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Research on Applying TRIZ for Improving Automatic Synchronization for Multi-machine Setup

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***Abstract*—Industrial automation with the purpose of pursuing higher productivity and product quality is an important trend seen in the manufacturing sector of most developed countries. Multi-machine's data synchronization is an important factor to its synergism. It provides a way to start the motors simultaneously, while improving the timing accuracy of a multi-machine motor receiving an order from a controller. This research utilizes TRIZ's substance-field analysis and system modeling to renovate and enhance the way of starting the motors synchronously. The modified method of starting motors synchronously not only enables the multi-machine motor driver to receive commands from the controller simultaneously, but also corrects the time delay for the signals of the controller that arrive at the motor driver. This decreases discrepancies in processing.**

Keywords- Automated synchronous setup; TRIZ; Substance-field analysis.

I. INTRODUCTION

Since the industrial revolution, technologies in mechanical engineering have improved rapidly. Upon the maturity in the development of microelectronics and microcomputer technology, industrial automation began to be prevalent, and hence triggered the advancement of mechatronics. Integration of machinery and facilities for industrial automation has undergone rapid changes. Hence, designing a time-energy efficient control is a necessity [1]. Industrial automation is an important trend seen in the manufacturing sector of most developed countries, and it is also an important aspect in advanced manufacturing. It has been a while since developed countries started to develop smart and automated manufacturing [2]. In respect to industrial automation, multi-machine's data synchronization is an important factor affecting the machine's synergism [3]. Collaboration or synchronization of the machines is required in many circumstances, for instance, spatial trajectory processing, multitasking of multi-machine's robotic arms, and vacuum pumping. If the controller is required to control several motor drivers, the motor drivers will not be able to receive commands from the controller simultaneously due to the differences in distance between the motor drivers and controller. The motors will be unable to start at the same time, and eventually cause discrepancies in processing. The "Theory of the Solution of Inventive Problems" (TRIZ) was proposed by an inventor from the Soviet Union, G. S. Altshuller, in 1946. He was also known as the father of TRIZ. Since 1946, Altshuller led various Sovietian research institutions, universities, and enterprises to form TRIZ research organizations. After analyzing nearly 2.5 million world-class high standard invention patents and utilizing dialectical materialism and System Theory, they proposed the fundamental theories related to invention. The core theories include: fundamental theory and principle. Currently, many scholars employ TRIZ in their research, for example Chang and Lin, Chang et al. and Lin et al. [4] ,[5] ,[6]. Their research utilizes the substance-field analysis and system modeling in TRIZ, to seek for improvement and enhancement of the methods.

II. INTRODUCTION TO INVENTIVE METHODS

A. *Flows of inventive method*

After discovering an issue, the technical problems are scrutinized. We utilize the ability of TRIZ's substance-field of analyzing the functionality of a product to discover the problem, and then use a feasible system modeling analysis to deduce a resolution. We then use logical thinking to list all the possible solutions, and choose the most appropriate solution.

B. *Substance-field analysis*

One more technique that is frequently used by inventors involves the analysis of substances, fields and other resources that are currently not being used and that can be found within the system or nearby. TRIZ uses non-standard definitions for substances and fields. Altshuller developed methods to analyze resources; several of his invention principles involve the use of different substances and fields that help resolve contradictions and increase ideality of a technical system. For instance, videotext systems used television signals to transfer data, by taking advantage of the small time segments between TV frames in the signals.

Substance-field analysis produces a structural model of the initial technological system, exposes its characteristics, and with the help of special laws, transforms the model of the problem. Through this transformation the structure of the solution that eliminates the shortcomings of the initial problem is revealed. Substance-field analysis is a special language of formulas with which it is possible to easily describe any technological system in terms of a specific (structural) model. A model produced in this manner is transformed according to special laws and regularities, thereby revealing the structural solution of the problem [7].

C. *The 76 Standard Solutions*

The “76 Standard Solutions” of TRIZ were compiled by G.S. Altshuller and his associates between 1975 and 1985. They are grouped into 5 large categories or classes as follows:

1. Improving the system with no or little change	13 standard solutions
2. Improving the system by changing the system	23 standard solutions
3. System transitions	6 standard solutions
4. Detection and measurement	17 standard solutions
5. Strategies for simplification and improvement	17 standard solutions

The standards may be used as templates to which problems may be matched: They provide a concise description of the generic situation and generally include a statement of high-level constraints or restrictions [8].

One of Altshuller’s contributions to TRIZ is the proposal of the descriptive method and modeling for the functionality substance-field. The principle is that, each functionality can be separated into 2 substances and 1 field, that is, 1 functionality is made up from 3 elements, the field and 2 other substances. A product is a result of functionalities, and hence the ability of the substance-field to analyze a product’s functionality could be used. This analytical method is one of TRIZ’s tools.

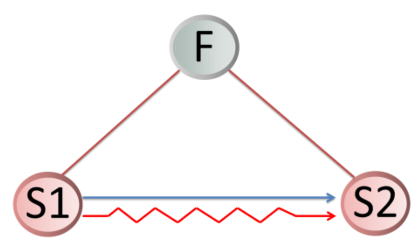
According to the model, Altshuller and others proposed 76 different types of standard solutions, and categorized them into the following 5 groups. For the specific problem of an existing system, converting a standard solution into a particular solution is known as the new concept [9]. TRIZ provides its user with a mindset for making use of principles flexibly. The principles behind each of the inventions are simple and basic, but the ideas that emerge from them could cover a whole new range of fields [10]. The layers and details in between different principles could produce different types of frameworks and content. Every principle, every mindset, could give creative people a new solution, i.e. “think about every single principle and then find out the answer”.

