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Interactive Aircraft Cabin Simulator for Stress-Free Air Travel System: A Concurrent Engineering Design Approach

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Abstract

In this paper, a study of the concurrent engineering design for the environmental friendly low cost aircraft cabin simulator is presented. The study describes the used of concurrent design technique in the design activity. The simulator is a testbed that was designed and built for research on aircraft passenger comfort improvement of long haul air travel. The simulator consists of an scale down aircraft cabin, an inventory section, a control section and a simulation section. The aircraft cabin simulator was designed with solid modeling system.

Keywords: aircraft cabin, simulator, concurrent engineering design

INTRODUCTION

Testbed is a platform on which an assortment of experimental tools and products may be deployed and allowed to interact in real-time. Successful tools and products can be identified and developed in an interactive testbed. A testbed also can be defined as an environment that is created for testing and validating purpose. In this research, the development of aircraft cabin simulator is aided by computer tools such as computer-aided design (CAD), finite element analysis (FEA) and total design (TD) method under a concurrent engineering perspective.

In the development of product within a CE environment, activities such as material selection, design and analysis, components specifications, customer experience, process selection and design modification play equally important roles for the successful development of a product as presented in 'CE wheel' in Figure 1 [1].

The developed aircraft cabin simulator is a testbed that used for European Project SEAT (Smart tEchnologies for Stress free Air Travel). The SEAT project aims to develop a new radical approach through integration of cabin systems with multimedia features. The aircraft cabin simulator is fully designed and built by us. The simulator consists of a small scale cabin-like testing platform, an inventory section, a simulation section and a control section. The interior of the aircraft cabin consists of an economy class section, a business class section, a galley and a lavatory. Each passenger seat and the lavatory are provided with a personal entertainment touch screen monitor. An inventory section is used to store the testing related equipments. A sky-like projection environment is created at the external location. In addition, the simulator is built with an innovative low-cost motion platform. The motion platform is used to simulate the flight environment such as taxi, taking off, turbulence, descending and landing. The control section is fully equipped with a state of art computer system that is used to control and monitor the simulator remotely.

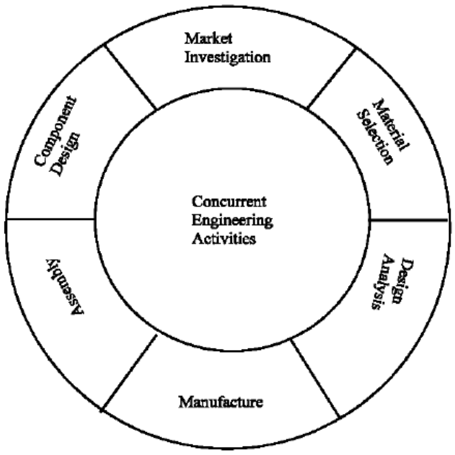

Figure 1: CE wheel [1]

In this paper, the design of the developed aircraft cabin simulator is carried out using total design method under concurrent engineering environment. The total design method is the systematic activity oriented, from the market need identification, to the final product that satisfied the need. The activity of total design includes product, process, people and organization [2].

DESIGN METHODOLOGY OF AIRCRAFT CABIN SIMULATOR

Design Process of Aircraft Cabin Simulator

A design process shown in Figure 2 is used in the development of the aircraft cabin simulator. At the product planning stage, a market survey about the current aircraft cabin simulator and market were conducted. The market survey was done mainly through company information, website, patents, and technical reports of the related design. The design knowledge and design experience of the designer as an important input to the planning stage. The design knowledge and design experience plays a crucial role in the new product development process.

The output from the design planning was the product design specification (PDS). The PDS is useful in the early stages of conceptual design. After that, conceptual design of the simulator was generated based on the project requirements and constraints. During the concept generation, brainstorming, think bubbles and morphological chart were used. For the detailed design, computer-aided design (CAD) was used to generate a three dimensional (3D) view. The 3D final design also evaluated by the finite element analysis for the strength and durability.

For the final design stage, designers, builders and customer were gathered to discuss the final design in detail. In this stage, the outcome from the preliminary stage was decided whether the design going to proceed or not. During the construction stage, the aircraft cabin simulator was built. After the completion of simulator, the simulator was tested for durability and safety.

