Technological Innovation, Industrial Competitiveness & Trading in Textile & Apparel with special reference to China

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Abstract: This paper presents an analysis and summary of China’s textile and clothing industry from technological innovation, industrial competitiveness and trading. Textile and clothing has been one of China’s traditional industries since 1949 and has remained one of the key industries in modern China. This industry has experienced dramatic reforms and reached high growth for a long period of time. China is the world’s largest exporter and producer of many products in this industry. However, there are a lot of problems within the domestic industry. This paper presents the policy, technological innovation methods, support program and achievements and future trends in China's textile and apparel industry which have being changed this traditional industry in China and to formulated good strategies for its development.

Keywords: Textile and apparel, technological innovation, industries transfer, national R&D program and awards

1. Introduction

China’s textiles and apparel industry is a traditional pillar industry in the Chinese economy. In the late 1990s, the central government launched a massive campaign to restructure the industry and reform unprofitable and debt-ridden state-owned enterprises. Major modernization and restructuring of the industry took place before 2000. The following five years, known as the 10th five-year period (2001-2005), witnessed considerable efforts in technology upgrading in the industry. During this period, China imported billion of advanced equipment, accounting for 50 percent of the industry’s total equipment investment. Meanwhile, domestic textile machinery manufacturing capacity also expanded significantly and from 2000 to 2005 (10th five-year period), the industry’s sales revenue rose sharply. Despite the advancements during the 10th five-year period, the Chinese government viewed the textile industry as facing many constraints going forward. Domestic enterprises on average are weak in innovation, with limited R&D activities and the industry still relies heavily upon imports of high-end equipment and technologies [1, 2].

In The 11th Five-Year (2006-2010) [3] Guideline for National Economic and Social Development (see Exhibit A-I-2), “optimizing and upgrading industrial structure” was laid out as a development focus. Under this overriding principle for industrial development, one of the priorities of the guideline is to increase the value-added in the textile industry, specifically: to strengthen the technological capability of the textile industry and increase the number of Chinese-owned brand names; to develop high-tech, high-performance, differential, and environmental-friendly fibers and renewable fibers, and to enhance the development and utilization of textiles for industry-use; to advance the gradient shift of the textile industry. In the spirit of the Guideline, the Chinese government mapped out a detailed development plan for the textile industry in The 11th Five-Year Plan for the Textile Industry. The Plan sets forth the following goals:

- To significantly enhance the independent innovation capacity of the textiles industry, develop influential technologies with intellectual property rights ownership and foster well-known global brand names.
- To optimize the industrial structure and upgrade technologies and equipment.
- To effectively control inefficient low-level manufacturing which consumes excessive amounts of energy and is not environmentally-friendly.

These goals echo the guideline and are designed to address existing problems in the development of the textiles industry [4-5].

2. Manufacture transfer and support program

Within the Chinese domestic market, manufacturing costs are increasing. This includes not only labor wages and cost for raw materials, but also the rising value of China’s currency, and the cost of shipping goods from China to points around the world. In the foreign markets, demand for clothing is shrinking due to the continuing uncertain economic conditions in the EU region and recession-induced drops in consumer spending. In addition, Chinese textiles exporters face strong competition from other countries such as Vietnam, India and Cambodia, Bangladesh. Some bands have cut its source from China or looked to build manufacturing sources in Africa in

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support of their need to expand their business across the global textile market. The competing countries possess not only lower wages, but also strong production capacity, adequate infrastructure and favorable regulatory policies. The increasing domestic cost, decreasing foreign demand, and strong competition from other countries represent great pressure for Chinese textile firms to adjust their business model. On one hand, they are in the transition process from Original Equipment Manufacturing to Original Design Manufacturing in which it will provide more value-added service than before in the global value chain. Chinese government also devote to cooperation and co-development with other countries. Textile industry is a pillar industry for a lot of developing countries and the production transfer of Chinese textile firms can devote to the economic development of those local countries [6].

In accordance with textiles development goals and policy support guidelines, the Chinese government has implemented many concrete programs and policies to subsidize textile companies and the textiles industry. The subsidies take the form of government grants and tax incentives, and include those available nationwide and those provided to selected regions. More specifically, the fund is utilized as follows:

- To support technology innovation and restructuring in the textile industry and facilitate the shift to the new growth mode in foreign trade.
- To provide lump sum direct grants to projects of technology innovation, development and industrialization of core technologies and equipment, establishment of innovation services platforms, and brand development and promotion.
- To support the establishment of overseas textile industrial parks, providing a favorable environment for textile companies in the course of “going global.”
- To provide loan interest subsidies for the construction of overseas textile industrial parks.
- To subsidize the provision of land, manufacturing facilities, infrastructure and services in overseas textile industrial parks.
- To support textile companies in “going global” through overseas investment and diversifying their products origin through overseas manufacturing.
- To subsidize the expenses of Chinese textile companies incurred in early stages of “going global” that may involve R&D, consulting services, feasibility study and project evaluation, and intellectual property rights protection.
- To subsidize the expenses of Chinese textile companies in the establishment of distribution channels in overseas markets.
- To support service companies and dragonhead textile companies in the organization of “going global” activities.

3. Technical innovation policy

Technical innovation is the key for economic success. Technological oriented innovation includes knowledge innovation, education and talents aggregation, technological innovation and innovative supply and absorption. Knowledge innovation aims at the basic and applied research knowledge dissemination and application services and the university innovation capability. Technological innovation is from the technology cooperation between research universities and enterprises. Education and talents aggregation are based on the combination of scientific research and education; training outstanding textile undergraduate and graduate students and developing elite talents. Innovative resource includes the flowing of innovative elements and efficient allocation.
of resources. In China, a new approach in innovation is a mode of market oriented and supply chain integrated and led by enterprise, supported by university.

Some key measures for effective innovation have been implemented in China such as funding innovation programs (973, 863, R&D programs), R&D centers, institutes and laboratories of companies, technology platforms, university-government-institute-industry collaboration, strategic alliance of partners and national awards and talent retention.

![China Innovation Approach in Textile Industry](image)

Fig. 2. China innovation approach in Textile industry

For example, 863 program has enhanced the capability of national innovation and strengthen national competitiveness and become a flagship of China’s high technology R&D. The 863 program focus on the frontiers of high technologies, key areas of long term significance & safety and future & leading technologies. From 1986 to 2005, there are 150000 researchers have been founded by total 33 billion RMB and published 8000 patents. Textile related projects are more than 30 items and range from natural, synthetic fibers, textile finishing to information technology, system integration and technical textiles.

To meet the demands of national economic and social developments in technologies, the National Key Technology R&D program has been implemented. This program focus on solving major common technology problems. The project holders maybe companies, alliances or industry leaders. Textile machinery, fibers, advanced fibrous materials and textile chemistry are included in the research areas.

China national awards is a tool to pivot technological innovations. Every year, there are 4 to 6 prizes for textile related projects.

Supported by the national program, the academic results have sharply increased recently. China ranks the second in the top 10 countries published textile research papers in SCI journals and the number of core authors in the world is 563.

![Top 10 Countries published textile research papers in SCI Journal](image)

(a) (b)

Fig. 3. Top 10 Countries published textile research papers in SCI Journal (a) and core author (b)

### 4. Future Trends

The 12th Five-Year-Plan(2010-2015) [7] aims at textile technology innovation and industrial transformation and upgrading, put forward eight key tasks for textile industrial transformation and upgrading: “The first is to enhance the capability of independent innovation. The second is to strengthen the technological transformation of enterprises. The third is to improve the level of industrial information. The fourth is the promotion of industrial green low-carbon development. The fifth is implementation of quality and brand strategies. The sixth is the development of a core group of competitive large enterprises and groups. The seventh is to promote regional industrial co-ordination and development. The eighth is to enhance the level and depth of opening up”.

