Benefit from Multi-Axial Textiles in Leather Products and Wastes Upcycling to Raise the Aesthetic Values of Women's Clothes

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Abstract

Towards green environment the trend to reuse wastes instead of their disposal that harm our planet is growing recently. Upcycling leather wastes is important aspect to achieve sustainability. Handmade weaving by multiaxial weave's structures is somewhat new to be used in women's fashion clothes. This paper discusses the upcycling of old items and leather wastes created at the cutting stage during leather goods production. Converting leather wastes into stripes with different widths and weaving in weaves (tri-axial, quart, hexagonal structures) with different patterns, using handloom. The innovated produced muti-axial weaves are applied in sustainable women's clothes, designs are created by using both 3D virtual CLO and Adobe Photoshop software. 95% of questionnaire respondents agree that the multi-axis leather weaves achieve the concept of sustainability. After gathering expert's opinions, design No. 3, 16, 1, 10, 8, 13, and 4 by sequence, are achieved the best results in achieving aesthetic added value.

Key words: multi-axial textile, Recycling, leather wastes, sustainability, women's clothes.

1. Introduction

Global environment is continuously deteriorating due to many socio-economic activities of human. Processing industries are causing much damage to the environment. Leather processing is one of such industries that harm environment (Thanikaivelan, Rao, Nair, & Ramasami2004; Germann, 1999).

Leather making is the process of converting raw hides into leather. Amounts of solid waste containing hazardous and high value components are generated during this process. Therefore, the elimination of the potential pollution and resource utilization of leather solid waste are the primary research hotspots nowadays (Li, Guo, Lu, & Zhu, 2019). Processing of skin or hides into stable material – leather- is known as tanning. The main product of the tanning industry, leather is used to create clothing, footwear, furniture, purses, and other items (Lawal & Odums, 2015; Li, Shan, Shao, &Shi, 2006).

In 2003, the worldwide leather market produced around 18 billion square feet of leather, with an estimated cost of US$40 billion (World Leather Magazine). 60 percent of the leather required by the globe is produced in emerging nations, including India (Doble & Kruthiventi, 2007). Worldwide, the production of chrome-tanned leather results in enormous amounts of solid leather wastes that contain chromium. Due to the presence of very dangerous chromium, disposing of these enormous amounts of leather solid wastes is a significant difficulty that must be overcome in order to use the dechromed waste to create valuable goods that don't harm or pollute the environment (Mwondu, Ombui, Kironchi, & Onyuka, 2021).

Leather wastes that generating from clothing and footwear industries from cutting process and old used leather products, leading to increased environment pollution. Ways of leather wastes get-riding of, is commercially and environmental expensive. The tendency to recycle the leftover of leather and turn it into high-value products in order to achieve the concept of sustainability and preservation of the environment is preferable

recently. Recovery, recycling and reuse of such industrial wastes as raw materials for other applications has posed a great challenge to green chemistry and circular economy for many years (Sole, Taddei, Franceschi, & Beghetto, 2019; Pfaltzgraff, De Bruyn, Cooper, Budarin, & Clark, 2013).

More than 600 kg of solid waste is generated during the transformation of one ton of raw hide (wet-salted) into leather. A significant proportion of this solid waste is actually tanned waste, consisting of shavings, trimmings, splits and buffing dust (Ozgunay, Colak, Mutlu, & Akyuz, 2007; Taylor, Cabeza, Dimaio, Brown, Marmer, Carrio, Celma, & Cot, 1998; Langmaier, Kolozmik, Sukop, & Mladek, 1999).

So that leather industry is considered as one of the major polluting industries which generates huge amount of solid and liquid wastes. The most important approach for environmental pollution prevention is getting an idea prevention is better than reuse which is better than disposal of wastes (Ozgunay, Colak, Mutlu, & Akyuz, 2007; Bhavya, Raji, Selvarani, Samrot, Javad, & Appalaraju, 2019).

Research problem

- The scarcity of scientific researches discussed the benefit of leather wastes recycling and upcycling, especially in the field of fashion and clothing.
- The importance of preserving the environment and achieving the concept of sustainability in the field of clothing and textile.
- The importance of handmade weaving and the extent of its contribution to advancement in the field of small entrepreneurship, the need to use different structures as multi-axes textiles is emerged.

Research question

-What is the degree of acceptance by specialists for designs made from multi-axial textiles in the field of clothing and fashion?

- What is the possibility of obtaining different effects from multi-axial weaving structures?
- What is the possibility of benefiting from multi-axial textile structures to enrich fashion design field?
- What is the possibility of achieving the aesthetic, functional and innovative aspects of the implemented textile multi-axial structures?

Research objectives

- Preserving the environment by reusing leather wastes instead of unsafe disposal.
- Sustainability achievement
- the benefit of multi-axial weaves (tri-axial- quadrilateral- and hexagonal) structures in improvement aesthetic value of clothes.

Importance of research

- Increase awareness of preserving the environment and achieving sustainability.
- implement of handmade textile weaves in an innovative way.
- Focus on handmade weaving structures as right way to begin small entrepreneurships.
- Usage of multi-axial weaves in fashion and clothes field.

1.1. Sources and Solutions for Pollution

1.1.1. Leather wastes sources and environment

Many fashion houses have launched complete lines that follow environmental protection standards from the polluting remnants of the fashion industry to preserve nature and organic resources. Materials and nature have inspired the concept of sustainability by not using leather or animal materials in the designs and using innovative approaches to sustainable and eco-friendly fashion. Those in charge of this industry created environmentally friendly fabrics and searched for alternatives to animal materials. Some fashion houses refrained from using animal skins and fur and used the most environmentally friendly techniques and practices

(Nofal, 2022).

The leather industry is one of the most polluting and highly resource consuming sectors. About 0.25 Mg of leather is produced from 1 Mg of raw material and requires 15,000 m3 - 120,000 m3 of water, finally generating 15–50 Mg of wastewater and 400–700 kg of solid waste (Hu et al., 2011).

Leather processing generates large amounts of waste, which may provide raw materials for various industries. In cutting stage, there are remains with different sizes that can be reused efficiently. In other words, the use of renewable resources and reuse of waste as secondary raw materials (Chojnacka et al., 2021). It will be beneficial to upcycling leather wastes instead of disposal that harm environment, to satisfy the leather goods demands.

A new trend in zero-waste production is the use of tannery residues for fertilizer production. The process of acid or alkaline hydrolysis of leather waste allows for obtaining a nitrogen-rich semi-product which can be one of the components of NPK fertilizers (Majee et al., 2019).

Chromium used in leather tanning is a source of significant contamination, especially the oxidation of chromium Cr3+ to the form of Cr6+, which is a threat to humans because of its mutagenic and carcinogenic potential. Leaks from chrome-tanned solid waste and high chromium concentrations in wastewater can lead to soil and groundwater contamination (Famielec, 2020).

So, there is international legislation to solve wastes pollution to protect environment as:

1.1.2. Recycling, upcycling procedures and sustainability to Fast fashion

Fast fashion has negative impacts on the garment business that are very similar to those of fast food in that it is inexpensive, harmful to the environment, and unhealthy for you. Despite being largely superfluous, it encourages modern consumers to spend money on cheap, low-quality clothes, which has grown in popularity over time. Fast fashion has created a significant environmental and social risk for the leather industry and the

processes of leather manufacturing, including rising wastage and leather disposal. Fast fashion has rendered leather less durable and more disposable by lowering its price and lowering its quality. A fabric that was formerly linked with leather's elegance and durability has also become another piece of non-recyclable material (Custom, 2019).

Recycling is essential as a substitute for creating new things and to meet the increasing demands, being a greener means of recycling. Recycling projects involve innovative ways of using old products and materials by using pre-consumer or post-consumer waste or even a blend of both "Upcycling" is that the advanced stage of cyclic utilization, a sort of value-added to waste or old materials, and the redesigning target of sustainable design (Pandit, Nadathur, Jose, 2019; Sung, 2015; Han, Tyler, & Apeagyei, 2015). The demand for leather goods has increased as a result of the quick changes in fashion trends that have influenced consumers' purchasing decisions. To meet this demand, unsustainable practises of overproduction and resource overuse that result in increased waste production are required. The cutting department is by far where the majority of waste produced in the leather product industry originates. Because leather scraps retain the majority of the chemicals used during processing, dumping this material in landfills causes further environmental damage (Hailu, 2021).

Linear economy is converting to circular economy, leading to zero waste and no disposal. The waste is treated towards as no longer waste polluting environment; rather they are reused in useful purpose as valuable products. Waste can be nutrients and food for other beings for the soil (Pandit, Ahmed, Singha, & Shrivastava, 2020).

1.1.3. Sustainability

Sustainability in textile and fashion industries can be implemented at various stages such as from manufacturing to end-use consumers. The "Three Rs" of sustainability such as Reduce, Reuse, and Recycle are effective for textile industries (Thiry, 2011).

