Technical Textile; Design & Methodology

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1. Abstract:

Currently, the use of Textile is being continuously expanded in fields including medical, military, structural, telecommunications, electronics, and aerospace etc. applications. Thus the importance of the textiles increases constantly. The specific and critical character of the technical applications imposed a dynamic change in the fields of the design, engineering, production and testing. The traditional empirical approach has been replaced by the careful modeling, calculation of the properties, prediction of the behavior and the final evaluation of the performance. The modern approach is reflected on the majority of the recent research results, the patents and the scientific publications of the academic and industrial research community.

Design is set to be a process for formulation of ideas and needs, then transforming these ideas to a product through adequate technology, technical characterization, and production processes.

Meanwhile when dealing with technical textiles design, we are addressing different design innovation concepts related to application; function, performance, manufacturing, and sustainability. Technical textile design is a structured engineered creative process depending on special needs of performance and functionality associated with industrial technical product design.

One of the major challenges for technical textile designers is the compromisation of all these needs, parameters, and requirements in a design that fulfill of all of these. Meanwhile the issue of aesthetics for the technical textile products became an interesting matter, where special fields of application of technical textiles can endure both, functionality and aesthetics.

However, for product design it is becoming essential to look at the entire Life Cycle Analysis of the material to address out both positive and negative values for using that particular material or method. For that reason designers should think about materials to be used in a different way through the design process in addition to production techniques and technology.

2. Keywords:

Technical textiles, Engineered design, Design process, Design materials

3. Introduction:

Currently, the use of Textile is being continuously expanded in fields including medical, military, structural, telecommunications, electronics, and aerospace etc. applications. Thus the importance of the textiles increases constantly. The specific and critical character of the technical applications imposed a dynamic change in the fields of the design, engineering, production and testing. The traditional empirical approach has been replaced by the careful modeling, calculation of the properties, prediction of the behavior and the final evaluation of the performance. The modern approach is reflected on the majority of the recent research results, the patents and the scientific publications of the academic and industrial research community.

The new technological position and role of the woven fabrics causes important changes and evolutions in some key fields. The use of intelligent materials which are capable of reacting to external stimuli is growing in the field of textiles.

The automation and integration of processes in the textile industry is dictated by the increasing need to offer specialized products at optimum quality and low cost, satisfying at the same time the fast cycles of technical applications the delivery of products of high quality and of exact properties. Under these premises, computer engineering tools, such as computer-aided engineering (CAE) and computer-aided design (CAD), have recently gained attention. The revolutionary role of CAE and CAD tools in the textile industry is the guaranty that the final product meets the set specifications, optimizing thus the quality control procedure. Especially nowadays that textile materials can be used for the production of a wide range of technical products, such as reinforcements in composites for aerospace or marine applications or textiles for medical applications, defense, Geotextiles, filtration, ballistic-proof,…etc. Thus the design, methodology, concept, and prediction of the end-product's mechanical properties are of major importance.

A R Horrocks and S C Anand [(1)] The definition of technical textiles adopted by the authoritative Textile Terms and Definitions, published by the Textile Institute1, is 'textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics.

Technical textiles are materials meeting high technical and quality requirements (mechanical, thermal, electrical, durability...) giving them the ability to offer technical functions ***[H. Laurent, G. Némoz, Encyclopaedia Universalis, Universalia 1995, PP 184-188]***

The growth in the technical textiles sector in developed countries, including is being driven by:

- increasingly stringent environmental regulations;
- the need for increased energy efficiency and utilization of waste;
- high performance/whole of life cost factors;
- changing needs of an ageing population; and,
- an increased focus on leisure.

4. Innovation of Product design

Innovation is a key word for design nowadays, as competitiveness pressures in products, productivity, and market-share are the driving powers of Industry and investments. However, Innovation in addition to adapting new technologies, information, and knowledge are set to be the driving forces within the industry for fulfilling market needs.

Innovative product design is concerned with addressing customer needs; performance, quality, ergonomics, form, fashion, aesthesis, in addition to economical aspects. That's to say product innovation is fitting to the purpose and adding a value. Moreover these aspects are not the only characteristics of an innovative design. Innovative design is a design that differs in shape, performance, production methods and applications from existing ones. They are set to be market and fashion drivers, through delivering unconventional products. [(2)]

Design is set to be a process for formulation of ideas and needs, then transforming these ideas to a product through adequate technology, technical characterization, and production processes.

