Application of Standard Solution to Human-Machine-Environment Coupling Effect

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Abstract. The reasonable design of human-machine-environment system is closely related to the automation and intelligence of industries. However, there is a lack of suitable analytical method and indicative solutions to the problems when the couplings of man, machine and environment fail to achieve the design. This paper compares the coupling as the Su-Field model, then the problems can be solved under the guidance of the standard solutions. Firstly, the set of constraint factors of the man, machine and environment are established respectively and the coupling between them are carried out. Secondly, the Su-Field model composed of people, machine and environment are established to analyze the problems in the coupling by analogy. Finally, under the guidance of the standard solutions, the problem are solved and the ideal coupling effects are realized. This method effectively solves the problem in the coupling of human, machine, environment and improves the rationality and effectiveness of the system design.

Keywords: Human-Machine-Environment System, Constrain, Coupling Effect, Substance-Field Model, Standard Solution.

1 Introduction

Human-Machine-Environment system mainly researches the interdependent relations and laws between the three elements: H=human, M=machine and E= environment[1-2]. In order to make the system more secure, efficient and economical for serving the human, we need to coordinate the relations among the three elements and optimize the system continuously.

The importance of ergonomics in modern engineering technology and product design has been recognized[3]. There has been a great deal of research and application on the design methods of the H-M-E system[4-5].The design process of the H-M-E system (see Fig. 1). generally includes the following steps:

Step 1: Establish the overall goal of human-machine interaction system design: operator attribute positioning, machine, working environment.

Step 2: Decompose the total target into multiple subsystems involving human-machine interaction: human-machine interaction, human-environment interaction, and machine-environment interaction.

Step 3: Analyze the relevant design constraints in the interaction process of each subsystem.

Step 4: Combine the above design requirements to design each subsystem.

Step 5: Perform the coupling of each subsystem to complete the system design.

Around this design process, the research content of human-machine system is mainly concentrated on the following aspects:

The geometric dimension design of products based on human body size measurement[6]; design for the comfort of the product based on human body working posture[7]; human-computer interaction design based on the research of user's vision, color attributes, human psychology etc[8]; research on reliability of Human-Machine operating system[9].

The above research content mainly focuses on the establishment of the front-end design of the system--the adaptation constraints of the H-M-E system. But for the post-design--there is a lack of further analysis on the problems and solutions to the problems in the coupling process of three elements based on the adaptation constraints built in the front-end design. According the characteristics of the three elements in the H-M-E system, this paper proposes to analyze the problems in the coupling process of the H-M-E system through the Su-Field model in the TRIZ theory. And then solve the problem under the guidance of the Standard Solutions. The research expects some useful explorations in the design of the H-M-E system.

2 Establishment of The Set of Constraints for The H-M-E System

The process of product design is to weigh the various design constraints in order to achieve design goals.In this process, designers need to coordinate various design constraints. So the product design is a process of solving constraints essentially[10]. Human, machine and the environment are the three basic elements of the system design and each element has its own special characteristics.These characteristics constitute the constraints when the elements fit and interact with each other (see Fig. 2).

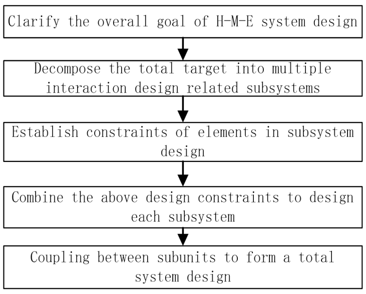


Fig. 1. H-M-E System decision process.

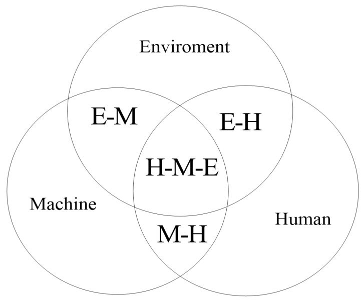


Fig. 2. A H-M-E System Relationship.

For the establishment of the H-M-E system ,designers and engineers must establish the design constraints of each of the three elements in conjunction with the design task at first. Then, do the coupling between the three elements of human, machine, and environment combined with the constraints. Discover problems that do not meet the constraints in the coupling process. The process is as follows:

2.1 The Set of Constraints for The Human , Denoted as H

Please According to human attributes and characteristics, human-related constraints in the H-M-E system mainly include two types, one is personal ability, that is, constraints related to physical strength and brain power; the other is limitation of personal experience.

Personal ability mainly includes age, gender, physical characteristics parameters, physical disability, work posture, etc. People's cognitive ability and psychological characteristics,etc;

Personal experience mainly includes the mother tongue, cultural background, cultural level, professional skills and experience in using technical products[1-2].