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To accomplish the various development goals, a variety of preferential policies to support the textiles industry are:

- To allocate special funds from the state fiscal budget to support the development of key equipment and technologies.
- To use tax incentives to encourage R&D spending and technological innovation of textile companies.
- To introduce the policy of increasing the magnitude of tax deductions for advertising expenses.
- To aid the brand development and overseas investment of domestic textile companies, rendering support in the establishment of overseas manufacturing facilities, R&D centers, logistics and distribution centers, and the application for international certificates and registration of trademarks.
- To implement preferential tax policies for the import of key spare parts and raw materials required for the manufacturing of textile machinery.
- To encourage the procurement of major domestically-produced equipment.

The key areas of development in textiles and clothing in China are:

- New fiber materials: Functional, smart fibers, natural and bio-fibers, high performance fibers and differentiated profile fibers.
- High performance technical textiles: Protective clothing, smoke and particle filtering, tent and covering materials, medical textiles.
- Advanced textile equipment manufacturing: Testing equipment, energy saving, environment protection and green technologies, high efficiency and automation.
- Applications of high-tech to traditional textiles: Information technology, Nanotechnology, 3D fabric technologies and new spinning methods.

5. References

Side Emitting Polymeric Optical Fibres for Safety Textiles

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Abstract: The main aim of this contribution is to discuss special results in the field of side emitting optical fibres for creation of safety textiles with active illumination in conditions of reduced visibility. Illumination intensity of polymer side emitting optical fibres measured in straight and bend state is described. Prototypes of textile structures with embedded optical fibres created in cooperation Faculty of Textile Engineering Technical University of Liberec and Czech company STAP A.S. are presented.

Keywords: Polymer optical fibres, side emission, attenuation.

1. Introduction
The main aim of this contribution is description of SEPOF optical properties and their efficient embedding into fibrous structures for creation of safety textile structures with active visibility in shadows. For preparation of textile structures containing SEPOF the braiding technology is used [1,2]. The SEPOF end connected with light energy source is prepared by cutting with heated wire and then by polishing with diamond powder. Illumination system with light emitting diode (LED) is used as light source (illumination intensity of source is 43.9 Wm⁻²).

The special device for measurement of light intensity on surface and cross section at various distances from light source is described. The dependence of surface and cross section light intensity on the distance from light source is expressed by the exponential type model with attenuation factor as the rate parameter. Second parameter defines quality of illuminating system; it is light intensity at the input to the fibre. The influence of the optical fibre type and diameter on the attenuation factor of light intensity at the surface and cross section is quantified.

Light intensity of textile structures is compared with light intensity of fibres [3-5].

2. Materials and methods
Optical fibres “Grace standard” and “Grace flexi” with different diameter were used for measurement of illumination intensity (Table 1).

<table>
<thead>
<tr>
<th>Table 1. Optical fibres specification</th>
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<tr>
<td>Grace</td>
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<tr>
<td>Powered/ Cladding material</td>
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<td>Diameter</td>
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<tr>
<td>Core refractive index</td>
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<tr>
<td>Cladding refractive index</td>
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<tr>
<td>Numeric aperture</td>
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<td>Maximal input angle</td>
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<tr>
<td>Mass density</td>
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<td>Wavelength</td>
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<td>Temperature of use</td>
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</table>

3. Results and discussion
Illumination intensity as function of distance from source for optical fibre „Grace-standard“ having diameter 0.25 mm is shown in Fig. 2 and for fibre „Grace-flexi” having diameter 14 mm is in Fig. 1.
Experimental illumination intensity data can be used for creation of regression model (see eq. (1)) and corresponding parameters can be obtained by the standard nonlinear or linearized regression using least squares criterion. Eq. (3) can be written into the model form

\[ P(L) = P(0) 10^{-\alpha L/10} \]  

(1)

where \( P(L) \) is illumination intensity at the distance from source \( L \), \( P(0) \) is illumination intensity on the fibre input and \( \alpha_L \) is attenuation rate. By logarithmic transformation of eq. (1) the straight line \( \log P(L) = -\alpha_L L/10 + \log P(0) \) results. Slope of this straight line \( k \) can be used for calculation of mean attenuation rate \( \alpha_L = -10 k \) and intercept \( q \) can be used for calculation of illumination intensity on the fibre input \( P(0) = 10^q \). By using of regression straight line parameters \( k \) and \( q \), coefficient of determination \( R^2 \) and parameters \( P(0) \) and \( \alpha_L \) were calculated, see table 1.

For expression of working length of optical fibre \( L_p \) must be illuminating power \( P_{Lp} \) on the end of this length at sufficient value of attenuation coefficient \( \alpha_{Lp} \)

\[ P_{Lp} = P(0) 10^{-\alpha_{Lp}/10} \]  

(2)

Illuminating power \( P_{Lp} \) can replace \( P(L) \) in Eq. (1) and then working length of optical fibre \( L_p \) can be calculated

\[ L_p = \frac{10}{\alpha_L} \log\left(\frac{P(0)}{P_{Lp}}\right) \]  

(3)

Model curve of illumination intensity expressed as standard power function derived from assumption of constant rate of attenuation is shown in Fig.2 and Fig.3 as gray curve [1]. It was found, that at short distances from light source is illumination intensity strongly decreasing especially for optical fibres with higher diameter (higher than 1 mm). Estimation of parameters \( P(0) \) and \( \alpha_L \) is not accurate and standard power function (Eq.(1)) is not suitable for these purposes. Black piecewise solid line in Fig.1 is so called LLF2 model, it is linear piecewise function consist from two different straight sections. This model is based on the assumption that in short distances from light source there are some no uniformity in side emission due to accommodation to aperture and critical angle. In second phase the illumination intensity is slowly decreasing with distance from source \( L \) (system is accommodated). Local slopes of LLF2 are in fact sensitivity coefficients \( a_1, a_2 \). Corrected illumination intensity...
on the fibre input is $P_{cor}(0)$. LLF2 model is described by equation (it is in fact linear regression spline with one knot)

$$LLF2 = P_{cor}(0) + a_1L + a_2(L - L_c)$$

(4)

where function $(x) = 0$ if $x$ is negative and if $x$ is positive, function $(x) = x$. $L_c$ is distance of transition between first and second phase. By using of modified linear regression parameters of LLF2 for optical fibre.

### 3.1 Illumination intensity of braided tubes

For preparation of textile structures containing side emitting POF the braiding and weaving technology was used [6, 7]. The differences between side illumination of textile structure (braided tube) with POF and POF only are shown in Fig. 2.

![Fig. 2. Comparison of side illumination of standard POF and POF embedded into textile tube.](image)

Illumination intensity as function of distance from source for POF and the same POF embedded into textile tube are shown in Fig. 3. It is visible that POF in tube is producing higher side emission intensity.

![Fig. 3. Side illumination intensity of POF and POF in textile tube](image)

### 3.2 Line fibre light source for safety textiles

Incorporation of side emitting POF into fibrous tube is useful for creation active safety textiles which provide sufficient side emission especially for POF with larger diameters. These structures can be used for typical applications.

Examples of application of textile tubes with embedded POF for active visibility protective textiles are shown in Fig. 4.
4. Conclusion
Illumination system with light emitting diode (LED) was created and used as light source. Prototypes for evaluation of side emitting optical fibre illumination intensity was developed and tested. The system of data treatment and evaluation of result was proposed and checked. Parameter for evaluation of quality of illumination system as illumination intensity on the fibre input was proposed. Parameters characterizing quality of optical fibres as mean attenuation rate and working length were defined. It was found that illumination intensity and mean attenuation rate are function of distance from light source. Method for calculation of their sensitivity was proposed. Despite of considerable variation in the mean attenuation rate (till 240 mm from light source for fibre "Grace-standard") it is clear that the incorporation of these fibres into active safety textiles will provide sufficient emissivity especially in larger diameter fibres. It is also supported by the working length of fibres, which reach values about 2 m. Results of this work should be used for incorporation of optical fibres into woven and knitting textiles. According to results of this work, it is suitable to use POF in straight state or with macro-bends for active visibility textiles. It is better to create fibres with textile cover from durability point of view.