Numerous definitions have been suggested for sustainability. The most usually recognized is found in the Brundtland report. It states that "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Veiderman suggested another definition of sustainability such as "It is a vision of the future that provides us with a road map and helps us focus our attention on a set of values and ethical and moral principles by which to guide our actions" [Munier, 2005; Blowers, Boersema, & Martin, 2012; Viederman, 1995). Due to the negative impact of agro/bio-waste disposing, designers are taking the challenge to use bio-based material. Though many innovations are still in development still many successful attempts have been implemented to make a move towards sustainability (Jose, Samant, Bahuguna, & Pandit, 2020). Sustainability is a huge challenge in the fashion industry and textile waste can be used as the raw material such as value-added products. Reusing and remaking of used clothes is a long-standing practice which started as a means of creating the most of valuable tools. In the clothing industry, you will find different kinds of sections including cutting, bundling and sorting, sewing, printing, embroidery (Smith, Baille, & McHattie, 2017).

over the centuries, cotton, wool, silk, and leather have dominated the textile and fashion industry but the sudden increase in demand for apparel and fashion products has put immense pressure on the limited natural resources. Synthetic fabrics are extensively used for producing cheaper and durable fashion products. However, they are the non-biodegradable and major contributor to toxins and microfibers to the environment (Niinimäki, 2014). The textile and apparel industry are now focusing more on sustainable products and technologies to meet the ecological, economic, social, and cultural aspects (Pandit, Ahmed, Singha, & Shrivastava, 2020). John Galliano is a designer who has developed his line of collection by using upcycled material. Other designers like Bottega Venetta and Gucci developed shoes by using waste leather. Viktor and Rolf in 2016 have designed their collection by using all fabrics from their previous collection and weaving them into a new innovative design (Moorhouse &

Moorhouse, 2017). Hence the importance of leather recycling in the service of sustainable leather clothing in order to avoid environmental pollution due to leather wastes accumulation and disposal.

1.2. Multi axis weaving origin (Mad weave history)

1.2.1. Hand weaving

Handicrafts and traditional industries occupy a large area of countries heritage where the artist relies on his individual mental and manual skills, using raw materials available in the local natural environment or imported raw materials. Small and medium entrepreneurships can achieve great material gains from its interest in handicrafts.

1.2.2. Multiaxial weaving

Woven structures are where a textile is made by interlacing warp and weft threads. There are three main structures: plain, twill and satin (O'Mahony, 2011). It has been accepted that a flat woven product composed of at least three thread systems joined by interlacements is called a multi-axial woven structure (Chrzanowska, 1999; Cybulska, Frontczak-Wasiak, 2002). Designing such a structure lies in creating a net whose nodes are the points of intersection of not more than two threads (Brook, 2002; Izabela& Snycerski, 2005).

1.2.3. Multiaxial weaving origin (Mad weave)

Mad weave (anyam gila) is a type of basketry originating in Indonesia. There is very little literature on the technique, and it is not widely used, but it produces a very pleasing fabric. Polyhedral baskets constructed with a small number of strands can be created if the edges do not lie along strand directions. different structures will produce in various ways of different substructures (Gailiunas, 2017). Fabrication of textile preform is made by weaving, braiding, knitting, stitching and nonwoven techniques (Bilisik & Mohamed, 2015).

1.3. Multi-axis weaving-Technology

In traditional textiles two sets of warp and weft threads are interlaced. In multi-axis textiles for composites consist of two (or more) interlaced sets of yarns; biaxial textiles consist of two sets of yarns, and triaxial textiles include a third set of axial yarns (Horrocks, 2000). The multi-axis four-axis is composed of multilayer of four in-plane yarn sets (warp, filler and bias yarns in +θ° and -θ° direction). These yarn sets are defined according to the orientation of their main axis relative to the loom main axis (Labanieh et al., 2016).

- ***Triaxial Weave Fabric Composites:***

Triaxial weave fabric (TWF) composites are of interest for future lightweight structures, both rigid and deployable. The fabric is made up of continuous, interlaced strips of composite material with longitudinal fibers (axes) in three directions, at 0 degrees and ± 60 degree as shown in figure 1. The structure is characterized by high degree of porosity. (Wanga, Baib, Sobeya, Xiongb, & Shenoic, 2018).

- **Figure 1.** Bending and interlacing of units of triaxial weave.

- ***Quadriaxial (0°, 90°, +45°, -45°)***

These four (4) layers fabric has leather stripes laid down parallel in the 0º, -45°, +45° and 90º axes (as shown in figure 2).

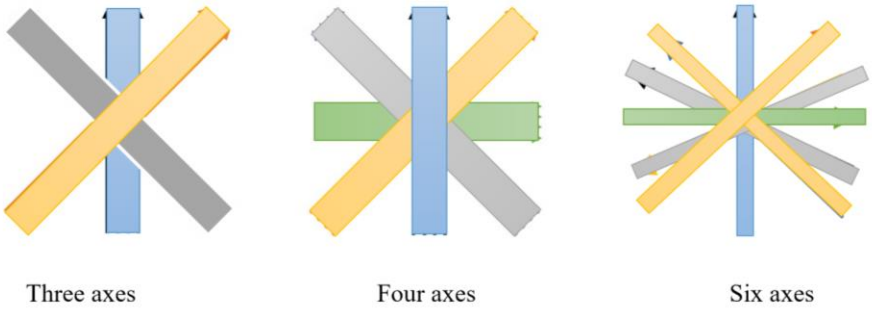


Figure 2. Illustration of axes direction and number of triaxial, quadrilateral, and hexagonal weaves.

These woven materials are flexible, able to be tailored to the specific needs and have better mechanical properties due to their weaving structures. Moreover, woven composites also have the ability to produce near net shape preforms or fabrics with high flexibility and stability (Aisyah, Paridah, Sapuan, Ilyas, Khalina, Nurazzi, Lee, 2021).

- ***Hexagonal (six-axial) weave:***

Hexagonal woven fabric assortments of six systems. Five warp and one weft systems. All filament systems are equally intertwined in a homogeneous or heterogeneous network, as shown in Figure 2.

There are different weaves manipulation by using leather braiding and weaving techniques and structures in world's fashion shows. Designers' runway is full of inspiration ideas of leather structures weaves as shown in figure 3. The leather multiaxial weaves structures can be used in as full or parts of blouse, skirt, sleeves, coat, or even dress.

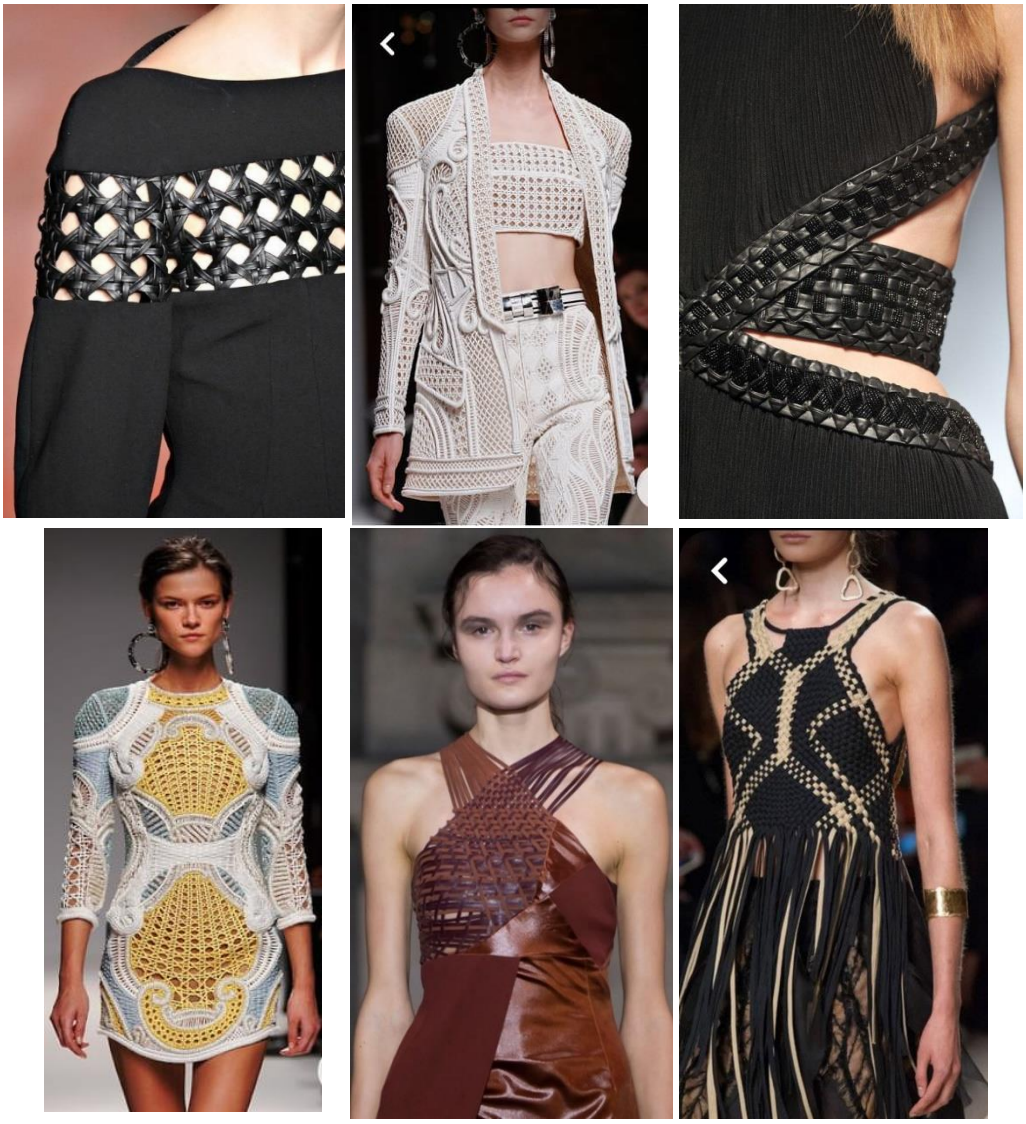


Figure 3. Examples of using leather weaves and braids in women's clothes in fashion shows (Rhondabuss.blogspot, 2017).

