Automotive Textiles

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Abstract

The automotive industry is one of the most important segments of global economy and employment generation. The industry has a turnover of more than USD 35 bn and provides direct and indirect employment to over 13 mn people in India. Based on the information gathered from various published data, this article attempts to review need and effect of specialty dyes and chemicals during processing of Polyester textile fabrics used in upholstery and other visible car interiors.

Key words – Automotive, technical textiles, disperse dyestuffs, uv resistance, light fastness

Introduction

Since the first automobile built by Karl Benz in 1885, the industry has rapidly grown over last 125 years of its existence. This industry primarily relates to the designing, manufacturing and selling of motor vehicles and in turn depends on supporting segments like rubber, glass, steel, plastic, aluminum, textile and other accessory part suppliers.It is estimated that over 75 mn motor vehicles were manufactured globally during 2011, out of which about 60 mn were passenger cars. India ranked 6th in the global automotive manufacturing countries with annual production of about 3.9 mn units and is expected to continue its growth at 16 to 18 % per annum. According to the Society of Indian Automobile Manufacturers, annual vehicle sales are projected to increase to 5 mn by 2015 and more than 9 mn by 2020.

Textiles in Automotive Industry

The non apparel, technical textiles form a part of automobiles interior in the passenger cars, especially in the premium segments. Textiles are used in terms of aesthetics of visible components - seat cover upholstery, head-lining, door panels, parcel shelf, carpeting, as well as in terms of concealed / safety components – airbag material, air/fuel filters, hoses and safety belts. Generally, it is estimated that about 12-15 kg of textile material is incorporated into a passenger car. The global consumption of textiles used in automobile industry is estimated to be over 0.5 mn tonnes, which amounts to about 2.2% of the overall weight of the car. Nearly 80% of the cars in India use woven fabric while the rest in the premium segment use knitted fabric. Thus, textiles are an essential component of automobiles. They not only serve to improve interior designs, but also increasingly comprise additional functions such as

- Comfort
- Durable good looks
- Easy care
- Hygiene and
- Security

Mobile-Tech is a term used for technical textiles used in automotive segment which includes use of textile in all aspects of transport - automobile, railway and space travel. It requires considerable technical input to provide both the aesthetic and durability requirements considering the important factors like comfort and safety of end users. Additionally, being light weight than metallic components, use of textile provides substantial fuel economy.

Some of the major visible components and their specific performance criteria are (Table 1)

Component/part	Textile material	Performance requirements
Seat Covers	Polyester, blends	UV resistance and light fastness, anti-pilling and abrasion resistance, soil and flame repellence
Seat belts	Polyester	Tensile strength, abrasion and UV resistance
Carpets	Polyester, Nylon	Light fastness, hygiene

