DESIGN AND CREATIVITY IN THE FIELD OF AGRO-TEXTILES

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Abstract

Technical textiles, respectively agro-textiles, a modern concept in the textile field are characterized by: alternative materials: lightweight, flexible, soft (multi/inter) functional, durable, a wide range of raw materials: processes, products and applications, new technologies: flexible, versatile, reliable, multifunctional, cost-effective, functional components, positive trend to increase the consumption of unconventional textile structures.

The global technical textiles market is expected to grow from $ 176.83 billion in 2018 to $ 220.37 billion by 2022 with an annual compound growth rate (CAGR) of 5.89%.

Among the factors that determine this growth, we can mention: new areas of application, modifying consumer requirements, the multifunctional character of the technical textile properties, new government regulations, climate change and global warming.

The word "agro-textiles" is used to classify the woven, non-woven or knitted materials applied in sectors like: agriculture, horticulture, aquaculture, floriculture, landscape, gardening, agro-engineering and animal husbandry and defines high-tech, high-performance textile structures designed to provide significant added value in terms of functionality.

Agro-textiles, as textile elements that can be used on their own or included in an agricultural system, are multifunctional products that can provide protection against climate change, solar radiation, insect and pest control, are light, flexible, biodegradable, resistant to microorganisms, with high potential for water retention, etc.

The need for new products, capable to find the balance between economic, social and environmental needs, must receive the answers based on a new way of thinking, namely putting into the same concept human needs, technological resources and constraints, establishing the cognitive link between knowledge, processes/ technologies and the requirements of the field of use.

In this context, the paper will present elements of agro-textile design with a problem- solving approach, based on common human skills/ technical/ scientific knowledge, starting from understanding and observing the phenomena of the field.

Keywords: *agro-textiles, crop protection, 2D membrane form designing, seam efficiency*

1. INTRODUCTION

According to Food and Agriculture Organization of the United Nations (FAO), the term "Agriculture" is defined as "total area, excluding area under inland water bodies. The definition of inland water bodies generally includes major rivers and lakes" [1].

By 2050 the world's population will reach 9.1 billion, 34% higher than today. Nearly all of this population increase will occur in developing countries. Urbanization will continue at an accelerated pace, and about 70% of the world's population will be urban (compared to 49% today). In order to

feed this larger, more urban and richer population, food production must increase by 70%, while the climate change is the second major challenge for Agriculture to adapt to.

The FAO's report argues that the required increase in food production can be achieved if the necessary investment is undertaken and policies conducive to agricultural production are put in place [2].

Income levels will be many multiples of what they are now and to find solutions requires a global approach of agriculture related fields, as:

- Genetic Engineering
- Information Technology
- Advanced Sensor Technology
- Data Engineering
- Networking
- Textile Industry

Agro-textiles is one of the 12 crucial growing areas of technical textiles, which are defined as "textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics" [3].

Nowadays, the term "agro-textiles" is used to classify the woven, nonwovens and knitted technical fabrics for agricultural applications [3].

Table 1. Classification of agro-textiles products [4, 5, 6, 7].

Fabric type	Photo	Category	Function
Nonwoven		Individual frost protection	Protects individual young plantings from bad weather.
		Large- surface frost protection	Protects young plantings from bad weather.
		Agricultural applications	Support for small- scale agriculture.
		Agricultural applications	Ensures the uniformity of watering process.
Woven		Weed control net	Reduces pests and diseases; Prevents growth of weed; Prevents loss of fertile soil.
		Agricultural applications	Support for small- scale agriculture.

		Post- harvesting applications	Transport and storage.
		Post- harvesting applications	Transport and storage.
Knitted		Shade net	Controls the distribution of solar radiation.
		Anti-hail net	Protects against hail damage.
		Wind- protection net	Protects against strong winds.
		Bird net protection	Protects seeds, crops and fruit from birds.
		Harvesting net	Reduces labour costs; Facilitates harvesting in hygienic and sustainable conditions.

