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Development of shrink resistance cotton using fluorocarbon

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Abstract

An attempt has been made to develop shrink resistance cotton textile by making it hydrophobic. The cotton fabric was made hydrophobic by treating with fluorocarbon resin emulsion at varying concentrations along with catalyst. The hydrophobicity was measured by carrying out water repellency test and also determining the water contact angle. The air permeability of cotton fabric was also determined and was not adversely affected. The untreated and treated cotton fabric was subjected to repeated domestic laundry condition and shrinkage was measured. In order to determine the impact of fluorocarbon treatment on fabric, the physical properties of treated and untreated cotton fabrics were compared. No adverse impact was observed in colour fastness properties. The tensile and tear strength showed good retention even at higher concentration of water repellent chemicals. This work finds wide use in home textiles and hotel industry. This work is of industrial interest as value added shrink resistance cotton textiles can fetch more export earnings.

Keywords: Hydrophobic, Cotton, Shrink resistance, Water contact angle, Water repellency

Introduction

Among cellulose fibres, cotton is still the most popular fibre because of its several advantages. Since cotton readily absorbs moisture, it is susceptible towards shrinkage. The moisture is absorbed in the amorphous region of cotton, water molecules then act as lubricant and helps in movement of internal polymer chains. The movement of internal polymer chains are facilitated by disrupting the hydrogen bonding among polymer chains in amorphous region. In order to relieve stress in a stressed cellulose fibre, the internal polymer chains of the amorphous areas move freely. The new hydrogen bonds are then formed in the swollen state of cellulose in new configuration in the amorphous region and are locked after drying. Therefore the wrinkled appearance of the cellulose fabric persists even after drying, in contrast to non swelling synthetic fibres (Lam et al. 2011) and also the fabric shrinks (Schindler and Hauser 2004).

The self cross linking agents like urea or melamine products helps in inhibiting swelling of cellulosic fibres when moisture is absorbed. It further prevents cellulose fibres to absorb moisture above 10%.

To produce non-swelling, durable press or shrink resistance cellulose fabrics, the following two different chemical approaches have been used. The first approach is to block the pores of the fibres by incorporating polymeric finish. It inhibits the penetration of water. The second approach is using multifunctional cross linking agents. The multifunctional cross linking agents reacts with the hydroxyl groups of nearby cellulose molecules thereby hindering the swelling of the cellulose fibre (Shahin et al. 2009; Lacasse and Baumann 2004).

The cross linking agents adversely affect the physical properties. The adverse effect of cross linking agents is that they reduce elasticity and flexibility of cellulosic fibres after reacting with hydroxyl group of cellulose. The reduction in elasticity and flexibility of cellulosic fibres gives rise to poor abrasion resistance and tensile properties. Other disadvantages are: stiff handle, release of formaldehyde, poor light fastness, shade change after finishing and objectionable fish odour (Schindler and Hauser 2004).

In the present study, a new approach has been explored in which the cellulose has been made hydrophobic using fluorocarbon polymer. The hydrophobic cellulose repels water and inhibits its penetration even in amorphous region. Consequently, inhibiting the internal polymer chain movements and swelling of cotton fibres. This will result in development of shrink resistance cotton textiles.

The super-hydrophobic surfaces can be seen in abundance in nature. The wings of butterflies (Chen et al. 2004; Genzer and Efimenko 2006), the feet of water striders (Gao and Jiang 2004), and the leaves of plants (Cheng et al. 2006; Koch et al. 2009) are few examples. The development of techniques like, Scanning electron microscopy, transmission electron microscopy and atomic force microscopy have made it possible to study the surface morphology at ultra micro scale and find out the possible explanations for super-hydrophobicity. The conclusion drawn is that both low surface energy and nano-roughness contribute directly to attain super-hydrophobic character. Any solid surface will exhibit wettability and repellency behaviour, depending upon the surface energy and roughness of material (Cassie and Baxter 1944; Genzer and Efimenko 2006; Koch and Barthlott 2009; Nakajima et al. 2001; Sun et al. 2005; Wenzel 1936).

