An Ergonomic Design of Flight Suit Pattern According to Wearing characteristics

Eun-Jin Jeon*, Jeong rim Jeong*, Hee-Eun Kim**, Seikwon Park***, Hee-cheon You*

* Dept. of Industrial & Management Engineering, POSTECH, Pohang, Korea

** Dept. of Clothing & Textiles, Kyungpook National University, Daegu, Korea

*** Dept. of Systems Engineering, Korea Air Force Academy, Choongbuk, Korea

The purpose of this research is to conduct a survey of the wearing characteristics of flight suits from current pilots and to design from this survey a new flight suit pattern suitable for the physical characteristics of Korean pilots. A pool of 563 pilots was surveyed in order to analyze the wearing characteristics. In order to confirm the improved effects of the newly designed suit compared to the current one, an evaluation was conducted by assessing the subjective satisfaction and objective functionality through a measurement of the range of motion. Results of the evaluation have shown that significant improvements have been made in the areas of suit that many of the respondents had indicated as being uncomfortable, such as neck circumference, armscye circumference, and crotch. This was achieved through increasing the ease in respective parts of the suit using anthropometric data of the pilot in the design process, thus correcting the pattern of the uncomfortable areas. The areas that showed the greatest improvements were the ones associated with lengthwise mobility; the fit and the mobility of the overall flight suits have ameliorated by a significant degree.

INTRODUCTION

A flight suit is an item of clothing worn for the protection of the pilot's body and for the efficiency of flight operations; its design must take into consideration not only the material characteristics and the physical and physiological responses but also the specific requirements through motion analysis and the fit of the wearer. However, the flight suits currently worn by Korean pilots are manufactured in the same way conventional apparels are made, without sufficient regard to their movements while worn in flight.

The current suit's system of 18 different sizes cannot be described as reflecting the physical characteristics of Korean pilots, since it was based on the anthropometric data of 3,973 Army soldiers in 2002. Moreover, the standards of selecting a suit include only chest circumference and stature, with no regard to any other specific measurement. A pilot therefore cannot choose a size that is true to his bodily measurements, and is expected to experience discomfort while wearing it.

Consequently, this research aims to: first, conduct a precise analysis of pilots' wearing characteristics of the flight suit and thus reach an accurate understanding of its problems and areas for improvement; second, design an improved flight suit on the basis of the analysis conducted; and finally, to evaluate the improvements made in the new suit by collecting responses from the pilots.

MATERIALS AND METHODS

Analysis of wearing characteristics

The analysis of wearing characteristics was conducted through questionnaires concerning the wearing experience, issues of discomfort, and areas for improvement of the current flight suit. The questionnaire targeted 563 pilots of the Air Force and was composed based on the results of a literature survey of the current suit and a tentative survey of a number of incumbent pilots. The items on the questionnaire concerned personal background, characteristics of usage, wearing characteristics, and free comments. The contents of each item mostly dealt with elements that are closely linked to the fit and the ease of movement on the wearer's side.

In the questionnaire, characteristics of usage include the length of wearing the suit, method of maintenance, ease of wearing, and material. Wearing characteristics include areas that are ill-fitting, uncomfortable in movement, vulnerable to damage or abrasion, or prone to pollution. Figure 1 is a sample of the wearing characteristics questionnaire

Designing the flight suit pattern

Based on the areas requiring improvement according to the results of the wearing characteristics survey, the researchers developed a reformed design with improvements in mobility (mostly in the widths of neck, sleeve, collar, and slacks,) comfort of wearing (mostly in