Textile design uses a blend of creativity and technology to create materials and patterns for a variety of industries. Design needs to be part of business strategy of any company, because it opens valuable opportunities. To deliver best results, any Design process must start from basic principles, centered on understanding end-user needs.

The research and prototype stages of the design process can generate innovative and competitive products and services that are suitable for the targeted market [8].

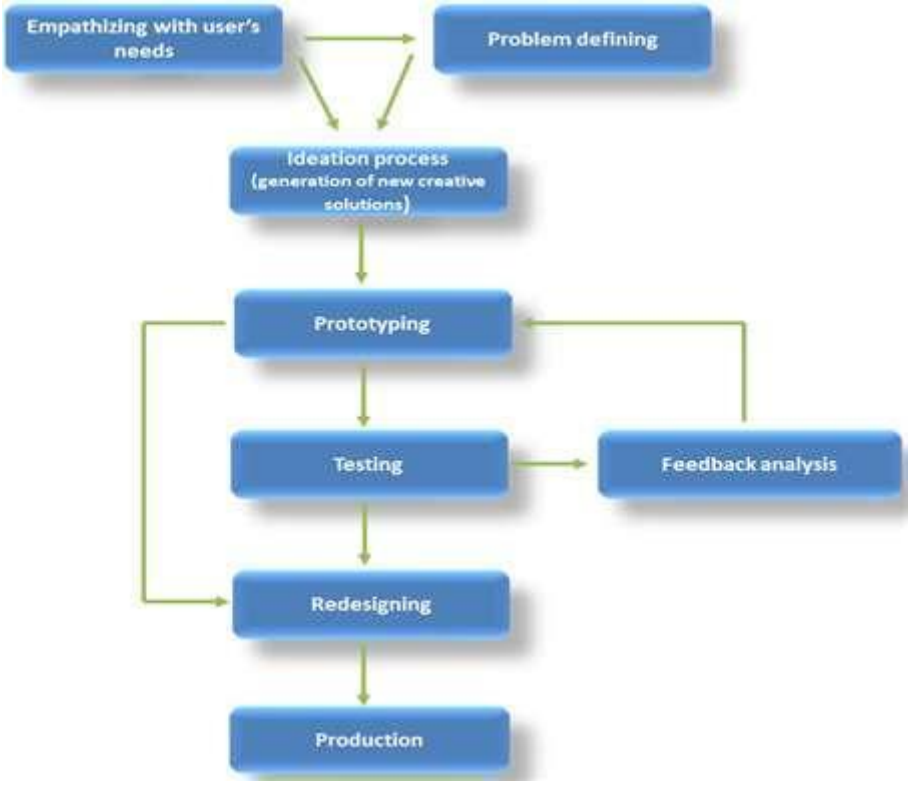


Fig. 1. Design Thinking Process [9]

The elements involved in the design of agro-textiles are: establishing the functions of agro-textiles in the end-use area, study of developments in the agro-textile applications, transposing end use requirements into raw material characteristics, knitting process, sewing process and establishing experimental conditions.

This paper aims to present a sewing assembly solution developed to obtain a membrane for covering agricultural crops, by using conventional technologies, production processes and materials for Textile industry, but not as conventional for the agriculture field.

2. MATERIALS AND METHODS

2.1. Materials

For the realization of multifunctional modules used as complementary elements in agriculture, with the role of crop protection, knitted mesh textile structures were designed from yarns with high resistance to mechanical stress. An important role in fulfilling the multifunctionality of the designed module was played by the Sewing process. The aim was to complete the assurance of the basic function, respectively the protection of the crops in variable weather conditions, and also to facilitate specific agricultural maintenance and harvesting operations.

For this purpose, a multilayer textile system was developed and the knitted mesh structure was the basic material support. It was obtained through a well-known knitting technology of processing different multifilament yarns, 100% Polyester, with fineness in the range 50-300 dtex. The knitted panels were strengthened on the edges, with durable tapes and straps (fig. 2), with fastener elements applied to the margins (fig.3). The membrane shape was obtained by joining together two reinforced panels of knitted structure, using the selected fastener device.