The configuration of materials, elements and components that give a product its particular attributes of performance, appearance, ease of use, method of manufacture. **Walsh et al**

'Design is the purposive application of creativity to all the activities necessary to bring ideas into use either as product (service) or process innovations.**' Bessant, Whyte and Neely (2005)**[(2)]

4-1- The Product/engineered design process (3)

Design is the act of formalizing an idea or concept into tangible formation. It is distinct from making or building. Taking the concept for an artifact to the point just before the process of converting it into a physical, or embodied, form begins may be termed as the process of designing it. According to ***Caldecote (1989)***, design is the process of converting an idea into information from which a product can be made.

From an engineering perspective, the application of scientific concepts, mathematics, physics, chemistry and creativity to envision a structure, a machine, system, or artifact that performs a pre specified function and performance is the definition of design. Design is used pervasively; its meaning being somewhat different for an engineer than an industrial designer.

While an engineer is more concerned about the arrangement of parts, the mechanics of the arranged parts, and their functionality when put together, an industrial designer is more concerned about the appearance of an artifact. Since, in designing consumer products, both form and function are important, both disciplines (engineering and industrial design) are crucial in the development of the final information from which a product can be made. The degree to which a product design depends on engineering or industrial design is determined by the product itself.

A product that relies mostly on aesthetics, such as textile products, and furniture, is within the design spectrum of an industrial designer while products that are function dominant, such as automobile engines, building foundations; technical textiles are within the domain of engineers. Consumer products depend on both engineers and industrial designers for success, on engineers for function and performance according to needs and required specifications and on industrial designers for aesthetics. The degree to which each discipline dominates the design varies from product to product. Figure (1) and (2) shows the design spectrum for both disciplines.

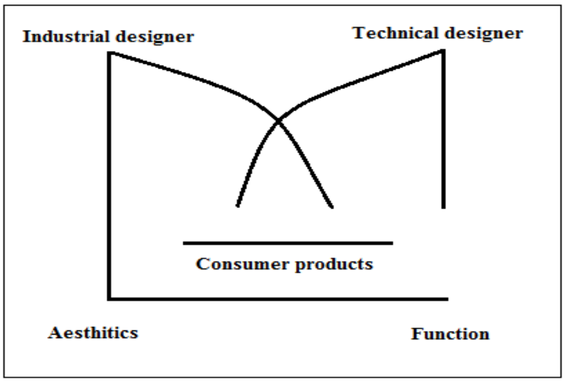

Figure (1) Design spectrum – adopted from Caldecote 1989 [4,5]

Understanding engineering design process is an important issue for managing the design activity process and to aid the product development and improvement. In addition to that design process assignments are relative to the creation process, product performance, & the resulting quality. [4,5]

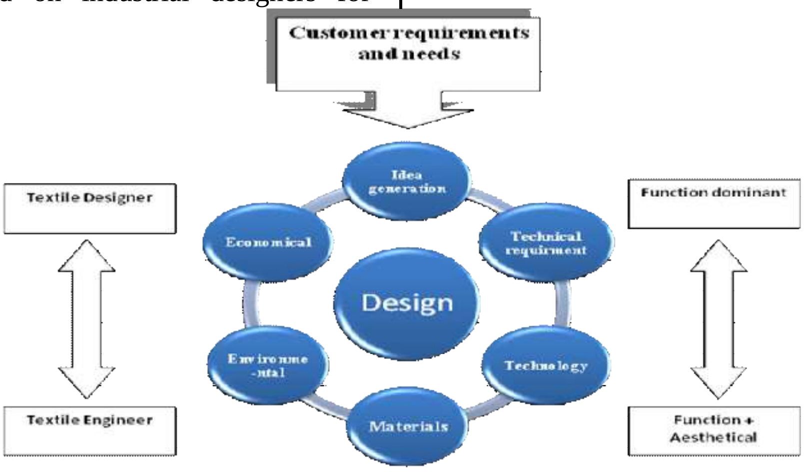

Figure (2) Technical textile Design spectrum

5. Technical textile design and innovation:

Innovation is always cited with: No rules, No boundaries, its creating something different. Meanwhile when dealing with technical textiles design, we are addressing different design innovation concepts related to application; function, performance, manufacturing, and sustainability. [2] Technical textile design is a structured engineered creative process depending on special needs of performance and functionality associated with industrial technical product design.