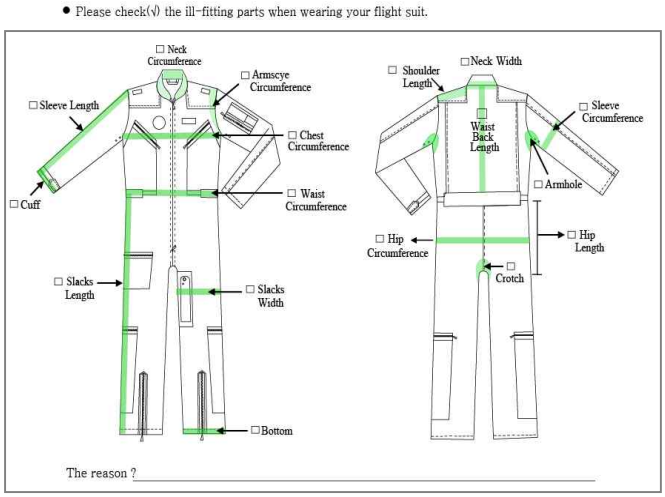

Figure 1. A sample of wearing characteristics questionnaire

the areas of waist, crotch, and hip,) and convenience (the pocket area.) Using the pattern of the 'M95 special' size (chest circumference: 92.5~97.4cm, stature 177cm and up) as the basis, the improved design was applied to create a new pattern. After calculating the amount of ease for respective areas of apparel by applying the anthropometric data of 1,238 pilots to the finished pattern, a reformed flight suit with appropriate added ease was finally designed.

Evaluation

The wearing evaluation of the reformed flight suit involved 38 pilots corresponding to the 8 sizes of the highest accommodation rate (M90 Medium, M95 Small, M95 Medium, M95 Large, M100 Medium, M100 Large, M100 Special, M105 Special Large) in the anthropometric analysis.

There are six items in the subjective satisfaction evaluation, which are: efficiency of wearing, fit, efficiency of movement, ease, efficiency of taking off, and fabric suitability. The evaluation used a five-level Likert scale, in which the respondents checked (∨) in the appropriate grid according to their subjective degree of satisfaction.

For the evaluation of functionality, the researchers selected 12 most common bodily movements of pilots consulting a precedent study on methodology of range of motion measurement (Adams & Keyserling, 1993; Huck, 1988; Kim, 2008). By having the pilots repeat these 12 movements and by using photography for analysis, the range of motion of each joint was observed.

RESULTS

Wearing Characteristic Analysis

Within the usage characteristic survey, the results of wearing convenience evaluation which consist of efficiency of fit, efficiency or ease, efficiency or wearing, efficiency of taking off, and efficiency of movement are shown in Figure 2. The evaluation shows that regarding the efficiency of fit, 205 of the responses (39.0%) were either 'strongly disagree' or 'disagree,' and for the efficiency of ease, 134 (25.6%) were negative; this reveals that the overall fit of the suit is quite poor, and that pilots are feeling discomfort in the areas where not enough ease had been inserted.

Among the sections on usage characteristics, the fabric evaluation section consists of 9 items: insulation, absorption, ventilation, durability, tactile sensation, static electricity, lint, and elasticity. In this section, the items that scored the most negative ('strongly disagree' and 'disagree') responses were absorption (406 responses, 79%), ventilation (397, 77%), insulation (392, 76.2%), elasticity (377, 74.2%), tactile sensation (337, 65.7%), lint (283, 54.7%) et cetera, showing that satisfaction was considerably low in most areas.

Table 1 illustrates the results of wearing characteristics analysis, according to which the most ill-fitting areas of the suits were the slack's length (125 responses, 18.4%), bottom (98, 14.4%), waist circumference (71, 10.5%), and slack's width (71, 10.5%). The areas that were most uncomfortable in flight were crotch (67, 19.0%), armhole (32, 9.1%), cuff (30, 8.5%), and slack's length (29, 8.2%).

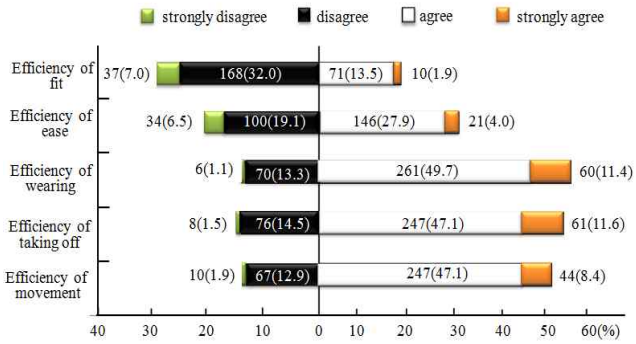

Figure 2. Analysis of usage characteristics

Designing the flight suit pattern

A proposition of pattern reform was made on the basis of the areas for improvement shown in the wearing evaluation, of which the general content is shown in Table