The research main idea is to achieve sustainability by upcycling of leather remains and wastes instead of disposal that cost money and pollute environment to get rid of them. Aim of the study is to produce different weaves structures based on multi-axes textiles. Three main weaves are produced tri-axial, quadrilateral and hexagonal textile structures. Each structure has different weaving parameters as axis width, angle, number and distance between subsequent axis. Applying these weaves in

women's apparel to add value, aesthetic, innovative, and functional properties are discussed later.

2. Experimental Work

2.1. *Methodology*

This research is followed experimental methodology. In addition to the theoretical study which is exposed to leather wastes and its environmental impacts, recycling and upcycling of these wastes to achieve sustainability and application in fashion field by CAD design.

2.2. Materials and Methods

2.2.1. Materials

Leather remains and wastes of shavings, trimmings and useless splits were obtained from different shoes and clothing leather factories and seller by kilogram in Bab-El-Sheria (Beer Homos), Cairo, Egypt. Collected wastes was buffalo, camel, goat and sheep leather.

2.2.2. Methods

Ragged and teared leather clothing items are collected and instead of their disposal, reusing is done. Sorting leather types and colours is done first, then cutting leather into stripes, Patterns is prepared, and hand weaving is executed in faculty of Specific education, Aswan University, Egypt as shown in figure 4 and 5 by researchers at manual loom.

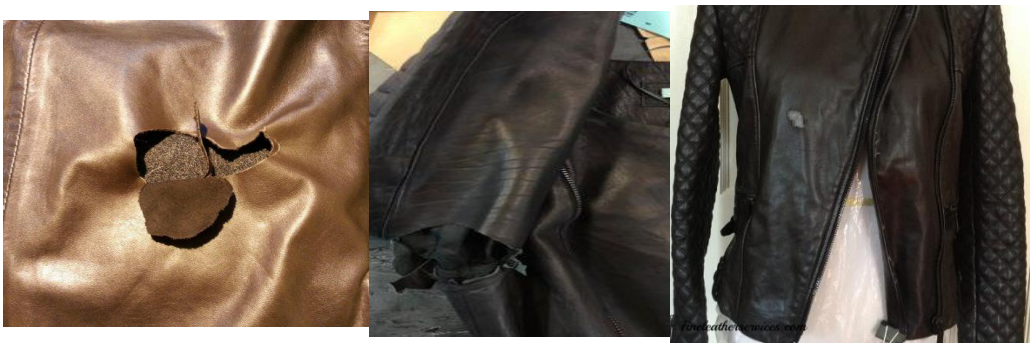


Figure 4. Ragged leather clothing items used in leather stripes making for subsequent weaving (poshmark,2020).

2.2.2.1. Sample collection and preparation

Leather wastes are collected and grouped according to animal source (Sheep, camel, cow, buffalo). leather wastes are then grouped according to colour, texture, thickness and colour match. Leather then is cut to stipes with different width 0.4, 0.8 and 1.2 cm.

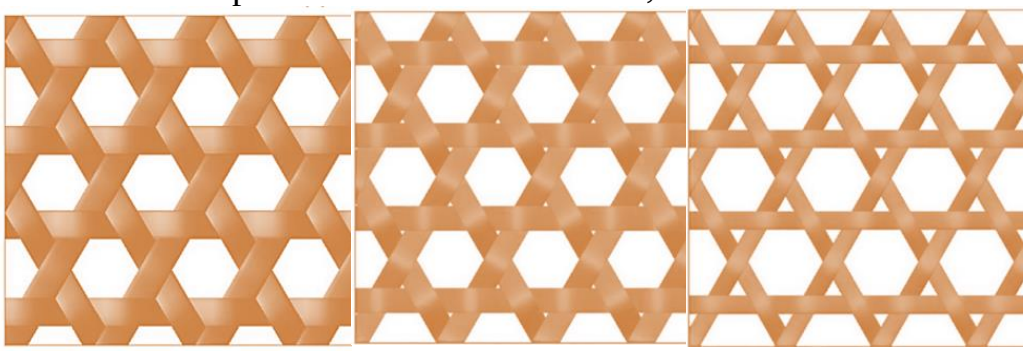
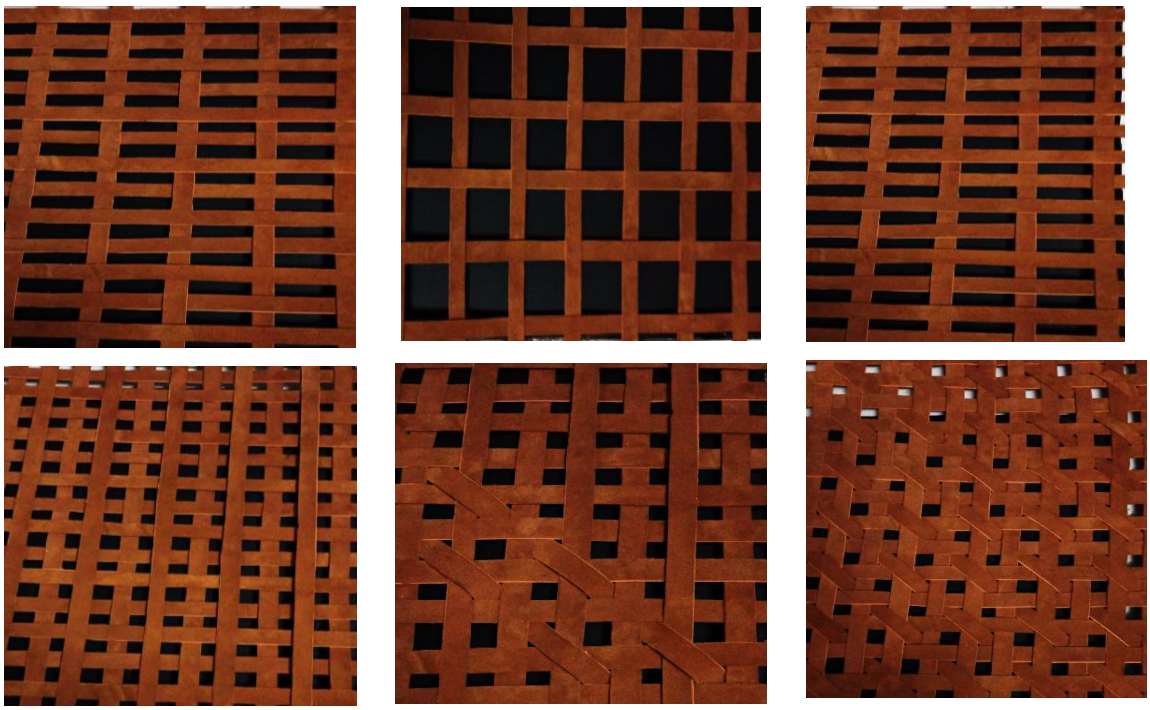


Figure 5. Example of triaxial leather weaving repeating unit with different leather stripes width 12, 8 and 4 mm-from left to right- (Chrzanowska, 1999).

In figure 6 steps are illustrated of how weaves are interlaced in leather multiaxial weave. The weave structure is of four axes. It is Quadriaxial weave structure.



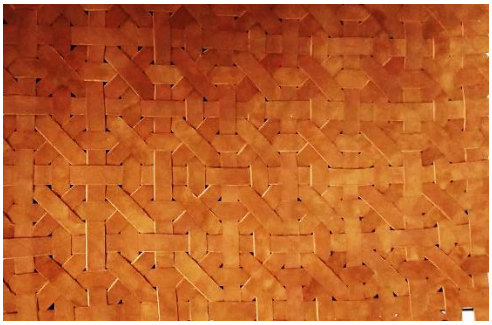


Figure 6. Example of hand weaving steps of leather stripes (Quadriaxial weaving steps of leather stripes laid down parallel in the 0º, -45°, +45° and 90º axes) in handloom.