World market for technical textiles is enormously growing to reach an average of 140 Billon $ dollars by the end 2012. Meanwhile the fiber consumption in this field is also growing with the diversity of fibers, reaching high performance fibers for special use.

Textiles materials are one of the earliest engineered products, having been around since the stone age. Each of us is in intimate contact with textile products every day of our lives from cradle to grave. In industrial applications, textiles tend to be jump out of the box as problem-solving materials, due to their properties and performance.

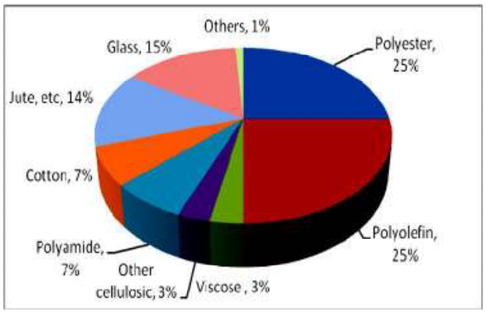

Figure (3) Fiber consumption in technical textiles

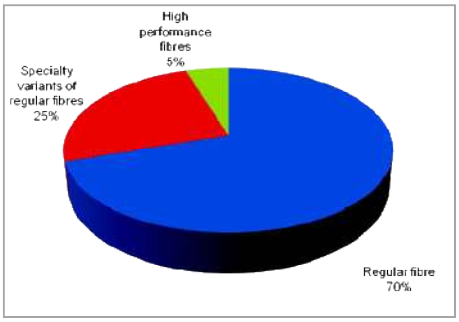

Figure (4) Categories of fibers used in technical textiles

Technical textiles are the term used to describe textiles that are constructed for their properties and function, rather than their appearance (although appearance can often be a factor). Textiles come in a multitude of knit, woven or fibrous forms including rope, cord, thread, netting, fabric, webbing, wadding and three-dimensional shapes. Textiles offer a high degree of functionality, weight reduction, and cost saving if applied and engineered properly.

New textiles developments are coming fast and furious, offering the possibilities of replacing metal and plastic with stronger, lighter and often cheaper alternatives. Engineers and designers often unknowingly employ technical textiles in the form of drive belts, composite materials, filters, insulation, hydraulic hose ,..etc. [(6)]

Textiles can be engineered to be hydrophilic or hydrophobic, fire retardant, electrically conductive or isolative, visible or invisible to radar or infrared, physically expand when stretched, energy absorptive or reflective, stiff or highly flexible - the possibilities are endless.

5.1. Technical applications of textiles (Fields of application)

Although conventional textiles are primarily used for clothing, the use of a variety of raw materials as well as the development of new manufacturing processes led to a considerable expansion of their possible applications. The importance of aesthetic and decorative characteristics of textiles has been decreased by the new materials' performance and functionality. [(1)]

Table (1) Fields of application of technical textiles

Agrotech	Agricultural (nonwoven for wind protection)
Buildtech	Building and construction (awning, concrete reinforcements)
Clothtech	Clothing (garments)
Hometech	Household (curtains, wall covering)

Indutech	Industrial applications textiles (filters)
Sportech	Sports and leisure (carbon-fibre composites for racquet frames)
Oekotech	eco-friendly textiles (recyclable composites)
Mobitech	Mobility (ropes, seat covers)
Geotech	Geotextiles (nonwovens for drainage, reinforcement)
Packteck	Packaging (nets, wrappings)
Protech	Protection (bullet-proof jackets, uniforms)
Medtech	Medical (bandages, sutures)

Over the last decades there is also an intensive need for high-tech materials with "life functions". Consequently, products with increased specific functionalities and performance properties according to defined needs and applications were addressed. Smart textiles development requires the synergistic action of different disciplines such as textile science and engineering, natural sciences, material science, mechanical engineering, electrical and computer engineering and informatics, making this promising research area extremely challenging. Furthermore, cost effective of innovative textile-based products aiming in the improvement of people's quality of life. [(1).]