5. References
Current Developments and Future Trends in Turkish Textile Industry as a Global Player

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Abstract: Textile and clothing sectors are the leading sectors of the Turkish economy and foreign trade. These two sectors are also the most critical sectors in Turkey in terms of contribution to the gross domestic product (GDP), employment and exports. Textile sector had a 12,754 billion USD export value which corresponds to 8% share in total Turkish export volume in 2013. The share of Turkey in world total textile export is around 3.5%. The target value for textile export in 2023 is 20 billion USD. According to social security institution statistics, there are 18,434 textile companies in Turkey with more than 441,357 employees. In recent years Turkish textile industry has grown rapidly and shifted from low value added commodities to high value added products both in fashion textiles and technical textiles. Advantages of Turkey in using advanced technology, richness in raw materials and geographical proximity to main markets, especially to EU market, contributed to market diversification for textile exports. Approximately 75% of textile machinery are younger than 10 years. Existence of a well-developed textile finishing industry in Turkey makes also possible production and marketing of high value added, fashionable and high quality products. Meanwhile, technical textile production and product diversification is increasing in Turkey in parallel to the developments of world markets. Turkey has an adequate infrastructure in terms of new materials, current technology, know how and human sources to achieve development and growth in the technical textiles field. Turkey has shown great success in the technical textile production thanks to close cooperation between university-industry and governmental institutions and increasing importance given to R&D. At the moment there are some governmental R & D funding systems in Turkey. The participation rate to EU framework programmes are also increasing.

Keywords: Turkish textile, turkish technical textiles, turkish economy, technical textiles, textile exports.

1. General features of turkish textile industry

The Republic of Turkey, stretching from south-eastern Europe across the Anatolian peninsula in western Asia, has a very long textile manufacturing history. The past three decades have been a time of great change for Turkey as the country introduced a series of fundamental economic reforms. In the early 1980s, Turkey initiated a series of economic liberalization policies that shifted the country to a market-based economy by abandoning protectionist import substitution policies and opening the economy to global trade. Today, Turkey remains one of the world's most important textile manufacturing countries. Textiles and clothing are among the most important sectors of the Turkish economy and foreign trade. Accounting for about 7% of the GDP together, these two sectors are the core of Turkish economy in terms of GDP contribution, share in manufacturing, employment, investments and macroeconomic indicators. These sectors had a 18.3% share in total export volume in 2013. There are more than 52,000 textile and clothing companies in Turkey with more than 918,000 employees. Turkey is one of the main actors in the world clothing industry. Turkey ranks 8th in world cotton production and 4th in world cotton consumption. Turkey also ranks 3rd in organic cotton production after India and Syria. The Turkish clothing industry with a share of 3.4% is the 7th largest supplier in the world, and the 3rd largest supplier to the EU. It has a share of 4% in knitted clothing exports and it ranks 5th among the exporting countries. With a share of 2.8%, Turkey ranks 9th among the woven clothing exporters in the world. The Turkish textile industry, which is listed in the world's top ten exporters, is the 2nd largest supplier to the EU. In more than 30 years from 1980 to 2013, the production and export of the industry shifted from low value added commodities to high value added manufactured items and fashionable goods. With its qualified and educated human resources, design capacity, accumulation of know-how, investment in technology, dynamic and flexible production capacity, advanced sub industry in clothing sector, concern about quality, health and environment. The Turkish textile and clothing industry has a significant role in world trade with the capability to meet high standards, and can compete in international markets in terms of high quality and a wide range of products. There is a remarkable machinery capacity in the country and both textile and apparel industry use modern technologies in production. This makes also possible production and marketing of high value added, fashionable and quality products. The strong textile industry in Turkey also stimulated the development of the textile

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machinery industry. Nearly all the textile machinery used were imported until 1980’s when some local production of small and medium-sized low-tech machinery began. At present, the line of products manufactured by the companies varies substantially from highly automated equipment to basic models. Local producers are able to compete with foreign companies in most machinery categories. The majority of textile machinery manufacturers in Turkey range from small to mediumsized companies mainly located in Istanbul. The Turkish textile machinery manufacturers/exporters follow European and international standards and norms. It is obligatory to affix the “CE Mark” in the Turkish market.

2. Strength of Turkish textile industry

- High technology investments in machinery, equipment and buildings. Approximately 75% of textile machinery are younger than 10 years.
- Technically good equipped and modern production facilities.
- Wide spread of products in cotton base and man-made fibres.
- A good supply of raw material and investments for raw materials.
- Possibility to produce small lots and to adjust to the shorter cycles of the apparel industry.
- Long lasting relations with customers.
- No entry barriers in the EU-market (customs-union) and free trade agreements with different countries.
- Still competitive price levels in value added goods.
- An increasing domestic market.
- Highly qualified and well educated human resources.
- Strong textile educational and research institutions, increasing R&D activities, closer cooperations between university-industry in recent years (Currently there are 17 different universities in Turkey offering textile engineering education).
- A strategic geographical location, advantages in transportations.
- Compatible production with EU technical directives, paying more attention to environment and human health issues.
- Capability to produce fast fashion goods, just in-time production.

3. Weaknesses of Turkish textile industry

- Heavy export dependence.
- Limited "own" markets abroad.
- Cost competition with new developing countries.
- Limited growth potential in the main delivery markets.

Table 1. Turkish textile & apparel sectors by 2013.

<table>
<thead>
<tr>
<th></th>
<th>Number of companies</th>
<th>Number of work places</th>
<th>Share (companies)</th>
<th>Share (work places)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textile production</td>
<td>18,434</td>
<td>441,357</td>
<td>7.4%</td>
<td>13.3%</td>
</tr>
<tr>
<td>Apparel production</td>
<td>34,338</td>
<td>477,139</td>
<td>13.7%</td>
<td>14.3%</td>
</tr>
<tr>
<td>Textile + Apparel</td>
<td>52,772</td>
<td>918,496</td>
<td>21.1%</td>
<td>27.6%</td>
</tr>
<tr>
<td>Total production sector</td>
<td>250,678</td>
<td>3,327,336</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Source: Ministry of Economy

Table 2. Turkish textile machinery export.

<table>
<thead>
<tr>
<th>HS No</th>
<th>Product Name</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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<tbody>
<tr>
<td>6441</td>
<td>Machines for including, drawing, texuing or cutting man-made materials</td>
<td>7.0</td>
<td>2.2</td>
<td>6.0</td>
</tr>
<tr>
<td>6442</td>
<td>Machines for preparing textile yarn, spinning, doubling or twisting machines and other machinery for producing textile yarns, textile reeling or weaving (including full-width weaving machines)</td>
<td>53.0</td>
<td>30.0</td>
<td>19.5</td>
</tr>
<tr>
<td>6443</td>
<td>Weaving machines (looms)</td>
<td>14.9</td>
<td>5.4</td>
<td>10.4</td>
</tr>
<tr>
<td>6445</td>
<td>Knitting machines, stitch binding machines and machines for making groom point, flat, flat, embroidery, trimmings, thread or needle machines for knitting</td>
<td>19.1</td>
<td>14.8</td>
<td>16.5</td>
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<tr>
<td>6446</td>
<td>Auxiliary machinery (table support parts, etc)</td>
<td>33.0</td>
<td>27.3</td>
<td>35.5</td>
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<tr>
<td>6447</td>
<td>Machinery for the manufacture or finishing of felt or non-woven materials in the piece or in shapes, including machinery for making felt rolls, pieces for making felt.</td>
<td>0.5</td>
<td>1.2</td>
<td>1.9</td>
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<tr>
<td>6448</td>
<td>Machinery other than machines of heading (6445) for weaving, embroidery, knitting, stamp, weaving, printing, embroidery finishing, finishing, coating or impregnating textile yarns, fabrics or textile articles and machines for applying the paste to the base fabric or other support or cut in the manufacturing of floor coverings such as linoleum, machines for weaving, knitting, tufting, cutting or printing textile fabrics</td>
<td>145.3</td>
<td>190.0</td>
<td>216.3</td>
</tr>
<tr>
<td>6449</td>
<td>Sewing machines, other than lock stitch sewing machines of heading (6445) for sewing, tufting, tufting, cutting or printing textile fabrics</td>
<td>18.2</td>
<td>18.2</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>291.0</td>
<td>298.4</td>
<td>337.3</td>
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Source: Ministry of Economy

Fig.1. Textile & clothing export projection for 2023.

