THE RESEARCH DEVELOPMENT OF MAN-MACHINE-ENVIRONMENT SYSTEM ENGINEERING TECHNOLOGY IN THE AIRCRAFT DESIGN OF CHINA

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Abstract

This paper has maintained review and conclusion work upon the research and state of development of Man-Machine-Environment System Engineering (MMESE) technology applied in the aircraft design domain of China. The research development discussed involves: Preliminary design of MMESE of aircraft, environment control and Life-support system design of aircraft, and, the environment simulate of aircraft.

1 Introduction

Man Machine Environment System Engineering (MMESE) is a new-type borderline subject formed in China in early 1980s under the circumstances that Professor Hsue-Shen Tsien advocates. Although it has close relationship with those subjects such as Human Factors Engineering, Ergonomics, Human Engineering, Man-Machine System and Engineering Psychology, etc., it includes more extensive content. This subject puts special emphasis on proceeding from overall system concept, regards human, machine and environment as an interacted and interdependent huge system, and manipulates the system engineering method with rational design to reach the system optimization goal [1]. The concept framework of MMESE is illustrated in Fig1. .

Aircraft system design is a typical MMESE, which comprise factors as Pilot, Airplane and Environment (PAE). Therefore, the methodology of MMESE is fit for applying in the design process. The purpose of this paper is to maintain review and conclusion work upon the research and state of development of MMESE technology applications in aircraft design domain of China. The related research development discussed involves three parts in detailed: (1) Preliminary design of MMESE of aircraft, (2) The environment control and Life-support system design of aircraft, and (3) environment simulate of aircraft.

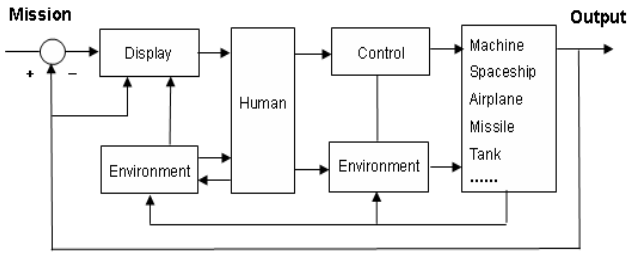

Fig.1 The concept framework of MMESE

2 Preliminary Design of MMESE of Aircraft

The object of preliminary design is a complicated system which is composed of Pilot, Aircraft and the concomitant Environment, to satisfy the Integrative Efficiency Index (IEI) of "Security, High- efficiency, Economy", the relative model of PAE must be built, and utilize the simulative technique to analyze the problem of PAE affected with the performance of total system, then, modify and perfect the structure mode of system, finally, the system

optimization goal could be achieved [2]. The MMESE technology shows the potential applicability in aircraft design domain that special research departments and laboratories have been built in many institutes and colleges recently years in China. The domain experts of aero-medicine, aero-psychology, ergonomics and aeronautical engineering, have done much research work on such aspects as: Characteristic of pilots; Characteristic of aircraft; Environment characteristic of Man-machine system; Human-machine relation; Human-environment relation; etc. The work has brought a great deal of date that established the fundament for the integrated design of aircraft MMESE.

2.1 Characteristic Research of Pilots

Study on characteristic of pilots has been developed using the simulative experiment to investigate physiological and psychological performance of pilot [3, 4]. The mainly research involves: dynamic physiological parameter of pilot testing; EEG character analysis during flight activities; analysis of psychological characteristic of pilot such as Cognitive, Workload, Decision-making, Situation Awareness and Error etc. Otherwise, mathematical modeling method has been used in 3D anthropometric and Human Regulation System Modeling (HRSM) of Chinese pilot [5, 6, 7, 8]. Prof. S.Z. Long developed a Fuzzy Control Model (FCM) of pilot in target tracking process, the compliance of this model was proved as a practicable one by using the validity verification method of parameters distinguish [2].

2.2 Characteristics Research of Aircraft and Modeling

Research of aircraft characteristic includes Maintainability, Reliability, Applicability and Life Cycle Cost (LCC) analysis [2], etc.

2.3 Environment Characteristic of Pilot-Aircraft System

The environment is complicated and multivariate when pilot-aircraft accomplish different task, thus, the way that investigate the environment dynamical characteristic is more valuable. Currently, experimental and numerical-simulated methods are common used, the subjects includes: the environmental simulation under the High-low temperature conditions; dynamical simulation of multiple conditions of aircraft environment such as Chemical, Radiant, Vibratory, Noise, Acceleration, and the Pressure Variable [1, 2, 15], etc.

2.4 Research of Pilot-Aircraft Relation

The important of aircraft MMESE design is that either the characteristic of pilot/crewmember, or the fact that human ability adapt to aircraft control system should be considered. The problems of Pilot-aircraft relationship are diverse, and the relative techniques include: Control Interface Design (CID) of pilot; Dynamic Function Allocation (DFA); design of the cockpit layout; Cognitive based design of display/control system of UAV control station; optimized design of ejection seat applying the Anthropometrical Database of Chinese pilot [9, 10,11,12,13]; etc. These studies are benefit from the progress of software technique of Virtual-design. Besides of advanced commercial software tools such as JACK, DELMIA, SPEOS and others, lots of applied software which secondary development independent based on platforms (i.e. CATIA, UG) employed in the Pilot-aircraft relationship design. The equipment such as Cockpit System Simulator, and the methods of “Human Factor Exponential Evaluation” or “Fuzzy Evaluation ” are utilized for evaluation technique of cockpit ergonomics design [13, 14, 15].

