scythes yarn are compared with standard images; considering the appearance, characteristics, smooth and transparent texture without scales and knots, it was determined that all fibers and colored yarn in the fabric were silk. According to the burn test, the fabric’s weft thread was likely protein based, but under the microscope, unlike other fibers, it was lumpy and knotted.

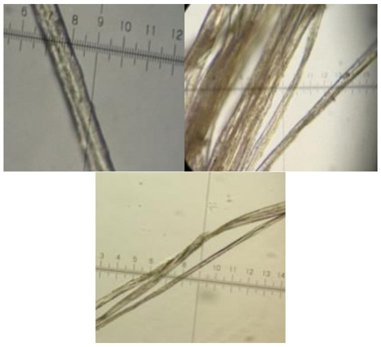

Figure 2. Microscopic image of brocade fabric's weft thread

To ensure that the fibers are protein based, a chemical solvent and FTIR instrumentation were used. According to the result, the weft thread was found to be silk. Based on the microscopic observation and the appearance of the fibers, the weft threads were without twist, and like a bunch of delicate yarns joined together by clinging to each other. These fibers, unlike other silk fibers, are dry with a rough surface. Thus, according to these characteristics, two possibilities were considered. However, weft yarn's characteristics could be from natural silk that is used in the fabric without the gum-making process. Also, the use of starch to increase the strength of the yarn in the fabric can be considered as another possibility. After removing the binder from fibers, according to the FTIR result and absorption tapes recorded in 1655 cm^{-1} and 1538 cm^{-1} areas, protein substance was detected.

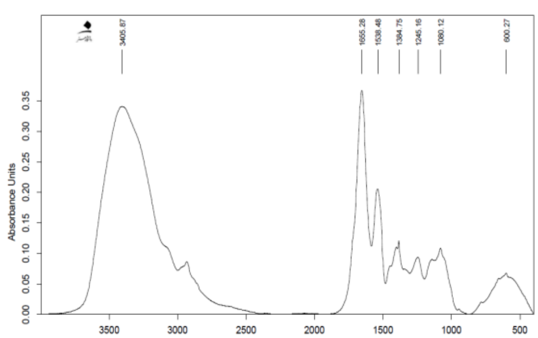

Figure 3. FTIR graph of weft yarn's starch in brocade (Art Univ. of Tehran)

2.2. Review of metal thread in brocade fabric

The main feature of the brocade fabric is the use of metal thread in the weaving process. In the fabric under study, metal thread in scythes form is used as a weft thread along with silk yarn. Scanning electron microscopy with energy-dispersive X-ray microanalysis (SEM/EDS) is the most frequently used analytical techniques to determine chemical composition [3]. To evaluate and identify the metal thread, a microscope and SEM device were used. Based on the analysis and result, the metal threads are a continuously twisted metal made of pure silver in 280-375 microns wide around the delicate silk thread and around 4-13 microns in the middle. Images show the furrow, which is created in the manufacturing process, is visible and shows that the metal strips are produced by rolling the metal.

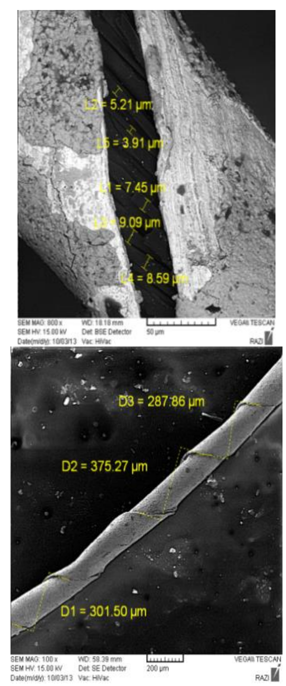

Figure 4. SEM images of brocade metal thread (*Raazi* lab)

2.3. Review and identification of fiber's pigment

Since the number of pigments used in traditional dyeing is high, based on the sources and historical review, the possibility of identification of Madder and Indigo was considered. Due to this possibility, methods of extraction of these dyes were studied.

