

Working Clothes Design and Production in the Mechatronics Machinery Industry with the Application of Faber Birren's Color Harmony Theory⁺

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Abstract

This study proposed a color scheme that is harmonious with the working environment of industrial sites using Birren's color harmony theory for color planning.

To apply the Birren's color harmony theory to working clothes, the basic colors were chosen, and six of the eight harmony formulas of Birren excluding achromatic colors (white + grey + black) and solid color harmony (solid colors + white + black) were used to form a palette for each case.

For the basic colors, the color chips of four dominant colors (yellow-green, sky-blue, blue, and violet), which were chosen from a field survey for preferences in the first step, and the production of materials in the second step were collected through the PANTONE color chips.

The selected color chips were PANTONE 13-0550 TPX, PANTONE 15-4105 TPX, PANTONE 18-3949 TPX, and PANTONE 19-3720 TPX. These color chips were scanned and their RGB values were extracted through Photoshop CS. Then the colors were arranged in accordance with the Birren's color harmony formulas (Color+Tint+White, Color+Shade+Black, Tint+Tone+Shade, Shade+Tone+Black, Shade+Tone+White, and Tint+Shade+Tone+Gray).

In addition, the proposed palette color schemes were applied through Birren's color harmony formulas using Texpro V 10.1 textile to the schematization of working clothes that were designed in the previous study.

Palette formation in line with Birren's color harmony formulas provided scientific color arrangement results. Visually presenting the color scheme of working clothes will help the color selection of working clothes in tune with the circumstances of industrial sites.

Key Words : Working Clothes, Faber Birren's Color Theory, Color Planning

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I . Introduction

Humans perceive colors by watching external objects through the process of a visual mechanism that causes a visual sensation: light → eyeballs → retinal cells → optic nerve → cerebrum. Colors are experienced when the four conditions of light, the observer, object, and environment are met, and it must be understood as an interrelated total process. The functions of colors are closely related to human needs because colors have many functional aspects that can satisfy those human needs. Thus, the functions of colors must be utilized adequately to create an environment that offers various supportabilities¹⁾.

Color functions that can be used in work clothing at industrial sites and contribute to a more comfortable and safer environment are the safety function, psychological function, identification function, symbolic function, and the aesthetic function. The adequate application of these color functions to work environment colors at industrial sites will provide a safer and more comfortable environment for workers. These color functions must be applied to the work environment at industrial sites, but the actual work clothes of workers at the sites do not make full use of the color functions as part of environmental colors. Up until now, studies on work clothes have focused on activity, functional mobility, clothing climate environment, and hygiene. Now, we need systematic research on the colors of working clothes as part of integrated environmental color planning for workplaces.

Research on colors²⁻¹⁰⁾ in the study of clothing led to personal purchasing of clothes or consumer behaviors, and progressed to research of preferred clothing colors and images. Colors

in the study of clothing are recognized as a most basic key element, and research on colors is being conducted actively. Conventional research of colors has mainly focused on the effects of colors on the decision-making process when people buy clothes, personal emotions or attitudes when people wear clothes, product development, and the sensibility of color images. As for research on color schemes, there have been studies on the color schemes of fashion collections and traditional clothes, but there have been no studies on the display of color functions in special situations.

As for research on the working clothes of workers¹¹⁻¹⁷⁾, there has been significant progress in fact-finding surveys and functionality research in human engineering and clothing construction areas, but it is no exaggeration to say that they have merely comprised of questions about preferred colors and satisfaction levels with current working clothes. As for research on the colors of working clothes at work sites involving people and environments^{18,19)}, there was a study that analyzed the work environment and working clothes with a spectrophotometer, and one which compared existing and newly developed working clothes. However, there has been no study on color conditioning to improve safety and efficiency through the planning of working clothes or that used the scientific method of Birren's harmony theory.

Color conditioning as part of color planning offers safety and efficiency by applying appropriate colors and color schemes to working clothes using the properties of colors, and it must be preceded by color planning of functional and aesthetic aspects. The basic approach to color conditioning can start from color harmony. Faber Birren suggested a color harmony practice process as a methodological

proposition. Birren's system is an ideal method for color harmony and planning and is recognized as a formula for providing a structured order in environmental color design²⁰⁾. The harmony principle of Birren is supposed to be used by planners in line with its purpose in relation to the functional role of colors. It is scientific and easy to apply because you simply need to determine the dominant color in relation to the area size, and compose a palette in accordance with the harmony formula²¹⁾.

