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STUDY OF OVERALL ANALYSIS METHOD OF THE MAN-MACHINE-ENVIRONMENT SYSTEMS

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Abstract

This paper has studied effect of the three essential factors (man, machine and environment) in man-machine-environment system on system performance according to Man-Machine-Environment System Engineering (MMESE) theory. Results indicate that parameter changes in the man, machine and environment produce great influence on the overall system performance. Experimental data of this study provides advantageous condition for optimal designing of the man-machine-environment systems.

I. Introduction

As it is well known that all machines are operated by man, and man and machine are working under certain environment, therefore, man, machine and environments are always in a state of mutual effecting and mutual depending on one another. According to Man-machine-Environment System Engineering (MMESE) theory[1,2], all artificial (or manual) control processes with human participation are a man-machine-environment system (see Fig.1).

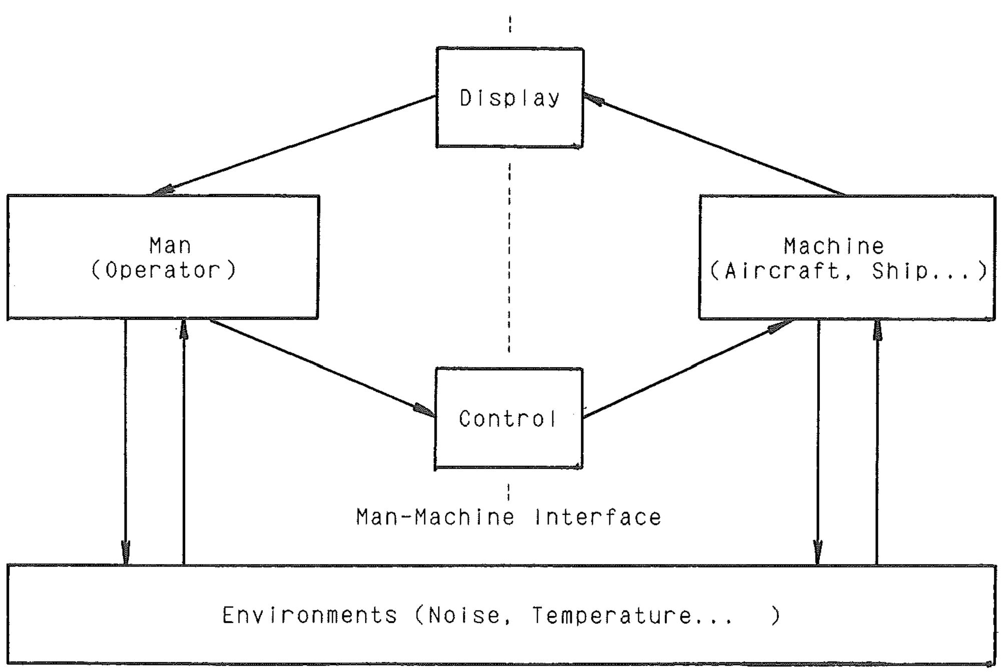

Fig.1 Diagram of the man-machine-environment systems

A pilot flying an aircraft in the atmospheric environment is also a typical one[3]. In order to ensure optimal performance of the systems, the MMESE theory especially emphasize the overall analysis of the whole system with the prerequisite that the overall requirements of the system be determined definitely[2].

The main point of this study is to stress the importance of the analysis and study of the effects of the three essential elements (man,machine and environment) on the overall performance of the system. This study was engaged in scientific laboratory simulation, in which the man's parameters are the selection of operators and the methods and times for the operator's training; the machine parameters are the changes in the dynamics of the controlled object; and the environment parameters are noise levels. System performance indexes are the duration of time and the precision of the controlled object reaching the target.

II. Methods

This study was engaged in scientific laboratory simulation where combating state of aircraft was simulated. Experiment diagram of the man-machine-environment system is shown in Fig 2.

In above man-machine-environment system, the man's parameters are:

1.Operator's training times;

2.Operator's training method;

3.Operator's selection.