Table 1. Analysis of wearing characteristics

	A		B	
Neck Circumference	6	(0.9)	11	(3.1)
Armscye Circumference	7	(1.0)	6	(1.7)
Chest Circumference	25	(3.7)	8	(2.3)
Waist Circumference	71	(10.5)	25	(7.1)
Sleeve Length	65	(9.6)	20	(5.7)
Cuff	39	(5.7)	30	(8.5)
Slacks Length	125	(18.4)	29	(8.2)
Slacks width	71	(10.5)	29	(8.2)
Bottom	98	(14.4)	24	(6.8)
Shoulder Length	22	(3.2)	21	(6.0)
Neck width	1	(0.1)	0	(0.0)
Sleeve Circumference	15	(2.2)	7	(2.0)
waist back length	30	(4.4)	23	(6.5)
Armhole	8	(1.2)	32	(9.1)
Hip Circumference	29	(4.3)	13	(3.7)
Hip Length	12	(1.8)	7	(2.0)
Crotch	55	(8.1)	67	(19.0)
Total	679	(100)	352	(100)

2. The pattern line of neck, sleeve, and collar was curved in order to increase mobility, and more ease was inserted in back waist (+1.5cm), crotch (+2cm), and hip circumference (+2cm) to improve the fit. The amount of ease adjustment followed the anthropometric data of the pilots and referenced the numbers from calculation equation used in menswear manufacture. Furthermore, in areas mentioned as being excessively baggy lengthwise, 1/4 of the total ease in each area was reduced: sleeve (-1cm), waist (-0.5cm), hip (-0.5cm), and bottom (-1cm). With collar and pockets, both the position and the angle were adjusted and the cutting direction was altered to increase convenience of use.

The methods of reformed pattern design and the amount of adjustment made to the improved areas are outlined in Figure 2.

Table 2. Improved flight suit pattern design

Item		Region	Improvement design
Mobility	A	Neck	Curved neckline
	B	Sleeve	Size adjustment (wrist, sleeve width)
	C	Collar	Curved neckline, Bias direction
Fit	D	Waist	Size adjustment
	E	Crotch	Adding ease
	F	Hip	Curved hipline, hipline down
Mobility	G	Slacks width	Size adjustment (Slacks width, Bottom)
Convenience	H	Pocket	Calf pocket length adjustment Brachial pocket angle adjustment
	I	Symbol	Unity of symbol position

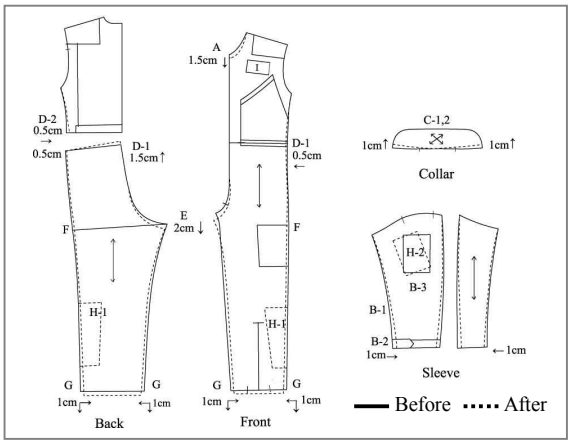

Figure 2. Improvements applied to the pattern design

Wearing evaluation of the reformed flight suit

According to the evaluation of subjective satisfaction concerning the new suit, the areas of the suit where the satisfaction increased in all points including efficiency of wearing, fit, efficiency of movement, ease, and efficiency of taking off were: neck circumference, armscye circumference, chest breadth, chest circumference, cuff, hip circumference, biacromion length, back interscye fold, crotch height, et cetera.

The areas that showed the greatest improvement in efficiency of movement as shown in Figure 3 were: neck circumference (0.75), armscye circumference (0.69), chest breadth (0.63), biacromion length (0.63), back interscye fold (0.59), waist back length (0.56) et cetera. Such result was arrived at by improving mobility through inserting sufficient ease in the areas that had been pointed out as being uncomfortable in the existing suit.

Table 3 represents the result of functionality evaluation; the areas of greatest improvement were: hip adduction (13.0%), upper leg abduction (11.7%), shoulder abduction (10.4%), shoulder flexion (9.9%), trunk extension (8.1%), trunk flexion (8.6%), et cetera.