Therefore, this study intends to investigate the colors of working clothes that play an important role as a medium between humans and the environment. This paper proposes an orderly and harmonious color scheme of working clothes in the work environment of mechatronics industrial sites, which have formed an industrial complex in Changwon, Gyeongsangnam-do, playing a pivotal role in Korean industries by using Birren's color harmony theory for color conditioning. Furthermore, this study aims to provide the foundations of color planning to build an integrated environmental harmony and safety at industrial sites by producing work clothes through the application of the proposed color arrangements.

II. Theoretical Background

1. Color Planning

According to Hasan Ozbekhan, planning is an act of controlling actual physical objects defined as the environment, which includes regulations on objectives and an action plan to execute effective changes in environmental perception and within the environment²²⁾. Thus, color planning refers to the objectives and scientific actions to ultimately improve the qualitative level

of the total environment, through the provision of visual and sensational balance to human behavior and thought by effectively controlling color stimulations.

In other words, it refers to controlling and planning the human living environment from the aesthetic and functional perspectives using the physical, biological, chemical, psychological, and psychophysical properties of colors²³⁾. Color planning and conditioning can secure the safety of workers, improve psychological satisfaction, and reduce fatigue, thereby creating personal profits for workers in an environment. For companies, color planning can decrease the risk of accidents and help generate order and harmony in the workspace. The improved satisfaction of workers can appear as satisfaction and pride of the company. The output of color planning can present the color planning and conditioning of work clothes in tune with the work environment in national industrial complexes and provide standardized information.

2. Faber Birren's Color Harmony Theory

Color harmony refers to imposing an order on a multi-color scheme of two or three colors. According to Birren's theory, when colors on the continuous lines of a color triangle are combined, they harmonize because these colors contain related visual elements²⁴⁾.

Birren assumed that the perception of colors is dominated by mental reactions rather than simple reactions to stimulations like cameras or scientific devices. He accepted the color system theory of Wilhelm Ostwald by placing the three colors of a visual-psychological solid color, white, and black at the apexes of a triangle²⁵⁾. He added the four categories of gray, tint, shade, and tone to points connected to the

triangle and grouped colors according to the seven basic categories. Furthermore, the amounts of the representative colors of white and black were indicated according to the position of each color. As the first number indicates the percentage of white and the second number the percentage of black, 100 minus the sum of these two values becomes the amount of solid color²⁶⁾(Figure2).

Birren's harmony theory states that when the three colors of solid color, white, and black and the four elements of gray, tint, shade, and tone

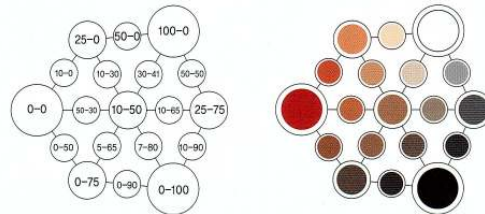
are expressed as circles, and one element among them is selected, the colors based on the elements on the line connected to it are harmonized with one another. Furthermore, because color elements that are located on one line in any direction have common properties, they necessarily harmonize with one another.

Birren's color harmony principle consists of white + gray + black, solid color + tint + white, solid color + shade + black, tint + tone + shade, shade + tone + black, shade + tone +



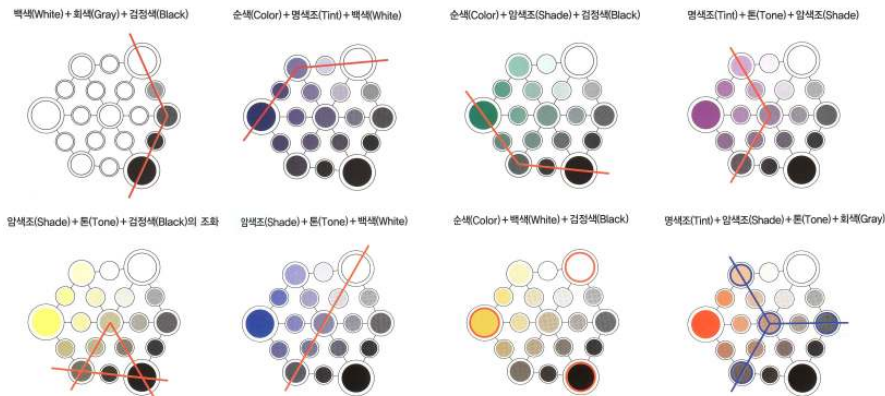
<Figure 1> Seven Basic Categories of Birren's Color Harmony Theory

- Source: Hye-Rim Yoon, *Color Perception Theory and System Theory*, Seoul: Gookje, p.165.