Machine parameters are dynamics changes of the controlled object. It includes four dynamics: 0.5/s, 0.5/s(0.25s+1), 0.5/s(0.9s+1), $0.5/s^2$.

Environment parameters are noise levels. They are 57, 80, 90, 95 and 100dB(A).

In the experiment, target is appeared

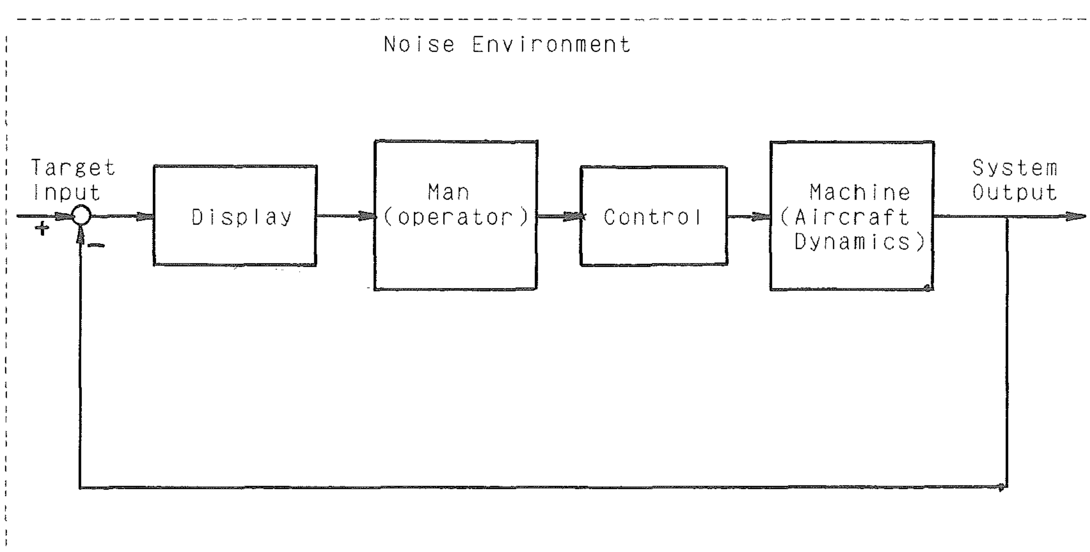

Fig.2 Experiment diagram of the Man-machine-environment System

at one of 12 air routes randomly from one of four directions: left up ,left down, right up and right down(see Fig 3). Based on the deviation between the

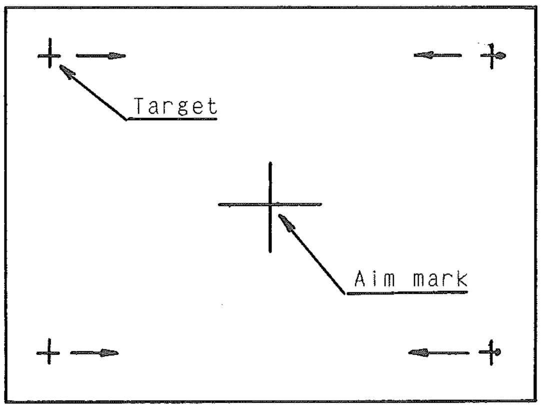

Fig. 3 Diagram of the target movement

target and the aim mark on the CRT display, the operator pursuits the target by the control and hits the target as soon as possible. We define the completing of operations of all air routes as "one person-time experiment". Overall performance indexes of the man-machine-environment system are:

1. T--The time duration of the aim mark reaching the target.

2. P--The precision of the aim mark reaching the target.

In the experiments, four aircraft dynamics and five noise levels are arranged randomly.