The basic and main characteristic of technical textiles that differentiates it from conventional or

traditional textiles is its purpose, i.e., **functionality and performance**. Technical textiles could be made from both natural and synthetic fibers. It can be used by both individuals for specialist personal use and requirements of industries. Terms such as performance textiles, functional textiles, engineered textiles, and high tech textiles are also used in various contexts sometimes as a substitute for the world **"technical textiles"** fig (5A to 5F)

Fig (5- A) Architecture technical textiles

Fig (5-B) Protective technical textiles

Fig (5-C) Geotextiles - technical textiles

Fig (5-D) Filtration technical textiles

Fig (5-E) Medical protective technical textiles

Fig (5-F) Agro-textiles

5-2- Materials

Materials are set to be one of the most important tools of the designer, and the base-line of the product. In addition materials endure the major properties of the final product. It is important to recognize that not all materials that seem to be sustainable are sustainable. However, for product design it is becoming essential to look at the entire (LCA) - Life Cycle Analysis of the material to address out both positive and negative value of using that particular material or method. For that reason designers should think about materials to be used in a different way, answering these questions:

- ***Where it come from?***
- ***What am I going to do with it?***
- ***Will it insure the properties and performance I need?***
- ***How it will work with other materials?***
- ***Are there any alternatives for it?***
- ***Where will it end up?***
- ***Can it be recycled?***

The science of flexible fiber assemblies is an extremely challenging subject and is little related to the mainstream 20th century development of applied mechanics. The combination of strength and flexibility in unbounded fiber assemblies held together by frictional forces makes wonderful products. [(7)]

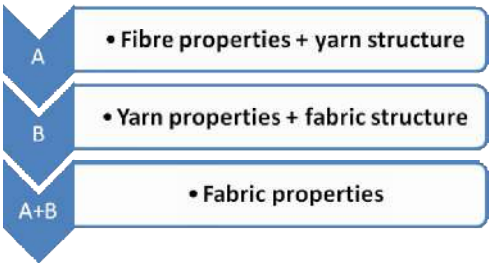

Figure (6) Technical textile total properties

5.2.1. Materials used for Technical textile.

Metals, like steel.

1. Minerals, like asbestos and glass.
2. Synthetic polymers, like PES, PA, PAN, PP etc.
3. Regenerated fibers like rayon fiber and acetate fiber.
4. Natural fibers like cotton fiber, jute fiber, wool fiber etc.

Not only a great variety of raw materials but a multitude of processes are also employed for manufacturing technical textiles that include basic processes like weaving and knitting and much advanced processes like stitch bonding, chemical, thermal bonding to needle punching and many more. All these processes result into various products like fibers, yarns, and threads that are further used for making the finished technical textile. Not only this, many processes also lead to the manufacture of end products like ropes, cords, bags, belts etc. Figure (7A, 7B and 7C)

Fig (7- A) Metallic copper

Fig (7- B) Glass fiber

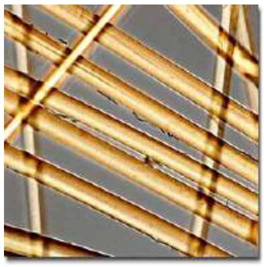

Fig (7- C) Kevlar filament

5.2.2. Material selection criteria.

The selection of an appropriate material and its conversion into a useful product with the desired shape, performance and properties is a complex process. The first step in the material selection process is the definition of the needs of the product (application field, performance level, and functionality).

Meanwhile, the complexity of technical textile design, is the merging of different components (materials) in the same design like in composites and hybrid textiles, where different materials base is used; fibers, resins, ceramics, metals,….etc. Figure (8) shows the factors affecting the material selection process:

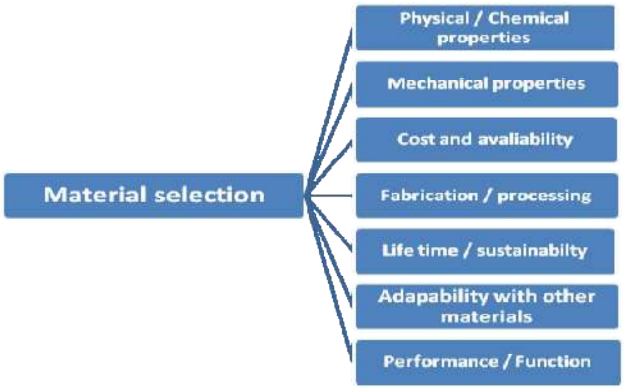

Figure (8) Factors affecting material selection for design process

1. Design processes:

Technical textile design process is a complex oriented process, where the design must fulfill all the demands and expectations concerning the product. These processes should be done and implemented according to a well defined and fully controlled strategies, methodologies and methods. Integration between science fields, aspects, materials, production techniques, technologies and methods breakdown to merge in a new design concepts and methodologies.