<Figure 2> Birren's Color Triangle Color Ratio and Color Application

- Source: Hyeon-Young Kim, Gyeong-Ae Sohn, Hwa-Seon Yeo (2008), *Color, Color, Color*, Seoul:Yegyeong, p.124.



<Figure 3> Birren's Color Harmony Theory

- Source: Hyeon-Young Kim, Gyeong-Ae Sohn, Hwa-Seon Yeo (2008), *Color, Color, Color*, Seoul:Yegyeong, p.124.

white, and solid color + white + black, tint + shade + tone + gray (Figure 3).

Birren's color harmony theory is easy to understand and is regarded as presenting the fundamental direction and framework for applying color planning, and suggesting the most practical method for assessing the harmony or disharmony of color schemes²⁷⁾.

III. Study Method and Content

1. Selection of Basic Solid Colors

For the basic solid colors, yellow-green, sky-blue, blue, and violet were chosen through the PANTONE color chips through preferences and field surveys in the first step, and the production of materials in the second step, in the previous study²⁸⁾²⁹⁾. The selected color chips were PANTONE 13-0550 TPX, PANTONE 15-4105 TPX, PANTONE 18-3949 TPX, and PANTONE 19-3720 TPX.

To apply Birren's color harmony theory to work clothes, six of the eight harmony formulas (Color + Tint + White, Color + Shade + Black, Tint + Tone + Shade, Shade + Tone + Black, Shade + Tone + White, and Tint + Shade + Tone + Gray) were used to set up a palette. The achromatic color harmony (White + Gray + Black) and solid color harmony (Color + White + Black) were excluded because they were not appropriate for a study on the arrangement of the selected basic colors.

2. Color Selection According to Birren's Color Harmony Theory

The selected color chips were scanned and their RGB values were extracted through Photoshop CS 4. Then, the colors were

arranged in accordance with Birren's color harmony formulas (Color + Tint + White, Color + Shade + Black, Tint + Tone + Shade, Shade + Tone + Black, Shade + Tone + White, Tint + Shade + Tone + Gray). Furthermore, the basic work clothes (jumper style top + pants) were schematized and the palette colors presented through Birren's color harmony formulas were then applied.

For color arrangement according to Birren's color harmony formulas, as the five harmony formulas had three colors, except for the Tint + Shade + Tone + Gray combination, they were divided into a main color, subsidiary color, and emphasis color. Then the color scheme was applied to the work clothes.

The main color must be recognized as the dominant color with the largest area. Thus, the four colors (yellow-green, sky-blue, blue, and violet) selected from the previous study were arranged as the solid colors of the harmony formulas. For color harmony formulas that do not contain solid colors, toned-down shade, lending a sense of stability, was used as the main color, in consideration of the nature of the workplace.

For subsidiary colors, tint, shade, and tone were used, excluding the achromatic colors, and gray was added only for the harmony formula of Tint + Shade + Tone + Gray. For emphasis colors, white, black and tint were used to play the role of a point.

3. Application of Color Scheme to Working Clothes

For the design of work clothes, a general type of working clothes used in general work processes was chosen among those produced in the previous study³⁰⁾, for the application of a color scheme to working clothes, the main

color, subsidiary color, and emphasis color were arranged by area size. The main colors that occupied the largest area were used in the main parts of top and pants, excluding those parts intended for subsidiary and emphasis colors.

The subsidiary colors were arranged in medium areas at the collar, yokes (front and back), and outer part of two-piece sleeves for harmony with the main colors. The emphasis colors arranged with the achromatic colors, white and black, and the bright tint were arranged in the shoulder epaulets, armholes, bosom and back lines, and the lines of a single pocket at the back of the pants to provide attractiveness and explicitness as points of work clothes <Figure 4>.

4. Production of Working Clothes

To produce working clothes by applying the color scheme in accordance with Birren's color harmony theory, yellow-green, sky-blue, blue, and violet materials were used as solid colors. For tint, tone, and shade materials, those obtained

by applying Birren's harmony formulas to the PANTONE colors of solid colors, as well as black, white, and gray materials, were used. For tint, tone, shade, black, white, and gray materials, 18 swatches for working clothes being sold on the market were collected to obtain similar color materials of each PANTONE color. 99 materials were collected for similar colors of PANTONE 13-0550 TPX, 119 for PANTONE 15-4105 TPX, 79 for PANTONE 18-3949 TPX, and 34 for PANTONE 19-3720 TPX <Figure 5>. Among the materials collected for each PANTONE color, the materials corresponding to tint, tone, shade, black, white, and gray were selected by applying a visibility measurement method, and the colors were applied according to Birren's harmony formulas. A total of 24 sets of clothes were produced.