Source: Ministry of Economy
4. Turkish textile foreign trade

Figures 2 shows the increasing export values of Turkey between 2002 and 2013. The continuous increase trend can be seen here clearly. The same applies for the textile & clothing industries which can be seen from figure 3. Table 3 shows the position of Turkey between leading textile exporting and importing countries.

![TURKISH TOTAL EXPORT (BILLION USD)](image)

**Table 3.** Position of turkey in world’s textile exports and imports.

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**Fig. 2.** Turkish total exports

(Source: Ministry of Economy)

**Fig. 3.** Turkish textile exports & imports

(Source: Ministry of Economy)

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</table>

**Table 4.** Turkish technical textiles exports.

<table>
<thead>
<tr>
<th>HS Code</th>
<th>Product Name</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>Change 2012/13 (%)</th>
<th>Share 2013 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5605</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>226,670</td>
<td>213,516</td>
<td>208,123</td>
<td>2.5</td>
<td>17.6</td>
</tr>
<tr>
<td>560521</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>284,690</td>
<td>156,903</td>
<td>216,870</td>
<td>7.9</td>
<td>15.8</td>
</tr>
<tr>
<td>560522</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>199,049</td>
<td>158,903</td>
<td>160,604</td>
<td>-5.2</td>
<td>8.6</td>
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<td>560523</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
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<td>158,903</td>
<td>116,418</td>
<td>34.0</td>
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<td>560531</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>102,634</td>
<td>100,559</td>
<td>110,860</td>
<td>10.2</td>
<td>6.3</td>
</tr>
<tr>
<td>560532</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>309,338</td>
<td>136,903</td>
<td>163,443</td>
<td>-0.9</td>
<td>5.9</td>
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<tr>
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<td>86,866</td>
<td>100,026</td>
<td>-15.1</td>
<td>5.7</td>
</tr>
<tr>
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<td>2.4</td>
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<td>3.7</td>
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<td>Yarns, whether or not impregnated, coated, covered or braided</td>
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<td>84,603</td>
<td>43,835</td>
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<td>2.5</td>
</tr>
<tr>
<td>560537</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>62,222</td>
<td>54,704</td>
<td>23,375</td>
<td>-59.0</td>
<td>1.3</td>
</tr>
<tr>
<td>560538</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
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<td>18,512</td>
<td>22,999</td>
<td>24.0</td>
<td>1.2</td>
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<td>560539</td>
<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>20,362</td>
<td>22,707</td>
<td>21,802</td>
<td>-2.7</td>
<td>1.2</td>
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<td>Yarns, whether or not impregnated, coated, covered or braided</td>
<td>22,222</td>
<td>24,704</td>
<td>23,375</td>
<td>-59.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Source: Ministry of Economy

5. Future trends in turkish textile industry

Under the current world situation, Turkish textile sector is aiming at to produce high value added, original and high quality products and to sell them at competitive prices. Additionally in parallel to the current trends in the world, Turkey has shown great success in technical textile production thanks to close cooperation between university-industry and importance given to R&D. Of course, great experience of the country in textile production is one of the main advantages.

Technical and functional textile segment of the textile industry is growing rapidly in the world markets and it is expected to gain more importance in the coming years. These products are being used almost every field of our everyday lives. Agriculture, building technologies, geology, medical uses, ecology, packing industry, protective
and sportive clothing are the main fields where technical textiles are being used. Table 4 shows the main exports items of Turkey in the field of technical textiles.

Meanwhile, technical textile production and product diversification is increasing in Turkey in parallel to the developments of world markets. Turkey has adequate infrastructure in terms of new materials, current technology, know-how and human sources to achieve development and growth in the technical textile field. Technical textile investments in Turkey can be considered as “new”, but it is known that many companies are active in different fields. For example, the followings may be considered as the most prominent fields and products:

- Nonwoven fabrics and products,
- Tyre cords
- Special felts,
- Filtration materials,
- Products of automotive and packaging industries,
- Military clothes and equipments,
- Medical or antibacterial products,
- Protective clothing like bullet-proof jackets or heat resistant garments,
- Easy-care and non-iron fabrics and garments,
- Isolation materials,
- Multi functional fabrics

Turkish producers of technical textiles are generally small and medium size companies (around 170-180 companies). There are also some very large scale companies. These large scale companies are well known in the world markets. On the other hand, investments in the promising fields of technical textiles like nonwoven products and automotive textiles are increasing regularly.

6. Conclusion
Although there can be some problems arising in the textile industry in different time periods, the size and the character of this industry sector will allow it to survive for a long time in Turkey. This will be the reason of the dynamic structure of the companies and the great experience gained in a long period of textile production. The increasing export values and the new machinery investments are the main proof this forecast. According to the ITMF statistics Turkey is still in the top 5 short staple spindles investors (Fig. 4). There are also some new investments in the other machine categories.

Fig. 4. Shipped short staple spindles in 2012
Source: ITMF

7. References
Abstract: In 2010, Asia accounted for nearly 84 percent of spandex output, with the American continent and Europe accounting for the rest. China with a capacity of 399,000 tons per annum accounted for nearly 70 percent of the global 575,000 tons per year spandex output. The North American market is the biggest consumer of spandex in the world with a share of 53 percent, followed by Latin America with 10 percent, with Europe, China and other countries making up for the rest of spandex consumption. Indian usage accounts for just 2 percent of global consumption. India’s Spandex Growth Drivers
- India has been clocking 2nd highest growth rate in GDP.
- Use of, bare spandex yarn in knitting, core spun yarn, Air Covered Yarns (comprising of Polyester textured yarn, with spandex) in denim/ Formal suiting, shirting, intimate wear, casual wear, sports wear etc.
- Robust growth in the organized retail segment & branded clothing.
Above factors are leading to growth of spandex consumption @ 15% CAGR as compared to world’s expected growth of 7-8% per year.

1. Introduction
A new chapter unfolded in Indian Textile Industry with Indorama Industries Ltd, owned by Indorama Corporation, Singapore setting up a spandex yarn manufacturing unit under the brandname INVIYA in Baddi, Himachal Pradesh producing 5000 MT/annum since March 2012. Presently capacity expansion project is underway to achieve 11000 MT/annum by March 2016.