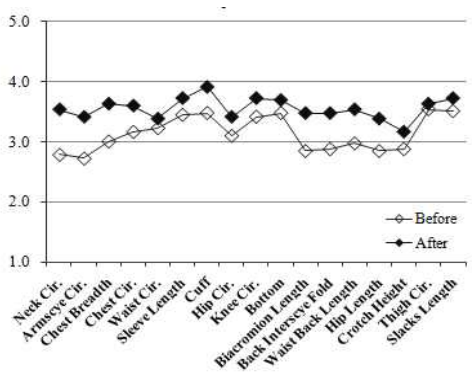

Figure 3. Subjective satisfaction: mobility

Table 3. Functionality evaluation : Range of motion

	Movement	Before		After			
		M	SD	M	SD	(%)	p-value
Lateral	Neck extension	60.5	11.3	64.7	9.9	6.9	0.002
	Neck flexion	112.8	12.4	118.1	12.2	4.7	0.000
	Shoulder flexion	62.5	15.7	68.7	13.3	9.9	0.002
	Shoulder extension	49.5	12.9	52.3	14.8	6.1	0.048
	Trunk extension	29.6	7.9	32.0	7.3	8.1	0.008
	Trunk flexion	89.8	20.2	96.9	16.8	8.6	0.002
	Hip flexion	79.0	12.3	81.8	12.5	3.5	0.009
	Knee flexion	66.5	16.4	70.5	14.1	6.6	0.007
Front	Shoulder abduction	40.9	10.7	45.2	10.4	10.4	0.004
	Trunk lateral flexion	45.1	6.1	46.5	6.3	3.7	0.025
	Hip adduction	58.5	18.0	65.8	15.9	13.0	0.000
	Upper leg abduction	51.1	12.1	57.1	11.8	11.7	0.001

These improvements signify that the lengthwise tightness of the current flight suit has ameliorated, which led to an improved fit and mobility in such areas as crotch, neck, and armhole.

In terms of the p-value of the functionality analysis as shown in Table 3, all movements except shoulder extension and trunk lateral flexion showed statistically significant difference. The reason for which the visible improvements were made in neck flexion and neck extension movements would be the application of lowered center-front neck line, curved lines, bias cutting of collars, and curving of the collar, among other enhancements.

DISCUSSION

In this research, a precise analysis of the wearing characteristics of the currently used flight suit was made through directly surveying pilots as the actual wearers. By designing a reformed version of the flight suit pattern that solves the problems of the current suit revealed through this analysis, a considerable improvement was made regarding the pilots' points of discomfort.

The wearing evaluation conducted inspect the quality of the improvement confirmed the effect in not only the ease of wearing but also the range of movement, by evaluating subjective satisfaction as well as objective functionality assessment. Previously, there have been studies that sought to analyze the movement efficiency of apparel through objective functionality evaluation of overalls items like a flight suit, such as that of Young Hee Kim (2002, 2009) or Huck & Kim (1997). Nevertheless, these studies were limited in their applicability to the actual design of the pattern of overall apparel since they only calculated the location and amount of required ease in regards to the range of motion in joint areas.

Therefore, in order to make progress in such points of limitation in preceding studies, this research first deducted a calculation equation for each respective sartorial part, from the anthropometric data of pilots. Then, it calculated the appropriate amount of ease and applied it to each of the parts. By inserting the right amount of ease at each part, both subjective satisfaction and objective functionality increased considerably, as seen in the evaluation. This seems to be due to the enhanced wear ability and fit of the uncomfortable areas through adjusting and correcting the drawbacks of the suit as overalls attire.

As an objective functionality assessment, the evaluation of the range of motion confirmed the improved effects by appraising the range of motion for the most common bodily movements of pilots. It is thus expected that the pilots wearing the reformed suit will see enhanced efficiency in flight operations as well as increased safety due to this advancement in mobility.

One limitation of this research could be that subjective elements could not be completely removed in evaluating range of motion even though the control of the movements was objectively set, for it still observed the range of movement in subjective individuals. In future researches, a study of a thoroughly objectified control of movements should be conducted in tandem.

ACKNOWLEDGEMENTS

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