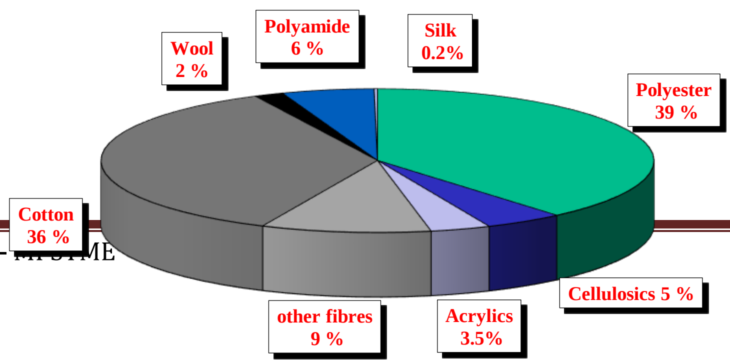
Technical Textiles

These are textile materials and specialised products used for their performance and functional application in varied industries like health care, transport, agro, packaging, construction, sports, etc. Textiles in transport are classified as technical because of the very high performance specifications e.g. seat coverings, roof lining are not easy to remove for cleaning and are fixed in place in many automobiles and must last the lifetime of the car without ever being washed. In addition, they have to withstand much higher exposure to day light and damaging ultraviolet radiations, should have high resistance to rubbing, pilling, staining and should conform to the easy care and safety requirements such as flame retardant. Technical Textiles are an integral part of the textile industry. Presently, about 23 % of the Indian textiles market comprises of technical textiles (remaining 70 % in apparel & 7 % in home textiles). Apart from apparel, a major driver for the industry is demand for *"Technical Textiles"* (fabrics used for automotives, mattress covers, bags, tents and parachutes, health care, construction, etc.) and the Indian Textile Industry is expected to grow to USD 220 bn by 2020 (from USD 70 bn in 2010). A number of factors including government support and increased investor interest because of the large untapped market are expected to positively impact the market for technical textiles in India. Technical Textiles is the sunrise sector of the textile industry in India and a growth rate poised to take off from the present 11%, to almost 20% during the 12th Five Year Plan. Further, the government is set to launch USD 44.21 mn mission for promotion of technical textiles, and has cleared setting up of four new research centres for the industry. The factors behind high growth of Automotive textiles in India are considered to be

- Improvement in the standard of living resulting in greater demand for personal vehicles.
- High time spent in the car (increased daily commuter distances, traffic jams, long distance drives) – more demand on improved aesthetics of car interiors.
- Replacement of metallic components by textiles to reduce weight & improve fuel economy.
- Stringent Govt legislations on safety devices in the form of seat belts, air bags.

Textile substrates

The estimated global usage of textile material is given below (Figure 1)

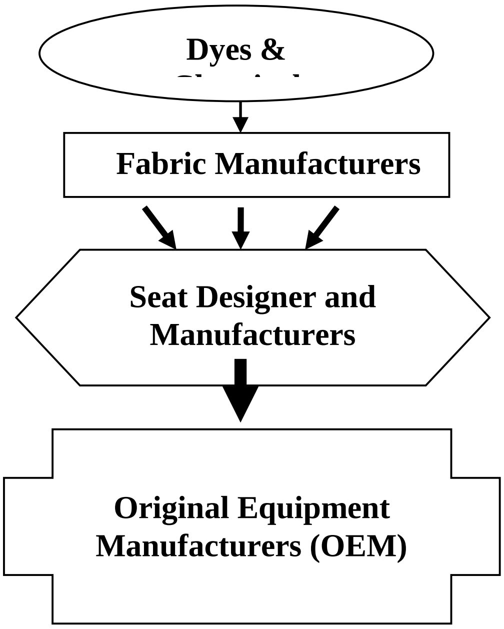


Polyester, discovered in 1941 and commercialised in 1948, is the second largest consumed fiber after cellulosic (natural & regenerated). Today an Indian organisation is considered to be the largest manufacturer of Polyester fibers in the world. Polyester being hydrophobic there is no significant change in its tensile properties when they are wetted. It exhibits high initial moduli of elasticity, high resistance to blending deformations, negligible creep under the low extensions and high resistance to abrasion. Unlike other textile substrates, polyester has high resistance to damage even under prolonged exposure to sun light. These inherent physical characteristics have made Polyester highly suitable for use in Automotive textiles. Polyester fibre development has triggered an intensive research effort into new class of synthetic dyestuffs, chemicals and application processes. Improvement of the light fastness value is of crucial importance in the textile industry since polyester fabrics dyed with disperse dyes are widely used in automobile coloured upholstery and are exposed to direct sunlight and temperatures above 50^0 C. In tropical countries the temperature inside parked cars can reach about 80^0 C on seat lining & roof covers to as high as 120^0 C at dash board & boot cover. Generally polyester textile material is used in below Automotive textile components

- Seat cover, Head-lining, Door
- Carpets, Boot-lining und Parcel shelves
- Safety belts
- Airbag material (tightly constructed polyester- or polyamide fabric)

The automobile producer, generally termed as Original Equipment Manufacturer (OEM), incorporates these textile components and the supply chain starting from the dyes and chemicals used till the car manufacturer is shown below (Figure 2)

Polyester is the most widely used fiber in Automotive textiles and accounts for about 90% of all textile seat covers worldwide. Owing to its physicochemical properties in terms of tensile strength, dimensional stability, light fastness and resistance of photo-oxidative degradation .