2. Advantages of Indorama INVIYA Spandex
- Long Term Sustainable Business
- No Currency fluctuation risk - as Spandex made locally available by IIL.
- No loss of shelf life - reduced transit time.
- Supply Various Products in one consignment.
- Assured consistent quality supply.
- In Time Door Delivery - Warehousing and distribution network all over India.
- Extended product range – Extensive Research and Development.
- Quick after sales service - by highly experienced and technically trained experts.
- Protection against changes in Market/Fashion by avoiding extra stocking

2. Applications
2.1 Life style
- Sportswear - Athletic, aerobic and exercise apparels
- Swim wears
- Bottom weight fabrics - Stretchable Jeans
- Top weight shirting & blouses
- Under wear
- Slacks & Leggings
- Socks
- Intimate garments - Shaped garments (bra cups)
2.2 Technical textile applications of Spandex
- Diaper
- Surgical hose
- Cycling shorts
- Rowing suit
- Home Furnishing
- Bed sheets

3. Products in which spandex is used
- Core spun yarn (CSY)
- Air covered yarn (ACY)
- Warp knitting (WK)
- Circular knitting (CK)

4. Conclusion
- Spandex production needs to consume about 13 to 15 different types of raw materials and all of them are imported. And the import duty is 7.5% to 10%, except two, on which the Govt. was kind enough, to reduce it to NIL, in the last Budget.
- There are other logistics, and financial cost, also this industry needs protection to make the dream come true of the Prime Minister as “Make in India”.
- The Govt. should encourage Spandex yarn industry, to reduce the cost, being a intermediary product, for textiles, to increase the consumption, as well as the value addition by taking all possible appropriate steps.
- Spandex yarn is becoming a very important raw material, as intermediary product, to produce all kind of textile items, and also gives lot of value addition in the textile products, for both domestic and exports.
- The end use of Spandex in India has great potential for it’s use in various segments in textiles and textile industry should invest in plant and machinery, to make best use of it.

5. References
Abstract: It is arguable whether it is Edward Thorp or Steve Mann, both pioneers using carried on body hardware, to be called the father of wearable computing. Back in the 1960's Thorp developed a wearable device designed to predict the motion of roulette wheels, while Mann is known for using head mounted camera and eye level display for over 30 years. Both were seeking to augment the human memory, computation ability and connectivity. These three qualities are the foundations of wearable computing in these days utilizing sensors, PDAs, and wireless communication to allow for humans to monitor and record their activity during the day and to allow data retrieval either for professional work or personal use and entertainment. Location based applications have a huge economic potential matching a person's location and known needs and preferences with relevant commerce, while social communication over networks (i.e. facebook, twitter, etc.) will greatly benefit from being always connected. Privacy as perceived today will no longer exist when all our activity, location, footage, and communication will be broadcasted to our social circles, data suppliers and credit card providers. Today, hand held devices, bracelets, and belts account for most of the wearable systems in the market while head mounted displays such as "google glass" start to take their share in the market with new mobile applications emerging daily. However, most of the apparatuses available today lack something to make it a really wearable technology. While wearing our clothes we expect them to perform without special attention and with minimal discomfort, the same is expected from Wearable Technology. When the technology allowing these advantages will be implemented and embedded within a wearable garment in a non-obstructing manner, true wearable systems will be made. Wearable technology garments will take care of our thrive for instant satisfaction for continuous communication, data mining, social sharing and other online activities. These garments will have to be fashionable, cost effective, washable, and mendable. The Textile industry will have to open itself toward new materials and production methods to allow for electronics integration, new fashion which is focused on communicating information, new designers and new markets. The early adapters of the wearable revolution among the textile manufacturers will benefit from being the market's leaders and setting manufacturing standards for the whole industry.

1. Introduction
For nearly 50 years, ubiquitous computing was sought after by individuals such as Eduard Thorp and Steve Mann who literately mounted hardware on themselves in order to achieve augmentation of the human memory, computation and ability to connect with the surroundings. The rapid advancement of hardware development and miniaturizing, as well as the emergence of mobile phones, made personal hand held devices available for a reasonable price. With multiple mobile sensors at the palm of our hand such as camera, compass, microphone, proximity, light, laser distance detector and more, many software applications are written daily to take advantage of all the data collected by these sensors. Miniaturizing the hardware paved the path for early research into wearable computing where electronics are either embedded into fabrics and clothes or fitted into devices that are worn (and not handheld) such as tiny screens on glasses, activity tracking bracelets, and other gadgets. Some of these apparatuses communicate wirelessly with a Smartphone or have their own connectivity with a data processing unit somewhere on the "cloud" and some collect data to be downloaded to a personal computer offline.

Although the term wearable computing is used widely for more than a decade, and many small scale research projects were carried out through the years, we are still looking for the Wearable Technology Revolution. According to market analysts, the market for wearables is growing faster than the rest of the IT industry and will reach between 20 Billions USD and 60 Billions by the end of the decade.
2. State of the art

Trying to review every single gadget on the market will be a little pretentious as new wearable developments are emerging daily. However, two main types of wearables can be defined today: gadgets worn on the body and textile garments with embedded electronics. The former account for the majority of devices available on the market as they take advantage of conservative electronics miniaturized to fit into reasonable sizes accepted by individuals to carry around all day. Activity recording bracelets are sold by many manufacturers such as Microsoft, apple, Samsung, Garmin and many others. These are designed in appealing visual appearance, light weight and can run off their internal batteries for a reasonable time of a few hours to a few days between recharging. Many companies invested in research for augmented reality glasses during the past ten years, Myvu, Mirage, Zise, and others had some kind of glasses that could project images on the device lancce visible only to the wearer. Google Glasses broke into the market mainly due to Google's marketing force rather than technology breakthrough. The hesitant acceptance of Google glasses can be accounted for lack of content, over pricing and most probably, the social problem associated with individuals who don't look you in the eye but are glancing up at their personal screen. It will take longer than expected for the society to accept many individuals wearing devices that take some of their attention of their conversation partner while giving them an edge by enhancing the wearer with instant accessibility to information.

Recently, Intel invested $24.8 million in Vuzix, a company that makes enterprise-grade smart glasses and in CES 2015 announced Curie, a button size processor specifically designed for wearable technology.

Fig. 1. Intel's Curie processor  
Fig. 2. Samsung Fit-Gear  
Fig. 3. Sensoria Fitness Sports Bra  
Fig. 4. BagirIpod Jacket  
Fig. 5. Myvu Glasses  
Fig. 6. TZI input glove, WearIT@work

Fig. 1-3 show some recent wearable technology for consumers and developers.  
Fig. 4-6 show development from 2006 through 2008.

The other category of wearable technology is where the electronics and sensors are embedded into the textile fabric or even the textile itself. The Sensoria Fitness sport bra shown in Fig. 3 and the Input glove from Fig 6 are examples of this category. Bagir's Ipod Jacket also includes a soft switch embedded in the fabric and a solid plastic Ipod cradle is sewn into the inner pocket.

Many research projects and manufacturing pilots were made with embedded electronics into the textile and few made it to be marketed. The later mainly include jackets with Ipod control and activity monitoring bras, shirts or chest-belts. Most of the major sports firms offer heart rate monitoring belts, some feature respiration monitoring as well. Some major running shoes offer pedometers embedded in the shoe sole with wireless communication to a Smartphone.

Embedding electronics into the textile can be made by weaving or knitting conductive threads into the fabric.
These conductive threads can be textile fibres plated with silver or other conductive metal, or made of metallic wire, usually copper, coated with insulated enamel. Conductive polymer based yarns are also available, however their conductivity is limited and they can be used mainly as sensors and cannot carry significant current to power any device or actuator.

The bare conductive textile yarns are used to transmit electric power within the fabric from place to place in order to connect electronics elements to each other. They can also be used as sensors, both by measuring difference in their electrical resistance when elongated and by closing a circuit. Being bare with no insulation makes these yarns vulnerable to wear and tear, to the elements and to washing. The metallic wire based yarns are more resistant to moisture but must be stripped in order to be electrically connected. Metallic wires are also more difficult to knit and weave. All types of conductive yarns can also be used as capacitive sensors by varying their electric charge when change in the dialectic field is occurred.

