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Effect of Mass Flow Index of UV Stabilizer on UV Resistance Property of Woven Fabric

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Abstract

Woven fabric materials provide simple and convenient protection against Ultraviolet (UV) radiation. To assign the degree of UV radiation protection of woven fabric, the Ultraviolet Protection Factor is commonly used. This paper reports the effect of MFI (Mass flow index) of UV stabilizer material on the woven fabric property. Extrusion is the process of conversion of raw material into a particular shape. The raw material for the woven fabric is polymer granules (polypropylene (PP), UV stabilizer, and calcium carbonate ($CaCO_3$)). This polymer is extruded to a certain temperature (260 to 280 °C). At this temperature these raw materials mix together in the screw of the extruder to show their property. If the mixing of these raw materials will be homogeneous, then we will get desired property of the fabric. This experiment shows that the UV stabilizer having high MFI will mix homogeneously during extrusion and fabric will achieve better retention property. The objective of this research is to attempt to correlate between "MFI of UV stabilizer and retention property (tensile strength) after UV test" for various GSM of woven fabric. Subsequent to this, deterioration of woven fabric due to environmental impact as UV light exposure was investigated.

Keywords

Mass flow rate, Extrusion, Retention, Tensile strength

Introduction

A confident understanding of woven fabric behavior is vital in the design and development of a functional packaging material (e.g., small bag and bulk bag). Long-term performance of woven fabric is also affected by fabric degradation via different mechanisms including moisture, UV light (sunlight), and other atmospheric attacks. UV resistance and other atmospheric attack testing is important in determining the ultimate lifespan of a woven fabric in an engineered system [1]. UV stability is an important endurance property related to woven fabric usage and is specified based on expected exposure to UV degradation. Recently, many professionals, environmentalists, dermatologists, meteorologists, biologists, and others have been warning us about UV radiation and its harmful effects. The increasing concentration of UV rays' impact on living as well as all on-living organization. In this condition, the woven fabric and other textile material will also be impacted. Woven fabric can be a very simple and convenient barrier against UV rays and can offer suitable or even excellent ultraviolet protection.

UV radiation is electromagnetic, emitted by the sun, which we cannot see or feel it. It is high energy radiation which dependent on its wavelength of the ray causes skin cancer, sunburn, skin ageing, eye disorders and other impact on nonliving things. The UV spectrum is divided into near UVA (315 - 400 nm), UVB (280 - 315 nm), UVC (100 - 280 nm) and UVD regions (10 - 100 nm) by biologists or into UV (320 - 380 nm), middle UV (200 - 320 nm) and vacuum

UV regions (10 - 200 nm) by physicists. The natural source of UV radiation is the sun, but there are also artificial sources like different types of lamps for phototherapy, workplace lightening, solariums, hardening plastics, industrial arc welding, resins and inks, sterilizations, authentication of banknotes and documents, advertising, medical care, etc. UVC radiation is extremely dangerous but almost all the dangerous ultraviolet radiation is absorbed in the atmosphere's ozone layer (also called blanket of the earth) before it reaches the ground, which is also valid for UVB radiation. UVB radiation is implicated as the major cause of skin cancers, sunburn and other damage of nonliving things. Heavy doses of UVB radiation also cause changes at a molecular level and they destroy the fundamental building element – DNA. UVA radiation has a lower mean energy than UVB radiation but higher intensity. It is necessary for formation of vitamin D and is also thought to contribute to premature ageing and wrinkling of the skin and has been recently implicated as a cause of skin cancer if we are too much exposed to it [2].

A good property of UV protection, which includes behavior, environment, legislation, and personal protection, is obviously needed to avoid the harmful effects of repeated exposure to ultraviolet radiation. Woven fabric has UV-blocking properties which are achieved and enhanced by UV stabilizer material, dye, pigment as well as by their construction. UV radiation can be classified as UVA (320 - 400 nm), it causes premature skin aging, wrinkling, and potentially skin cancer [3]. Generally, the high energy of solar radiation (200 - 400 nm) is known as UV radiation. This ray may cause of some undesirable effects on living organisms and may also re-duce service life of materials due to its high energy. The ozone layer is blanket of the earth and almost all the radiation of wavelength below 290 nm is filtered out by the ozone layer in earth's atmosphere. The rays having large wavelength doses, especially in the short UVB range (280 - 315 nm) may cause cancer, sunburns, skin cancer, etc. In addition to its dangerous effects on human beings, it also deteriorates the material properties of polymers, apparel, upholstery, paints, carpets, furniture, electronic parts, draperies, building construction materials - wood, plastic panels, etc. and other articles of outdoor use and limits their life span and durability. In a few decades, with the alarming increase in the rate of ozone layer depletion in the earth's atmosphere, the risks involved due to prolonged exposure to solar UV radiation are increasing day by day. Hence it becomes imperative to protect the materials from harmful effects of solar UV radiation [4].