The automotive textiles are generally produced from the bulked continuous filament (BCF) textured polyester yarns. Typical yarns for weaving are 167dtex/48 filaments primary feed stock yarn which when quadrupled produces 668dtex/192 filaments and 835 dtex/240 filaments yarn made from five ends of a primary yarn. The fabric construction is usually made into a tri-laminate consisting of face fabric and polyurethane foam with a scrim lining on the back. The temperature in the vehicle can exceed 100ºC and relative humidity can vary from 1-100% during the course of the day. These factors combined with sun light, contribute to the fading of color. Polyester exposed behind glass exhibits better performance compared to polyester exposed directly to the sun. Significant improvements in the light fastness can be obtained by the addition of certain chemicals that are UV absorbers.

Textile dyestuffs

The Indian dyestuff industry comprises of about 1,000 small scale units and about 50 large organized units, who produce around 1,30,000 MT of dyestuff. India contributes about 7.5% of the share in the global market. Being one of the largest producers of cotton and polyester fibers, the Reactive and Disperse class of dyes contribute to more than 75 % of market share.(Table 2). Disperse dyes are sparingly soluble in water and are able to retain comparatively better substantivity for hydrophobic fibres, such as polyester, nylon and acetate. For efficient diffusion into textiles, the particles size of the disperse dyes is controlled and made as fine as possible. It is essential for disperse dyes to be able to withstand various dyeing conditions, pH and temperature, resulting in negligible changes in shade and fastness. Chemically, disperse dyes are based on substituted azo, anthraquinone or diphenylamine compounds which are non-ionic and contain no water solubilising groups. The dye particles are thus held in dispersion by the surface-active agent and the dyes themselves are called disperse dyes. The Disperse Dye Committee of the Society of Dyers and Colourists has now classified the dyeing characteristics of disperse dyes according to the results of several tests which can be performed on the dyes. High light fastness under hot and humid conditions is a major and critical requirement for textile material used in automotives.

Stringent light fastness tests with different specifications for temperature and UV radiation have been developed by many car manufactures to maintain and ensure a good looking textile interior. Hence the most important considerations in determining the suitability of disperse dyestuffs for this application is their light-fastness. Dyestuffs tend to undergo photo-degradation upon exposure to light, especially in the UV spectrum, resulting in fading of the dyed polyester fibre. Automobile interiors are not just exposed to direct sunlight over extended periods of time but also to extreme high temperatures and humidity. bFurther, the modern design lead developments have introduced more pale shades and micro-fibre materials thus compounding the challenge faced by the dyer to achieve the high level of light-fastness required by the car manufacturers. In addition to the high light fastnesses of the individual dyestuffs, on-tone fading of the combination of dyes in tri-chromatic dyeing coupled with non-metameric matching are required. Generally, anthraquinone based disperse dyes exhibit high light fastness which are further enhanced by the use of high performance UV absorbers whereas many commodity azo based dyes do not withstand the specific requirements. The light fastness and fading of color in automotive textiles is influenced by

- chemical structure of disperse dyestuffs, electron density by functional group
- catalytic fading - affected by dyestuffs used in combination
- range of irradiated light wavelength and amount of UV radiation
- presence of moisture and temperature - severely affected at elevated temperature & high relative humidity
- fiber structure - easily affected in case of finer microfibers

Dyes	% share
Reactive	**41**
Disperse	**37**
Vat	**5**
Sulphur	**6**
Acid	**3**
Indigo	**3**
Direct	**1**
Others	**4**
TOTAL	**100**