The water contact angle (WCA) at the liquid/solid interface on any solid surface determines its hydrophilic and hydrophobic characteristics. If WCA at the liquid/solid interface, becomes lower than 90°, the surface becomes hydrophilic (water loving). On the other hand, if WCA becomes higher than 90°, the solid surface becomes hydrophobic (water hating). However, any solid surface will attain super hydrophobic characteristics, if WCA is greater than 150° (Song and Rojas 2013).

In the present work, an attempt has been made to impart hydrophobicity to cotton fibre so that water molecules when come in contact with cotton fibre can be repelled. To impart hydrophobicity to cotton, water repellent fluorocarbon polymer with C8 chemistry has been used.

Methods

Materials

The plain weave fabric used for experimentation was of two types; 100% bleached cotton and 100% reactive dyed cotton having weight of 145 g/m^2 without application of any finishing chemical.

The water repellent chemical used was fluorocarbon resin emulsion with C8 chemistry, supplied under the trade name of Bioguard 581X by Biotex Ltd., Malaysia along with Biocat M as universal catalyst.

Preparation and Characterization

Application of water repellent chemical

100% bleached cotton fabric was padded with solutions of 10, 20, 30, 40, 50 and 60 g/L, Bioguard 581X along with catalyst, Biocat M with concentrations varying from 2, 4, 6, 8, 10 and 12 g/L respectively, at pH 5 to 6 using acetic acid. The following padding conditions were used to get 80% pick up:

Mangle pressure: 4.5 bar.

Speed: 2.50 m/min.

After padding, the treated fabric samples were dried in Shirley Development Limited (SDL),—Mini dryer at 150 °C for 2 min followed by curing at 185 °C for 1 min.

The 100% dyed cotton fabric sample was treated with 60 g/L, Bioguard 581X along with 12 g/L Biocat M catalyst at pH 5 to 6 maintained using 0.5 g/L acetic acid. The padding conditions like mangle pressure, speed and % wet pick up was same as above.

Determination of wet pick up

The wet pick up of 100% cotton fabric was determined, at different pressure readings (2, 3, 4 and 5 bar) at constant mangle speed of 2.50 m/min, using two bowls laboratory vertical padding mangle, manufactured by Mathis, Switzerland.

The wet pick up was calculated by calculating the weight difference of wet and dry fabric and expressed in percentage on the basis of weight of dry fabric. The padding mangle pressure of 4.5 bar, was used to get 80% pick up in the application of water repellent chemical.

Determination of water repellency (WR)

The WR of bleached cotton fabric samples were determined employing SDL water spray tester using AATCC Test Method 22-2001.

Determination of durability of WR effect

The durability of WR effect of bleached cotton fabric samples treated with various concentrations of fluorocarbon were determined by subjecting to 10 washing cycles employing DIN EN ISO 6330 standard for domestic laundry using launderometer supplied by Mesdan Lab, Italy.

After completing 10 washing cycles, the water repellent efficacy test was done employing SDL water spray tester using AATCC Test Method 22-2001.

Determination of WCA

The WCA of water repellent cotton fabric samples were determined by spreading cotton samples on flat table. One fine drop of water was placed on fabric samples using medical syringe of 0.5 mL capacity. The pictures were taken using Kodak 15X Zoom camera. Horizontal and tangential lines were drawn on pictures and WCA were measured using protractor.

Determination of shrinkage of untreated and treated cotton samples

The shrinkage of untreated and treated bleached cotton samples were determined employing DIN EN ISO 6330 standard for domestic laundry using launderometer made by Mesdan Lab, Italy.

Determination of air permeability

The air permeability of various untreated and treated samples were determined using FX 3300 type calibrated air permeability tester supplied by Textest AG, Switzerland employing ASTM D737-96 method.

Determination of colour fastness to washing

The colour fastness to washing of both untreated and treated dyed cotton fabric samples were tested employing ISO-2 test using launderometer supplied by Mesdan Lab, Italy.

Determination of colour fastness to crocking

The colour fastness to crocking of both untreated and treated cotton fabric dyed samples were tested employing AATCC Test Method-8-2004, using Crock meter supplied by Mesdan Lab, Italy.

Determination of colour fastness to perspiration

The colour fastness to perspiration of both untreated and treated cotton fabric dyed samples were tested employing ISO 105-EO4 1994 (Acid and Alkaline perspiration) using Perspirometer supplied by Mesdan Lab, Electrical Heat Thermostatic Culture Box., Model DH-4000B, Italy.