Wearable Technologies which can withstand washing are one step closer thanks to a technology which integrates electronic micro devices into yarns. Researchers at Nottingham Trent’s Advanced Textiles Research Group have integrated the electronics into the fibre by embedding sensors, smaller than the size of a pinhead, into the heart of the yarn. A garment was formed using light emitting diodes (LEDs) to showcase the application of the technology, which they say could transform the manufacturing of smart and interactive textiles. A “smart bed” is offered on the American market which not only monitors the child movements and respiratory during the night, but allows for the parent to interact with the bed turning on lights under the bed to help their youngsters coop with the darkness. Clothes with embedded LEDs and controllers were shown already in 2006 by Philips Lumalive (Fig. 11) and recently made a comeback in the latest CES in Vegas (Fig. 9). Was there a big progress in the last 8 years?

3. Challenges to the textile industry

Until these very days, most if not all of the commercially available smart textiles witch employ some embedded electronics are made by hand. Which means, the fabric is mostly machine made, with or without conductive yarns placed in desired positions. All the electronic elements, i.e. sensors, processors, communication modules, battery holders etc. and in some cases the wires also, are manually sewn or glued in position and electrical connections are manually made one by one. This manufacturing technique can not allow for mass production on one hand and raise conflicts between textile style manufacturing and electronics style. If in the textile industry a 3-5% tolerance is usually acceptable, the electronic industry will not tolerate such variations. The electronic
manufacturers, expect very tight tolerance in measurements for their automatic machines. The textile manufacturers, who wish to take part in the wearable technology revolution, will have to be open minded for the needs of the electronics manufacturers, will have to adopt new manufacturing methods and procedures to ensure exact fit to the rigid demands electronics. Another challenge is the washing and drying of electronics and of the conductive yarns used within the fabric. Fashion and Textile Designers will have to be educated to take into consideration implementation and integration of electronics into the fabric and garment. New designs will emerge utilizing the ability to change the visual effects of the garments interactively.

4. Conclusion
Embedded electronics within the garments that will free our hands from holding and operating these communication systems, allowing for truly wearable computing are just over the corner. Many companies as well as research institutes are developing new wearable technology garments and gadgets daily. The acceptance of wearables will increase as more people will start using them, and questions like "How many gigabyte are in your shirt" will soon sound normal to us. Health care businesses and homeland security organizations will be the first adaptors of the technology as both will see quick return for their investments, and the general public will enjoy more mature technology and better designed garments to follow.
Abstract: A novel method of producing electronic textiles is described where electronic functionality is achieved by incorporating semi-conductor chips into the core of textile yarns to create fibre electronics. This method ensures that the resultant textiles retain the desired textile characteristics of softness and flexibility and can be produced on conventional textile machinery with only minor modifications. Resin micro-pods are used to protect the active components to ensure that the resultant fabrics and garments can be machine washed and tumble dried. Examples are given of working prototypes that have been produced to demonstrate the technology.

Keywords: Electronic textiles, wearable devices, wearable electronics.

1. Introduction
The first generation of electrical equipment containing valves was bulky and somewhat fragile. In the second generation, transistors were packaged in smaller more robust boxes which led to the development of radios, TVs and ultimately the mobile phone. Now the integration of electronics within textiles promised to produce a quantum leap in the production of wearable devices. In early electronic textiles pre-packaged equipment was inserted into pockets. Later functionality, was introduced by incorporating electrically conducting yarns into fabric structures. There is now the potential to fully encapsulate integrated circuit chips within the fibres of textile yarns to provide a robust, inexpensive, flexible platform for a host of functions.

A United Kingdom government report stated the US market for Smart and Interactive Textiles was $70.9 million in 2006, and rose at an average annual growth rate of approximately 40% to $391.7 million in 2012. The US based Market Research Company, Markets&Markets, predicts that the total market revenue for Wearable Electronics is expected to reach over US$2 billion by 2018 growing at an estimated CAGR of 22%.

2. Materials and methods
Minute semi-conductor chips are connected to conducting filaments and inserted into the core of textile yarns. The chips are typically less than 500 microns in diameter. Fig.1 shows a light-emitting diode (LED) chip pictured among grains of salt.

![Fig. 1. LED chip shown next to grains of salt.](image)

The chips are then encapsulated within a resin micro-pod that protects the chip and interconnects during use and when the resultant textile is machine washed and tumble dried. An example micro-pod is shown in Fig. 2.
The technology can be used to produce a range of electronic textiles. There are numerous potential applications in areas such as retail, medicine, sports, fashion, defence, automotive and aerospace. The technology will lead to the integration of smart textiles into the internet of thing and ultimately clothing-based wearable computing. Clothing and other textile products will be able to sense, monitor, record changes in the surroundings and respond appropriately. The full integration of fully embedded RFID devices will enable textile items to be tracked through the supply chain and beyond. The market for fully embedded RFIDs is enormous with the potential to tag trillions of textile products. In addition to clothing, sensors in textile-based composites could provide lifetime monitoring of structures in the automotive and aerospace industries.

Prototypes have been produced using the technology. For example Fig. 3 shows an illuminated top. The appearance of the fabric is the same on both sides as the electronics are fully embedded within the structure.

Another application would be body temperature monitoring. Fig. 4 shows a temperature sensing armband with Bluetooth connectivity.
3. Results and Discussion

The electronic textiles produced using the new technology have been machine washed (Fig.5) and tumble dried and been shown to retain full functionality. The textiles retain the desired softness and flexibility and the embedded electronic components are not visible on either side of the resultant fabrics.

The next step is to produce a range of electronic textiles with greater functionality for a range of applications. In order to achieve this the Advanced Textiles Research Group at Nottingham Trent University has teamed up with the University of Southampton to work towards the integration of bespoke electronics.

4. Conclusions

The new method of producing electronic textiles has been shown to produce functional electronic textiles with the desired characteristics and demonstrators have been produced. The technology offers the potential of a large number of applications in many fields with high growth potential.
5. References
1. Technology and Innovation Futures, Technology Annex, BIS Foresight Horizon Scanning Centre, BIS/10/1252an. 
The Ethiopian Textile and Garment Sector: Present and Future Prospects
Sileshi Lemma and Fiker Tesfu
Ethiopian Textile Industry development Institute, Addis Ababa, Ethiopia
<fikeradi@gmail.com>

Abstract: Textile and Garment (TAG) sector is a major sector globally. Since the initial stages of global industrialization, TAG sector has remained at the forefront in generating employment and adding significantly to manufacturing output and exports for countries. The current global garment market is estimated at approximately US$ 1.15 trillion which forms nearly 1.8% of the world GDP. Almost 75% of this market is concentrated in EU-27, USA, China and Japan. From 2008 to 2013, the global textile and garment trade has grown at a CAGR of 4%. (FICCI 2014 TAG). Africa in general and Ethiopia in particular, have a lot of potential for growth of textile and apparel industry owing to availability of land at low rates, availability of good quality power at reasonable rates, cheap labor and duty free market access to all major markets in the world under various bilateral and multi-lateral agreements like African Growth and Opportunity Act (AGOA) with USA and Everything But Arms (EBA) with European Union. Ethiopia is current textile and garment export hits more than $120 MN annually. Before five years, this was only $23 MN. Currently Ethiopia imports about $650 MN annually textile and garment products majorly from India and China. The main constraints of the sector are poor human resource development system, insufficient industrial inputs and infrastructure, lack of well-established investment and technology development, poor market diversification and development and inadequate institutional support. The government is undertaking construction of mega hydro-electric power generating dams, industrial zones, roads and rail ways in addition to tapping up further potential in cotton. It is expected that these measures will enable the TAG sector to achieve milestones for the bright future.