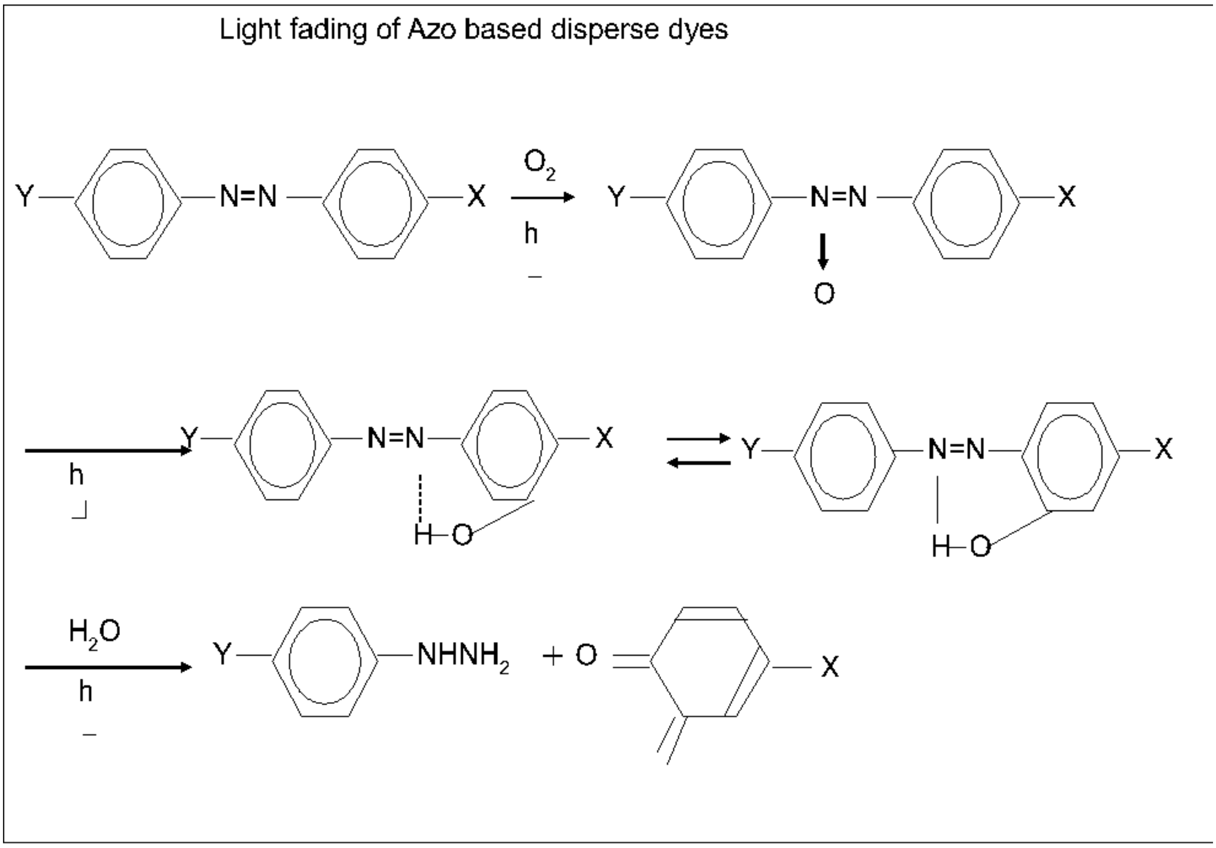
Mechanism of photo reaction of dyestuffs

Sunlight is associated with color fading and fiber degradation**.** Light shorter in wavelength than about 400nm is called ultra violet, light longer in wavelength than 760nm is called infrared. Color fading and textile damage is caused by only a small part of the sun's energy- the portion called ultraviolet radiation. Though ultraviolet (UV) comprises only 2% of the sun's energy, it accounts for an estimated 70% of the damage. Colourfastness to light is the resistance of a material to change in its colour characteristics (hue, depth, brightness, etc.) as a result of exposure to sunlight or an artificial light source. The action of light involves a very complex series of processes. Most technological problems that arise in this field are due not only to the photochemical properties of the dye itself but also to the subsequent interactions that the photoexcited molecule may undergo with its environment. The spectrum of sunlight extends from 290 nm to 1700 nm and is composed of Ultraviolet (290-400 nm), Visible (400-760 nm) and Infrared (760 – 1700 nm) regions. The process of absorption of light raises the molecule to an electronically excited state, which tends to be more polarised, i.e. has greater charge separation, and is hence more reactive than the ground-state molecule.