There are various methods and scientific approaches that have been used to tackle this problem. Now a day for the protection of packaged material, use of woven fabrics capable of blocking harmful UV radiation during outdoor activity is increasing in use. The UV stabilizers used in these applications must perform dual tasks: at the same time should be able to block/absorb the harmful UV radiation to protect the life and materials under the shelter and the polymer should have a good UV resistance for a reasonably long service life [4].

Now a day, woven fabric is being used for packing applications of food, pharmaceutical, and other material. It is also used in packing and storage of goods for a period of time. Sometimes, the packed materials are also stored outside of the premises. The performance of the woven fabric should be in a way that it can carry the material without failure. The woven fabric should have better resistance to UV rays.

Methodology

Mass flow index

This test method covers measurement of the rate of extrusion of molten resins through a specific diameter orifice under prescribed conditions of temperature, load, and piston position in the barrel in the specified time. The test was done as per ASTM D 1238-20. In this test, the entire material sample was extruded at 230 °C and 2.16 kg load. The unit of the MFI is gm/10 min. In this experiment, we have selected different types of UV stabilized having different MFI. The change in UV stabilizer change in MFI because, there are many suppliers who used PP as carrier resin and some use PE as carrier resin. The ratio of UV:PP is 20:80. So, the change is base material results the change in MFI. The homogeneous mixtures of material assure the UV retention property. It plays a major role in all property including UV retention. In this experiment we have taken weaving machine, weaving pattern and UV wavelength as constant because these all experiment was done on same weaving machine, UV test machine. There was a drastic change in retention property due to the change in MFR of raw material. Hence, we have focused on this parameter to improve the retention property.

UV resistance test

General

Materials often undergo rapid photochemical degradation under the influence of sunlight unless they have been stabilized in a durable fashion. An accelerated ageing that simulates ageing caused by sunlight may be brought about by irradiation with light of a UV type. Samples cut from the load-bearing materials of the FIBC (flexible intermediate bulk containers) (e.g., fabric, webbing, rope, sewing thread, and glues) are subjected for a certain period of time to irradiation from a light source of the UV type with specified spectral distribution. A number of factors of uncertainty are inherent in the procedure, so comparisons should be available between the method used and exposures in the environment in which the product is to be used. Certain types of UV stabilizing additives are rapidly leached out, especially in an alkaline environment. This should be taken into consideration in applicable situations. The performance of UV stabilizing additives may be affected by color and the type of pigment used. Therefore, each combination of UV stabilizing additive and pigment should be tested separately [5].

Test standard

The UV resistance test is based on the standard ISO 21898:2004. Packaging - FIBCs for non-dangerous goods.

Apparatus

Q.U.V. Weathering Tester equipped with UVB 313 lamps. The apparatus should be in accordance with ASTM G154-98, using a UVB lamp.

Figure 1: MFI (Melt Flow Index) tester.

Figure 2: Weathering tester.

Figure 3: Samples for UV resistance test.

Test condition

The wavelength at which peak emission occurs 313 nm cycle of 8 hours UV exposure at 60 ˚C and condensation of 4 hours at 50 ˚C, exposed at 0.71 W/m^2/nm.

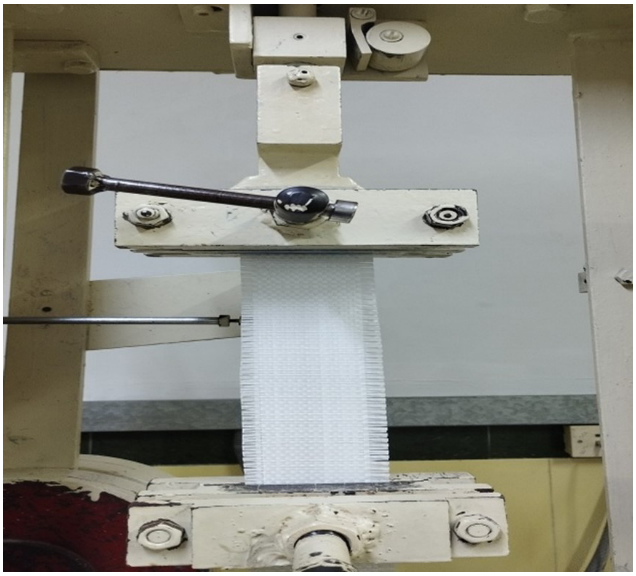

Figure 4: Tensile test of woven fabric.