2.1.1. Accessories selection:

The below accessories were identified to reinforce the panel edges. The characteristics of tapes and straps in different widths and thicknesses, straight or bias cut, plain or fold in the middle are presented in table 2.

Table 2. Selected textile accessories.

Sample code	Fabric Characteristics			Supplier
	Type	**Fiber composition (%)**	**Width (mm)**	
B.T.1	Bias tape	100% PES	120	Topp Textile GmbH
B.T.2			150	
W.T.1	High width tape	73% PA+ 27% PES	100	Pasmatex SA
W.T.2		100% PP	100	SC Romlink Invest SRL (Gordius)
T1.1	Tape	100% PES	20	SC Farzat SRL
T1.2			25	
T1.3			30	
T2		100% PES	25	Pasmatex SA
S1.1	Strap	100% PP	20	SC Romlink Invest SRL (Gordius)
S1.2			30	
S2.1		100% PES	20	
S2.2			25	



a) b) c)

Fig. 2. Types of accessories: a) tapes for panel edges; b) tapes for buckles; c) straps for loops [10, 11]

2.1.2 Fasteners selection:

For joining the panels, a variety of constructive fasteners were identified, such as: zippers, plastic trident buckles, hook&loop tape (Velcro); hook&eye tape; magnetic discs (table 3).

Table 3. Selected fasteners.

Sample code	Category	Description		Supplier
		Type	**Others**	
Z1	Zipper	Open- end	100% PES composition; Plastic slider.	YKK Romania SRL
B1	Buckle	Plastic trident	Min. 85 kg breaking strength.	SC Farzat SRL
H&L1	Hook & loop	Regular	High life cycle average.	Emidale International
H&E1	Hook & eye	Tape	100% PES composition; Nickel free fittings.	Emidale International
M.D.1	Magnetic disc	Cylinder	Nickel free	SC Farzat SRL



a) b) c) d) e)

Fig. 3. Types of fasteners: a) Zipper; b) Buckle; c) Hook &loop; d) Hook &eye; e) Magnetic disc [12, 13, 14, 15, 16]

2.1.3. Sewing Threads Selection:

For the Sewing Process of the covering membrane, three different technical threads were identified, with a linear density between 80 and 135 tex. The details are given below, in table 4.

Table 4. Selected sewing threads.

Sample code	Category	Fabric characteristics		Supplier
		Linear Density (Tex)	**Others**	
S.T.1.1	Continuous filament polyester	80	Lubricated thread made from pre-stabilized high tenacity continuous filament polyester.	Coats, Romania
S.T.1.2		135		
S.T.2	Bonded nylon 6.6	105	Anti-wicking thread with high abrasion resistance.	

All the accessories mentioned above: tapes, straps, zippers, buckles, hook&loops, hook&eyes, and sewing threads, are conventional accessories for Textile Industry, so, in fact, they were purchased from local suppliers.

2.2. Methods

The targeted methods in this study aim to obtain the optimal pattern design, the best cutting process and proper solutions for assembly through sewing.

For testing the performance of the textile accessories (tapes, straps and sewing threads), apparatus and equipment from INCDTP laboratories, accredited by Romanian Accreditation Association, RENAR were used [17].

For the realization of the covering membrane, different types of sewing stitches were necessary. The sewing process involved 4 types of sewing machines, available in the experimental stations of National Institute of R&D for Textile & Leather, as shown in table 5.

The durability of the seam was calculated and evaluated through the equation of seam efficiency (1).

Table 5. Sewing equipment used [18, 19].