Key factors influencing Photostability / Fading (Figure 3)

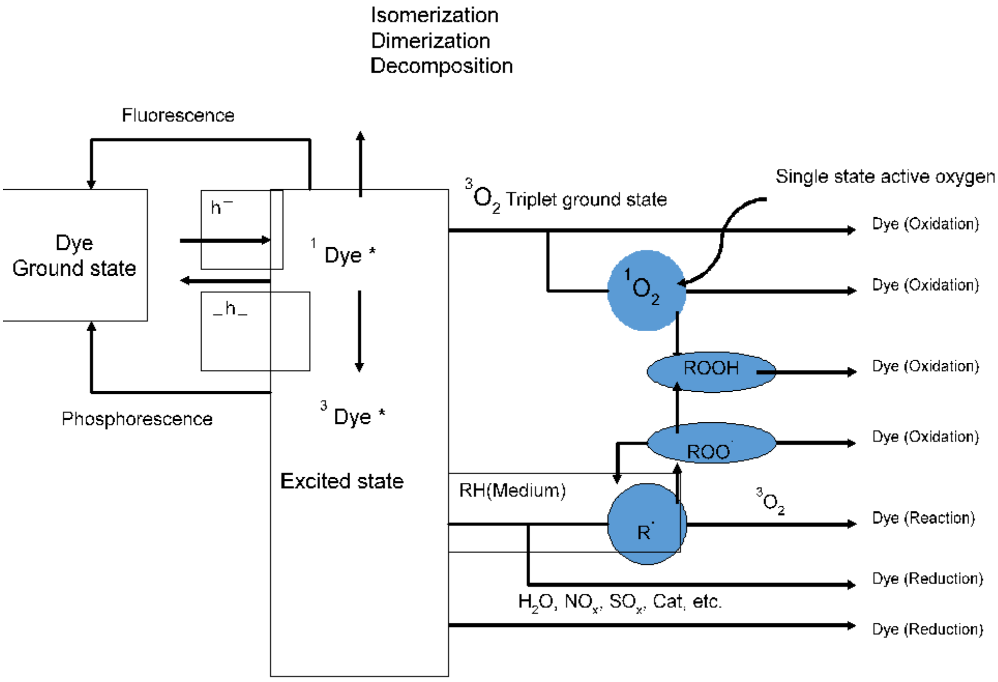
- Presence of Oxygen
- Humidity & Temperature
- Atmospheric contaminants viz. sulphur dioxide, oxides of nitrogen, ozone, etc.
- The degree of dye aggregation, dye structure and depth of shade

- The presence of metal ions, either inextricably bound in dyes or bound in impurities
- Chemical / physical structure of textile substrate and textile auxiliaries / chemicals
- Wavelength distribution of incident radiation
- Abnormal behavior of dyestuffs in mixtures



The photodecomposition of dyestuff involves (Figure4)

- Isomerization / Dimerization
- Oxidation with active oxygen, peroxide, or electron transfer
- Reduction through hydrogen extraction, or electron transfer
- Reaction with radical, water, NOx, SOx, etc.



Ways to improve light fastness of dyestuffs

Although a close relationship does exist between the chemical structures of a dye and its light fastness rating, few other factors are also of relevance, like

- The inherent photostability of the dye molecule; in general, the chromophoric nucleus is the most important element in determining the light fastness of a dye, but nuclear substituents may alter the fastness significantly.
- The concentration of the dye within the fibre; usually the fastness of a dyed fibre increases with increasing dye concentrations.
- The nature of the fibre in which the dye is dispersed; different fibres contain different chemical groups and these substituents can have a significant effect on the light fastness rating of a dye on a given fibre.
- The wavelength distribution of the incident radiation; not all the absorption are

  equally effective in starting a fading process.

- The composition of the atmosphere; the moisture content of the atmosphere can have a marked effect on the fading rates of certain dyes.