Determination of colour fastness to light

The natural sunlight source was used for determining the colour fastness towards light of both untreated and treated cotton fabric dyed samples.

All the eight blue wool standard samples were exposed to natural sunlight source along with untreated and treated cotton fabric. The light fastness rating was given comparing the fading of blue wool standard number and tested samples placed parallel to blue wool standard.

Determination of tear strength

The tear strength of both untreated and treated cotton dyed fabric samples were determined after conditioning at 65% relative humidity (RH) and at temperature of 20 ± 1 °C, employing ASTM D 1424 method, using SDL, Atlas M008E Digital Elmendorf Tester.

Determination of tensile strength

The tensile strength of both untreated and treated cotton dyed fabric samples were determined after conditioning at 65% RH and at temperature of 20 ± 1 °C, employing

ISO-13934/1-EN 13534/1, using Fabric Traction Strip method with Tenso Lab Strength Tester, Mesdan Lab, Italy.

Results and discussion

Effect of fluorocarbon concentration on WR of cotton

In order to make cotton hydrophobic, the bleached cotton samples were treated with various concentration of fluorocarbon emulsion along with catalyst. The results are given in Table 1 (water repellency of cotton fabric before and after domestic laundry).

The description of spray test rating as per the pictures on standard chart (AATCC Test Method 22-2001) is given below:

100—no sticking or wetting of upper surface; 90—slight random sticking or wetting of upper surface;

80—wetting of upper surface at spray points; 70—partial wetting of whole of upper surface;

50—complete wetting of whole of upper surface; 0—complete wetting of whole of upper and lower surfaces;

The spray test rating of 100 before wash, indicates that there was no sticking or wetting of upper surface by water even at lowest concentration of 10 g/L fluorocarbon. However, after 10 washes, a rating of 90 was obtained showing that there was slight random sticking or wetting of upper surface with water at 10 and 20 g/L fluorocarbon only. This clearly indicates that hydrophobicity of cotton fabric was maintained even after 10 washes at almost all concentrations of fluorocarbon.

WCA of fluorocarbon treated cotton before and after 10 washes

As described in introduction, hydrophilic materials are water-loving substances with WCA lower than 90° while hydrophobic ones are water hating, displaying a WCA higher than 90°. The super-hydrophobic characteristics are attained when the WCA is greater than 150°.

It can be seen from Fig. 1 that WCA of treated cotton fabrics are above 90° indicating that cotton fabric has become hydrophobic and its hydrophobic behaviour has also been sustained even after 10 washes. Another observation is that WCA are almost constant between 123° and 127° before and after 10 washes. It shows increase in concentration of fluorocarbon from 20 to 60 g/L have minimal impact on hydrophobicity of cotton.

Table 1 Water repellency of cotton fabric before and after domestic laundry

Concentration of fluorocarbon (g/L)	Water repellency spray test rating	
	Before wash	After 10 washes
10	100	90
20	100	90
30	100	100
40	100	100
50	100	100
60	100	100