1. Overview of textile and garment sector
Textile and Garment (TAG) industry can be attributed as the first organized industry when it grew out of the industrial revolution in the 18th Century. Countries like Britain, Italy, France, Japan, etc. had a thriving TAG industry during their initial phase of growth, which supported their economic growth. The same is true today for nations like Bangladesh, Vietnam and Cambodia. Since the output of TAG industry is a basic requirement for sustenance, the long term growth trend of industry had always been positive. However, production bases have kept shifting all along. Increase in manufacturing costs in developed countries, which were the main markets also, caused growth of TAG sector in Asian countries which had raw material advantage as well. Soon enough the manufacturing base spread to smaller nations, particularly those which got preferential access to major markets of USA, Europe and Japan. The Government of Ethiopia is pursuing Agriculture Development Led Industrialization (ADLI) strategy for development of the country. Textiles and clothing has been identified as one of the priority sectors for development with the objective of promoting exports.

2. Macroeconomic indicators of Ethiopia
- Second largest population in Africa with slightly over 80 million people.
- Fourth largest economy and second fastest growing economy in Sub-Saharan Africa.
- An average 11.2% annual GDP growth and 8.3% annual average real per capita growth over the last eight consecutive fiscal years.
- Average annual export was 13.6% by GDP (nominal) and annual average export growth was 29% over the last seven consecutive years.
- Industry contributes 13% to the GDP.

3. Investment opportunities in textile and apparel manufacturing in Ethiopia
- Textile manufacturing considered as number one priority sector by the governments industrial development strategy.
- Close geographic proximity to the EU and Middle East markets.
- Availability of some 2.6 million hectare of land and climate suitable for cotton cultivation, equivalent
to Pakistan the fourth largest cotton producer in the world, but only some 5 % utilized so far.

- Huge potential for organic cotton cultivation.
- Ethiopia, known as the water tower of Africa, provides one of the cheapest environmentally friendly hydroelectric power supplies in the world (5US cents/kwh). A very good source of energy for electric boilers in dyes-houses.

- Cheap and easily trainable unskilled labor force (wages 35 USD for low level, 100 to 200 USD for supervisory and up to 1500 USD for managers per month), less than Africa’s average.
- Skilled labor in the sector is increasing rapidly as a result of fast growing education and training institutions in textile technology; two institutes, a couple of textile engineering departments in different universities and a lot of TVET schools and private training institutions.
- Growing FDI investments, locals also giving an eye to the sector.
- Quota and duty free market access to the US and EU as markets. Also bilaterally to over 16 nations Including China, India, Turkey and Russia.
- One of the largest domestic markets in Africa.

4. Production capacity of Ethiopian textile and garment industry

Table 1. National attainable textile production capacity

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Sectors</th>
<th>Unit of measurement</th>
<th>Yearly Production (×100,000)</th>
<th>AAGR %</th>
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<td>Ginning</td>
<td>kg</td>
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<td>173</td>
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<tr>
<td>2</td>
<td>Spinning</td>
<td>kg</td>
<td>35</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>Weaving</td>
<td>Meter</td>
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<td>92</td>
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<tr>
<td>4</td>
<td>knitting</td>
<td>kg</td>
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</tr>
<tr>
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<td>Knitted</td>
<td>kg</td>
<td>27</td>
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<tr>
<td></td>
<td>processing</td>
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<td>6</td>
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<tr>
<td></td>
<td>garment</td>
<td>Number</td>
<td>35</td>
<td>56</td>
</tr>
</tbody>
</table>

*Yearly production is for 300 days.

5. Import and export

Ethiopia current textile and garment export hits more than $120 MN annually. Before five years this was only $23 MN. The growth rate is more than 400%. Currently Ethiopia imports about $650 MN annually textile and garment products majorly from India and China.

6. Main constraints of the Ethiopian textile and garments

- Poor human resource development system and shortage of highly qualified human resource
- Insufficient industrial inputs and infrastructure
- Lack of well-established investment and technology development
- Poor market diversification and development
- Inadequate institutional support and enterprise development

7. Future prospects

Besides the current promising performance of the textile and garment sector the future of the sector is even more attractive because of:-

- **Generation of hydro electric power:** Ethiopia is constructing a mega hydro electric power generating
Global Textile Congress, Bangkok, 13-15 Feb 2015

The Ethiopian textile and garment sector: present and future prospects
Sileshi Lemma and Fiker Tesfu

- Only the Renaissance dam can produce 6000 MW. As we will have double capacity of power generation from Gilgel Gibe hydro electric power III (~1600MW) by the coming year. This creates power stable supply with competitive price. The specific power cost rate is $0.06/kwh.
- **Un-tapped cotton potential:** From land of 2.6 million hectare favorable for cotton growing not more 5% is utilized.
- **Industrial zone:** another striking measure taken by the Ethiopian government is constructing Industrial zone in different areas of the countries. For leasing of factory within the industrial zone the lease year is 60 years and $1.25/SQM per year, the lease payment will be renewed every five years.
- **Roads and rail ways:** another big measure is constructing high ways and rail ways which networks the country to the port areas with shortest time. This also expected to be one of the pillars in booming FDI.

8. References
1. ETIDI reports.
2. Ethiopian textile and garment sector Growth and transformation plan 2 (GTP2) document
Abaya – a Barrier to Thermal Comfort in Hot Environment

Lijing Wang1 and Salwa Tashkandi1,2

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Abstract: The abaya is a black outer garment mandated to be worn by all women (especially Muslims) in Saudi Arabia when they are outside their homes. It is designed to cover the whole body and reveal only the face, feet and hands. The black abaya absorbs most of the heat from sunlight in a hot climate. Multiple layers of clothing worn underneath the abaya add more thermal stress. Hence, abaya tends to make the wearer very uncomfortable in hot environments. This paper summarises findings of abaya thermal comfort performance from recent publications by the authors. It first presents an overview of the types, variety and comfort of abayas through a survey in Saudi Arabia regarding the issues of thermal discomfort associated with the current type of abaya. It then reports results of objective evaluations of the thermal performance of abayas as well as their constituent woven and knitted fabrics. The results indicate that the abaya type, fabric structure, fibre composition, fabric weight and fabric thickness all greatly influence their thermal comfort performance. The fabric physical properties related to the heat transfer and moisture management of abayas were also evaluated with a female sweating thermal manikin. The outcome of the research confirms that the wearing of abayas causes discomfort in hot environments.

Keywords: Abaya, clothing comfort, thermal manikin, muslim women dress.

1. Introduction

The basic requirements of mankind are clothing, food and housing and transportation, among which clothing is on the top of the list. Clothing provides a portable environment maintaining human body comfort. It also imparts aesthetic appeal and indicates the wearer’s character and identity. Religious dress is acknowledged as a means of visual communication that reflects the wearer’s beliefs in certain religious principles and practices. Many Islamic societies expect a girl to wear clothing covering her body, hair and neck once she attains physical maturity.

Muslim women in the Arabian Gulf region show their modesty and deflect male attention by wearing abaya, an Islamic outfit that should be worn with a light and long veil/scarf wrapped in a way that completely covers the head, neck and hair. Statistics reveal that 49.7% of women in Saudi Arabia aged over 10 years (an estimated 9.5 million females) wear the abaya [1]. The abaya signals that the wearer is a devout Muslim and there is a tacit cultural agreement that men should accord abaya-clad women respect and distance.

Modern consumers aim for certain features of clothes that need to be ethical as well as comfortable. Comfort refers to physiological, psychological, and physical aspects of comfort and is a pleasant state of harmony between the body and the environment, freedom from discomfort. Clothing thermal comfort is an intimate environment maintained by the clothing through the heat interchange and moisture transfer processes between apparel and the outside environment in which the wearer is in. In view of the extreme climate in Saudi Arabia, with a summer daytime temperature occasionally exceeding 45°C, wearing an abaya can be uncomfortable.