2.2 The Set of Constraints for The Machine , Denoted as M

Mainly include the Industry manufacturing standards, functional specifications, process constraints, physical size constraints, component connection methods, maintainability, error-proof design, costs and other requirements[1-2].

2.3 The Set of Constraints for The Environment , Denoted as E

Environment constraints mainly refer to working conditions and external environmental conditions when the machine is running. Extreme conditions have a great influence on the human, operating processes and the run of the machine.This section mainly includes temperature, humidity, light, ventilation, color, and ideology under specific conditions[1-2].

2.4 Establish Coupling between Elements and Discover Problems in The Coupling

Applying the necessary constraints, designers and engineers need to find problem in the coupling process of the three elements. The coupling between the three elements of the H-M-E system is established in two steps in combination with system design tasks.

Step1: Establish the coupling model between“Human and Machine”,“Machine and Environment”, “Human and Environment” separately (see Fig. 3). Identify whether the couplings between elements meet the constraints, and point out the problems that do not meet the constraints;

Step2: Establish the coupling model between “ Human, Machine, and Environment” (see Fig. 4). Identify whether the couplings between elements meet the constraints, and point out the problems that do not meet the constraints.

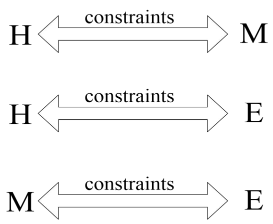


Fig. 3. The first step of the coupling.

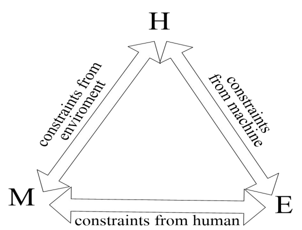


Fig. 4. The second step of the coupling.

3 Analysis of The Problems in the Coupling Process of The Elements

In the design of the H-M-E system, the establishment of the set of constraints is the “front-end”of the system design process. For the problems in the coupling of the three elements, we need to make further analysis and propose appropriate solutions to improve the design of the H-M-E system.

3.1 Su-Field Model

Translate complex system problems into simple models is a common problem analysis method. The Su-Field model is applied to describe the technology system and analyze system problems from the perspective of functional effects. Three elements(two substances and one field) are used to describe a technical system[11](see Fig. 5). In the figure, F represents the field, S_1 and S_2 represent the substance.The significance of this model is that: S_2 has an action on S_1 in order to change S_1, through the role of field F [12].

The realization of the system functionality is a result of the interaction between multiple components in the system.Considering the results of the functionality, there are three types :

(1) Effective functionality with all three elements: the function of a technical system with all three elements(F, S1 and S2) are effective. Designers pursuit of this effect. The model is shown in Fig. 6 (a).

(2) Non-effective functionality with all three elements: All three elements in a technical system exist, but the effects pursued by the designers have not been fully realized. E.g the generated force is not large enough and the temperature is not high enough.So the design of the system ought to be improved to meet the requirements. The model is shown in Fig. 6 (b).

(3) Harmful functionality with all three elements: The three elements in a technical system are all present, but the effect of the system is conflict with the designer's pursuit. The harmful functionality model is shown in Fig. 6 (c). In the process of product design, it is necessary to eliminate the harmful functions in the system.

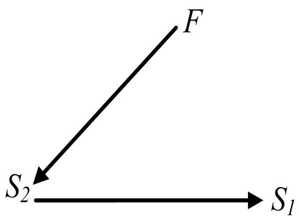


Fig. 5. Su-Field Model.

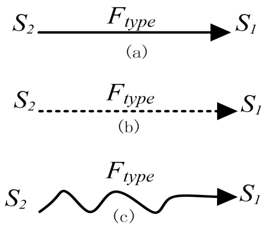


Fig. 6. Effect of Components.

The Su-Field model describes the specific problem in a system as a simple relationship between three elements. It can more intuitively analyze the functional relationships and effects between system elements.This is very important for designers to further analyze and solve problems improving the system design.

3.2 Establish the Su-Field Model for The Coupling of The H-M-E System through Analogy

The relationship between the three elements in the H-M-E system can be simply described as: The interaction between any two elements occurs under the influence of the third element. Therefore, through the analogy to Su-Field model, the relationship between the three elements of the H-M-E system can be further described as the following three kinds of conditions:

(1)Under certain environmental conditions, human and machines can interact with each other.At this point, the role of the environment is seen as field F, denoted as F_E. Human and machine are regarded as substance S, and denoted as S_H and S_M respectively. The relationship between the three is represented in Fig. 7(A) and (a).