2.3.1. Red pigment extraction test

A sample of red yarn, around 3cm, is mixed with the Hydrochloric Acid 37% and ethanol in the beaker and is then heated in a water bath. After 4 minutes, the red yarn was almost white and colorless. After separating the soluble material from the impurities and then evaporating the liquid, the remaining material was mixed with some Potassium Bromide in a mortar and was completely pulverized to prepare the disc. The disc was then analyzed through FTIR. According to the result, the absorption peak in 1637 cm^{-1} area is related to Alizarin.

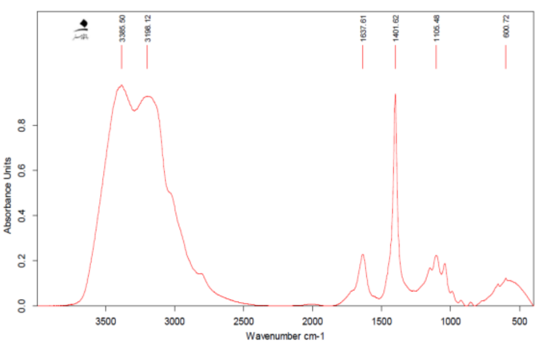

Figure 5. Red pigment FTIR graph (Art University of Tehran)

2.3.2. Identification test of blue pigment

Considering the possibility of Indigo, a chemical solubility test was used to prove the existence or non-existence of the pigment. For this purpose, 10cc water + 5gr NaoH + 5gr Sodium Hydrosulphide were mixed and a sample of green thread was placed into the test tube containing the transparent solution and was shaken. In seconds a yellow liquid was formed which is known as white indigo. Afterwards, a few drops of ethyl acetate were added to the liquid, and the tube was shaken vigorously. Thus, the liquid inside the pipe gets separated into two phases, and the blue liquid which contains indigo was formed on top of the yellow liquid. Since this blue color is characteristic of indigo, it was concluded that the green fabric was dyed with the plant Indigo.

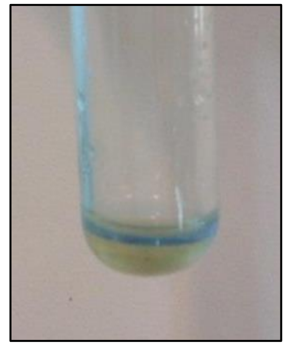

Figure 6. Two phase's solution of Nile pigment

2.4. Evaluation of weaving technique and fabric design (Technical analysis of fabric)

Fabrics are usually distinguished based on technical and artistic factors. In fact, characteristics of each fabric are determined based on material, type of fiber, and texture. This knowledge is necessary to achieve accurate results for the fabric's technical analysis.

2.4.1. Determination of warp and weft

The first step to analyze the fabric is determining the warp and weft, in order to study and determine the features and texture of the fabric. Brocade fabric has two warp strings which are involved in the weaving; One relating to the background and the other is the sewing thread that connects to all threads in the weave. The sewing thread is the main indication which determines the warp and weft direction. In most brocade fabrics, the multiplicity of weft color is an indication for diagnosing the warp and weft, and usually, warp thread is monochromatic. In the sample under study, a noteworthy point was the presence of colored thread in the warp strings. Another indication was the metal thread used in the weft yarn.

There are two groups of warps and three groups of wefts in this brocade fabric.

Warps include: 1) Background warp: colorful silk/ 2) Sewing warp: white silk.

Wefts include: 1) Silk weft: white silk (same as sewing warp)/ 2) Scythes weft: silk with silver cover/ 3) Silk weft (lumpy and thick silk).

2.5. Identification of front and back of the fabric

In all fabrics, the front side has the main usage and reveals the quality of the fabric. In the brocade under study, the front side is patterned by a flower motif and woven with colorful threads.