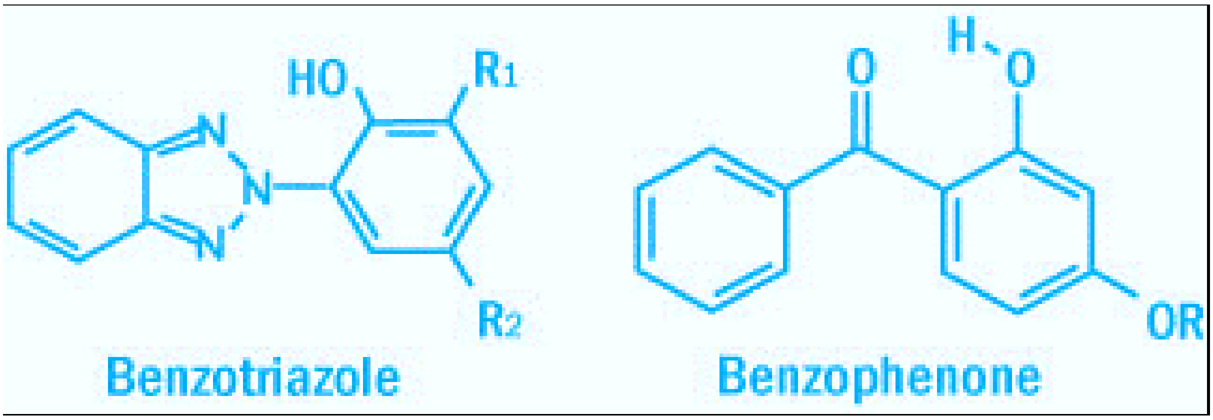
Considering the various factors influencing light fastness of disperse dyestuffs, some of the possible ways to minimise this impact are

- Selection of high light fast dyestuffs

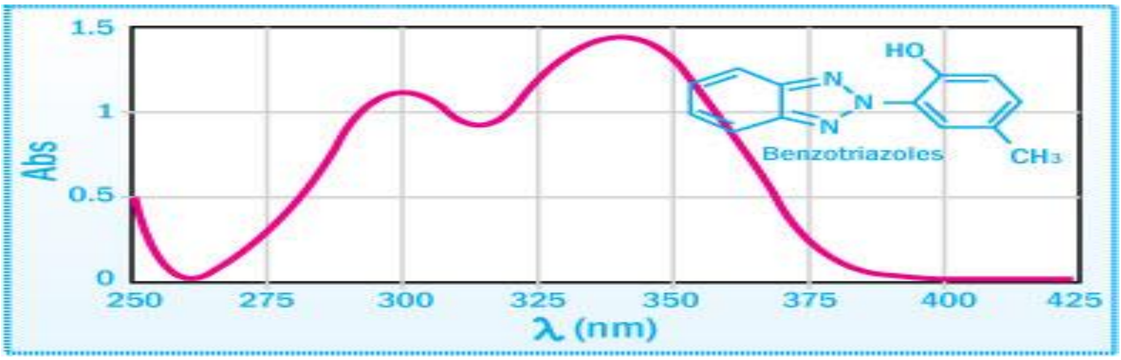
- Masking or absorbing ultraviolet rays
- Researching dyestuff's basic chromophore and improving dyestuff chemical structure
- Adding active oxygen and peroxide quencher
- Adding a radical quencher
- Use of adequate UV absorbers

Influence of UV absorber

Incorporation of a suitable UV absorbers during disperse dyeing of polyester helps improve light fastness of dyed fiber. UV absorbers protect textiles against harmful effect of UV light by reducing the amount of light absorption by dye chromophores, which function by preferentially absorbing harmful ultraviolet radiation and dissipating it as thermal energy. The more severe the light fastness test and the more critical the substrate, the more an addition of UV absorber is required. It is important to use the right amount to get the desired light fastness. When the fabrics are submitted to a heat treatment (post setting, finishing at higher temperature or thermosol dyeing of seat belts) the use of temperature stable UV absorbers like derivatives of below specified products are strongly recommended.(Figure 5)



The different substituents in the benzotriazole group affect various properties, such as polarity, volatility, compatibility, physical condition and - last but not least - maximum absorption levels. The absorption curves show that the requirements are met: strong absorption in the UV range between 295 and 400 nm and a large reduction in absorption in the visible range above 400 nm. (Figure 6)



Owing to the high fastness requirements, only selected disperse dyes can be used for this application. Light fastness in automotive fabrics is very crucial because the car upholstery is often subjected to sunlight during long periods of parking.

