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UV Rays And Paraglider Canopy Deformation

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ABSTRACT

Background/Objectives: *This study investigated changes in the paraglider canopy due to exposure to ultraviolet rays through differences in air permeability and chromaticity.*
Methods/Statistical analysis: *This experiment used the fabric called Nylon 66 Double-Rip Stop 30D(DENIER) used for manufacturing paraglider. In the period and method of experiment, the changes in air permeability and chromaticity were observed according to UV exposure hours by irradiating UV for one week(168 hours), two weeks(336 hours), 3 weeks(504 hours), and 4 weeks(672 hours).*
Findings: *In the results of this experiment, first, the UV had effects on air permeability of paraglider canopy. Second, the chromaticity of paraglider canopy was gradually changed according to UV exposure hours.*
Improvements/Applications: *In the conclusion obtained from such results, the UV exposure reduced the airworthiness by having effects on air permeability and chromaticity of paraglider canopy. Thus, the aging of paragliding canopy by UV rays can cause safety problems and malfunction of paraglider by reducing the air permeability, so it would be necessary to improve the certification method of paraglider.*

Keyword: *paragliding, ultraviolet ray, Canopy, Air permeability, chromaticity, ultraviolet ray*

I. INTRODUCTION

Paragliders began in 1984 when French mountaineer Jean-Marc Buovins modified a square-shaped ram-air parachute for the purpose of descending after climbing and succeeded in paragl[1]iding for the first time, and has continued to develop since then. Over time, it developed into the high-performance paraglider that it is today.[1]
Paragliding requires canopy, harness, radio, and the instrument system(GPS, altimeter, and etc.) necessary for long-distance flight[2]. Among the paragliding equipment, the canopy takes up the biggest weight, and most of the canopies are made Nylon 66 Double-Stop fabric(10D(Denier)~30D). When the Denier is low, it is light with excellent take-off performance while the color fastness to light is decreased. For this reason, most of the canopies use 30D. The color fastness to light shows differences according to the number of Denier and color. Generally, the yellow or olive green is reported to be the strongest. The canopy fabric is aged and damaged by passage of time, problem of use, and surrounding natural environment. Many factors like time, light, contamination, temperature, and humidity are complexly working on the aging of canopy. Once a canopy is exposed to many meteorological elements, first, it is influenced by the rays of the sun. The rays of the sun could be largely divided into infrared rays, visible ray, and ultraviolet(UV) rays[3]. Due to the characteristics of activity, the paraglider is aged by light[4], and among them, the UV

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rays have effects on canopy. The strong
chemical activity of UV rays is the main cause for aging and discoloration/fading of material[5].
After production, a paraglider should get certified by going through the performance & safety tests according to the purpose of use before entering the arket. The paragliders that are currently used in the whole world are released based on grade after going through the safety test like flight test(flight safety) using LTF or EN, and the load test(tensile strength test on fabric, suspension line, riser, and etc.). For the load test on fabric, the airworthiness standards of LTF in Germany are used as the basic premise. The airworthiness means that an aircraft is suitable for flight safety within the operating range[6], and the paraglider canopy is measured through air permeability. The air permeability is measured by an air permeability instrument for canopy, which shows a bit of differences depending on measuring instrument.
Paragliding is an outdoor activity, so the air permeability of canopy is raised by coloring and coating the fabric. However, the paragliding is flying in the air, so it is directly exposed to UV rays. Even though the UV rays have a small amount of light, its high energy activates the major binding in organic matter, causes the sequential decomposition[7], and generates the degradation of canopy. For this reason, in order to see the durability of canopy fabric and changes in mechanical properties and color fastness to light, the tensile strength and air permeability should be measured[8]. Even when feeling something strange from paragliding, however, most of the club members simply check it with the naked eyes, which is led to the loss of value and safety management. Considering the characteristics of paragliding activity, there should be researches on changes in properties including the air permeability of canopy by UV exposure.
Therefore, changes in the paraglider canopy due to exposure to ultraviolet rays were identified through differences in air permeability and chromaticity..

II. RESEARCH METHODS

I. Research Subjects

As the sample for analysis, this study used the Nylon 66 Double-Rip Stop 30D(DENIER) used in E-Glider, a Korean paraglider manufacturer. The colors of subject sample show the high color fastness to light, which includes three colors such as Yellow, Green, and White that are mostly used in Korea. In the results of measuring the size, it was a square in 15×15 (cm). The list of subject sample for analysis is shown as <Table 1>.

