The study of Industrial design: The transformation of welder based on Tandem double-wire MIG welding

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Abstract. With the advent of industry 4.0, the new demands of welding industry are to adopt advanced welding technology and to realize automation. As a typical representative of welding technology, Tandem double-wire Metal-Inert Gas (MIG) welding could be used in precision welding and high-quality welding occasion. It has some superiority in higher welding efficiency and achieves automatic control easily. The paper presents a possible solution with transforming the common MIG welding tractor into special welding machine based on Tandem double-wire MIG welding. On the basis of product design and improvement methods, this paper integrates systems science and ergonomics to deeply discuss the application of Tandem MIG welding. The aim of transformation design is available to enhance the welding quality as well as to lower the production cost. And the research has consulting value on the design improvement of welding equipment for the manufacturing industries.

1. Introduction
Modern manufacturing industry reflects the level of a national integrated productivity. Welding, regarded as joining technology with low cost, is one of the most important synthesis techniques in the manufacturing. Therefore, welding equipment sales increase greatly to meet demand growth of welding work with the rapid development of manufacture. Under the background of market globalization and production modernization [1], the welding machine has been the development trend in the following areas. They are adopting advanced welding technology, increasing productivity and achieving automation in production operations.

Metal-Inert Gas (MIG) welding occupies the most important position among the fusion welding processes, due to its flexibility and cost effectiveness. Significantly higher travel speeds and deposition rates were achieved by Tandem double wire welding(Fig.1) compared to a common double wire welding(Fig.2). The Tandem MIG equipment comprises of two power sources, two wire feeders and a special torch for accommodating the two wires. The torch houses two contact tips which are electrically isolated from each other [2].
2. Background
Welding operators apply gas-shielded welding technology and use simple and crude single-wire welder manually in the mechanical manufacturing industry. And welding machine focuses on the realization of function rather than the Man-Machine-Environment System. In conclusion, welding machine is backward with low degree of automation in production operations. Aiming at the current situation, we carry on the study and transform MIG welding tractor (Fig.3) to special welding machine based on Tandem double-wire MIG welding. Therefore, special welder can improve not only automation degree but also welding efficiency, and ensure welding quality through systematic design theory.

3. Study approach
The system is the combination or interrelation of hardware, software, people and the operating environment. This paper takes the man-machine-environment system as the research object and discusses several influence factors from the angle of systematic design and ergonomics. And it emphasizes how to achieve top performance by uniting and coordinating the three elements: man, machine and environment [5]. According to the systematic design thought, human factor engineering introduces the method to study users and the operating environment to design the most human-friendly welding equipment.

Figure 1. Schematic of double wire welding process
Figure 2. Schematic of Tandem double wire welding process

Tandem MIG welding can only be employed as a robot integrated system or integrated equipment, such as the special welding machine [4]. Special welding machine, as carrier of automatic welding technology, plays an important role on the welding of large equipment. It could increase welding speeds and enhance productivity, and the main advantages of the Tandem welding process are claimed to be faster travel speeds, higher deposition rate, and better comprehensive mechanical properties. Hence, special welding machine with Tandem welding could improve welding quality and reliability of engineering machinery. Compared with robot welding, it is easier to maintain or operate and has high performance cost ratio.
3.1. **Welder**

People engaged in welding shall be composed of manual welders with work permits, relevant technical management fellows and occupations (boilermaker, pipe fitter and so on) [6]. After the transformation, the whole welding process depends on the motion of the tractor on the track to complete automatically. The welder has a high degree of automation and low labor intensity. Furthermore, this welding equipment will have wider range of application because there are no requirements in welding work license or experience on welding.

3.2. **Special welding machine**

Industrial design concerning user, an important tool of realizing product diversification, refers to the appearance and interface design of product. This paper elaborates the design of special welding machine based on the purpose and direction.