2.3. Fashion design software:

In executing fashion designs two software are used:

1-Adobe Photoshop CC 2021, version (22.4.2)

2- 3D software, CLO Standard Virtual fashion, version 5.1,2019.

After weaving different multiaxial structures, they are scanned and takes their photos and add pattern by using both CLO 3D- graphic 2D pattern- (as shown in figure 7) and Photoshop software.

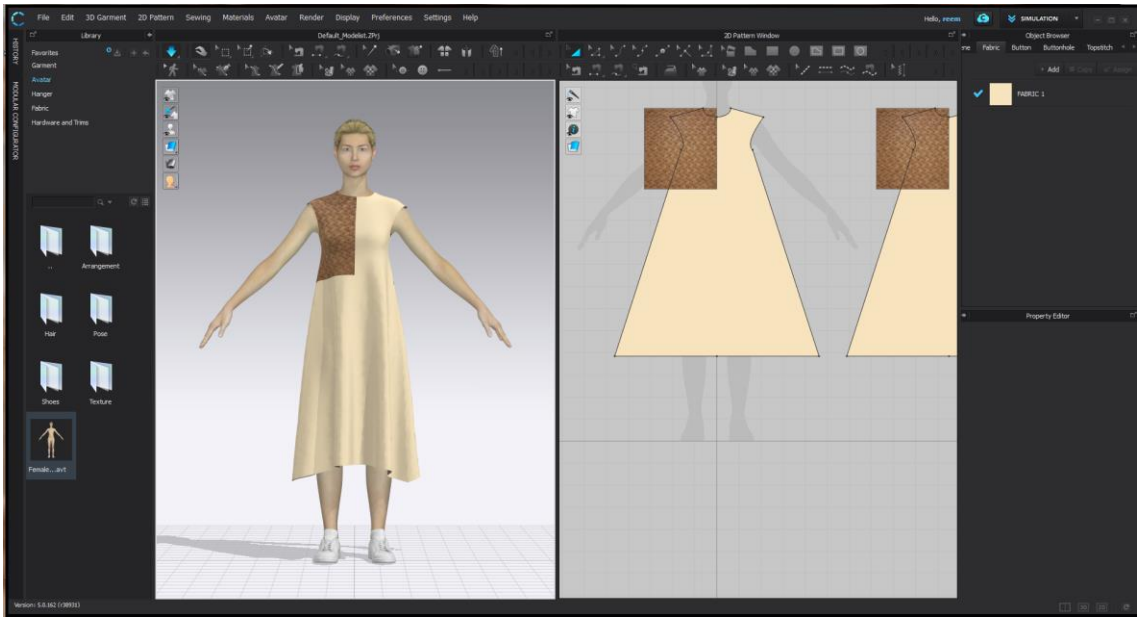


Figure 7. Clo 3D fashion design software and applying graphic pattern of tri-axial leather weave.

2.4. Questionnaire:

Questions for textile and clothing field experts were introduced to evaluate the idea of recycling leather remains and rags and innovative usage in multi-axis weaves to serve aesthetically and functionally in women's fashionable clothes. Researchers recommended that the opinion of specialists in textile and clothing field in necessary, as they have a deep vision about textile weaving, designs and clothes application. If it is applied in a wide field in the industry, the researchers suggest taking into account the opinion of consumers. More than 35 questionnaires were distributed (which included online submissions) and were returned to the researchers. The questionnaire was served in four basic topics: Achieving sustainability for recycled leather, The aesthetic aspect of the proposed designs, the innovative aspect of the proposed designs, and the functional and marketing aspect of the proposed designs.

3. Results and Discussion

The leather industry is currently between two opposing paths: on the one hand, recent legislative trends in terms of the eco-sustainability of industrial processes are leading leather manufacturing towards the development of cleaner production methods; on the other hand, the spread of new alternative materials to leather is driving the leather industry to improve its competitiveness by developing new innovative and high-quality products (Gargano et. Al., 2023).

The main aspects of sustainability are society, the environment and the economy. The community will be served by the availability of many job opportunities and small projects based on hand weaving. While environmentally, society will benefit from not disposing of leather waste safely and reusing it to produce contemporary, valuable products with an economically acceptable price.

3.1. Multiaxial weaves structures designs:

Three main multiaxial weave structures are introduced in this research as following: triaxial, quad axial, and hex-axial weave. Each of the following introduces some designs according to replacement of axis, number of axes in each direction, spaces between axis, and axis width.

3.1.1. Tri-axial hand weaving structure

3.1.1.1. First textile weave structure design (Fig. 8)

Figure 8. Triaxial weave structure of leather.

As shown in table 1, first textile weave structure design specifications are demonstrated. The three interlacing axes width is all the same which is 12 mm, without spaces between axes during handweaving.

Table 1. Triaxial weave structure specifications.

Material	Number of axes	Number of axes in each direction	Space between axes	Axis width
leather recycled and wastes	3	1	0	12 mm

- ***The effect of leather axis width***

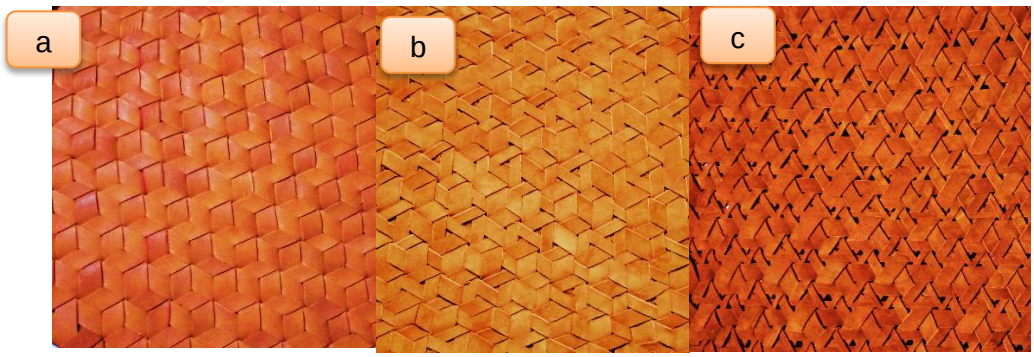


Figure 9. leather triaxial weave structure (a) axes width 12mm, (b) axes width 12mm, 8 mm, (c) axes width 4mm, 8mm, and 12 mm.

The triaxial weave as shown in (Figure. 9), is composed of vertical axis with two diagonal axes (45° angle) for both directions. As shown in table 2, first weave structure design with different axis widths specifications is demonstrated.

Table 2. Triaxial weave structure specifications.

Figure	Number of axes	Number of axes in each direction	Space between axes	Axis width (mm)
a	3	1	0	12
b	3	1	0	12,8
c	3	1	0	12,8,4

3.1.1.2. Second textile weave structure design (Fig.10):

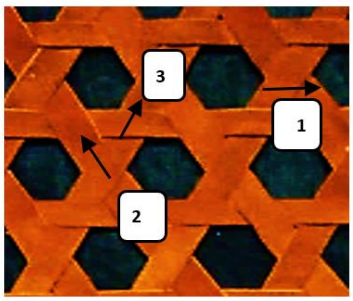


Figure 10. design (2) of triaxial weave structure unit of leather.

As shown in Table 3. Second textile weave structure design specifications are demonstrated.

Table 3. Triaxial weave structure unit specifications.

Material	Number of axes	Number of axes in each direction	Space between axes	Axis width
recycled and leather wastes	3	1	2 cm	12 mm

The weave is triaxial (Figure 10), and it is composed of horizontal axis with two diagonal axes (60° angle) for both directions, all axes width is 12 mm, with 2 cm distance between interlacing axes, that produced a geometical hexagonal decorative sapce .

- ***The effect of leather axis width and space between axes (Fig. 11)***

In this design three different alternating axes are weaved together and the effect of weaving axis variations as leather stripes width (a- 12 mm, b- 12, 8 mm, c- 4, 8, 12 mm) and space between interlaced axes are shown in fig. 11.

Figure 11. leather triaxial weave structure with space between axes (a) axes width 12mm, (b) axes width 12mm, 8 mm, (c) axes width 4mm, 8mm, and 12 mm.

As shown in table 4, second textile weave structure designs specifications are demonstrated with different widths and spaces between axes.

Table 4. Triaxial weave structure specifications.

Figure	Total number of axes	Number of axes in each direction	Space between axes "Cm"			Axis width (mm)
			Axis NO. From	to	Axes space	
a	3	1	1,2,3	1,2,3	2	12
b	3	1	1	1	2.4	8
			2	2	2	12
			3	3	2	12
c	3	1	1	1	2.8	4
			2	2	2	12
			3	3	2.4	8

3.1.1.3. Third textile weave structure design (Fig. 12)

Triaxial main weave structure are demonstrated in fig. 12,

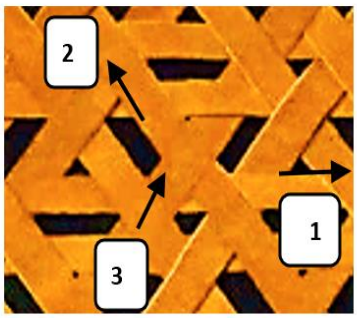


Figure 12. design (3) of triaxial weave structure unit of leather.