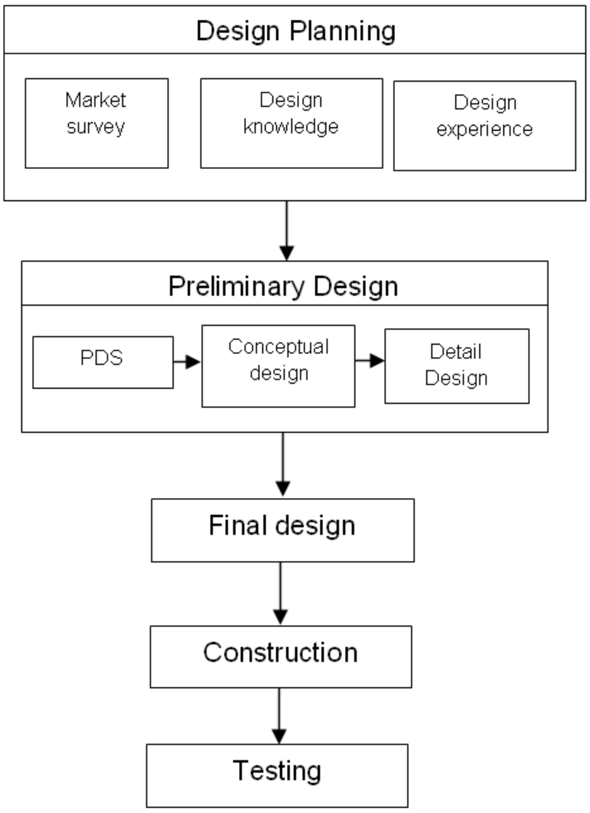

Figure 2: The architecture of aircraft cabin simulator design process

Preliminary Design of Aircraft Cabin Simulator

In the preliminary design stage, the PDS was developed as a design guideline for the aircraft simulator. The PDS for the aircraft cabin simulator is shown in Figure 2. The descriptions of the PDS elements as follows:

Performance: the simulator able to work for 10 hours per experiment without failure. The simulator also provides a real flight experience such as vibration, sound and temperature for the test subject during the 10 hours experiment.
Materials: The simulator could be constructed from a mixture of high quality and durable materials such as aluminum, steel, composite and wood. These materials are selected from European Standards wherever possible.
Size: the simulator must be able to fit into provided space in the building.
Weight: the weight of the simulator must not exceed 2000kg.
Strength: The construction will be designed to withstand the loads, shocks, and vibrations that occur during transportation to site, installation and in service. Fail-safe design is adopted wherever possible for those areas where a failure could disable or damage equipment and cause injury to personnel
Safety: Safety is an integral part of all aspects of design. Due consideration will be given to the safety of all personnel whether operating the equipment, maintaining the equipment or installing the equipment.

Standards: The International Standards (ISO) would be employed as applicable in the design and build of the simulator.
Design simplicity: In the interests of production, reliability and maintainability, simplicity of design is a key factor. Features such as modular packaging and a wiring interface which simplifies future expansion or modifications, are standard practices applied within the design review.
Cost: the total cost to build the simulator must be less than €20,000.

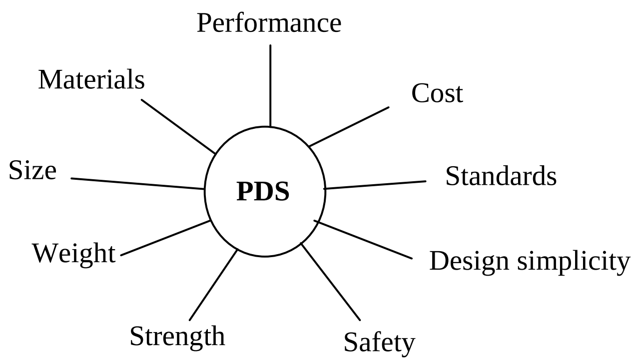

Figure 3: The PDS of aircraft cabin simulator

The development of the aircraft simulator employed different methodologies for the concept generation. At the conceptual design stage, think bubbles, brainstorming and the morphology chart was used. Think bubbles is a graphic technique for organizing the thoughts. It creates an actual, physical picture of the way people's mind blueprint a challenge. Think bubbles able to record, store and manipulate information in a variety of ways, as well as to understand the relationship between different concepts. The brainstorming was designed to encourage a group to express various ideas and to defer critical judgment until later. Everyone offer idea that are listed, combined, improved, and changed into various other ideas. In the end, the group agrees on a final resolution. The morphological chart is a method used to generate design solution in systematical way. It is a method of automatically combining the parameters (characteristic, factor, variable, or aspect) of a challenge into a solution [3]. Figure 4 shows an example of morphological chart of projection installation.