Light fastness test and requirements

There are different light fastness test methods and light fastness requirements worldwide. Light fastness tests try to simulate in a testing machine and in a shorter testing time what happens with the textile under different climate conditions after certain time of exposure. The light fastness requirement for the same end-use varies according to the country, quality, brand name. Also, the car makers update their test specifications from time to time. The requirements normally vary according to where a textile is to be used in a car (seat upholstery, interior trim, head lining, etc).

Some of the major global car brands and their specific light fastness test methods (Table 3)

Major Car brands	Test method
Honda	JASO M 346
Toyota	TSL 2100G
Nissan	M 0154
Peugeot, Citroen, Renault	PSA D 47 131
Volkswagen , Audi, Skoda,	PV 1303
Opel	GME 60292
B M W, Mercedes Benz	DIN 75202 (FAKRA)
Ford	DVM 0067 MA
GM motors	GMW 3414
Chrysler	SAE J 1885

The following are the parameters of these light fastness test conditions: (Table 4)

- Type of illumination (daylight, xenon lamp and carbon arc lamp).
- Degree of exposure (intensity of illumination and exposure time).
- Test temperature.
- Humidity

Test method	Chamber temp	Black Panel Temp	Relative Humidity %	Intensity of radiation
GMW 3414	65	-	25	420 nm
SAE J 1885	63	89/38	50/100	340 nm
TSL 2100 G.B	63	89/38	50/100	340 nm
DIN 75202	65	100	20	420 nm

