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Total Design of Active Neck Support System for Economy Class Aircraft Seat

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Abstract. Travel by air with long hours will create discomfort feeling for aircraft passenger especially economy class aircraft passenger. Long hour air travel will create physiological stress on aircraft passenger. It may due to seat space limitation, noise, vibration, cabin humidity as well as seat comfort. Seat comfort is a subjective feeling that related to psychological aspect of aircraft passenger. The current aircraft passenger seat is equipped with a passive function where the passenger themselves needs to adjust the seat for comfort seating position. The aircraft passenger will not able to adjust the seat when the aircraft passenger is in the low activity condition. The active seat support system was developed to support the aircraft passenger actively. The first prototype of active seat support system is focus on neck section. The head position of the aircraft seat was embedded with the system to detect the head position of the passenger. During the development of the active seat support system, total design technique was used. Five conceptual designs were generated for selection. To determine the final design of active neck support system, the matrix evaluation method was used. The weight of the concept was obtained through weight analysis.

Introduction

During travel, passenger will experience different level of discomfort. The literature review showed that seating comfort and discomfort is subjective and interchangeable. Objective measurements and subjective measurements can be used to measure and understand seating comfort and discomfort. The current economy class aircraft seat is a passive system where the passenger needs to do the adjustment manually. There were different type of support that available in the market, such as inflatable neck pillow, memory foam travel pillow and feather filled pillow. Neck is one of the important body parts during travel. During air travel, the economy class aircraft passenger is unable to lie down and need to perform sleeping while seating. When aircraft passenger is sleeping, their head will turn to left or right without awareness. Passenger neck will be discomfort if their head is facing one side for long time. The head facing forward is the most comfortable head position (Tilley and Dreyfuss, 2002). Therefore, the active system prototype was developed that focuses on active neck support. The objective of the active system is to reduce the neck muscle stress of the economy class passengers during air travel.

The total design technique (Pugh, 1990; Ion, 1995) was used to design and develop a smart neck support system. Pugh (1990) defined total design as the systematic approach in product development. Total design includes the activity of market investigation, conceptual design, product evaluation and marketing of the final product. Total design is an integrating framework that includes all product development aspects (Ion, 1995). Total design is a design method used in the development of commercial products. For this subsection, total design is used for the development of working and functional active neck support system (ANeSS) prototypes.

Several idea generation methods like brainstorming and morphological chart have been used. Extensive application of the morphological charts enabled the researcher to identify the sub-solutions to each sub-function of the simulator. The evaluation matrix was used to decide on the final concept of ANeSS. ANeSS is used to support and reduce the seating discomfort of the economy class aircraft passenger. The aim of this section is threefold. First, it describes the design methodology of ANeSS. Next, it describes the application of different methods to design and determine the design. Lastly, the section concludes the development of ANeSS with the total design method.

Design Methodology

The first step in the design process is to conduct the literature and market study on the proposed product. The related information can be found from websites, patents, journals and technical report. There is various information, such as basic technology, industry analysis, legal issues, engineering definition, industry analysis and benchmarking will be input to the design process. The output from the market survey is the product requirement. The product requirement is a guideline for the development of ANeSS. Next, creative method and morphological chart were used as a tool to develop the conceptual design. Subsequently, the design was visualized in three dimensional views for evaluation purposes. Different conceptual designs were evaluated based on weighted objective method.

Conceptual Design

Based on the product requirement, the design concepts were generated. The development of the ANeSS employed two methodologies for concept generation. Brainstorming (Cross, 2008) and morphological chart (Pugh, 1990; Cross, 2008) were used in the conceptual stage of design. The product requirement of AneSS are performance, materials, size, reliable, weight, strength, safety and design.

Brainstorming is the creative method that used in the design of ANeSS. The technique is used to generate as many ideas as possible and as many solutions to each idea as possible. The brainstorming was conducted in a small group session of about five individuals. The author also participated in the brainstorming session. Four individuals were invited as volunteer in the brainstorming session. They were working people. Each individual was encouraged to express their ideas freely without critical judgment. Next, the recorded ideas were identified through the final discussion. Lastly, the agreed ideas were changed into five design concepts.