2. Thermal comfort issue of abaya in hot environment

In hot environments, the garment should ideally be able to release heat from the body to the environment. The black abaya is considered the most conservative way for women to dress in the Arabian Gulf. However, black garment absorb more solar heat, adding heat stress in hot summer. A survey conducted by the authors revealed that the degree of discomfort depends on the type of the abaya fabric and design as well as the type of clothing worn underneath the abaya. Most abayas were made from woven fabrics that masked female body contours and synthetic fibres (polyester) were mainly used because they have high strength and resistance to stretching with low wrinkle and shrinkage and are easier to care for. The preferred abaya fabrics are of medium thickness, lightweight, dark shades, opaque and with a tightly woven structure. Such fabrics could slow heat dissipation from the body to the environment.

Women wearing abayas with multilayers of clothing perspire a lot. Jeans or slacks with shirt were commonly worn underneath the abaya, though short sleeves or sleeveless dresses increased the comfort. Slacks provided the freedom of movement compared to other clothing such as skirts. Abaya forms a barrier to thermal comfort in hot
environment, and several layers of clothing underneath an abaya caused more heat stress in hot environment. This paper presents some results from recent thermal comfort studies on abaya fabrics and garments [2-8].

3. Properties of abaya fabrics
Most of abaya fabrics are lightweight, medium thickness and opaque. Table 1 shows that abaya fabrics can have a wide range of properties. The average value of the fabric drape coefficient (DC) considered to be suitable for abayas is between the limp and medium fabric drapability. In other words, abaya fabrics should not be too drapeable to reveal body contours or too stiff to affect esthetical appearance or obstruct body movement. Comparing similar data for woven fabrics (Table 1), the preference was that most of the knitted abaya fabrics should be thicker and heavier, which may lead to thermal discomfort in hot weather.

The high air permeability of abaya fabrics shown in Table 1 helps to remove heat from body in hot conditions. All the abaya fabrics studied in Table 1 had low resistance to moisture transfer and the overall moisture management capacity of these fabrics ranged from poor to very good. Based on the Hohenstein Institute's Comfort Rating System [9], the abaya fabrics are extremely breathable and comfortable at higher activity rate. An investigation was conducted to compare the suitability of knitted fabrics for abayas [7]. It was found that different knit structures such as interlock, single jersey and double jersey appear to be suitable for abayas and their performance is comparable to the woven fabrics (Table 1). However, knitted fabrics are normally not as dimensionally stable as woven fabrics and knitted abayas could reveal body contours. This could be avoided by using thicker fabrics with a heavier mass per unit area, which may cause thermal discomfort.

The thermal resistance of fabric mainly depends on the resistance offered by the entrapped air within the fabric and the inherent thermal resistance of fibre content [10]. Air is known to be less heat conductive as compared with any textile fibre, so the amount of trapped air pockets very much influences the overall thermal resistance of abayas. Despite the favourable comfort performance of abaya fabrics, abaya still caused heat stress in hot conditions.

<table>
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<th>Table 1. Abaya fabric properties [5,7].</th>
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<td>Fibre composition</td>
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<td>Fabric thickness (mm)</td>
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<td>Fabric weight (g/m²)</td>
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<td>Water vapour resistance (m² Pa/W)</td>
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<td>Overall moisture management capacity</td>
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| Fibre composition | 100% nylon, 50/50 wool/nylon, 96/4 polyester/elastane, 65/35 polyester/cotton, 100% wool |
| Knit structure | Interlock, Single jersey, Double jersey |
| Blend ratio | Various |
| Fabric thickness (mm) | 0.5-1.15 |
| Fabric weight (g/m²) | 127-349 |
| Cover factor (mm tex) | 0.95-1.78 |
| Drape coefficient (%) | 20-50 |
| Air permeability (ml/cm²/s) at 50Pa | 16-85 |
| Thermal resistance (m². °C/W) | 0.03-0.034 |
| Water vapour resistance (m² Pa/W) | 1.8-5.0 |
| Overall moisture management capacity | 0.00-0.75 |
4. Thermal comfort performance of abaya garments

A female sweating thermal manikin dressed with daily wear clothing and one of three abaya designs (Figure 1) was used to determine the physical values related to the heat transfer and moisture management properties. The study [3,4] concluded that among the types of abaya design evaluated, the abaya worn on the head offered slightly higher thermal and evaporative resistance than those worn from the shoulder with tight or loose sleeves. In addition, abaya combinations in woven fabric could be slightly more comfortable than knitted abaya combinations, although the abaya itself contributes heavily to thermal stress in hot weather. These results highlight the importance of the air trapped in the microclimate between the body and garments on thermal comfort properties.

Fig. 1. The female thermal manikin with: a) underwear; b) underwear, long sleeve shirt & skirt; c) underwear, long sleeve shirt & slacks; d) abaya worn from shoulder with tight sleeves & scarf; e) abaya worn from shoulder with loose sleeves & scarf; and f) abaya worn from top of the head with tight sleeves & scarf.

Fig. 2 shows examples of the effect of wearing abaya over the daily wear clothing. The heat loss through the daily wear clothing and abaya combination was much lower than that through only the daily wear clothing, in particular in the head and torso areas. The low heat loss in the head area is because of the contributions provided by the scarf component and the air layer between the skin and the scarf. The scarf was wrapped in two layers around the head while there was no scarf in the daily wear clothing. The torso was covered with more layers (abaya and scarf), resulting in higher thermal insulation than the daily wear clothing only, and hence reduced heat loss. The multilayers of fabric in the chest area create high thermal resistance and hence more heat stress.

It is clear from Figure 2 that the woven abayas had similar, if not lower, insulation than the knitted abayas. This could be because the woven abaya fabrics were lightweight and thinner which results in a slightly lower thermal resistance value than knitted abaya fabrics. Nevertheless, the knitted abaya fabrics tended to insulate more heat than the woven fabrics. In terms of design, thermal resistance of the abaya worn on head is significantly higher than that worn from the shoulder with tight sleeves or loose sleeves [2], because the former has three layers, two from the scarf and the third one from the abaya worn on head. Due to the multiple layers of scarf and abaya, heat stress in the neck area of the body is predominant.

Abaya hangs from the shoulders, and this might block the air ventilation between the garment and the body. In addition to covering the female convex body geometry, the abaya was shaped to fit loosely in the chest area, which creates more air gaps, resulting in higher thermal insulation. It is certain that wearing an abaya as an outer layer reduces heat loss from the body and can lead to discomfort in hot environments.

When fabrics are made into clothing, the air gaps between the skin and clothing influence the heat transfer more than the intrinsic thermal insulation of the fabrics. Therefore, the fabric selection for abayas appears less important than abaya design. However, sometimes when the weather is very hot, women wearing sleeveless tops should feel more comfortable in the abaya because abayas are sometimes worn next to skin and should be able to transfer moisture to the outside environment as well. Nevertheless, an abaya is a barrier to thermal comfort in hot environment.

5. Conclusion

The abaya fabrics were mainly woven structures and made from polyester and its blends. Though the current abaya fabrics may have good properties as comfortable textile material, this does not imply that abaya garments will be thermally comfortable in hot climates. Wearing an abaya with multilayers of clothing creates problems of...
feeling uncomfortable in many circumstances. The skirt ensemble of daily wear clothing had higher thermal and evaporative resistance than the slacks ensemble in the stationary standing mode of manikin testing. Irrespective of the type of abaya, the thermal resistance in the abaya combinations were higher than for the daily wear clothing ensemble by itself. An abaya is a barrier to thermal comfort in hot environments.

![Diagram of Daily Wear Clothing and Abaya Combinations](image)

**Fig. 2.** Dry heat losses (w/m²) of daily wear clothing with and without abaya of different designs in the stationary mode [4].

6. References