Table 1. Sample of parachute fabric for analysis

Sample type	ample color	Size(cm)
Paraglider canopy	Yellow, green, White	15×15

2. Experiment & Measurement Methods

1) Irradiation of UV rays

In this study, the experiment of irradiating the UV rays used a UV testing equipment produced by referring to the KS M 5982 (Paint accelerated weathering test method – Condensation of fluorescent UV). This testing equipment used total eight fluorescent UV lamps as light source. This study produced and used the facility with a rack for specimen, which could control and record the operating time and temperature. After attaching the specimen to the rack for specimen to make the lamp and tested surface face each other, they were exposed for 1 week(168 hours), 2 weeks(336 hours), 3 weeks(504 hours), and 4 weeks(672 hours).

2) Measurement of Air Permeability

To measure the air permeability, this study used the HELLO POROZIT of Hungary. Following the manual of HELLO POROZIT, the air permeability of each Week0, Week1(168 hours), Week2(336 hours), Week3(504 hours), and Week4(672 hours) was measured. The air permeability evaluation standards are different depending on each measuring device. The evaluation standards of this instrument are as <Table 2>.

Table 2. Air permeability evaluation standards

Air permeability/sec	Evaluation
200/sec	-Excellent
70-200/sec	-Good
25-70/sec	-Medium
18-25/sec	-Weak
18/sec or lower	-Inappropriate

3) Measurement of Chromaticity

As the system that marks colors, the color system is divided into two types such as color appearance system and color mixing system. As a method to systematize and mark the perceived colors, the color appearance system decides the color chart in advance, attaches the number or mark suitable for the color, and then comparatively marks it with the color of object [9].

There are many types of color system such as CIE X Y Z system, CIE system L*a*b*, L*C*H*, and Hunter Lab[10]. In this experiment, the color difference was marked by using the color system called CIE system L*a*b*< Fig 1>. In this CIE L*a*b*, L* means brightness while a*, b* means chromaticity coordinates, that is chroma of Red and Yellow[10]. The coordinate +a* on the right from the center means Red. The –a* on the left means Green while the coordinate –b* on the bottom means Blue. The upper coordinate +b* is Yellow, which shows the yellowing phenomenon. In the achromatic center, the a*, b* is marked from –60 to +60. As the value increases, the chroma increases when it gets farther from the center. The L* is marked from 0 to 100. When the value increases on the basis of 50, the chroma gets high. The △E*ab means the overall color change aspect, which was calculated in the formula below.

$$\triangle E^*ab = \sqrt{(\triangle L^*)^2 + (\triangle a^*)^2 + (\triangle b^*)^2}$$

L = lightness a = red index b = yellow index

The chromaticity was measured by using the spectrum color meter(KONICA MINOLTA, CM- 2600d, Japan). In order to understand the aspect of change according to UV degradation, the changes in chromaticity were measured before/after exposure. The color difference was evaluated on the basis of <Table 3> by the NBS(National Bureau of Standard Unit). As a method to reduce errors, total five parts were measured and then the mean value of three parts was calculated by excluding the maximum value and minimum value. The colors of specimen were marked by using the colors shown in the chromaticity management software program(KONICA MINOLTA, SpectraMagic NX CM-S100w, Japan).

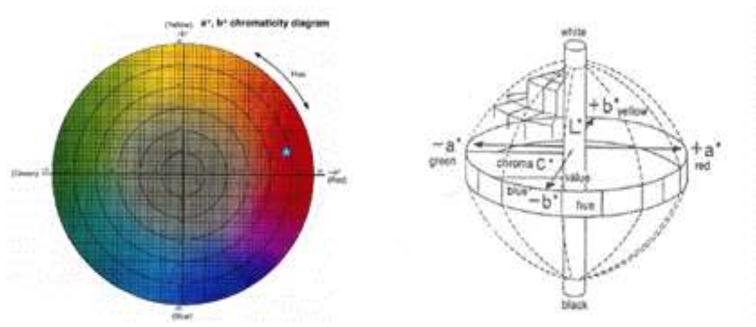

Fig 1: Cie L*, A*, B*, Cie L*, A*, B* Measurement System.

Table 3: Evaluation standards by the National Bureau of Standard Unit(NBS)

△E*ab value	Evaluation
0 ~ less than 0.5	Trace
0.5 ~ less than 1.5	Slight
1.5 ~ less than 3.0	Noticeable
3.0 ~ less than 6.0	Appreciable
6.0 ~ less than 12.0	Much
12.0 or higher	Very much

III. RESULTS

1. Changes in Air Permeability According To UV Irradiation Hours

1) Results of Measuring the Air Permeability for The Measurement Of Airworthiness

Table 4: Results of measuring the air permeability for the measurement of airworthiness(sec)

Sample	pre	Week1(168hr)	Week2(336hr)	Week3(504hr)	Week4(672 hr)	Change value
Yellow	4516	4048	142	069	03.00	-4513.00
Green	3865	1415	032	031	01.70	-3863.28
White	4947	0832	035	011	03.00	-4944.00