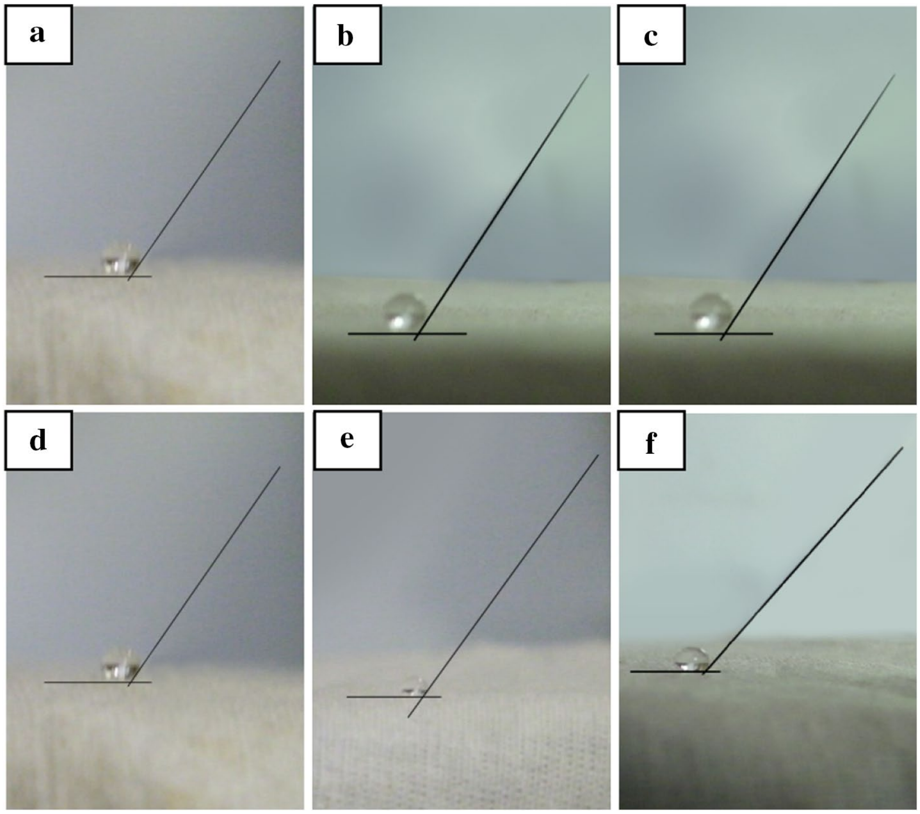

Fig. 1 WCA of treated cotton with fluorocarbon at 20 g/L, 40 g/L and 60 g/L before and after 10 washes. **a** 20 g/L—unwashed-WCA (123°); **b** 40 g/L—unwashed-WCA (123°); **c** 60 g/L—unwashed-WCA (127°); **d** 20 g/L—10 washes-WCA (125°); **e** 40 g/L—10 washes-WCA (126°); **f** 60 g/L—10 washes-WCA (127°)

Shrinkage behaviour of hydrophobic cotton

It can be seen from Fig. 2 (warp wise shrinkage of untreated and treated cotton with fluorocarbon) that the shrinkage in warp direction increased with increase in number of washes. The shrinkage became almost constant after seven washes. The untreated cotton showed shrinkage of 9.5% after 8 washes. However, the fluorocarbon treated cotton showed shrinkage varying from lowest 3.5% (at 60 g/L) to maximum 5% shrinkage (at 10 g/L) treatment. The fluorocarbon treated cotton samples from 20 to 50 g/L showed shrinkage varying from 4.0 to 4.5%. About 58% to 53% reduction in shrinkage has been observed in treated cotton samples at varying concentration of fluorocarbon (20 to 50 g/L).

The weft direction shrinkage is shown in Fig. 3 (weft wise shrinkage of untreated and treated cotton with fluorocarbon). The weft direction shrinkage became almost constant after 2 washes. The untreated cotton showed maximum shrinkage of 2.5% after 2 washes. However, the fluorocarbon treated cotton showed shrinkage varying from 0.5 to 1.0% at various concentrations of fluorocarbons. This 0.5% variation in shrinkage was probably due to the uneven stress applied in the cotton fabric because of uneven tension exerted. About 60% to 80% reduction in shrinkage has been observed in treated cotton fabric samples at varying concentration of fluorocarbons.