As shown in table 5, third textile weave structure designs specifications are demonstrated. As three axes, two stripes in each direction are interlaced together and the difference from previous designs and patterns is number of adjacent axes in each direction.

Table 5. Triaxial weave structure unit specifications.

Material	Number of axes	Number of axes in each direction	Space between axes	Axis width
recycled and leather wastes	3	2	1.2, 2.5 cm	12 mm

- ***The effect of leather axis width and space between axes (Fig. 13)***

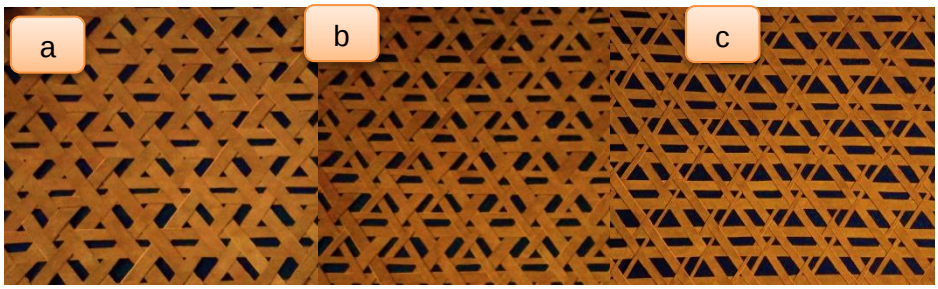
- 

Figure 13. leather triaxial weave structure with space between axes (a) axes width 12mm, (b) axes width 12mm, 8 mm, (c) axes width 4mm, 8mm, and 12 mm.

As shown in table 6, third textile weave structure designs specifications are demonstrated with different widths and spaces between axes. It produces amazing sustainable pattern of leather stripes.

Table 6. Triaxial weave structure specifications.

Figure	Total number of axes	Number of axes in each direction	Space between axes "Cm"			Axis width (mm)
			Axis NO. From	to	Axes space	
a	3	2	1,2,3	1,2,3	1 / 3	12
b	3	2	1	1	1.4 /3	12/ 8
			2	2	1.4 /3	12/ 8
			3	3	1.4 /3	12/ 8
c	3	2	1	1	1 /3	12
			2	2	1 /4.6	4
			3	3	1 /3.8	8

3.1.2. Quadrilateral axial hand weaving structure (Fig. 14)

Four leather axes are interlacing in a manner that produces geometrical hexagonal gaps. The main quadrilateral design is with two leather stripes in vertical and horizontal adjacent axes, and single strip in other two diagonal axes.

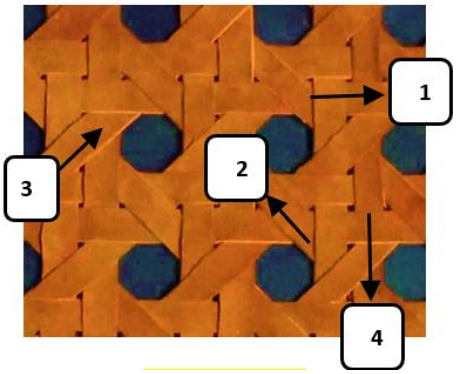


Figure 14. design of quadrilateral weave structure unit of leather.

3.1.2.1. First quadrilateral weave structure design (Fig. 15)

Different variations are carried out to the main quadrilateral design (fig. 14).

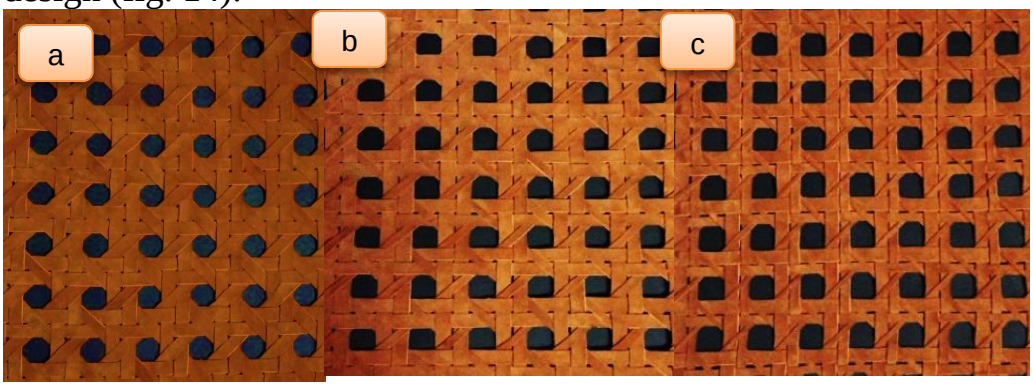


Figure 15. leather quad-axial weave structure with space between axes (a) axes width 12mm, (b) axes width 12mm, 8 mm, (c) axes width 4mm, 8mm, and 12 mm.

As shown in table 7, and figure (15) 12, 8 mm, and 12, 8, and 4 mm. first quadrilateral textile weave structure designs specifications are demonstrated with different widths and spaces between axes, (a) 12 mm, (b) 12, and 8 mm, and (c) 12, 8, 4 mm. with variable spaces between axes as demonstrated in table 7.

Table 7. Quadrilateral weave structure specifications.

Figure	Total number of axes	Number of axes in each direction		Space between axes "Cm"			Axis width (mm)
		axis	No.	Axis NO. From	to	Axes space	
a	4	1	2	1,4	1,4	0/2.5	12
				2,3	2.3	2.5	
b	4	2	1	1,4	1,4	0/2.5	12
				2,3	2,3	2.5	8
c	4	2,3 1,4	1 2	1/4	1/4	0/2.5	12,8
				2/3	2/3	4	4

3.1.3. Hexa-axial hand weaving structure

3.1.3.1. First weave structure design (Fig. 16)

As shown in (fig. 16), main design of hexa-axial weave is composed of six interlacing leather axes. It is composed of interlacing 90° vertical and horizonal axes, 60°, and 30° two diagonal axes.

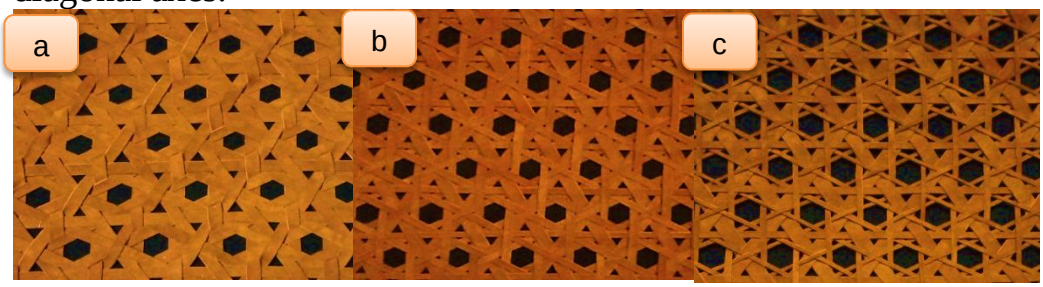


Figure 16. leather hexa-axial weave structure with different axis widths and spaces(a) axes width 12mm, (b) axes width 12mm, 8 mm (c) axes width 4mm, 8mm, and 12 mm.

As shown in table 8, first hexagonal textile weave structure designs specifications are demonstrated with different widths and spaces between axes.

Table 8. hexagonal weave structure specifications of design 1.

Axis number	Angle °C	Axes width (mm) design			Distance between axis (cm)		
		a	b	c	a	b	c
1	60	12	12	12	5	4	4
2	60	12	12	12	5	4	4
3	Horizontal 90	12	8	8	5	4	4
4	Vertical 90	12	8	4	2.5	2	2
5	30	12	8	4	2.5	2	2
6	30	12	8	4	2.5	2	2

3.1.3.2. Second weave structure design (Fig.17)

By changing both of spaces between interlacing axes and widths, different variety of weaving patterns are introduced as figures 17 and 18.

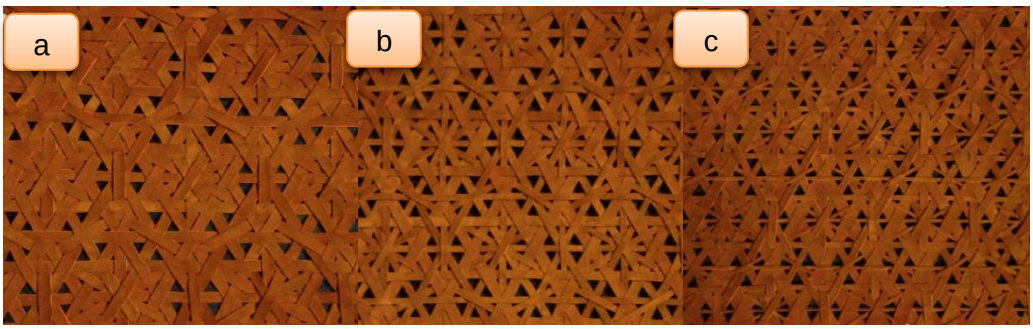


Figure 17. leather hexa-axial weave structure with different axis width and spaces(a) axes width 12mm, (b) axes width 12mm, 8 mm, (c) axes width 4mm, 8mm, and 12 mm.