No.	Photo	Equipment name	Advantages
1.		Single Needle Lockstitch Machine (SNLS)	-very simple mechanism stitch formation: interlacing threads through or around textile materials.
2.		Double Needle Lockstitch Machine (DNLS)	-same principle as SNLS, but results two parallel rows of lockstitch; -the distance between needles, therefore the parallel lockstitch, can be adjusted.
3.		Overlock Machine	-professional cut and clean of the edges; -clean the edges of small details more faster than traditional operations of: boarding and bending, followed by sewing.
4.		Bartacking Machine	-computer- controlled; -ensure the maximum resistance level for the critical parts of the module (e.g.: plastic buckles).

3. RESULTS & DISCUSSIONS

3.1. Accessories testing for covering membrane:

3.1.1. Tapes and Straps testing:

Five samples of each accessory type, coded in table 2, were subjected to the tensile strength test, on longitudinal direction, as in real conditions from end use area. The tensile test results of the selected accessories to reinforce the panel edges, along with the stitch type used, are shown in table 6.

Table 6. Tested Tapes and Straps.

Sample code	Tensile Strength Test (EN ISO 13934-1)			Remarks
	Specimen disposal	**Mean**		
		Tensile (N)	**Elongation (%)**	
B.T. 1	Middle folded	1520	69	Selected for reinforcing the panel edges, using lockstitch and double-lockstitch.
B.T. 2		1786	69	Not selected.
W.T. 1	-	-	-	Not subjected to tensile strength test: improper with the knitted panel characteristics.
W.T. 2		-	-	
T1.1	Plain	967	23.6	Not selected.
T1.2		1058	29.9	Not selected.
T1.3		1817	30.2	Not selected.
T2		2932	28.7	Selected for buckles fixing on the reinforced margins, using Bar tack stitch and lockstitch.
S1.1	Plain	3129	27.9	Not selected.
S1.2		4723	30.3	Not selected.
S2.1		3780	25.6	Selected for loops fixing on the reinforced margins, using overlock and lockstitch.
S2.2		7671	25.4	Not selected.

3.1.2. Sewing Threads testing:

The performance of the sewing threads subjected to breaking force and elongation at break tests are recorded in table 7.

For the Sewing process, a very high sewability rate was achieved by using S.T.1.1 thread code, due to similar characteristics with the knit yarns in terms of fineness, tensile strength and fiber composition.

Table 7. Tested sewing threads.

Sample code	Breaking Force Test (SR EN ISO 2062:2010)		Remarks
	Tensile Strength (N)	**Elongation (%)**	
S.T.1.1	55	22.43	Selected for all types of stitch: lockstitch; double-lockstitch; overlock and Bar tack stitch.
S.T.1.2	96	28.42	Not selected, because it's not in the same fineness range with the knitted panel yarn and with the tape used to reinforce the panel edges.
S.T.2	73	35.82	Not selected because has low resistance under U.V. action due to raw material Polyamide composition.

3.2. Experimental process:

In order to ensure the imposed requirements, the following aspects of technological design were taken into account:

- to use the basic technologies and processes from Textile Industry;

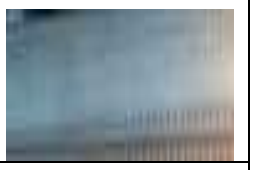
- to select the proper fineness and strength of the sewing thread in accordance with type of assembly and with structural characteristics of the knit to be assembled;

Under technological design aspects, the module was consisted of the below materials and accessories:

- 2 panels of mesh knitted structure;
- bias tape, code B.T.1, selected to reinforce the panel edges;
- tape, code T2, selected for buckles fixing on the reinforced margins;
- strap, code S.2.1, selected for loops fixing on the reinforced margins;
- plastic trident buckles, B1, selected as optimal variant of fastener, to joint the panels.

Assembly technology through sewing was consisted of four main phases (table 8), which were undertaken to obtain the final membrane shape (fig. 4).

Table 8. Sewing assembly process.