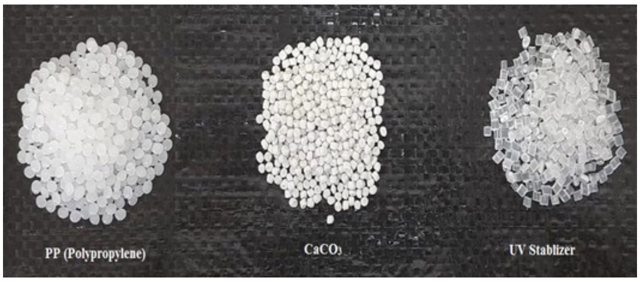

Figure 5: Raw material (PP, $CaCO_3$, and UV stabilizer).

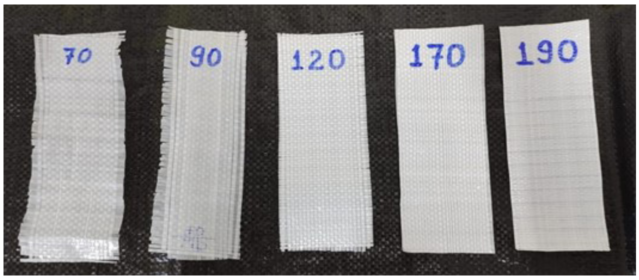

Figure 6: Samples of different GSM.

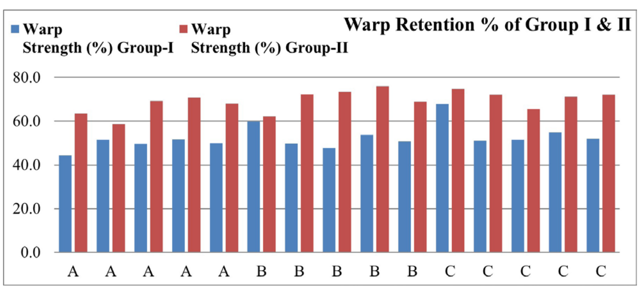

Figure 7: Warp retention % of group I and II.

Procedure

Expose a test fabric sample to a fluorescent UV lamp at 200 hours, having a test cycle of 8 hours at 60 ˚C with UV radiation and alternating with 4 hours at 50 ˚C with condensation. After exposure is complete, test the specimen (fabric

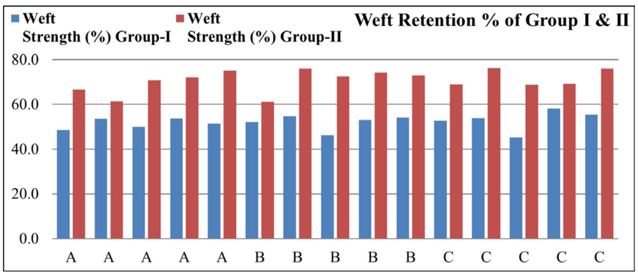

Figure 8: Weft retention % of group I and II.

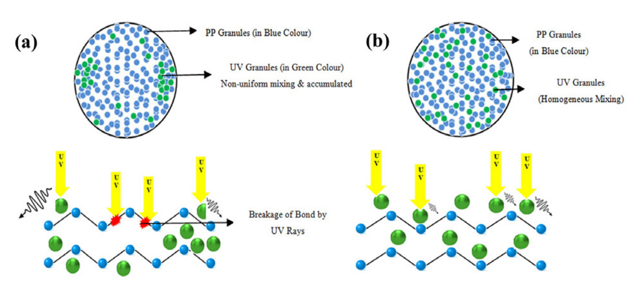

Figure 9: (a) Non-Uniform mixture of UV and PP and **(b)** Uniform mixture of UV and PP.

sample) for breaking force and elongation at break is done accordance with ISO 13934-1 using the prescribed condition requirements given in 5.2.2 (ISO 21898:2005). Compare the tensile strength and elongation of the sample performed on simultaneously cut test specimens that have been stored under dark and cool conditions [5].