As shown in table 9, second hexagonal textile weave structure designs specifications are demonstrated with different widths and spaces between axes.

Table 9. hexagonal weave structure specifications of design (2).

Axis number	Angle °C	Axes width (mm) design			Distance between axis (cm)		
		a	b	c	a	b	c
1	60	12	12/8	12/8	2	2	1.5
2	60	12	12/8	12/8	2	2	1.5
3	Horizontal 90	12	12/8	12/8	2.5	2	1.5
4	Vertical 90	12	8	4	2/6	5.2	3.4
5	30	12	8	4	2/6	5.2	3.4
6	30	12	8	4	2/6	5.2	3.4

3.1.3.3. Third textile weave structure (Fig. 18)

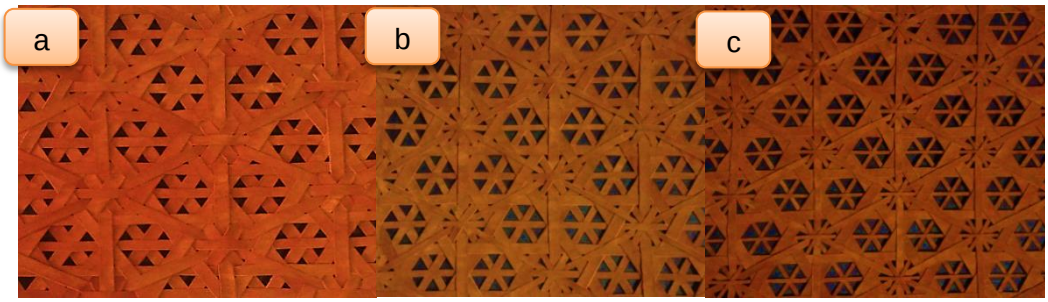


Figure 18. leather hexa-axial weave structure with different axis width and spaces(a) axes width 12mm, (b) axes width 12mm, 8 mm, (c) axes width 4mm, 8mm, and 12 mm.

Table 10. hexagonal weave structure specifications of design (3).

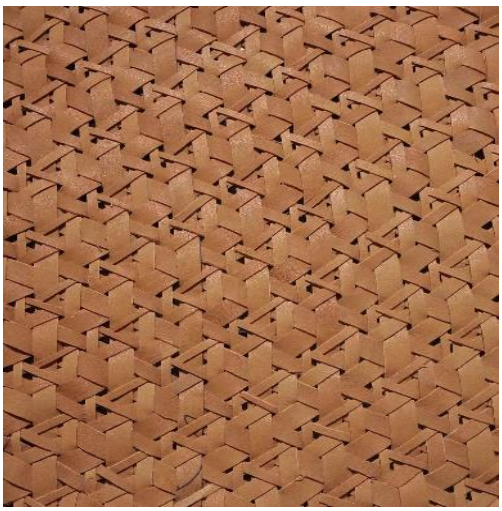
Axis number	Angle °C	Axes width (mm) design			Distance between axis (cm)		
		a	b	c	a	b	c
1	60	12	12/8	12/4	2	1.5	1.5
2	60	12	12/8	12/4	2	1.5	1.5
3	Horizontal 90	12	8	12/4	2	1.5	1.5
4	Vertical 90	12	12	8	0.8	0.8	0.8
5	30	12	12	8	0.8	0.8	0.8
6	30	12	12	8	0.8	0.8	0.8

As shown in table 10, third hexagonal textile weave structure designs specifications are demonstrated with different widths and spaces between axes

To achieve sustainability of recycled leathers, the executed different patterns and structures of multi-axes weaving (tri, quadrilateral and hexagonal axes weaves) is applied in fashion field. Adding multi-axis leather weaves structures to women's fashionable clothes to add value and achieve aesthetic effects to fashion field, by using Virtual CLO 3D software and aid of Adobe Photoshop software to produce sustainable clothes.

3.2.Fashion designs

Design (1):



Weave description: the structure is tri-axial weave- each axis has three consecutive width of leather 0.4, 0.8, and 1.2 cm.

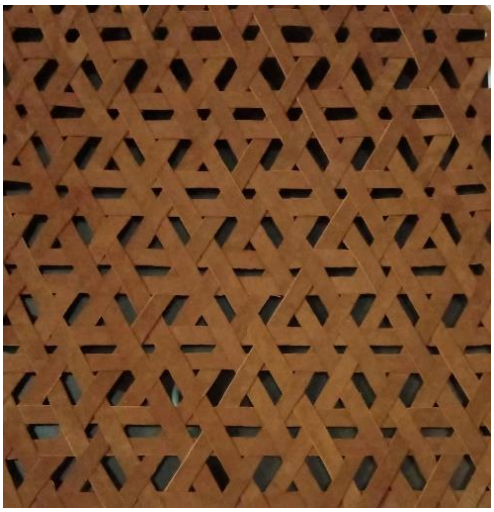
Design description: Dark red dress of velvet fabric with cross upper part with triaxial leather weave -of three different widths- structure of upper part and belt. The lower part of dress is above knee length with rounded edge.

Design (2):

***Weave description*:** the first structure is triaxial weave with three leather stripes 0.8 cm without spaces between axes. The second, the structure is tri-axial weave- the first vertical axis is double leather stripes 0.8 cm width; the two other perpendicular axes are single in each direction.

***Design description**:* mustard color and jade green blouse and skirt (the left design). The blouse is asymmetrical cuts of printed fabric and quadrilateral leather weave of two colors (bronze brown and navy blue) and jewel neckline. The above calf skirt is A-line. The right design is dark golden rod color with triaxial weave structure leather.

Design (3):



Weave description: is triaxial weave (0.8 cm leather stripes width) with two parallel lines in each direction with spaces between each line about 1.2 cm

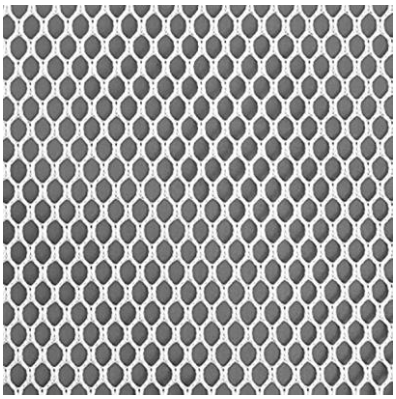
***Design description**:* Black and brown color sheath short dress. It is sleeveless and decorated with triaxial leather weave -with spaces between axes and two leather stripes in each axis -in the upper part and lower skirt.

Design (4):

Weave description: hexagonal weave with 1.2 cm leather stipes with two colores. Six axes are interlaced with different angles 90°, 60°, 30°

Design description: Crimson and dark steel blue color maxi length dress, its upper part of hexagonal leather weave. The dress lower part and sleeves are pleated cotton fabric.

Design (5):



Weave description: is triaxial weave with two colours (0.8 cm leather stripes width) with two parallel lines in each direction with spaces between each line about 1 cm and 3cm

Design description: Pale blue sheath color short fitted dress. It is sleeveless and decorated asymmetrically with triaxial leather weaves (of two colors of brown and dark blue) and perforated white fabric.

Design (6):

Weave description: is triaxial weave with two colours (0.8 cm leather stripes width) with two parallel lines in each direction with spaces between each line about 1 cm and 3cm

Design description: Light ivory colour shift long dress. Decorated with blue and brown triaxial leather weave in upper and lower parts and lower parts of sleeves.

Design (7):

Weave description: is triaxial weave with two colours (0.8 cm leather stripes width) with two parallel lines in each direction with spaces between each line about 1 cm and 3cm.

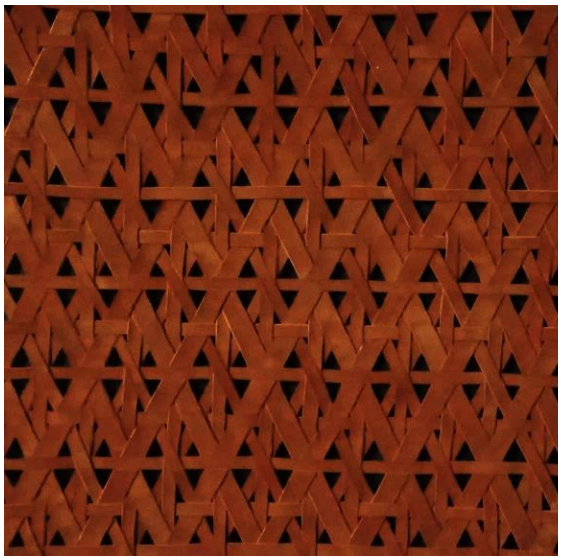
Design description: Dark eggplant colour fitted dress, above knee length, decorated with different cuts of multiaxial weave (triaxial) leather stripes of dark blue and bronze brown.