The morphological chart (Pugh, 1990; Cross, 2008) is a method used to combine design ideas in a systematic way. The combined ideas generate a solution as well as search for possible new solutions. The morphological chart of the airbag system for ANeSS is shown in Table 1. The sub-functions identified are material, control medium, shape, feedback system and actuator. For each sub-function, there are between two to four solutions being generated. The combinations of the final solutions were highlighted. The final concept of the airbag system is an airbag that is made from polyester and rectangular in shape. The polyester has been chosen because it is easy to purchase from a shop and low cost. The airbag is rectangular in shape because it is easy to seal with the heat sealer machine. The air had been chosen as control medium because of the simplicity of design and control, good in reliability and safety (Wikipedia, 2010). An air pressure sensor was selected to detect the air pressure change inside the airbag. A proportional valve was used to control the deflation and inflation of the airbag proportionally. Arduino (Arduino, 2010) with an embedded ATmega microcontroller was chosen to be the main controller for ANeSS.

Table 1. The morphology chart for ANeSS airbag prototype

Sub-function \ Solution	1	2	3	4
Material	Polyurethane	Natural rubber	Neoprene	Polyester
Control medium	Liquid	Air		
Shape	Round	Rectangular	Triangular	Cylindrical
Feedback system	Air pressure sensor	Load cell	Membrane potentiometer	
Actuator	Directional valve	Proportional valve		
Microcontroller	ATmega	PIC	ARM	Motorola
Programming language	C++	Arduino	Java	Processing

Evaluation of Concepts

The evaluation of the five concepts was carried out by using the weighted objective method (Pugh, 1990). The five concepts were evaluated based on the requirements. The evaluation of the five concepts is shown in Table 2. Eight requirements have been set to evaluate the five concepts. Each element was provided with relative weight e.g. performance (0.20), materials (0.10), size (0.10), reliable (0.20), weight (0.05), strength (0.15), safety (0.05) and design (0.15). Two requirements, namely performance and reliable, were rated with highest weight because the ANeSS prototype should be functional and support the passenger's head as well as reliable during the validation experiment. During the brainstorming session, each concept is rated with scores (S) using ten point scales. Each point is multiplied by the objective weight to give relative values (V). Each value is summed up to get the total value for each concept. Subsequently, the total values for each concept are compared and the highest values are selected. Concept 5 as shown in Table 2 represented the highest values and was selected as best concept. Concept 5 was selected because the concept is able to perform with good functionality, cost effective material, adjustable size, reliable, light weight prototyping material, good strength, safe and easy to maintain.

Table 2. Weighted objective evaluation of ANeSS prototype concepts

			Concept 1		**Concept 2**		**Concept 3**		**Concept 4**		**Concept 5**	
No.	**Element**	**Weight**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**
1.	Performance	0.20	2	0.40	2	0.40	5	1.00	5	1.00	6	1.20
2.	Materials	0.10	3	0.30	2	0.20	4	0.40	4	0.40	4	0.40
3.	Size	0.10	5	0.50	2	0.20	5	0.50	6	0.60	6	0.60
4.	Reliability	0.20	5	1.00	3	0.60	3	0.60	5	1.00	5	1.00
5.	Weight	0.05	4	0.20	5	0.25	3	0.15	3	0.15	4	0.20
6.	Strength	0.15	3	0.45	2	0.30	4	0.60	4	0.60	5	0.75
7.	Safety	0.05	3	0.15	2	0.10	3	0.15	4	0.20	4	0.20
8.	Design	0.15	3	0.15	3	0.45	4	0.60	4	0.60	5	0.75
	Total value			3.15		2.50		4.00		4.55		**5.1**

Based on the evaluation results, the active neck support system prototype was built. Fig. 1 shows the installation of the final ANeSS prototype to the economy class seat in the aircraft cabin simulator. The ANeSS were tested for their functionality and performance in the economy class aircraft cabin like testbed that located at Eindhoven University of Technology, the Netherlands.

Figure 1. Three ANeSS prototypes embedded in an economy class aircraft seat

Conclusion

The ANeSS was successfully developed by using the total design approach. The total design approach is able to guide the designer to develop the functional ANeSS prototype. The total design approach is a useful tool for the development of a product from concept to functional prototype. The market survey, design knowledge and design experience were important in the first stage of the project. The product requirements provided the designer with a way to keep track of the design process. The morphological chart helped the designer to identify the various design solutions and product functions in a systematic way. The weighted objective method was used in the brainstorming and mind mapping session to generate and determine the final concept. The final setup of active neck support system contains a head cushion, a neck cushion, two side airbags, an Arduino microcontroller with air pressure sensors and a proportional solenoid valve connected. The open-source programming language, namely Arduino and Processing, were used for programming implementation in ANeSS.

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