Tensile test

This test method covers measurement of tensile strength of fabric sample before and after UV test. The test was carried out with UTM machine (Analogue Machine). The test was done as per ISO 13934-1 (Strip Method). The grab length of the machine was 200 ± 1 mm and rate of extension was 100 ± 1 mm/min. The dimensions of sample specimen of fabric are 50 mm wide and 350 mm long.

Specimen preparation

Tape is a necessity in the fabric making process. Raw material granules are extruded in the form of tape. Then these tapes are used in the weaving process. Weaving is the process of inclination of woven tape at perpendicularly. There are basically three raw materials that are used for woven tape extrusion. PP is a major component, and it is base material of the fabric, $CaCO_3$ is added to improve the performances (heat deflection, impact resistance, and stiffness), improve processing and sustainability properties and UV is used for UV protection. These are the basic compositions used for all types of woven fabric. The major property and composition of raw materials is given below.

In this experiment, fifteen types of sample fabrics have been made using the same recipe. The PP and $CaCO_3$ used to make all samples are the same but there are three different types of UV stabilizer used (i.e., A, B, and C). The property of all UV stabilizers (A, B, and C) is also approximately same, but they are received from three different suppliers. As described above, that fabric is made up by the inclination of tape perpendicularly. Initially, the tape is extruded as per fabric GSM (Gram per square meter). The description of tapes used to make the fabric is given below. The tape used in the vertical direction is known as warp and the tape used in the horizontal direction is known as weft. There are five types of fabric that are taken for the test. The fabric GSM and warp and weft tape used during weaving is given below.

Test samples group-I

In these samples, the recipe was the same as mentioned above (Table 1). In this sample group the base material PP and $CaCO_3$ is same but three different types of UV material (UV A, B, and C) is used having the low MFI between 10 - 15 gm/10 min.

Test samples group-II

In these samples, the recipe was the same as mentioned above (Table 1). In this sample group the base material PP and $CaCO_3$ is same but three different types of UV material (UV A, B, and C) is used having the low MFI between 30 - 40 gm/10 min.

Results and Discussion

Test result group-I

The below table shows the result of samples in which UV stabilizer was used having low MFI (10 - 15 gm/10 min). As per ISO 21898:2005 (Annex A), the sample should be retaining at least 50% of the original value but the retention of the samples is below 50% or near to boundary.

Table 1: Standard recipe of woven fabric.

S. No.	Material	Density Test Standard - ASTM D 792 Unit	MFR (Mass Flow Rate) Test Standard - ASTM D 1238 Unit	Composition
		(g/cc)	(gm/10 min)	(%)
1	PP (Polypropylene)	0.90	3.4	93
2	$CaCO_3$ (Calcium carbonate)	0.95	0.4	4
3	UV (Ultraviolet stabilizer)	0.91	-	3

Table 2: Fabric GSM and tape used (Warp and Weft).

GSM	UV Stabilizer			Warp Denier	Weft Denier	Standard Warp Fabric Strength (N)	Standard Weft Fabric Strength (N)
70	A	B	C	750	750	700	650
90	A	B	C	1000	1000	800	800
120	A	B	C	1350	1350	1200	1080
170	A	B	C	1675	1500	1700	1530
190	A	B	C	1675	1900	1800	1710

Table 3: Sample group-I recipe having low MFI.

S. No.	Material	Density Test Standard - ASTM D 792 Unit	MFR (Mass Flow Rate) Test Standard - ASTM D 1238 Unit	Composition
		(g/cc)	(gm/10 min)	(%)
1	PP (Polypropylene)	0.90	3.4	93
2	$CaCO_3$ (Calcium carbonate)	0.95	0.4	4
3	UV-A (Ultraviolet stabilizer)	0.91	12.3	3
4	UV-B (Ultraviolet stabilizer)	0.91	14.1	3
5	UV-C (Ultraviolet stabilizer)	0.91	10.5	3

Table 4: Sample group-II recipe having high MFI.