Final Concept

In the final concept, five design concepts were generated. All concepts draw in 3D view to visualize and compare the concept clearly. The computer-aided drawing of concept two is showed in Figure 5.

Sub-function \ Option	1	2	3	4
Wall color	White	Grey	Light blue	Tan
Display resolution	WXGA	XGA	SVGA	VGA
Projection distance	Very short	Short	Long	Very long
Projection angle	Very narrow	Narrow	Wide	Very wide
Fitting location	Floor	Roof	Ceiling	Wall

Figure 4: The morphological chart for projection installation

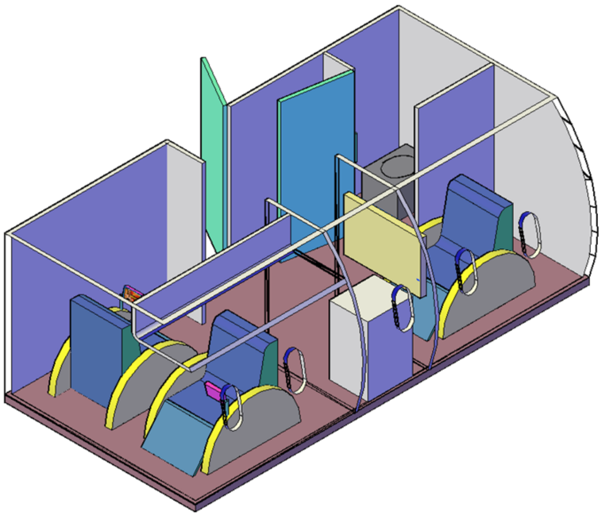

Figure 5: Concept 2

The detail explanation of concepts as follows:

1) *Concept 1*: the simulator has economy class area only. There are two rows of economy class seat. The simulator is built on the static platform.
2) *Concept 2*: the simulator has galley, lavatory and two business class areas. There are two individual business class seats. The simulator is built on the static platform.
3) *Concept 3*: the simulator has galley, lavatory and two economy class areas. There are two rows of economy class seat. The simulator is built on the static platform.
4) *Concept 4*: the simulator has galley, lavatory, economy class areas and business class area. There is one row of economy class seat and one row of two person business class seat. The simulator is built on the motion platform.

5) *Concept 5*: the simulator has galley, lavatory, economy class area and business class area. There are two rows of economy class seat and one business class seat. The simulator is built on the motion platform.

Concept evaluation

The evaluations of the five concepts were carried out by using the weighted objective method. The evaluation of five concepts is shown in Table 1. Seven objectives have been set to evaluate the concepts. Each objective was provided with relative weight. During the brainstorming session, each concept is rated with points using ten point scales. Each point is multiplied by the objective weight to give relative values. Each value was summed up to get the total values for each concept. Subsequently, the total values of each concept are compared and the highest values were selected. Concept 5 as shown in Table 1 represented the highest values and selected as best concept.

Table 1: Evaluation of simulator concept using weighted objective method

objective	weight	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5	
		S	V	S	V	S	V	S	V	S	V
Low cost	0.25	9	2.25	8	2.00	8	2.00	7	1.75	6	1.5
Function	0.10	4	0.4	5	0.50	7	0.7	7	0.7	9	0.9
Motion	0.10	4	0.4	4	0.40	4	0.4	7	0.7	7	0.7
Size	0.15	6	0.9	7	1.05	7	1.05	5	0.75	8	1.2
Fit-ability	0.10	8	0.8	7	0.7	7	0.7	6	0.6	5	0.5
Strength	0.20	8	1.6	8	1.6	8	1.6	7	1.4	8	1.6
Environment friendly	0.10	7	0.7	7	0.7	7	0.7	7	0.7	7	0.7
total value	1.0		5.05		6.95		6.45		6.6		**7.1**

FINAL DESIGN

The final design of aircraft simulator was designed and tested with CAD/CAM system. Figure 6 shows the final design from top view. The aircraft simulator included an economy class section (with two rows 3 person economy class seat), a business class section (with a business class seat), a galley and a lavatory. The simulator was built with wood and medium density fiberboard (MDF) material. There are eight touch screen in-flight entertainment system for each passenger as well as inside the lavatory. The foundation was enhanced to withstand the dynamic impact that caused by the motion action.