(2)Under the control and intervention of human, machine and environment can interact with each other. At this time, the role of the human is considered as field F, denoted as F_H. Environment and machine are considered as substance S, denoted as S_E and S_M respectively. The relationship between the three is shown in Fig. 7(B) and (b).

(3)Under the cooperation of the machine, human adapt to or change the environment. At this time, the role of the machine is considered as field F, denoted as F_M. Human and the environment are regarded as substance S, and are denoted as S_H and S_E. The relationship between the three is represented in Fig. 7 (C) and (c).

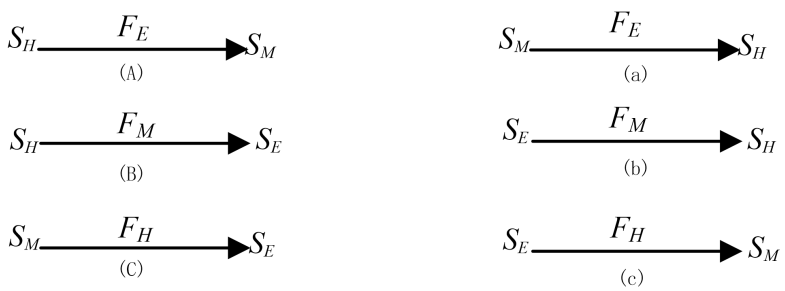


Fig. 7. Su-Field model of the H-M-E system.

3.3 Analysis of The Problems in The Coupling Process

Process 1.4 describes the coupling process of the three elements of the H-M-E system and find out the problems in the process. Combined with the description in 2.2.1, establish the Su-Field model for the specific problems in the coupling process. The specific operation is as follows:

Step 1: Establish the coupling between the three elements of the H-M-E system combined the system design tasks.

Step 2: Apply the necessary constraints and then analyze whether there is a problem in the coupling between the three elements. Do a further analysis of the specific issues in the coupling, identifying the S1 and S2 (Human and Machine, Machine and Environment, Human and Environment) and the F(Human, Machine, Environment)affecting the interacting components.

Step 3: Combined with the model in Fig. 7, establish the corresponding Su-Field model of the problems above according to the types of functionality between components (Effective functionality, Non-effective functionality, Harmful functionality).

4 Solution to The Coupling Problem in The Design of The H-M-E System

The essence of the H-M-E system design is to solve the problems in the process of the coupling between three elements of human, machine and environment under the guidance of constraint factors, and constantly optimize the system design to make the system more secure, efficient and economical.

Through the above process, the specific problems in the process of coupling have been standardized and described—the Su-Field model. The standard solutions in the TRIZ theory, provide a variety of effective guidance for the specific issues which have established Su-Field model. The standard solutions can inspire designers to quickly find solutions to problems.

For this study, designers mainly uses the first, second, and third standard solutions to solve the problems in the coupling of the elements in H-M-E system, and uses the fifth standard solutions to improve the new. The specific process is as follows:

Step 1: Identify the types of functionality according to the Su-Field model of the problem to be solved, and then select the first or the second category of standard solutions. Under the guidance of the standard solution, try to solve the specific problems in the coupling with the analyze the resources around the system;

Step 2: Apply the third kind of standard solutions to optimize the solution above combined with the specific problems in the coupling process, making the H-M-E system achieve the goals expected;

Step 3: Identify whether the solutions provided based on the guidance of the standard solutions is feasible. If the recommended solution is not fit the problem, you need to further analyze the initial coupling problem; if you can accept it, apply the category 5th solutions to simplify the recommended solutions so that the final solution of the problem is closer to the ideal state.

5 Case Study

X-ray detectors were used to check whether lollipop density is uniform and whether the lollipop is mixed with other matter in the production of lollipops. Fig. 9 (a) shows the working process of the X-ray detector. According to the design method proposed in this paper, the relevant constraints are established to analyze the problems in the existing system and the system is further optimized.

5.1 The Main Constraints of Each Element Are as Follows:

H ={the physical parameters and age of the staff, the main operating position is standing, the machine should be easy to operate and the information should be easy to identify, work space and personal safety are required, etc.}

M ={meet functional and technical requirements, functional modules are built-in as required, buttons are easy to operate, efficiency (correlated with the speed of the belt

in the production line), suitable for mass production, safety and reliability, and necessary weather resistance etc.}
E ={normal room temperature, weak electromagnetic interference, adequate lighting, certain humidity and noise, fixed test location, etc.}

5.2 Identification and Analysis of The Problems

Firstly, establish a coupled model of the three elements:the staff, X-ray detector, and working environment (see Fig. 8). Identify whether the coupling between elements satisfies the system constraints and point out the problems that do not meet the constraints step by step.