2.5 Research of Pilot-Environment Relation

The emphasis on study of Pilot-environment Relationship characteristic is the physiological and psychological performance of pilot/crewmember affected with the environment factors, these problems involves response detecting and analyses of the cognitive performance and body symptom of pilot who equipped physical protective arming under the environmental conditions of Weather,

Weightlessness, Over loading, Impact, and the composite factors of cockpit [14, 16].

2.6 Integrated Design of Pilot-Aircraft-Environment System

Generally, it is impossible that the Integrative Efficiency Index (IEI) of "Security, High-efficiency, Economy " could be satisfied synchronously because of the conflicts being. According to the System Engineering Theory (SET), the implementation of aircraft MMESE preliminary design should content those courses as below [1, 2].

- Analyze the definite task of system exactly;
- Based on the date results from the experiments and Mathematical simulations which before-mentioned, build up a Value of Integrative System Evaluation (VISE) considering the affection of PAE to the performance of total system as equation (1):

$$\boldsymbol{Q}=\boldsymbol{W_1}\times(\boldsymbol{Security})+\boldsymbol{W_2}\times(\boldsymbol{High\text{-}efficiency})+\boldsymbol{W_3}\times(\boldsymbol{Economy}) \quad (1)$$

  Here, the $\boldsymbol{Q}$ is the VISE, W_1, W_2, W_3 are the weights of each IEI, and $\boldsymbol{W_1}+\boldsymbol{W_2}+\boldsymbol{W_3}=1$, the $\boldsymbol{W}$ is selected according to the factors such as Flight Situation, Type of aircraft, and the Status of national financial;
- Gained the diagram of PAE affect with $\boldsymbol{Q}$ through the transform shows in Fig2. ;
- The optimal parameters of PAE could be predicated upon Fig2. , and then ,the correlation matrix of different projects with $\boldsymbol{Q}$ is found based on those parameters, and draw in Fig3. ; Finally, the optimal project of preliminary design of aircraft MMESE can be collected.

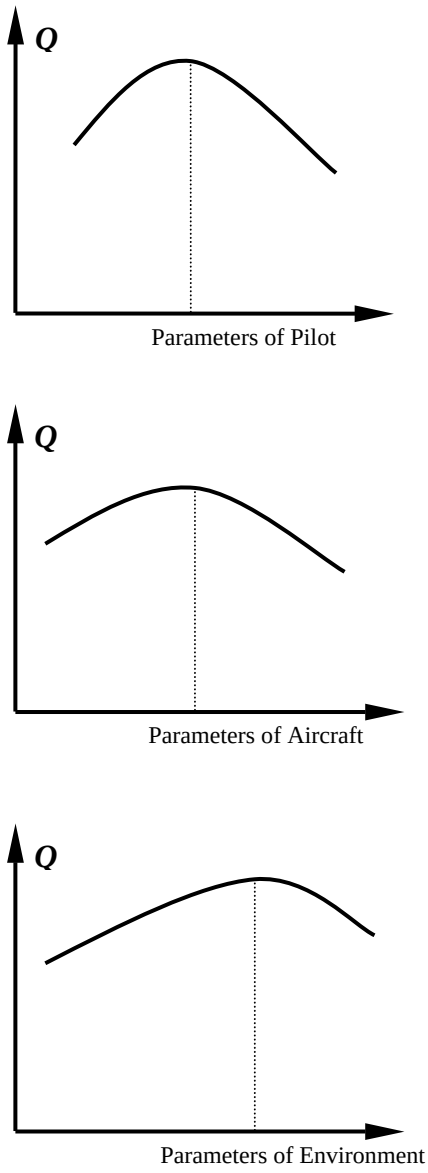

Fig2. Value of Integrative Evaluation affected
With parameters of Factors

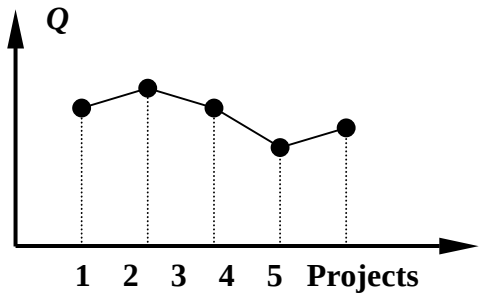

Fig3. Relations of different projects with *Q*

3 The Environment Control and Life-support System Design of Aircraft

Environment Control System (ECS) is a main component of modern aircraft system design, it lead achievement of Security, Comfort, and Reliability of pilot/crewmembers and equipments [16].