Phase no.	Description	Objectives	Photo
1.	Panels cutting	-to respond to the dimensional requirements from the final end-use, according with the crops necessities.	
2.	Bias tape sewing on the panels edges.	- to avoid structural damage of the edges; -to obtain a support point for the module on the sustaining system; -to obtain a shape of the meshes according with the module requirements for variable weather conditions.	
3.	Plastic buckles fixing.	-to obtain an infinite dimension in length and width of the module; -to facilitate the specific agricultural activities;	
4.	Loops fixing on the panel edge.	-to provide a second solution for fixing the module on the sustaining system.	



a)



b)

Fig. 4. Membrane shape: a) top view; b) lateral view.

3.3. Sewing assemblies evaluation:

During the assembly process, a high sewability rate was achieved through the high-performance characteristics of the sewing thread.

The durability of a seam is expressed in terms of seam efficiency and define a balanced construction that will withstand the forces encountered during use: [20, 21, 22]

$$Seam\ efficiency\ (\%) = \frac{seam\ tensile\ strength}{fabric\ tensile\ strenth} * 100 \qquad (01)$$

The seam efficiency was tested and analysed, in the most vulnerable part of the membrane, the reinforced edges with bias tape.

Table 9. Specimens coding for seam efficiency test.

Sample code	**Fabric Characteristics**	
	Specimen Type	**Remarks**
B.T.1	Reference fabric	No-sew bias tape
B.T.1- L.S.	Reference fabric with lockstitch	Sew bias tape

The reference fabric was the bias tape, B.T.1, coded in table 9. Samples were consisted of specimens of no - sew bias tape, tested folded by middle, and the same bias tape fabrics sewn with lockstitch, tested in the same folded conditions.

Five samples of reference fabric, B.T.1, and five samples of fabric, sewn with lockstitch, B.T.1-L.S., were subjected to the tensile strength test, on longitudinal direction, as in real conditions from end use area.

The tensile strength values obtained for reference fabric and for fabric sewn with lockstitch, are presented in table 10. The seam efficiency was determined by applying equation (1), and the results are also available in table 10.

The experimental results reveal a seam efficiency value of 53.4% (table 10). However, taking in consideration that the samples were tested folded at the middle, not unfolded, we can appreciate a theoretical percent decreasing of tensile strength for the reference fabric, BT1, with 30% at least. Applying again the equation (1), will lead us to a valuable seam efficiency rate at least 75%.

Table 10. Seam efficiency test results.

Test Direction	Tensile Strength (N)		Seam Efficiency (%)	Seam Efficiency Mean (%)
	BT1	**BT1-L.S.**		
Longitudinal	1291	665	51.5	53.4
	1225	684	55.8	
	1270	655	51.5	
	1196	683	57.1	
	1348	690	51.1	

4. CONCLUSIONS

Design process of agro-textiles has a problem-solving approach centered on understanding the requests of which the fabric should respond in end-use area.

This paper presented a sewing assembly solution developed to obtain a membrane for covering, to ensure protection for agricultural crops in variable weather conditions, by using conventional technologies, production processes and materials for Textile Industry, but not as conventional for the agriculture field.

The purpose was to fulfil the multifunctionality of the designed module: to complete the assurance of the basic function, respectively the protection of the culture in variable weather conditions, and to facilitate specific agricultural operations by increasing the handling of the module.

In order to ensure the imposed requirements, the following aspects of technological design were taken into account:

- to use the basic technologies and processes from Textile Industry;

- to select the proper fineness and strength of the sewing thread in accordance with type of assembly and with structural characteristics of the knit to be assembled;

During the assembly process, a high sewability rate was achieved through the high-performance characteristics of the sewing thread, correlated with the stitch type and sewing machine characteristics.

The advantages of the proposed solution:

- No need for advanced technology: almost entire manufacturing process is realized with Single Needle Lockstitch Machine, of which mechanism of stitch formation is similar to that created during the nineteenth century- that of interlacing threads through or around textile materials [22].
- A large number of the module shapes could be obtained by the variety of technology solutions offered by the sewing machines, stitch type and sewing thread characteristics.

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