The business class section (Figure 7) equipped with a massage chair, a touch screen monitor, a high quality surround sound system and a 47 inches ambient LCD television. The setup is to test the user reaction in the comfort environment during the long haul flight. Two rows of economy class seat were setup; each of the seats was equipped with a touch screen monitor and a noise reduction ear phone. The seat was embedded by a series of sensors to detect the physiological and posture change of the passenger. Figure 8 shows the economy class section.

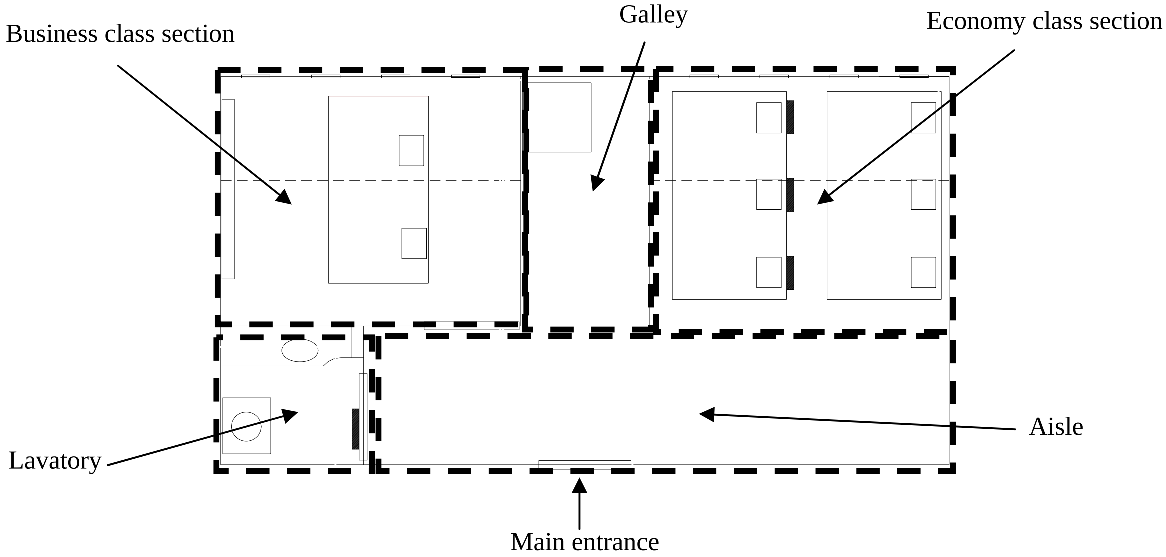

Figure 6: Final design from top view

Figure 7: Business class section

Figure 8: Economy class section

The simulator was designed with a galley function with the setup of shelves to store items. The galley was equipped with a refrigerator, a microwave and a peripheral compartment. The galley was used to provide the food and beverage to the passenger Figure 8 shows the galley of aircraft cabin. The lavatory was equipped with a portable toilet, a wash basin and a touch screen monitor. Figure 9 shows the external view of the lavatory. Both galley and lavatory were purposely built for the passenger during the 10 hours flight experiment. Figure 10 shows the external view of aircraft cabin simulator.

Figure 9: Galley

Figure 10: Lavatory

Figure 11: External view of aircraft cabin simulator

CONCLUSION

The aircraft cabin simulator was designed with the systematic concurrent engineering design approach. The total design and concurrent engineering were useful for the development of aircraft cabin simulator from concept to real buildup. The market survey, design knowledge and design experience were important at first stage of project. PDS provided the designer a way to keep track and refer with the specification. 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. Various concurrent engineering design methods were extensively used and it was proved to be a useful tool in the development of aircraft cabin simulator. For future work, a motion platform will integrate to the aircraft cabin simulator.

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