IV. Results and Discussion

1. Results of Color Selection According to Birren's Color Harmony Theory



<Figure 4> Application of a Color Scheme to Work Clothes(designed by researcher)







<Figure 5> Selection Process for Material Swatches and Materials for the Production of Work Clothes(collected by researcher)

<Table 1> shows the color arrangement of the selected colors PANTONE 13-0550 TPX, PANTONE 15-4105 TPX, PANTONE 18-3949 TPX, and PANTONE 19-3720 TPX in accordance with Birren's harmony formulas.

Color and shade were applied for the main colors, tint, shade, tone, and gray for subsidiary colors, and white, black and tint for emphasis colors.

<Table 1> Substitution Results of the Birren's Color Harmony Formulas

 Yellow Green (PANTONE 13-0550 TPX)			 Sky Blue (PANTONE 15-4105 TPX)		
(Color) +(Tint) + (White)	(Color) +(Shade) +(Black)	(Tint) +(Tone) +(Shade)	(Color) +(Tint) + (White)	(Color) +(Shade) +(Black)	(Tint) +(Tone) +(Shade)
Harmony of (Shade)+(Tone) +(Black)	(Shade) +(Tone) +(White)	(Tint) +(Shade) +(Tone) +(Gray)	Harmony of (Shade)+(Tone) +(Black)	(Shade) +(Tone) +(White)	(Tint) +(Shade) +(Tone) +(Gray)
 Blue (PANTONE 18-3949 TPX)			 Violet (PANTONE 19-3720 TPX)		
(Color) +(Tint) + (White)	(Color) +(Shade) +(Black)	(Tint) +(Tone) +(Shade)	(Color) +(Tint) + (White)	(Color) +(Shade) +(Black)	(Tint) +(Tone) +(Shade)
Harmony of (Shade)+(Tone) +(Black)	(Shade) +(Tone) +(White)	(Tint) +(Shade) +(Tone) +(Gray)	Harmony of (Shade)+(Tone) +(Black)	(Shade) +(Tone) +(White)	(Tint) +(Shade) +(Tone) +(Gray)

2. Results of Color Planning According to Birren's Color Harmony Theory

The basic working clothes were schematized with the vector function of Texpro V 10.1 textile, and the colors obtained from Birren's color harmony formulas were arranged using the PANTONE function and color change function. As a result, a total of 24 color schemes for working clothes were derived.

The main colors were applied to the overall parts of tops and pants. The subsidiary colors were arranged in medium areas at the collar, yokes (front and back), and outer parts of two-piece sleeves. The emphasis colors were arranged in the shoulder epaulets, armholes, bosom and back lines, and the lines of a single pocket at the back of the pants.

<Table 2> shows the results of applying the color schemes of Birren's color harmony formulas to working clothes design. The colors of the schematization of no. 1 working clothes were arranged in accordance with Color + Tint + White. The PANTONE colors were used as the main colors, tint as the subsidiary color, and white as the emphasis color – demonstrating a generally bright color arrangement.

The colors for the schematization of no. 2 working clothes were arranged in accordance with Color + Shade + Black. As with the arrangement in no. 1, the PANTONE colors were used for the main colors, shade for the subsidiary color, and black for the emphasis color. Thus, the subsidiary and emphasis colors were darker.

The colors for the schematization of no. 3 working clothes were arranged in accordance with Tint + Tone + Shade, which was a color harmony formula with no solid colors. Considering the nature of the workplace, the toned-down shade lending a sense of stability

was used for the main color, a tone for the subsidiary color, and a tint for the emphasis color. It was a tone-on-tone color arrangement.

The colors for the schematization of no. 4 work clothes were arranged in accordance with Shade + Tone + Black. Shade was used for the main color as with no. 3 work clothes, a tone for the subsidiary color, and black for the emphasis color.

The colors for the schematization of no. 5 working clothes were arranged in accordance with Shade+Tone+White. Shade was used for the main color, a tone for the subsidiary color, and white for the emphasis color.

The colors for the schematization of no. 6 working clothes were arranged in accordance with Tint + Shade + Tone + Gray. Shade was used for the main color, tone and gray for the subsidiary colors, and tint for the emphasis color.