All design demands of different phases should be considered according to the function and performance needs. Design parameters differ from one situation to another according to the needs and their priorities, compromising all of these in a design solution. [8]

The most addressed needs and requirements of a product design are:

(Customer requirements + Product design parameters)

- Customer parameter needs (Voice of customer (VOC))
- Materials parameter requirements
- Production technology parameters
- Function needs
- Performance & quality needs
- Design demands and needs
- Economical requirements
- Standards and regulation compliance
- Sustainability and environmental requirements

One of the major challenges for technical textile designers is the compromization of all these needs, parameters, and requirements in a design that fulfill all of these. Meanwhile the issue of aesthetics for the technical textile products became an interesting matter, where special fields of application of technical textiles can endure both, functionality and aesthetics [9,12,13]

That’s to say, that the design process of the product should answer these questions:

- What the product should do (perform / function)?
- What kind of technology of manufacturing to be applied?
- What it should look like?
- How it would be installed?
- How long the product will last (product life cycle)?
- How much it will cost (economical aspects)?

- How it will affect the environment?

Therefore establishing a design framework (illustrating design processing in sequence) fig.(9) is set to be an essential and important design tool, not only this but a design matrix, addressing all requirements with respect to design parameters, that's to say customer needs and requirements in the product (function, performance, aesthetical, life time,…) together with design parameters that would fulfill the design requirements (properties, alternatives, techniques, materials, technology of production,…..).

- [X] illustrates the customer needs in the product, and it is addressed according to the priorities and value of the item with respect to the customer. While [Xn] represents the sum of the customer requirements according to the functions required.
- [Y] Illustrates the design parameters for the product, according to the technical textile designer expertise, researches, literature, experiences, practice, special requirements, consultancy, know how,…. While [Ym] represents the sum of the design parameters (elements) suggested fulfilling the customer design requirement.
- Connections are determined according to design team discussions (Brainstorming, Analysis, Mind mapping…) example (Ox3y2) - then assign the grade of connection.
- The direction and the strength of the connections are to be highly considered.
- Number grading (From 1 – 5) for evaluations according to the priorities are based on subjective evaluation for the relation between (Needs & design parameters);