The results of measuring the air permeability for measuring the airworthiness of paraglider are as <Table 4>. In the results of measuring the air permeability according to the measurement of airworthiness, the pre-measurement was shown in the order of White(4947/sec) > Yellow(4516/sec) > Green(3865/sec). A week later, it was shown in the order of Yellow(4048/sec) > Green (1415/ sec) > White(0832/sec). Two weeks later, it was shown in the order of Yellow(142/sec) > White(035/sec) > Green(032/sec). Three weeks later, it was shown in the order of Yellow(069/sec) > Green(031/sec) > White(011/sec). Four weeks later, it was shown in the order of Yellow0.30/sec), White(03.00/sec) > Green(01.70/sec). The overall change value of air permeability in the final test results after pre-test, was shown in the order of White – 4944> Yellow –4513> Green –3863.28>.

2) Changes in Air Permeability of Each Week after UV Irradiation

Table 5: Changes in air permeability of each week after UV irradiation(%)

Sample	pre	Week1(16 8hr)	Week2(33 6hr)	Week3(50 4hr)	Week4(67 2hr)
Yello w	0	10.36	96.49	51.40	95.65
Gree n	0	63.38	97.73	95.12	94.45
Whit e	0	83.18	95.79	68.57	72.72
Tota l	0	52.30	96.67	71.69	87.60

The rate of change after UV irradiation on paraglider canopy is as <Table 5>. The difference of air permeability in each time was shown as Yellow(10.36%), Green(63.38%), and White (83.18%). Two weeks later, it was shown as Yellow(96.49%), Green(97.73%), and White (95.79%). Three weeks later, it was shown as Yellow(51.40%), Green(95.65), and White (68.57%). Four weeks later, it was shown as Yellow(95.65%), Green(94.45), and White(72.72%). The mean value of each time was shown as 52.30% for week1(168hr), 96.67% for week2(336hr), 71.69% for week3(504hr), and 87.60% for week4(672hr).

2. Changes in Chromaticity According to UV Irradiation Hours

The chromaticity of paraglider canopy was measured by using A4-size paper to make the same condition in the bottom part of canopy<Table 6>. To provide the reference point, after measuring it five times with a blue sticker in the upper left corner, the mean value wasdrawn by excluding the maximum/minimum values, and then the results were drawn on the basis of SCI.

The ΔE*ab value means the overall color difference. The color change was greatly shown in the order of Green BACK (69.19) > Yellow back (68.85) > Green (67.6) > Yellow (65.16) > White (13.54) > White Back (12.79).

The L* value means the brightness. The changes in brightness were greatly shown in the order of Yellow back (12.29) > Yellow (11.79) > Green (9.07) > Green BACK (9.04) > White Back (-2.6) > White (-1.47). Both Yellow and Green got higher brightness while only White got lower brightness.

The a* value means it is close to RED when it is near (+), and it is close to Green when it is near (-). The range of change was greatly shown in the order of Yellow back (21.42) > Yellow (20.38) > Green BACK (21.38) > Green (21.34) > White Back (4.94) > White (5.05).

The b* value means it is close to Yellow when it is near (+), and it is close to Blue when it is near (-). The range of change was greatly shown in the order of Green BACK (21.38) > Yellow back (21.42) > Green () > Yellow (20.38). Thus, the (-) value showed such great range of change, which shows that it is close to Blue.

The range of change in (+) value of White was shown in the order of White (4.94) > White Back (5.05), which was the only sample that showed the yellowing phenomenon.

Table 6: Results of chromaticity change in sample

Yellow					
Week	L*	a*	b*	ΔE*ab	color
0	77.15	20.32	73.63	-	
1	78.06	10.72	43.73	31.42	
2	83.57	4.29	29.48	47.4	
3	87.38	0.67	19.25	58.72	
4	88.94	-0.6	13.05	65.16	
Yellow BACK					
Week	L*	a*	b*	ΔE*ab	color
0	75.89	20.7	76.83	-	
1	76.32	11.41	50.27	28.14	
2	82.4	3.92	31.27	48.99	
3	86.08	0.58	19.71	61.41	
4	88.18	-0.72	12.56	68.85	
Green					
Week	L*	a*	b*	ΔE*ab	color
0	82.43	-22.9	67.27	-	
1	83.57	-9.02	22.59	46.8	
2	89.75	-2.83	6.96	63.99	
3	91.09	-1.57	3.79	67.53	
4	91.5	-1.56	3.78	67.6	
Yellow BACK					
Week	L*	a*	b*	ΔE*ab	color
0	75.89	20.7	76.83	-	
1	76.32	11.41	50.27	28.14	
2	82.4	3.92	31.27	48.99	
3	86.08	0.58	19.71	61.41	
4	88.18	-0.72	12.56	68.85	
Green					
Week	L*	a*	b*	ΔE*ab	color
0	82.43	-22.9	67.27	-	
1	83.57	-9.02	22.59	46.8	
2	89.75	-2.83	6.96	63.99	
3	91.09	-1.57	3.79	67.53	
4	91.5	-1.56	3.78	67.6	
White					
Week	L*	a*	b*	ΔE*ab	color
0	93.48	4.35	-13.05	-	