The no. 3 arrangement of Tint + Tone + Shade, no. 4 arrangement of Shade + Tone + Black, and no. 5 arrangement of Shade+Tone+White had the same main and subsidiary colors with different emphasis colors. Furthermore, the no. 6 arrangement of Tint + Shade + Tone + Gray was the result of adding gray as a subsidiary color in the sleeves to the no. 3 arrangement of Tint + Tone + Shade.

As a result, in four of the six color arrangements, shade was used for the main color and tone for the subsidiary color. Thus, a toned-down shade and tone that presents stability played a key role in the color arrangement results in this study.

3. Production of Working Clothes According to Birren's Color Harmony Theory

To produce working clothes in accordance with Birren's color harmony formulas, materials

of yellow-green, sky-blue, blue, and violet, which were selected as the solid colors, were used. Similar color materials of PANTONE colors corresponding to these solid colors were collected

and then Tint, Tone, Shade, Black, White, and Gray materials were selected through the application of the visibility measurement method.

For the design, the basic design of work

<Table 2> Color Substitution Results in Accordance With Birren's Color Harmony Formulas

 Yellow Green			 Sky Blue		
1	2	3	1	2	3
					
4	5	6	4	5	6
					
 Blue			 Violet		
1	2	3	1	2	3
					
4	5	6	4	5	6
					

<Table 3> Working Clothes Produced with Color Arrangements by Birren's Color Harmony Formulas

Color Birren Formulas	Yellow Green	Sky Blue	Blue	Violet
①				
②				
③				
④				
⑤				
⑥				

clothes used in general work processes was used. The working clothes produced by applying the color arrangements according to Birren's color harmony formulas are shown in <Table 3>.

V. Conclusions

This study investigated the colors of working clothes that play an important role as a medium between humans and the environment, and proposed scientific color arrangements for working clothes using Birren's color harmony theory for color conditioning in the work environment of a mechatronics industrial site. Furthermore, this study aimed to provide the foundations of color planning to build an integrated environmental harmony and safety at industrial sites by producing working clothes through the application of the proposed color arrangements and analyzing the colors.

The four colors of yellow-green, sky-blue, blue, and violet, selected through a previous study, were selected as the solid colors using PANTONE color chips. The selected colors were PANTONE 13-0550 TPX, PANTONE 15-4105 TPX, PANTONE 18-3949 TPX, and PANTONE 19-3720 TPX.

The colors were arranged in accordance with Birren's color harmony formulas (Color + Tint + White, Color + Shade + Black, Tint + Tone + Shade, Shade + Tone + Black, Shade + Tone + White, and Tint + Shade + Tone + Gray). Color and Shade were applied for the main colors, Tint, Shade, Tone, and Gray for subsidiary colors, and White, Black, and Tint for emphasis colors.

For the application of color arrangements to working clothes, the main colors were arranged in the overall parts of the tops and pants: the

subsidiary colors in the collar, yokes (front and back), and outer parts of two-piece sleeves; and the emphasis colors were arranged in the shoulder epaulets, armholes, bosom and back lines, and the lines of a single pocket at the back of the pants. The colors for work clothes were arranged using Texpro V 10.1 textile.

For the solid color materials in the production of working clothes, those selected through the production of materials in the previous study were used. After collecting materials of similar colors to the PANTONE solid colors, the materials corresponding to Tint, Tone, Shade, Black, White, and were selected using the visibility measurement method.

As a result of arranging colors in accordance with Birren's color harmony formulas 24 color arrangements were derived. In four of the six arrangements, shade was used for the main color and tone for the subsidiary color. Therefore, toned-down shades and tones lending stability played a key role in the color arrangements in this study.

This study obtained scientific color arrangements through a palette setup according to Birren's color harmony formulas, and visually presented the color arrangements of working clothes. The results of this study may assist the color selection for working clothes in accordance with the circumstances of the particular industrial sites. Furthermore, they can be effectively applied to the color arrangement system of each company with a corporate color as the main color.

In the future, site colors and working clothes colors should be compared through field surveys of the produced working clothes. And the evaluation will be needed in field site.

For limitations of this study, small color errors occurred in the process of scanning PANTONE

color chips and the process of extracting colors through Photoshop. Furthermore, as the arrangement process in accordance with Birren's color harmony formulas was carried out on the Web, it may be affected by the type and specifications of the computer and monitor used. And not only working clothes evaluation but also between with work places and working clothes will be needed.

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