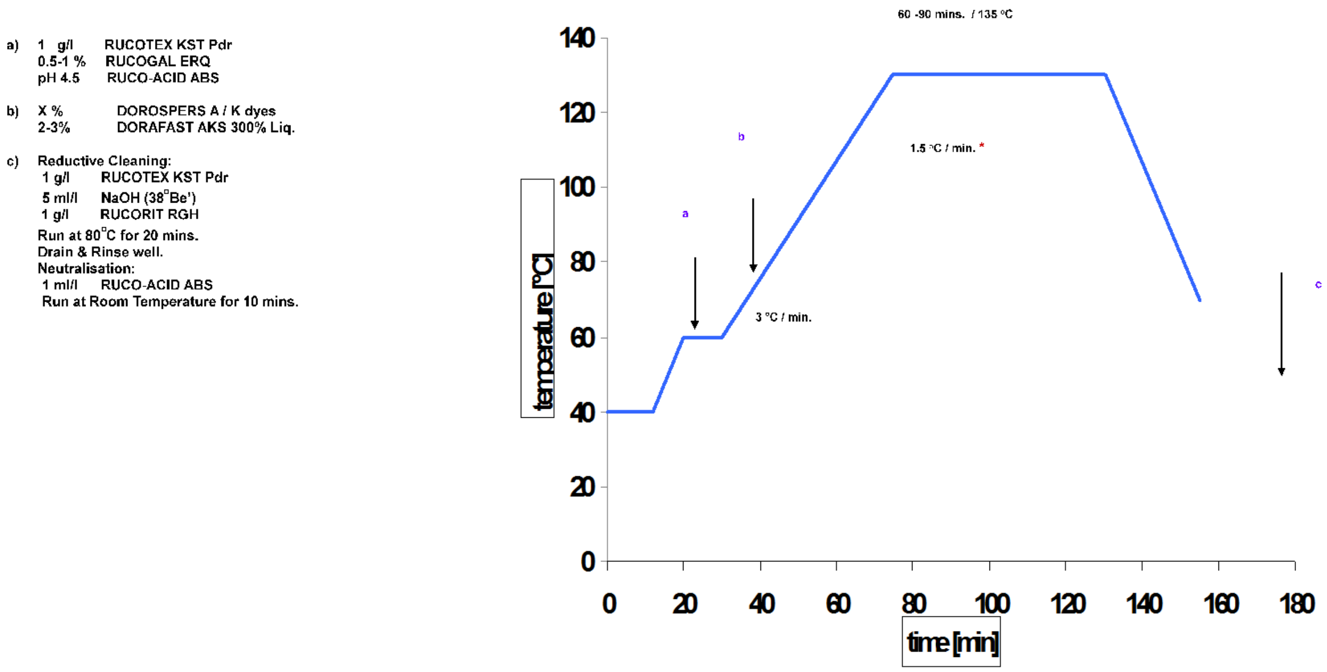
Light Fastness Testing equipment

There are generally three light sources used for artificial light fastness testing:

- Xenon arc lamp

- Mercury vapour lamp
- Carbon arc lamp

The most common type of artificial light source is the xenon arc lamp. An electric current is passed through an enclosed xenon vapour under high pressure, causing ionisation. There are currently several testing units available. Test units are programmed to operate under specific conditions of temperature and humidity as specified defined by a standard test method. Generally, beige and grey shades are popular in automotive textile fabrics, which are usually matched with selected, high light-fast brilliant yellow, red and blue dyestuffs. However, these trichromatic combination dyeing cause shift in tone during exposure to light due to differences in the stability to light in different concentrations. The optimum light fastness is achieved when the combination fades on-tone and the loss of strength is minimal. To achieve the highest light fastness on critical substrate and under severe exposure conditions, dyes with a high and similar light fastness level and the right amount of UV absorber are required (Figure 7)



RUCOTEX KST Pdr - Specialty Dispersant
RUCOGAL ERQ - Levelling agent
RUCO-ACID ABS - Thermostable Acidic pH controller
RUCORIT RGH - Specialty reduction clearing agent

The specific benefits are in terms of

- On-tone fading
- Non metameric matching
- Fastness to crocking
- Lower shade tolerance limits (DE $\leq$ 0,2)

Further, for improved reproducibility, levelness and even fastness results, the substrate for automotive textiles should be dyed at 135°C, avoiding shade corrections/toning adjustments. Subsequent repeated high temp treatments should also be avoided as it may impair light fastness due to a migration of dyes to the fibre surface and to a loss of UV absorber.

The textile processing route includes

- Polyester yarn dyeing – with selected specialty high light fast disperse dyes and UV absorber.
- Weaving or knitting of fabric
- Finishing with functional chemicals to impart desired effects

Functional finishes

Apart from high light fastness, the automotive textiles need specialty effect finishes to confer desired functional properties. Rudolf GmbH, a German multinational organisation, globally acclaimed for its range of effect chemicals for Technical Textiles, has developed products like ®RUCO-GUARD USR, RUCO-DRY DHY & ®RUCO-GUARD UCS (stain-repellent finish, uniting flame retardancy with anti-static properties) for imparting various functional effects including

- Improved stain repellency
- Improved soil release effects
- Protection from aqueous soil
- Protection from oily soilings
- High wear resistance
- High abrasion resistance and anti-pilling
- High antistatic effect
- Flame retardency

Conclusion

About 7-9 % of total cost of automobile is due to the interiors. An average of 5-6 m^2 of fabric is used in cars for upholstery. Textile fabrics play an important role by providing desired comfort, aesthetic appeal, adequate safety parameters and being light weight – fuel economy. Consumers expect that the interior textiles should last the life of the vehicle and show no significant signs of wear. As the car interiors are subjected to varying temperatures and relative humidity, the seat fabric must always appear without noticeable colour fading. The most important factor governing the selection of the fabrics for car seat cover is resistance to light (UV radiation). Polyester dyed with high light fast disperse dyes and treated with functional effect chemicals is the obvious choice.

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