S. No.	Material	Density Test Standard - ASTM D 792 Unit	MFR (Mass Flow Rate) Test Standard - ASTM D 1238 Unit	Composition
		(g/cc)	(gm/10 min)	(%)
1	PP (Polypropylene)	0.90	3.4	93
2	$CaCO_3$ (Calcium carbonate)	0.95	0.4	4
3	UV-A (Ultraviolet stabilizer)	0.91	32.4	3
4	UV-B (Ultraviolet stabilizer)	0.91	36.8	3
5	UV-C (Ultraviolet stabilizer)	0.91	35.5	3

Test result group-II

The below table shows the result of samples in which UV stabilizer was used having high MFI (30 - 40 gm/10 min). As per ISO 21898:2005 (Annex A), the sample should be retaining at least 50% of the original value and the retention of the samples are above 50%. There is no failure of retention. In fact, the fabrics have achieved the good property of UV resistance.

Test result comparison, group-I and group-II

The warp retention % of sample group-II is higher than group-I. The graphical representations of the results are shown below.

Conclusion

The experiment shows that the UV stabilizer having high MFI gives better retention property. These materials mix homogeneously throughout the whole recipe (PP, $CaCO_3$, and UV) and show better results. This happened because there is no coagulation of material in any place, and it is distributed and bonded properly throughout the whole crystal. There is no grain boundary of the same material. When UV rays fall on the crystal of the material, they are not able to break the molecular bond due to the presence of UV stabilizer on each bond. The samples having low MFI was used (10 - 15 gm/10 min) do not merge properly during extrusion. As a result, the retention property was failed or near to boundary. The samples having high MFI (30 - 40 gm/10 min) merge properly during extrusion. As a result, it shows a better UV retention property. The molecules of the UV material having high MFI merge with other molecules of the PP and $CaCO_3$ homogeneously. They do not coagulate or create grain boundaries and merge easily. As a result, they protect the fabric from sun radiation and show good UV retention property.

Table 5: Test result group-I.

GSM	UV Stabilizer	Standard Strength Required		Before UV Test		*After UV Test		Retention %	
		Warp Strength (N)	Weft Strength (N)	Warp Strength (N)	Weft Strength (N)	Warp Strength (N)	Weft Strength (N)	Warp Strength (%)	Weft Strength (%)
70	A	700	650	790	680	350	330	44.3	48.5
90	A	800	800	855	860	440	460	51.5	53.5
120	A	1200	1080	1310	1120	650	560	49.6	50.0
170	A	1700	1530	1820	1640	940	880	51.6	53.7
190	A	1800	1710	1905	1830	950	940	49.9	51.4
70	B	700	650	810	690	485	360	59.9	52.2
90	B	800	800	865	895	430	490	49.7	54.7
120	B	1200	1080	1310	1135	625	525	47.7	46.3
170	B	1700	1530	1805	1620	970	860	53.7	53.1
190	B	1800	1710	1920	1840	975	995	50.8	54.1
70	C	700	650	810	710	550	375	67.9	52.8
90	C	800	800	890	910	455	490	51.1	53.8
120	C	1200	1080	1290	1140	665	515	51.6	45.2
170	C	1700	1530	1840	1610	1010	935	54.9	58.1
190	C	1800	1710	1930	1840	1005	1020	52.1	55.4

Table 6: Test result group-II.

GSM	UV Stabilizer	Standard Strength Required		Before UV Test		*After UV Test		Retention %	
		Warp Strength (N)	Weft Strength (N)	Warp Strength (N)	Weft Strength (N)	Warp Strength (N)	Weft Strength (N)	Warp Strength (%)	Weft Strength (%)
70	A	700	650	810	690	515	460	63.6	66.7
90	A	800	800	910	920	535	565	58.8	61.4
120	A	1200	1080	1320	1145	915	810	69.3	70.7
170	A	1700	1530	1855	1680	1315	1210	70.9	72.0
190	A	1800	1710	1940	1830	1320	1375	68.0	75.1
70	B	700	650	820	710	510	435	62.2	61.3
90	B	800	800	865	895	625	680	72.3	76.0
120	B	1200	1080	1335	1145	980	830	73.4	72.5
170	B	1700	1530	1895	1605	1440	1190	76.0	74.1
190	B	1800	1710	1915	1790	1320	1305	68.9	72.9
70	C	700	650	790	710	590	490	74.7	69.0
90	C	800	800	895	880	645	670	72.1	76.1
120	C	1200	1080	1335	1105	875	760	65.5	68.8
170	C	1700	1530	1785	1625	1270	1125	71.1	69.2
190	C	1800	1710	1935	1815	1395	1380	72.1	76.0

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Conflict of Interest

None.

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