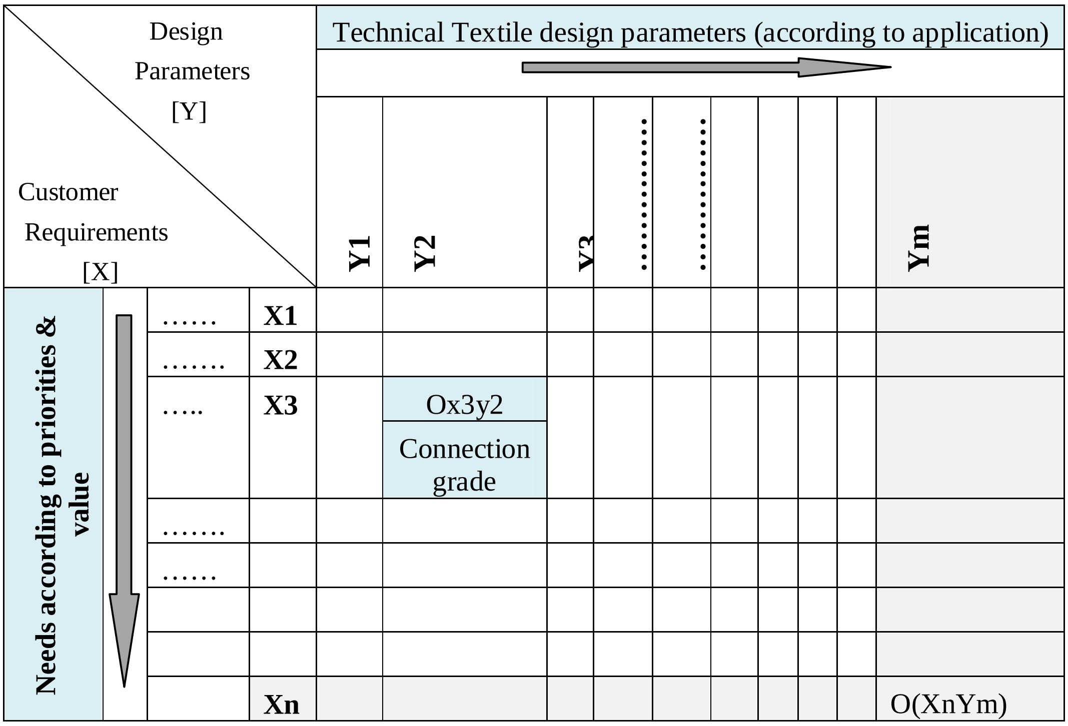

Figure (9) Design matrix [8]

Grade	**1**	**2**	**3**	**4**	**5**
Connection	Strong/positive	Weak/positive	------	weak/Negative	Strong/Negative

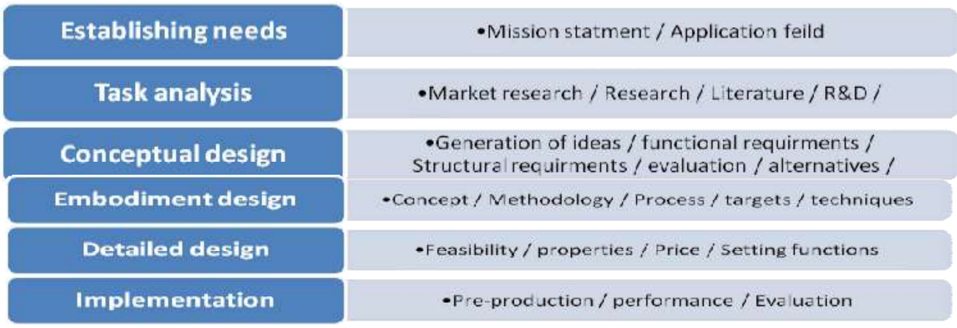

Figure (10) Engineering design model [(4)]

- *Positive connections* (1,2) (strong / weak); that's means that the increase value of design parameters results in reduction in the level of fulfilling the customer requirements.
- *Negative connections* (4,5) (strong / weak); that's means that the increase value of design parameters results in an increase in the level of fulfilling the customer requirements.
- *No connections* (3); that's means that there is no relation between design parameters and the requirements of the customer in their product.
- Then the design parameters are presented according to their connection grade. Meanwhile weak connections are revised for improvements or alternatives.

That's to say that designing of technical textiles, follow defined modeling process, i.e. solution-focused design process. The designing process is based upon three concepts, fig (11) "Analysis - Ideation – Executive". [(13,14)]

a. **Analysis:** It is the analytical phase, and the base for making further decisions. Where the designer applies his tools like; Observations, measurements, research, ideas generation, addressing sources and parameters, addressing factors and specifications… All these are done according to the required application field, thus defining design goals and aspects.

b. **Ideation:** It's the phase where the designer may lead to a feasible and adaptive solution, where the designer then begins to combing solutions, addressing alternatives, evaluation, judgment, elements of design are featured, the level and relationship of aesthetical appearance and functionality selection, analyzing, plotting solutions,…..Where at the end of these phase the designer begins selecting the best idea after refining design ideas, and selecting between alternatives concerning material, techniques, and technology, and addressing all aspects of design situation.

c. **Executive phase:** It is the phase where the designer develops the final design phase (design prototype), evaluate and test the product according to its design aspects. Addressing production process, techniques, in addition to economical factor

6- Results &Conclusion:

Designing of technical textiles, is not a one man show work, but rather a group or team working, as the diversity of application fields, and the required properties and performance level, requires a team work of designers/engineers/chemists/biologists/…. depending on the field of application working together in a relationship. These relationships are forming because each party recognizes and values a particular quality of knowledge that they wish to access in one another in order to develop and further their practice in their field.