3.2.1. **Appearance design.** The appearance design of welder was illustrated through explaining the working principle, function division and the appearance design style. Firstly, there is a welding power, a wire feeder, a welding torch, a gas cylinder, a travelling mechanism and a controller in welding tractor. Special welding machine includes two welding powers, two wire feeders, a welding torch, a gas cylinder, a travelling mechanism and a controller [8]. Comparison between special welding machine and MIG welding tractor in structure (Tab.1) must be the basic premise of transformation.

| Structure         | MIG welding tractor | Special welding machine |
|-------------------|---------------------|------------------------|
| Welding power     | 1                    | 2                      |
| Wire feeder       | 1                    | 2                      |
| Welding torch     | 1 (single wire)      | 1 (double wire)        |
| Gas cylinder      | 1                    | 1                      |
| Travelling mechanism | 1              | 1                      |
| Controller        | 1                    | 1                      |

This paper analyzes theoretical points how to transform the welding equipment from welding tractor into special welding machine. The conversion was done by combining welding tractor with additional wire reel from another wire feeder (Fig.4). The preliminary result of special welding machine is as shown in the figure 5. Two power supplies were adopted, and two wires are fed into a single molten pool through the same torch, but they are electrically isolated from each other in the tandem MIG welding process.

![Figure 5. Preliminary result of special welding machine](image)

Then, the confinements and influences of function factors of welding equipment on appearance design are studied. Given structure and principle, distributing the function between human and welder need to research in depth. For instance, operators are responsible for adjusting welding parameters of controller rather than welding manually with the application of special welding machine.
Finally, frequently-used representative welding equipment looks rather crude in appearance and lack of variation or change. Nowadays, the market considers not only the function of products, but also pay special attention to the appearance design. Therefore, welder machine need change the low-quality image and completely meet the demand of users with emphasis on industrial design.

3.2.2. Interface design. The man-machine interface of welding machine exhibits the following characteristics: ① Higher efficiency of the operation interface. The accurate information transfer and human-machine interaction contribute to the steady operation of the system [9]. ② Friendlier operation interface. It should reduce skill requirements for operators and costs of study.

Firstly, how to optimize so many welding parameters in human interface is a problem to be solved imperatively. We need reconsider the availability and priority of parameters in control panel (Fig.6) because some of them cannot adapt to the demand of special welding equipment. For instance, MIG welding tractor has two modes to choose from manual mode and automatic mode. We take the actual situation of transformation into account and then eliminate the manual welding button in the special welder.

Then, the study targets the welding operator group and focuses on mental structures, emotional features and behavioral properties in the view of man-machine engineering. The parameters of button in control panel (such as type, distribution and precision) need conform to human's physiology and psychic mechanism completely. Except the welding current and voltage and weld speed system use knob switch, other switches use touch button. It is worth considering what we can greatly simplify the operation of the welder in the interface prototype (Fig.7).

Finally, the interface design asks the request of keeping the complexities of operation to a minimum and achieving optimal functionality. Reasonable division of welding parameter is a critical contributor to improve the operation interface. Therefore, welding parameter need be rearranged and divided into different control areas [11], such as the main menu, welder control area, traveling control area and torch control area. Obviously, when users find a button or knob accurately without thinking, that means the control system has good and easy operation interface.

3.3. Welding workshop

During the welding process, the bad operating environment includes electrical hazards, fume, arc radiation and noise. Due to its severe application environment [12], more factors should be taken into account in design. Welding smoke and dust dispersing in workshop influence welders directly. Designing dust cover can improve the severe condition effectively. And the welding equipment is
required to provide good mechanical and environmental performance.

4. Main conclusion
The research of the transformation design focuses on the integrated effect of man, machine and environment. The paper thoroughly studies the advanced weld technology of Tandem double-wire welding. And then MIG welding tractor is transformed into special welding machine with good operability and high degree automation. Additionally, it highlights the combination of human and environmental factors with welding machine design based on the man-machine-environment principles. In short, the appearance and interface design points in industrial design concerning user are as follows.

- Combining with wire feeder, two power supplies, two wires through the same torch
- Distributing the function between human and welder
- Pay special attention to the appearance design
- Reconsider the availability and priority of welding parameters
- Conform to human's physiology and psychic mechanism completely
- Rearranged welding parameters and divided into different control areas

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