Figure 7. Front and back of brocade fabric (Moghadam Museum)

2.6. Determining the fabric's width

To measure the width, the fabric is placed horizontally on a flat surface without tension and wrinkles, and the fabric is then measured with a ruler. The brocade's width is 51.5 cm, but due to lack of border, the exact width of the brocade weaving machine is unclear

2.7. Density of warp thread

In weaving this brocade, two groups of warp yarns were used, and the application of variable density was an important point. The first group was background warps which are colored silk with a density of 20, in some areas 30, and 40 in other ones. The second group was the sewing warp with a density of 20. A group of warp yarns that entered into the weave has affected the density and has reached 40. Since the average sewing warp density is 20 throughout the fabric, the remaining densities in different areas will be 40, 50 and 60.

- Density of background and sewing: 40/cm, 50/cm, 60/cm.
- Density of sewing warp: 60/cm.

A change in the density of warp threads with changes in the arrangement of the warp in each section was done due to the flower motifs on the fabric, shown in figure 8. These changes can be seen clearly on the front and back of the fabric.

Figure 8. Variable density of the warp on the front and back of the brocade fabric

2.8. Weft density

Weft threads used in the fabric texture were examined carefully by microscope. Observation shows that this thick yarn consists of a number of delicate yarns which are bundled together in bunches of 10 and attached using starch or natural gum sizing. There are groups of 10 silk threads in a weft span, and this grouping is repeated ten times in a centimeter, altogether containing 100 delicate silk threads. During the weaving process, after 10 groups of weft yarns, one silk and 1 Scythes weft are woven, according to the following table, and repeated. The silk threads density in 1 cm is 130, and with the scythes density that is 20, the overall density of fabric will be 150.

Silk weft with density 130 + Scythes weft with density 20 = Final density = 150/cm.

2.9. Fabric texture

In the weaving of brocade fabric usually, there are two sets of warp threads. The sample being researched also two types of warp threads used in the weaving process. The first group, containing the silk thread, is used for making the pattern and the other group is warp thread that is a characteristic of brocade fabric, and is used for making the effect on brocade fabric and is famous as a warp figure. Nowadays, in traditional weaving, this kind of texture is called *Lape' tari'.*

This set of warp threads are in specific parts of the fabric that are explained in the weaving map. In this fabric, some parts with a density of 60 are marked (figure 8). Parts of the warp threads are entered in the weaving machine. These warps are red and in some parts of the map take weaving commands and in other parts are not involved in weaving and are released in the back of the fabric freely. In other words, the warp threads and the cuts are visible on the back of the fabric.

The main task of the second group is creating sewing between warps and wefts because wefts do not weave with the first group of warps, which are the silk threads used for creating patterns, and link only in the place of the flower design and other warps are not involved with wefts.

2.10. Review of fabric design

As can be seen in the picture the brocade pattern consists of different flowers with colorful threads. According to historical and artistic studies, the fabric's design represents *Shafie' Abbasi* design school and belongs to the Abyaneh-Safavid period. In addition to showing historical and artistic value, it proves that the fabric dates back to the Safavid period.

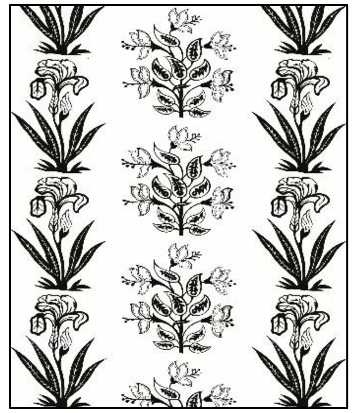

Figure 9. Reproduce map of brocade fabric

3. Condition Survey

Textiles are among the most fragile objects in museum collections due to their organic nature. Their long-term preservation is affected by numerous agents of deterioration, including light, incorrect relative humidity (RH), incorrect temperature, pests, physical forces, and pollutants [4]. The results of technical and structural studies, a condition survey of the fabric, alongside a review of destructive factors which caused damages on samples, an experiment, and analysis will be studied.