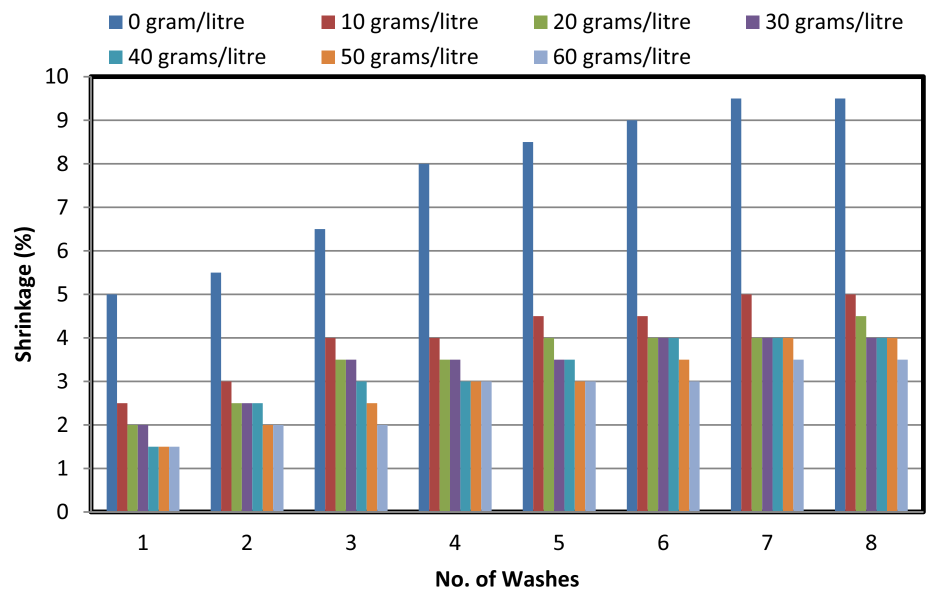

Fig. 2 Comparison of warp wise shrinkage of untreated (0 g/L) and treated cotton with fluorocarbon at 10 to 60 g/L. Warp-wise shrinkage of untreated and treated cotton

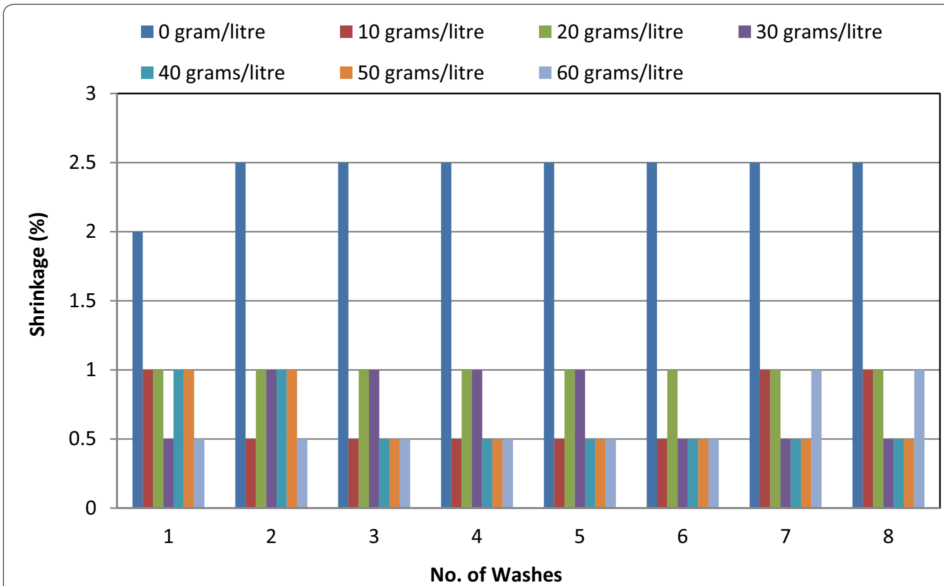

Fig. 3 Comparison of weft wise shrinkage of untreated (0 g/L) and treated cotton with fluorocarbon at 10 to 60 g/L. Weft-wise shrinkage of untreated and treated cotton

Air permeability of untreated and treated cotton with fluorocarbons

The air permeability results are shown in Fig. 4 (air permeability of untreated and treated cotton with fluorocarbon at varying concentrations).

The above figure shows that from 0 g/L (untreated cotton) to 40 g/L fluorocarbon treated cotton samples, the air permeability varied from 40 to 44 Pa. It indicates that air permeability/breathability of treated cotton fabric was closer to untreated cotton.