Design (8):

***Weave description*:** it is triaxial weave with three leather stripes widths 0.4, 0.8 and 1.2 cm with spaces between axes. the vertical axis is double leather stripes 1.2 and 0.8 cm width; the other perpendicular axes (black colour) are single in each direction, 0.4 cm width.

Design description: Black mid-calf dress of quadrilateral weave structure of black and sienna color leather stripes. The leather weave structure is composed of different leather stripes widths. The weave structure gives star shapes of axes interlacing and colors. The V-shape of dress hem line is making harmony with the weave structure that simulate geometrical shapes.

Design (9):



***Weave description*:** The structure is triaxial weave with three leather stripes. the first vertical and horizonal axes is 0.4 cm. The diagonal axes are consecutive three widths from 1.2, 0.8, to 0.4 cm.

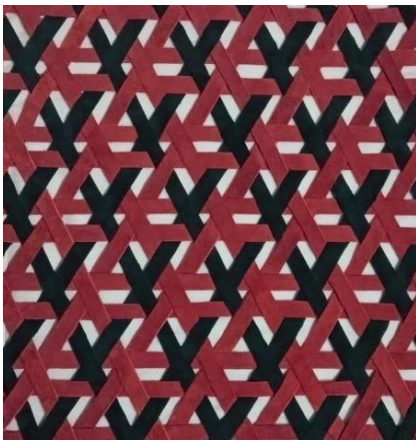
Design description: Brown copper color knee length skirt. The weave structure is quadrilateral. The top cardigan is striped colored woven fabric.

Design (10):

Weave description: hexagonal weave with 1.2 cm leather stipes with two colores. Six axes are interlaced with different angles 90°, 60°, 30°.

Design description*:* Dark blue fitted sleeveless dress. The dress is above knee of hexagonal weave structure. Dark blue velvet color fabric is making harmony with blue and brown leather stripes weave.

Design (11):

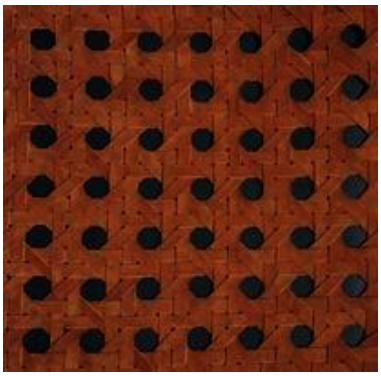


Weave description: is triaxial weave with two colours (0.4 cm leather stripes width) with two parallel lines in each direction with spaces between each line about 1 cm and 3cm alternatively.
Design description: Rust color long, A-line dress with Sabrina neck opening. Triaxial weave structure of red and black leather stripes with space between axes, are inserted in upper front part.
Design (12&13):

Adding multi-axis leather weaves structures are added to women's fashionable clothes by using Adobe Photoshop software.

Weave description: is triaxial weave (0.8 and 1.2 cm leather stripes width) with two parallel lines in each direction with spaces between each line about 1 cm and 3cm

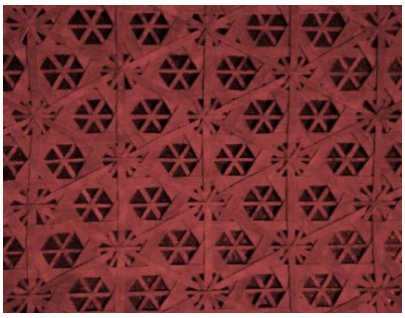
Design description: Dark blue fitted jeans pants decorated with parts of brown leather stripes of triaxial weave (two axes in each direction).

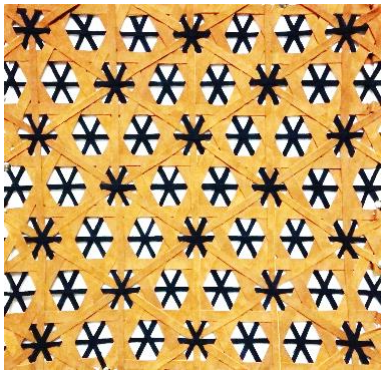


Weave description: is quadrilateral weave (0.8 cm leather stripes width) with two parallel vertical lines without spaces and two diagonal lines with 3 cm spaces between each other.

Design description: sienna color short leather skirt decorated with quadrilateral weave (two stripes in orthogonal axes and single stripes in diagonal axes).

Design (14&15):



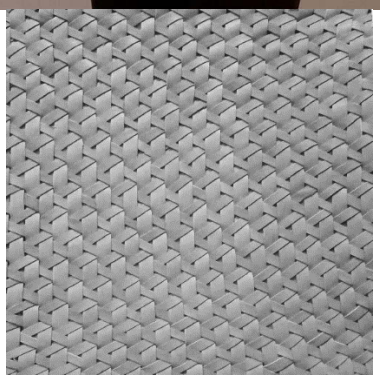


Design description: Dark plum color sleeveless fitted vest for the upper body usually worn over a shirt. It is decorated with hexagonal weave structure (with different axes widths and spaces).

Design description: Wide waist ivory color band, made of hexagonal (six-axes leather stripes) weave structure of dark blue and creamy color.

Weave description: is hexagonal weave (1.2, 0.8 and 0.4cm leather stripes width), with spaces between each line about 5.2 cm and 2 cm.

Design (16&17):



Weave description: is quadrilateral weave (0.4, 0.8 and 1.2 cm leather stripes width) with spaces between axes about 1.2 cm.

Design description: Red-orange color quadrilateral weave structure used in decorating front and back cuts of winter leather coat.

Weave description: is triaxial weave with leather stripes width 1.5 cm without any spaces between axes.

Design description: Random polygonal cuts black and sage color of plain leather and triaxial weave of fitted top. Long fitted sleeve also decorated by mixing triangles of plain and triaxial

with different leather stripes width. The leather knee length fitted coat is decorated with leather braiding's also in cuts edges.

weave structure of leather without spaces between axes.

3.3. Questionnaire for textile and clothing field experts

Table 11. Questions of questionnaire for textile and clothing field experts.

Topics	Questions	Agree	Somewhat agree	disagree	Any remarks
Achieving sustainability for recycled leather	The proposed design of women's clothing from recycled leather and remains achieves the concept of sustainability	95%	5%	-	
	The leather wastes recycling idea adopted in the research has a positive impact on the environment	100%	-	-	
	Suitability of recycled leather as a multi-axis textile for women's suggested apparel designs	89%	9%	2%	
	Leather recycling can be used in textile weave structures and functionalized in women's clothing	92%	4%	-	
The aesthetic aspect of the proposed designs	Innovative muti-axes structures, emphasize the aesthetic values of the proposed fashion designs	96%	4%	-	
	Adequacy of the space and place of execution of the leather multi-axes structures with the total area of the clothing design.	90%	10%	-	
	The compatibility and harmony of recycled leather as textile weaves in fashionable women's clothing	98%	-	-	
The innovative aspect of the proposed designs	The utilization of recycled leather in multi-axle textiles is an addition to the fashion design of women's clothing	95%	3%	2%	
	There is distinction and uniqueness in the integration of multi-axis textiles made of leather and women's clothing	89%	4%	7%	
	The usage of recyclable leather added a distinctive texture to the proposed women's clothing	99%	-	-	

	Tri-axial, quart, hexagonal weaving structures are produced fantastic artistic effects	97%	2%	1%	
The functional and marketing aspect of the proposed designs	The uniqueness of the innovative clothing design from what is available in the market contributes to the marketing of the final product	100%	-	-	
	The clothing design is in keeping with the fashion lines	85%	5%	5%	
	The proposed fashion design can be executed and applicable.	100%	-	-	
	Handmade leather weaves craft can be applied in small and medium entrepreneurship	99%	1%	-	

The initial state of the questionnaire are assessed by a group of experts in the field of clothing and textiles at the academic degree of (Professor, Associate Professor), In terms of linguistic formulation, clarity of aspects, scientific formulation, organization, sequence, number of phrases for the questionnaire, and the extent of comprehensiveness on the research objectives. And they agree with its validity for application after making the amendments related to the arrangement and reformulation of some phrases as shown in table (11).

After questionnaire data were gathered, percentages of respondent's opinions are recorded and analyzed (Table 11). The proposed design of women's clothing from recycled leather and remains achieves the concept of sustainability, gives a result 95% of respondents agree and 5% somewhat agree. The second question as to whether the leather wastes recycling idea adopted in the research has a positive impact on the environment, 100% of respondents agree. 89% of respondents agree in that recycled leather is suitable as a multi-pronged textile for women's suggested apparel designs, 9% somewhat agree and 2%disagree. Also 92% of respondents agree that leather recycling can be used in textile structures and functionalized in women's clothing, otherwise 4% somewhat agree.