III. Results

In order to make comparing between different experimental data, we first selected an experiment state as reference value and compared the reference value with other experiment in order to obtain relative system performance indexes P and T. P and T were defined separately as follows:

$$P(\text{relative value})=\frac{Po(\text{experiment value})}{Po(\text{reference value})}$$

$$T(\text{relative value})=\frac{To(\text{experiment value})}{To(\text{reference value})}$$

Then, we systhesized two performance indexes P and T to one system performance index SP. SP was defined as follows:

$$SP=\sqrt{0.5P^2+0.5T^2}$$

It is quite evident that the smaller is the value of the SP, the better is the system performance.

In this study, we carried out 2240 person-time experiments on 24 male subjects around the age of 20. Results show that parameter changes of the man, machine and environment in the man-machine-environment system produces great influence on the overall system performance. They are described as follows:

1. Effect of the operator's skill on the system performance

We have studied the effect of the operator's skill on the system performance form three aspects: training time, training methods and individual difference. The results are shown in table 1 and figure 4.

Table 1. Effect of the operator's skill on the system performance

Operator's Skill		System Performance P	T	SP	SPx100%
I	A	1.00	1.00	1.00	100
	B	2.54	1.28	2.01	201
II	C	1.00	1.00	1.00	100
	D	0.38	0.93	0.88	88
III	E	1.00	1.00	1.00	100
	F	2.15	0.69	1.59	159

A--After training;

B--Before training;

C--Normal training;

D--Adaptive training;

E--Excellent operator;

F--Poorest operator.

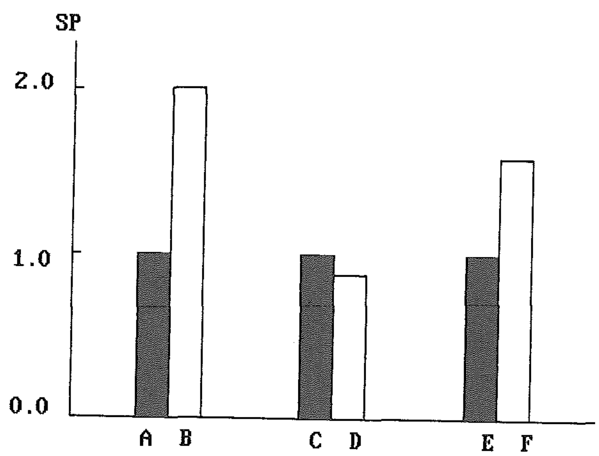

Fig.4 Effect of the operator's skill on the system performance

a. Effect of the operator's training times

We found that operators can keep a stable skill level in about 80 time trainings. And operator's skill after training can improve about 100%.

b. Effect of the training methods

We have taken two training methods: normal training and adaptive training. Normal training means that the degree of the difficulties of the operator's task remains the same from the beginning to the end. Adaptive training means that the degree operator's task difficulty increases step by step from low to high. Results show that the adaptive training method can improve operator's skill about 18%.

c. Effect of the individual difference

An excellent operator can improve the system performance about 60%.

2. Effect of the machine dynamics on the system performance

The results are shown in table 2 and figure 5.

Table 2. Effect of the machine dynamics on the system performance

Machine Dynamics	System P	T	Performance SP	SPx100%
0.5/S	0.64	0.90	0.78	78
0.5/S(0.25S+1)	1.00	1.00	1.00	100
0.5/S(0.9S+1)	1.38	1.12	1.26	126
$0.5/S^2$	1.95	1.22	1.62	162