1	92.23	2.42	-9.31	4.47	
2	92.17	0.79	-4.72	9.16	
3	92.08	-0.24	-2.07	11.97	
4	92.01	-0.7	-0.57	13.54	
White BACK					
Week	L*	a*	b*	ΔE*ab	color
0	92.3	4.46	-13.22	-	
1	91.42	2.96	-10.82	3.84	
2	91.36	1.2	-6.16	7.83	
3	91.37	0.08	-3.14	11.03	

IV. DISCUSSIONS

The purpose of this study is to examine changes in properties(air permeability, chromaticity) of paragliding canopy by UV exposure. Based on the results of this study, the discussions could be made as follows. In the results of measuring the air permeability, the pre-measurement was shown in the order of White (4947/sec) >Yellow(4516/sec) >Green(386 5/sec), and overall, the air permeability was very excellent. However, the deviation of color was greatly shown according to each sample, and the cause for this could not be verified in this study. Except for White, the measurement value of air permeability of canopy in each week by UV exposure passes the airworthiness passing standards(25-70/sec(weak)) until the week3(504hr). Thus, the approval of airworthiness for paraglider canopy could follow 504 hours as the reference point under the condition without any influences by external factors. However, the airworthiness of paraglider is also influenced by air permeability and tensile strength of fabric, suspension line, and riser, so considering only the exposure hours of canopy might have some problems. Still, when considering only the standards of airworthiness according to the exposure of canopy to UV rays, the UV exposure hours can be considered.

In the paraglider test standard by the Korea Paragliding Association, it is recommended to repackage the auxiliary chute every six months, and to inspect the canopy every two years. However, this inspection standard is limited to the general flight of paragliding pilot, so more detailed reference point needs to be presented. Considering the results of this study, overall, the air permeability was very excellent. But the deviation was a bit different depending on color difference. Thus, there should be follow-up researches on if this resulted from simple color difference or it came from difference in adhesion according to color. Based on just canopy, the total flight hours could be 504 hours. In the results of air permeability shown in Table 5, it was beyond the Weak(18-25/sec) of the air permeability standards four weeks later, which does not mean something huge. Considering only the airworthiness passing standard, the biggest rate of change(96.67%) was shown between Week1 and Week2(336hr), which was followed by 71.69% between Week2 and Week3, and 52.30% in Week1, Therefore, the air permeability of paraglider canopy shows the biggest change during 336 hours, so the management of paragliding during this period of time would be important.

Such results are similar to the result of a study verifying the great ΔE value(color fastness to light) in light-colored combat uniform such as Beige gray and Forest green, and the durability vulnerable to UV rays[12]. Thus, it would be necessary to consider the colors vulnerable to UV exposure for the design of paraglider canopy. This means [13] red color has the weak color fastness to light. Such results are similar to the results of a study reporting that the color was faded by UV rays when the brightness got higher, and the differences in UV blocking rate according to color were caused by color and concentration[14]. In the results of measuring the chromaticity, overall, the great changes were shown in the order of Green > Yellow > White. Compared to other samples, White showed relatively-gradual changes. In case of Green, the color was rapidly changed in Week2. Such results are similar to the results in which Green showed the highest rate of change(97.73%) in air permeability compared to Week1. Considering such results, it would be necessary to arrange colors for the production of paraglider canopy.

V. CONCLUSIONS

The purpose of this study is to examine changes in properties(air permeability, chromaticity) of paragliding canopy by UV exposure. The results of this study are as follows.

First, the UV rays had effects on air permeability of paraglider canopy. The air permeability of canopy rapidly dropped within 336 hours after UV exposure.

Second, the chromaticity of paraglider canopy was gradually changed according to UV exposure hours. Examining it in each color, Green showed rapid changes in Week2(336hr).

In conclusion based on such results of this study, the UV exposure was verified as a factor that could reduce the airworthiness by influencing the air permeability and chromaticity of paraglider canopy. Especially, it was reduced by 96.67% within 336 hours after UV exposure, which shows the importance of canopy management after this period of time. Also, the chromaticity showed great changes in the order of Green > Yellow > White. Therefore, it would be necessary to consider the composition of chromaticity for the production of canopy. The aging of canopy by UV rays could decline the performance of paraglider by reducing the air permeability, which could be led to safety problems. Thus, the follow-up researches including the characteristics of dye and tensile strength, would need to present the measures for protecting canopy from UV exposure.

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