Where different raw materials, production techniques, technology, and field of application, requires developing a design methodology based upon design concept and goals. According to the application field, requirements and needs are addressed (whether aesthetical, performance, aesthetical/performance). Through assigning the design goals, functions and requirements are translated to properties, upon which designers begin setting design elements (materials, techniques, production process, alternative materials …) through a creative process. Reaching finally the pre-ultimate design after several refining processes, to move forward to design evaluation and testing, reaching at the end the design that fulfill the use, needs, environmental, and the economical aspect. Fig (11) (12) (13) (15)

That's to say that a technical textiles designer would usually be responsible for the following :[11]

Figure (11) Design model analysis

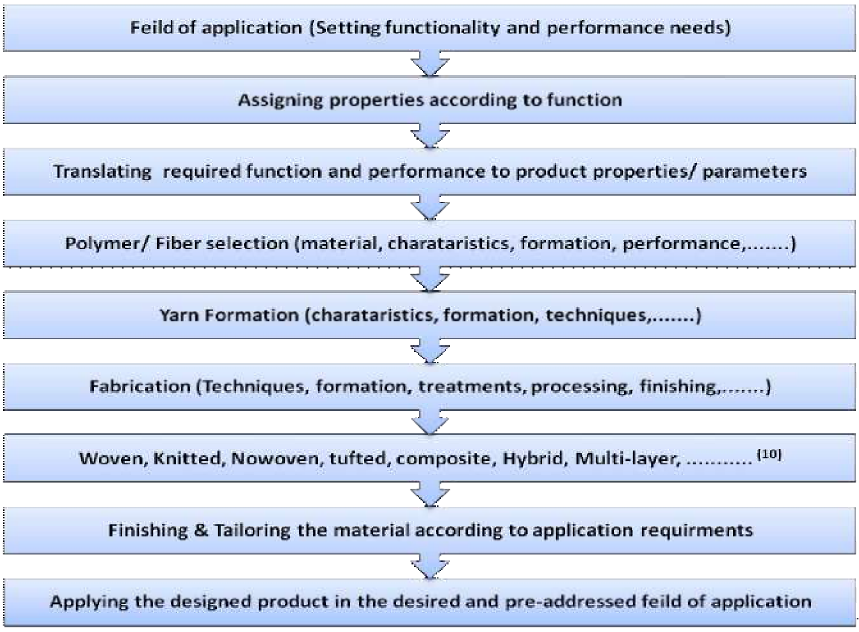

Figure (12) Design processing scheme of technical textiles

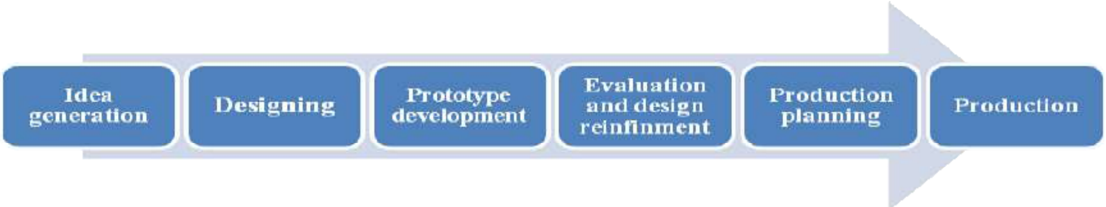

Figure (13) Technical textiles - product development process [11]

- Design idea generation and development.
- Devising products to meet performance specifications (design elements).
- Developing prototypes and refining designs.
- Using specialist Computer Aided Design (CAD) software to produce a range of designs
- Exploring and testing new fibers and fabrics and recording the results.
- Researching new processes, techniques and technologies of production.
- writing reports and cost estimates
- Working in teams with other specialists.

A technical textiles designer is responsible for the design, product development and participating in the manufacture process of technical textiles. In addition to the interpretation of the design requirements into properties that fulfill the design desires through the design tools (elements) concerning the textile engineering concepts; starting from the polymer composition and characteristics, fiber, yarn, and then the fabric structure. Meanwhile other materials, manufacturing techniques are also integrated into the design according to the required product and the field of application. Textile technical designer does not work solely, but rather in a team work concerned with the application field and function required.

The promise of technical and performance textiles is an emerging generation of products combining the latest developments in advanced flexible materials with advances in computing and communications technology, biomaterials, nanotechnology and novel process technologies such as plasma treatment. These will eventually have a direct impact on all sorts of consumer textile markets, where technical textiles is offering a unique designed material offering a unique properties and performance applicable in many fields. [16]

Textile has to be used as a multifunctional material having high level of physical, mechanical, thermal, chemical properties. Technical Textiles offer the "best material of the world": lightest, strongest, biocompatible, smart, even intelligent.

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