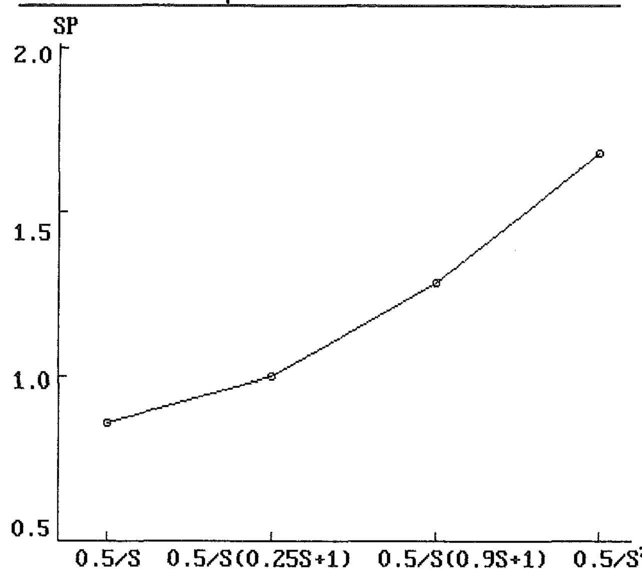

Fig.5 Effect of the machine dynamics on the system performance

As indicated in table 2, 0.5/S is the best machine parameter in the four dynamics. In order to improve the system performance, machine design ought to fit operator's requirements. And system performance can improve about 2 times.

3. Effect of the the level of environment noise on the system performance

The results are shown in table 3 and figure 6.

Table 3 Effect of the environment noise on the system performance

Environment	System		Performance	
Noise dB(A)	P	T	SP	SPx100%
57	1.00	1.00	1.00	100
80	0.91	0.98	0.94	94
90	1.23	1.00	1.12	112
95	1.14	0.99	1.07	107
100	1.07	0.98	1.02	102

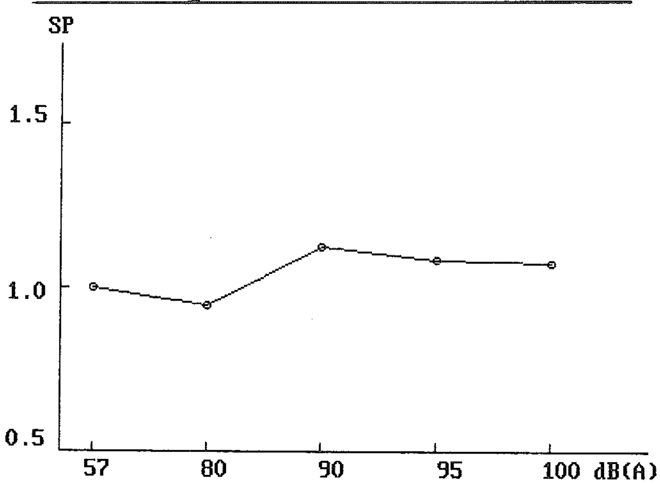

Fig.6 Effect of the environment noise on the system performance

The results show that the system performance is the best in the 80 dB(A) noise level among the five noise environments. Therefore, a proper noise level will enhance operator's work efficiency about 18%.

To sum up, in order to improve the overall performance of the man-machine-environment systems, we can make selections of the parameters of the three essential elements (man, machine and environment) in the system as follows:

1. Considering the human factor,the operator ought to suit machine requirements,i.e. to select and train the operator in the system.

2. Considering the machine factor the machine designing ought to fit human requirements, i.e. to select a optimal machine dynamics so that the operator can operate it easily.

3. considering the environment factor, the man and machine ought to work in proper environments.

It should be stressed that we can not simply seek an optimal value of the man, machine and environment separately. According to overall viewpoint (safety, high efficiency and economy) of the man-machine-environment system, must all-sidedly balance them and draw a distinction between main factor and secondary factor. In this study, the very important factor is the selection of the machine dynamics. The secondary factor is the selection and training of the operator. The last one is the selection of the noise environment. These experimental data will create advantageous conditions for optimal design of the man-machine-environment systems.

IV. Conclusions

According to the Man-Machine-Environment System Engineering (MMESE)theory, when designing any man-machine-environment system, we should select the parameters of the man,machine and environment in order to make the system to be in optimal work state.

1. When machine dynamics changes, overall system performance changes about two times.

2. After operator's selection, overall system performance can be improved about 60%;

3. Overall system performance have improved about 18% by selecting proper noise environment.

Above results will create an advantageous condition for optimal designing of the man-machine-environment systems.

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