III. MODIFICATION TO THE DESIGN OF REVOLUTIONARY MULTI-MACHINE SYNCHRONOUS SETUP

A. *Substance-fields analysis (S-Fields)*

This research applies TRIZ’s substance-fields analysis to seek for improvement in paradoxical problems, as shown in Figure 2. In Figure 2, F is the mechanical field, S1 is multi-machine synchronous processing, and S2 is the quality of processing parts. Industrial automation and multi-machine synchronous processing will save manpower, however due to the lack of synergism when using multi-machines, there is still room for improvement and advancement regarding quality.

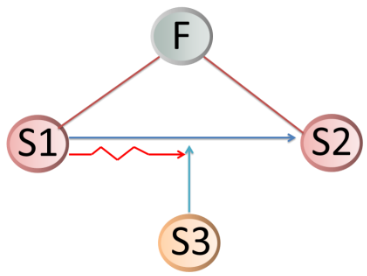
Therefore, this research uses the S1-2-1 standard solution with TRIZ’s substance-fields analysis on multi-machine synchronous setups and introduces S3 to eliminate detrimental effects so that beneficial and adverse effects could co-exist in the system, S1 and S2 do not necessarily need to cancel each other out, but S3 can be introduced to eliminate the adverse effect. Hence, by adding S3 to the multi-machine synchronous setup, it can enhance the synergism of multi-machines, while improving the quality of parts and rectifying the paradoxical problem, and at the same time implementing the TRIZ’s substance-fields analysis transition (Fig.1).



Figiure 1. Substance-fields analysis diagram

B. *System model of multi-machine synchronous setup*

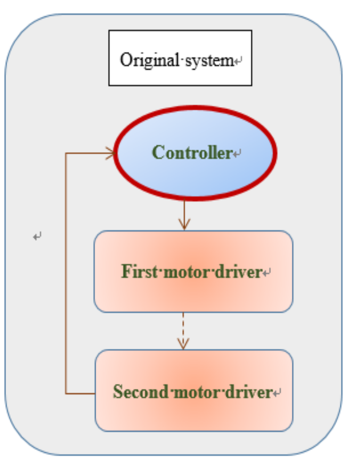
A system model can be constructed particular to the multi-machine synchronous setup. Through the functionality analysis of components in the system model, the composition and function of each component in the system and their inter-relationship can be determined. The controller is required to control several motor drivers, the motor drivers will not be able to receive commands from the controller simultaneously due to differences in distance between the motor drivers and controller. Therefore, the motors will be unable to start at the same time, and eventually cause discrepancies in processing (Fig.2).



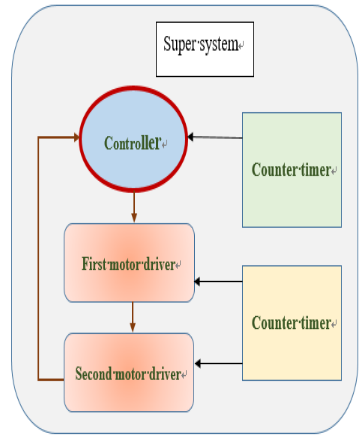
Figiure 2. Substance-fields analysis after transformed

C. *Thinking and improvement*

Therefore, this research provides a super system that starts the motors simultaneously, as shown in Fig. 4. The control method for driver includes: outputting a first signal from the controller to the first motor driver:; making the first timer start to count for a first time; returning a first feedback signal from the first motor driver to the controller; dividing a value of a first count time of the first timer by two to get a value of a first delay time, wherein the first delay time is defined as the time of transmitting signals from the controller to the first motor driver; adding the value of the first delay time to the value of the first count time of the first timer to get a first sum; and transferring the first sum to the second timer to replace a value of a count time of the second timer.



Figiure 3. Original model



Figiure 4. Super system model

IV. Conclusion

As manufacturing advances, production gradually turns to automation and flexibility, while products are diversified. Industrial automation not only saves a vast amount of manpower, but also solves the problem of labor shortage and the need to reduce production costs. The differences in distances between each motor and controller prevents the motor drivers from receiving simultaneous commands from the controller, therefore the motors cannot start simultaneously causing processing discrepancies. Using the TRIZ inspired multi-machine synchronous setup in industrial automation could potentially solve this issue.

There are many applications for TRIZ, it is not only focused on a single product, but also many other entities. Regardless of the type of job, there will be times of difficulty. Having an understanding of TRIZ widens your view. It can locate the root of the problem, and help us to analyze it. Then, by using the logic provided by TRIZ, we can adopt an appropriate solution. This research uses TRIZ to provide a method to outline the production flow and promote logical thinking. This procedure from consideration of the problem to its resolution, has improved the feasibility of resolving problems during the design modification phase. After this research and all of the innovative ideas involved, the practical use of the modified multi-machine synchronous setup has been successfully improved.

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