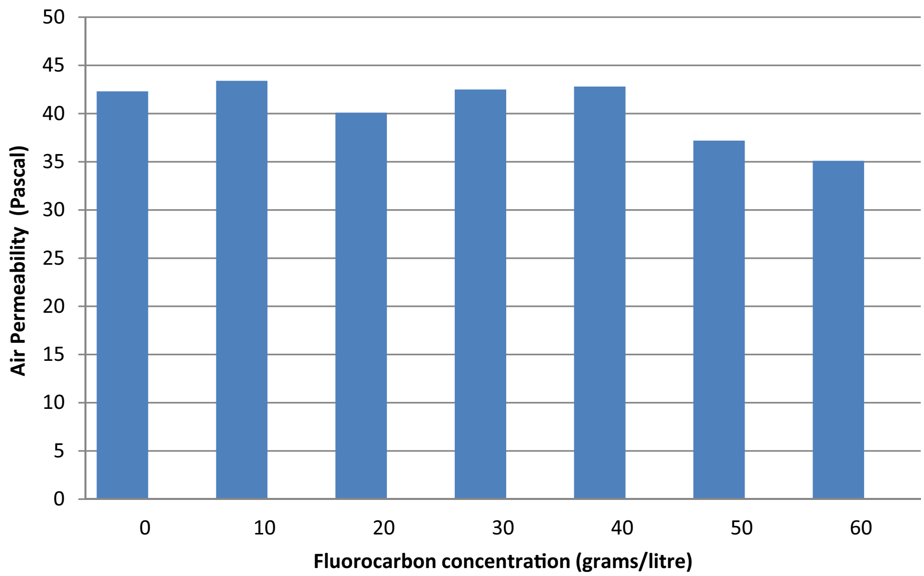

Fig. 4 Comparison of air permeability of untreated (0 g/L) and treated cotton with fluorocarbon at 10 to 60 g/L. Air permeability of untreated and treated cotton

However, at 50 to 60 g/L of fluorocarbon, little deterioration was observed. This further shows that no continuous film of fluorocarbon polymer was formed and porosity of fabric was sustained.

Comparison of colour fastness and physical properties of untreated and treated dyed cotton fabric

In order to compare, various colour fastness and physical properties of untreated and treated cotton fabric, the dyed cotton fabric was treated with highest concentration of fluorocarbon (60 g/L). The reason for selection was that if the tested properties are comparable at this concentration of fluorocarbon, the properties will remain comparable at lower concentration of fluorocarbon also. The results as shown in Table 2 (comparison of fabric properties between untreated and treated dyed cotton) are self explanatory and shows no significant change in properties except little deterioration in tensile and tear strength (below 10%).

Conclusions

It has become possible to produce shrink resistance cotton textiles by making it hydrophobic using fluorocarbon polymer. The desired shrinkage results can be achieved even at lower concentration (10 to 20 g/L) of fluorocarbon. The spray rating test before and after ten washes (100 and 90 respectively) and WCA (above 120°) confirm the hydrophobicity of cotton. The water repellency imparted to cotton inhibits penetration of water in its amorphous region thereby resisting shrinkage.

The reduction in shrinkage 50% and above (in both warp and weft direction) is possible, in comparison to untreated cotton even after eight domestic washes.

The air permeability test indicated that breathability of untreated and treated cotton fabric is similar.

Table 2 Comparison of fabric properties between untreated and treated dyed cotton

S. no.	Parameters	Untreated dyed fabric	Treated dyed fabric
1	Colour fastness to washing		
	Change in colour	4 to 5	4 to 5
	Staining on adjacent fabric	4 to 5	4 to 5
2	Colour fastness to rubbing		
	Staining on adjacent fabric		
	Wet rubbing	4 to 5	4 to 5
	Dry rubbing	4 to 5	4 to 5
3	Colour fastness to perspiration		
	Acidic		
	Change in colour	4 to 5	4
	Staining on adjacent fabric	4 to 5	4 to 5
	Alkaline		
	Change in colour	4 to 5	4 to 5
	Staining on adjacent fabric	4 to 5	4 to 5
4	Colour fastness to light	> 3	> 3
	Change in colour		
5	Tensile strength (Newtons)		
	Warp	256	236
	Weft	240	224
6	Tear strength (Newtons)		
	Warp	37.85	35.10
	Weft	37.52	34.34

The fabric properties of untreated and treated dyed cotton fabrics (60 g/L, fluorocarbon) were found similar in terms of various colour fastness and tear and tensile strength indicating no deterioration of fabric performance.

Abbreviations

WCA: water contact angle; SDL: Shirley Development Limited; WR: water repellency; RH: relative humidity.

Authors' contributions

AK did literature search and brought forward the concept of developing shrink resistance cotton using fluorocarbon. He further planned all experiments. He along with AF written "Introduction", "Results and discussion" and "Conclusions". AH get it performed all the planned experiments. He also made all graphs All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

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