By the above analysis, it was found that X-rays emitted from the X-ray detector (M) can shine on staff (H) in the working environment (E), doing harm to the staff. Because, the curtain on the detector need to be opened when the lollipop enters the X -ray detector. However, the X -rays will shine on the workers around the X-ray detector. The process of the detection is shown in Fig. 8. In this system, X-ray detector (S_M) needs to check the quality of lollipops($S_{lollipop}$), but the X-ray detector (S_M) has a detrimental effect on the staff (S_H) under the work environment (S_E). A Su-Field model of the problem is established, as shown in Fig. 10.

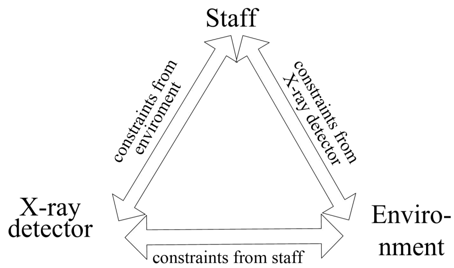


Fig. 8. The coupling between the elements.

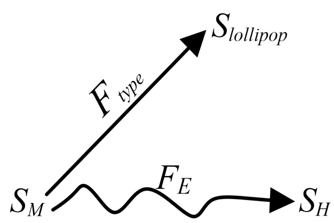


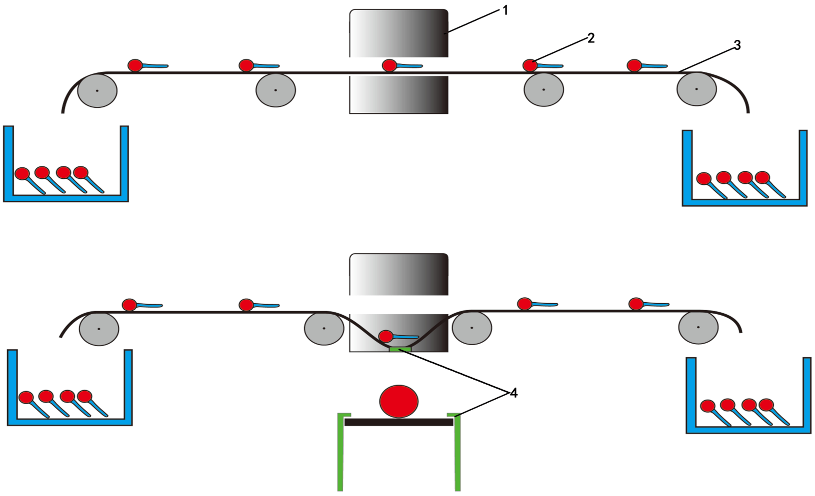
Fig. 10. The Su-Field model of the problem.

5.3 The Solution to The Problem

The harmful effects, for the safety of the staff (SH), caused by X-ray detector (SM) need to be eliminated. The standard solutions NO.9 and NO.10—add a substance or field to eliminate harmful effects provide solution to the problem.

With the same constraints and the system structure existed, the amount of change to the system is as small as possible, the cost is as low as possible, and it does not affect the operation of the staff.Under the guidance of the standard solutions, The improved scheme is shown in the Fig. 9 (b):

Before the lollipops enter the X -ray detector with the conveyor belt, the straight conveyor belt is changed by the addition of guide rollers. The conveyor belt carries the lollipop, under the action of a guide roller, into the X -ray detector. As shown in Fig. 9(b). The improved design avoids the X-rays doing harmful effect on the staff and meet the constraints of the system design.



1. X-ray detector, 2.Lollipop, 3.Conveyor belt, 4.Guide roller added

Fig. 9. The Lollipop detection system.

6 Conclusion and Outlook

This paper proposes an analogy between the coupling of human, machine and the environment and the Su-Field model in TRIZ. Then solve the problems in the coupling process with the aid of standard solutions.The process mainly includes:

In combination with design tasks, establish the constraints for human, machine and the environment, and make couplings between the three elements;

Establish Su-Field models consisting of three elements: human, machine, and the environment to analyze problems in the coupling;

According to analysis of the Su-Field models, the problems in the coupling process are solved under the guidance of standard solutions, and the ideal coupling effect is obtained.

This method can effectively solve the problems in the coupling of human, machine and environment in the H-M-E system; improve the system design process and make the H-M-E system design more reasonable and effective. The design of the H-M-E system requires a large number of experiments. Further research is needed in the establishment of database and systematic design method.

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