3.1 Techniques of Environment Control System (ECS) of Aircraft

The ECS of aircraft consist of muti-layer subsystems interrelated such as Air-inducing, Air-condition, Pressure-regulation, and Control system. Considering the complicacy of the system, the Parallelism Design Technique (PDT) has been applied widely in the design process. To realize the PDT, it is important that the integrated framework which incarnate the multiple concept relationships of Requirement-Function-Structure-Behavior should be set up, using Mathematical Simulate Methods to workout the simulated tools considering factors status of human, devices and the dynamic characteristic of pivotal parts. The key problem is the methods how to matching the parameter of subsystem and parts, the method of enthalpy-matched has been developed in the design of Air-inducing system of ECS, it is more simple and exactly for parameter matching compare with the conventional method which is complex and less accuracy due to the design of Dry-exchanger and Damp- exchanger apart. Along with the complication of ECS of aircraft, the techniques of Refrigeration System design, Failure Diagnose, Digital Integrate Control of ECS have been also applied and developed [17, 18, 19, 20].

3.2 Research of Life-support System Design of Aircraft

For aircraft system, design of the Life-support System is the key technology for increasing the survival probability of pilot, the technique of Eject-lifesaving take part the important place in this research area. With the methods of mathematical-simulate and experimental, depend on the advanced devices and equipments, lots of results of the study have been applied in the development of Lifesaving products successful. The research using mathematical-simulate involves: study of dynamic comfortable of eject-seat; simulation of 9-freedom dynamics model of Human-chair system; visualized analysis of Fluid-field during eject process; dynamic system model of Human-parachute; technology of automatic eject [21, 22]; etc. In the aspect of experimental study, the performance of full size eject-seat and the aerodynamic character of pilot-helmet for high capability aircraft ware tested using low speed wind tunnel in the R & D Center of Aerodynamic of China; many experimental devices such as the High-precision Rocket-powered Slider Test-bed (Fig.4); Vibratory test platform; Large test platform of horizontal impact; Joint test bed of eject power; and the equipments of light-remote testing [23, 24, 25]; etc. were built in the Institute of Aeronautical Lifesaving Equipment of China. These equipment conditions put a great progress of the technology of Life-support products in China.

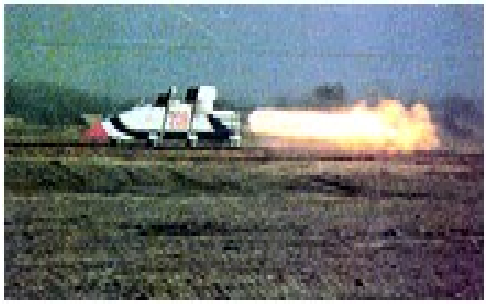

Fig4. High-precision Rocket-powered Slider Eject Test-bed

4 The Environment Simulate of Aircraft

Environment simulation technology mainly covers artificial Man-made reappearance techniques of all kinds of nature environment and product test techniques under the simulated environment [25]. For the development and quality testing of a new type of aircraft system and its' components, it is important that the

disadvantages could be detected and overcome in the initial stages of aircraft design.

4.1 Methods of Environment Simulation

The techniques of environment simulation equipment and environment test of aircraft design engineering have gone through the development from single parameter to multi-parameters, from static simulation to dynamic simulation [26]. The technical path is: first, take the simulate research of aircraft MMESE based on the mathematical models setting according to previous knowledge and information; to prepare the prototype of system upon the results of simulation; third, the experiment of pilot-aircraft system should be finished under the conditions which of static or dynamic state to obtain relative parameters; finally, apply analysis of the parameters to exam and evaluate the performance of pilot-aircraft system, providing the reliable date for ECS design of aircraft.

4.2 Techniques of Environment Simulation

There are two kinds of environment simulate techniques with different equipments such as Ground -simulate and the Aerial-simulate, the types of Ground –simulate involves: Low Temperature Environment; High Temperature Environment; Thermal & Heat Environment; Sunlight Environment; Sand & Dust Environment; Rain Environment; Infuse-simulate; Acidity Environment; and Icing/Ice rain Environment [25, 26]; etc. The types of Air-simulate experiment include Air Environment Simulated Experiment of aircraft ECS which simulate the pressure outside, and the Resume Temperature of Heat-boundary-layer of Faying Surface, the parameters of Air-inducing and Air-pressing of engine during flight etc. with the simulate techniques which mentioned above, the experiments such as Parts Testing, ECS and cockpit examination, Joint Equipment bay Testing, and Engine Performance Testing on high altitude, and so on [27, 28].

Nowadays, the technology of ECS in aircraft design domain has developed rapidly in China, different size and purpose of environment simulate equipments (experiment box, environment simulate wind tunnel, etc.) have been built in collages and institutes [25, 26, 27, 28].

5 Conclusions

The MMESE puts special emphasis on proceeding from overall system concept, regards human, machine and environment as an interacted and interdependent huge system, and manipulates the system engineering method with rational design to reach the system optimization goal as security, high- efficiency and economy, this concept is fit for the technology of complex aircraft system top-layer design, the facts indicate that MMESE technology will play an important role in the improvement of the overall level in aircraft system integrated design engineering of china.

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