The questionnaire evaluates the aesthetic aspects of the proposed designs as 96% of respondents agree that innovative multiaxial structures emphasize the aesthetic values of the proposed fashion designs, and 4% somewhat agree. 90% of respondents agree that

the space and place of execution of the leather multi-axes structures with the total area are adequate and appropriate of the total apparel design, and 10% somewhat agree. The compatibility and harmony of recycled leather as textile weaves in fashionable women's clothing, 98% of respondents agree that the weaves are compatible and harmonies with women's clothes.

The innovative aspect of the proposed designs was also evaluated by questionnaire aspects as 95% of respondents agree that the utilization of recycled leather in multi-axes weaves are valuable and add value to the fashion design of women's clothing, 3% somewhat agree, and 2% disagree. 89% agree that there is distinction and uniqueness in the integration of multi-axis weaves whatever tri-axial or quadrilateral or hexagonal weave made of leather and women's clothing, while 4% of respondents somewhat agree, and 7%disagree.

99% of respondents agree that the usage of recyclable leather added a distinctive texture to the proposed women's clothing. Also 97%of respondents agree that tri-axial, quart, hexagonal weaving structures are produced fantastic artistic effects, 2% somewhat agree and 1% disagree.

The final aspect of questionnaire is the uniqueness of the innovative clothing design from what is available in the market contributes to the marketing of the final product. The proposed fashion design can be executed and applicable, 100% of respondents agree. The clothing design is in keeping with the fashion lines ,85% of respondents agree and 5% somewhat agree and 5% disagree. Handmade leather weaves craft can be applied in small and medium entrepreneurship, all of respondents agree, and 99% %of respondents agree that the clothing design is in keeping with the fashion lines.

The questionnaire four basic topics-Achieving sustainability for recycled leather, the aesthetic aspect of the proposed designs, the innovative aspect of the proposed designs, and the functional and marketing aspect of the proposed designs- are evaluated and the total average value are introduced in figure 19.

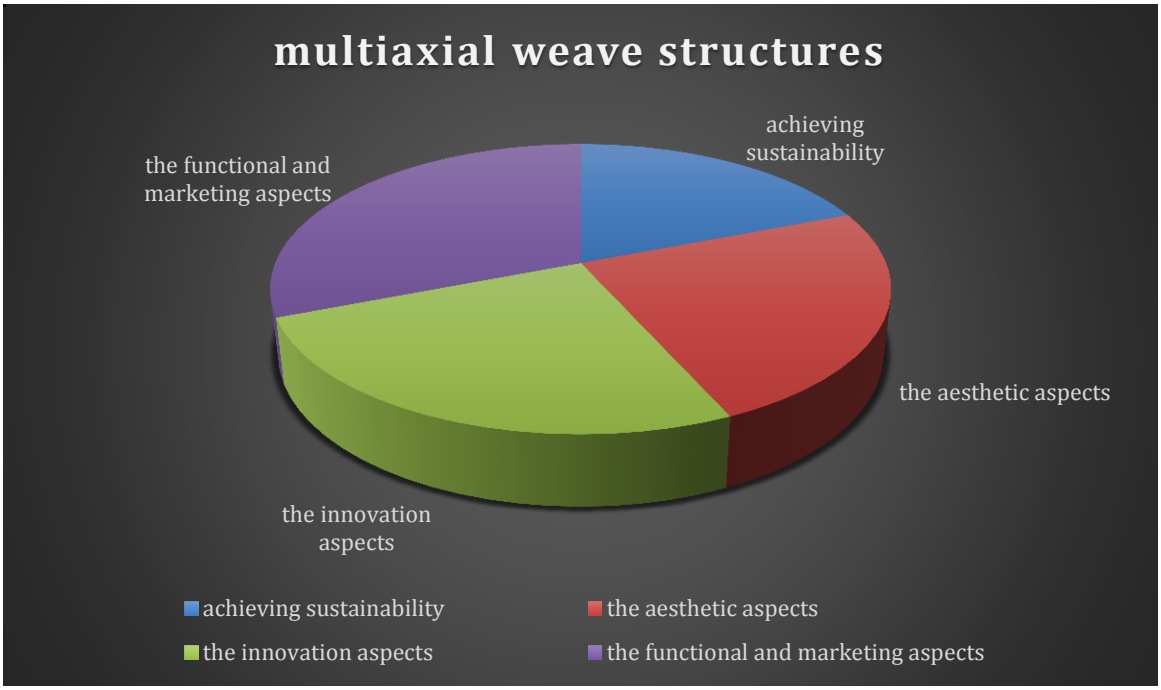


Figure 19. The questionnaire evaluated basic topics-Achieving sustainability for recycled leather, the aesthetic aspect of the proposed designs, the innovative aspect of the proposed designs, and the functional and marketing aspect of the proposed designs.

As shown in figure 19 the innovative aspect of the proposed designs is the greatest achieved goal according to experts' opinion, followed by the functional and marketing aspect of the proposed designs then the aesthetic aspect and Achieving sustainability for recycled leather of the proposed designs.

After gathering expert's opinions, design No. 3, 16, 1, 10, 8, 13, and 4 by sequence, are achieved the best results in achieving aesthetic added value. Designs No. 2,7, and 12 is the least aesthetic value.

According to textile and clothing expert's opinions, the using of leather wastes is of a great importance in wastes upcycling and transformation to a valuable innovative product. It is aesthetically succeeded in improve women clothes value. Adding different weaves (tri- quadrilateral, or hexagonal), textures and colors attract eye by producing different geometric shapes. The uniqueness of the innovative clothing design from what is usual

available in the market contributes to the marketing of the final product.

4. Conclusion

- In this research three main multiaxial weave's structure are used as textiles. The first is triaxial weave, three designs are produced of triaxial structure. The second is quadrilateral weave structure, with one design. The third multiaxial weave is hexagonal weave with three designs are introduced in our study. The variations in each triaxial weave design are by alternating axes number in each direction, spaces between axes and axis widths.
- The application of multiaxial weaves is done virtually by both 3D CLO and Adobe Photoshop software. Then seventeen women's clothes are produced. Questions for textile and clothing field experts were introduced to evaluate the idea of recycling leather remains and rags and innovative usage in multi-axis weaves to serve aesthetically and functionally in women's fashionable clothes.
- More than 35 questionnaires were distributed and were returned to the researchers. The questionnaire was served in four basic topics. The innovative aspect of the proposed designs is the greatest achieved goal according to experts' opinion, followed by the functional and marketing aspect of the proposed designs then the aesthetic aspect and Achieving sustainability for recycled leather of the proposed designs.
- After gathering expert's opinions, design No. 3, 16, 1, 10, 8, 13, and 4 by sequence, are achieved the best results in achieving aesthetic added value. Designs No. 2,7, and 12 is the least aesthetic value.

Recommendations

- To execute more multiaxial weaves structures.
- To experiment more colors interlacing that will produce more aesthetic effects.
- Using more interlacing axes with different axes numbers, widths and spaces between them will produce numerous weaves.

- Caring about handmade weaving and braiding techniques and arts.
- Proper usage handmade multiaxial weaves in small and medium enterprises.
- Seeks for new materials to be used in handmade weaving techniques.

Disclosure statement

No potential conflict of interest was reported by the author (s).

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الاستفادة من المنسوجات متعددة المحاور في إعادة تدوير المنتجات الجلدية وبقايا الجلود لرفع القيم الجمالية لملابس السيدات

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الملخص

يهدف البحث الحالي إلى إعادة تدوير المنتجات الجلدية المستخدمة وبقايا الجلود الناتجة عن مرحلة القص أثناء إنتاج المنتجات الجلدية وذلك بعد قصها لشرائط و استخدامها في تنفيذ منسوجات متعدد المحاور واستخدامها فى تصميم ملابس خارجية للسيدات، وتكمن أهمية البحث في إضافة قيمة أعلى للجلود المعاد تدويرها كمنسوجات يدوية مبتكرة وتقديم تصميمات غير تقليدية وأكثر اقتصادية لملابس السيدات، تم تنفيذ تراكيب نسجية (ثلاثية، رباعية، سداسية المحاور) وذلك بعرض واحد(1,2سم) أو عرضين(1,2 ،0,8 سم)، أو ثلاثة عروض(1,2 ،0,8 ، 0,4 سم) في العينة الواحدة باستخدام النول اليدوي، وتم تصميم عدد (17) قطعة ملبسية باستخدام كل من برنامج CLO الافتراضي ثلاثي الأبعاد وبرنامج Adobe Photoshop ،تم تقييم التصميمات المقترحة عن طريق استمارة استبيان موجه للمتخصصين في مجال الملابس والنسيج وأسفرت النتائج عن تحقيق التصميمات المقترحة مفهوم الاستدامة ودرجة قبول ونجاح في ضوء متوسطات المتخصصين.

الكلمات المفتاحية: النسيج متعدد المحاور، إعادة التدوير، بقايا الجلود، الاستدامة، ملابس السيدات.