3.1. Condition Survey of Safavid brocade fabric

According to the fabric condition and review of deterioration factors, internal, external, and numerous human factors caused damages to the fabric over time. Considering the sensitivity of natural fiber towards light, the fabric being exposed to light caused the characteristic and molecular structure to be affected, a reduction in strength and transparency of the fabric, and discoloration of colored threads. The harmful effect of radiation alongside temperature and humidity fluctuation over the years leads to weakness, dryness, and loss of elasticity of fibers to the point that the mechanical stress causes the rupture of the fabric structure. In addition, the severity and persistence of physical destructive factors (light, temperature, and humidity) provide chemical degradation and transformation of the material in the fabric.

Figure 10. Tearing the warp and weft and losses in different areas of fabric

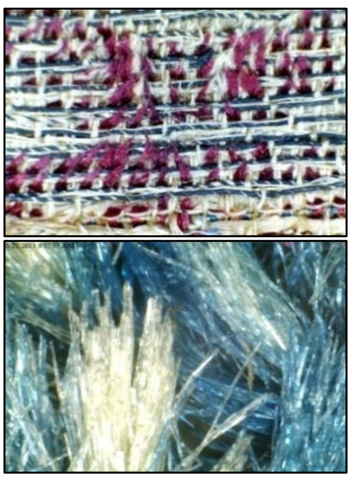

Figure 11. Discoloration, abrasion, and lack of colored threads

Chemical degradation factors such as air pollution and dust on fabric create a good place for concentration of acidic gases. Suspended particles in urban air pollution combined with water cause stains and dirt on the fabric. Pollution, Nitrogen Oxide, and Ozone in the air can react with dye even in the absence of light, and cause discoloration of fibers. Sulfur gases are the main cause of damage to fabric with metallic threads, since Hydrogen Sulfur reacts with silver braid and creates a dark layer which covers the entire surface of scythes strings.

Another combination of Sulfur is Sulfur dioxide which is one of the urban and industrial pollutions combined with Oxygen and water in the air producing Sulfuric acid, and it leads to acidification of fabric and fiber erosion. According to fabric pH measurement, acidic threads can be seen around the fabric. Acid, while damaging silk threads, can cause a chemical reaction on metal braids as well. Based on SEM result there is a small amount of chloride, light, and heat which could be the reason for the presence of chlorine and its components. So, creating silver chloride in addition to sulfur is another reason for the darkened and matt colored silver. Applied forces and mechanical tension such as too much stretch of silk and metal threads caused damages like disruption of twist fiber and metal thread, and by increasing the applied forces caused tear and rupture of fibers and metal threads. Lack of twists especially in weft yarns is a factor that can reduce the fiber strength and resistance against mechanical forces, and chemical and photochemical reactions created by starch used in the fiber increased weakness and fragility of fibers. Due to mechanical forces, pressure, and tension faced by metal threads, metal filaments were slumped and crushed. Considering the harmful effects of physical and chemical factors that reduce the structural strength of fibers and metal threads, the influence of tension and mechanical destructive elements was higher.

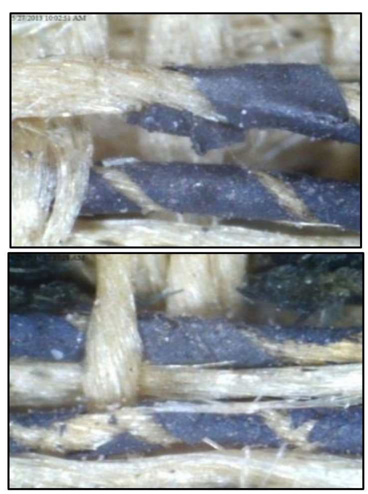

Figure 12. Damages of scythes strings

It is important to note that the complicated weaving technique, stress incurred during the weaving process, and high density of warp and weft can be influential factors in the fabrics susceptibility towards degradation. Moreover, different applied forces in the production of metal thread, and twisting the metal around the middle yarn, are internal physical, chemical, and destructive mechanical factors. The past maintenance, restoration, and irreversible strengthening method have been an important factor in its destruction. Dryness of material used in the fabric and chemical reaction of adhesive with fibers has provided conditions for biological degradation. The dark and dirty spots which can be seen on the fabric are due to such factors.

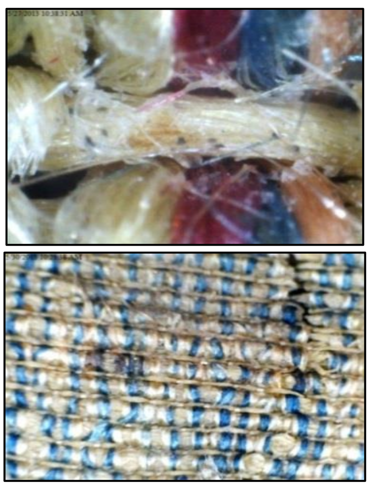

Figure 13. Examples of remnants of adhesive and fiber contribution behind the brocade fabric

4. Conclusion

In this research the curtain piece belonging to Safavid period which is currently kept in the Moghadam museum is examined in terms of technique, texture, color, and metal decorations and information collected and result of tests conducted will review from a collection survey point of view. Visual observation shows that the fabric is very dry, fragile, and without strength and flexibility. A closer examination by digital loop made visible the disruption of fibers, contaminated areas, darkening, lack of metallic decoration, and any improper handling which caused separation of the warp and weft threads and contributed to the tear of the fabric. According to the results of the polarized light microscope, chemical spot tests and FTIR, all fibers were silk. A chemical method was used to extract pigment from red thread. Then, the sample was tested by FTIR instrumentation and madder pigment was detected. To identify the green pigment, chemical reagent for indigo pigment was used. Based on the reaction in the test, the presence of indigo in the green fibers was confirmed. So, madder and indigo that are common and high-quality dyes in the Safavid period were used for dyeing the threads.

Sunlight, especially ultraviolet rays, in addition to causing discoloration and damaging the dye, reduced the fiber's strength, and mechanical stress caused abrasions and loss of colored threads on the fabric surface. The complicated weave technique and high-density texture, as well as indicative master artist weave in Safavid period, increased vulnerability of fabric against destructive agents, especially mechanical factors. This is due to the increase in the density and congestion of fibers leading to increased mechanical stress. Due to the very delicate nature of metal threads and their vulnerability, chemical reactions in some parts and physical and mechanical damages in others, such as crushing, loss, or opening of twisting in metal threads can be seen. Because of improper storage and inappropriate restoration with the use of non-reversible adhesive, irreparable damages were done to the fabric. The corrupting influence of the adhesive and patchwork on fabric decreased strength and fiber elasticity, destroying the metal thread. Dark spots were created by biological damage and complete destruction of fibers and fabric in these areas. According to the microscope and SEM images and results, the metal threads were made of pure silver and wrapped continuously around the middle white silk thread. Atmospheric pollution especially Sulfur gases in urban and industrial air mixed with the silver metal and silver sulfuric covered the metal thread making it appear black. In SEM images, silver corrosion in some parts was smooth and in some areas laminated layers can be seen on the metal surface. However, the mechanical forces involved in the production process of scythes strings caused tension in the metal and increased damages on the metal thread.

In order to prevent further degradation and protect the fabric from environmental factors, the fabric has been removed from the initial frame and all patches were removed from the verso. Adhesives used were scraped off and the fabric was stored using the mounts method. This method of maintenance is suitable for woven fabric with high stiffness and weakness because the fabric is greatly protected from the impact of damaging environmental factors and can prevent more degradation. The brocade fabric as a combination of natural and metal fibers requires complex, protection maintenance, restoration, and the selection and application of any treatment should be done with detailed knowledge of the properties of each component, how they are influenced by destructive factors, and their erosion.

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