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Optimization Design of Automatic Tea Ceremony Teacup Equipment Based on TRIZ Principle

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Abstract. With the development of science and technology and the accelerated pace of society, people are increasingly pursuing a convenient way of life. The art of making tea in traditional Chinese tea culture, although rich in deep cultural heritage, is difficult to adapt its cumbersome steps to the modern fast-paced life. In order to solve this contradiction, this paper applies TRIZ theory to optimize the design of fully automatic tea cup equipment, aiming to realize the automation of the tea brewing process, while retaining the cultural essence of traditional tea art. Through the automation design of the steps of blancher, tea brewing and aroma shaking, combined with modern mechanical design and intelligent control technology, this study proposes an innovative fully automatic tea ceremony teacup equipment program. The solution not only improves the efficiency of tea brewing, but also ensures the quality of tea soup and the experience of traditional tea ceremony through careful design. Ultimately, the feasibility and effectiveness of the proposed scheme are verified through kinematic analysis, prototype testing and user experience evaluation. This study is of great practical significance for the modernization and transformation of the traditional tea ceremony, and also provides a reference for the automation of other traditional processes.

Keywords: TRIZ; automation, tea ceremony, tea cup equipment, mechanical design.

1. Introduction

Chinese tea culture, as an important part of oriental culture, not only contains deep historical traditions, but also is the artistic embodiment of daily life [1]. The traditional tea ceremony, with its unique sense of ceremony and aesthetic value, elevates tea drinking to a spiritual and cultural level [2]. In this process, tea brewing as the core link, its every detail is full of elaboration. However, with the accelerated pace of modern society, the complexity and time-consumption of traditional tea-making has gradually become a luxury. How to closely integrate the traditional tea ceremony with modern life, so that it can adapt to the fast-paced needs without losing its cultural heritage, has become a topic worth exploring.

In order to solve this problem, this paper adopts the TRIZ theory, which is a systematic problem solving and innovation method, and the TRIZ theory has extracted a series of tools and methods for solving technological contradictions and physical contradictions by analyzing a large number of invention patents [3], such as "Nine Screens Method", "Technological Contradiction Matrix", "Physical Contradiction", "Physical Field Model" and so on. Contradiction Matrix", "Physical Contradiction", "Physical Field Model" and so on [4]. These tools and methods can effectively guide designers to identify problems, analyze them and propose innovative solutions.

In this paper, we first use the "Nine Screen Method" [5] to comprehensively analyze the traditional tea brewing process, identifying the key steps such as blanching, brewing, and aroma shaking, and discussing in depth the cultural significance and technical requirements of each step. Subsequently,

through the analysis of "Technical Contradiction Matrix" [6] and "Physical Contradiction" [7], we revealed the potential contradictions in the process of tea brewing, such as the need for uniform heating and rapid cooling of the tea cups in the blanching step, and the stability of the tea cups and the flexibility of the pouring action in the tea brewing step. In response to these contradictions, we constructed a problem model using the Physical Field Model and explored possible solutions by applying the principles of invention in TRIZ.

Through an in-depth analysis of the traditional tea ceremony brewing process and the application of TRIZ tools, this paper proposes an optimized design solution for a fully automated tea ceremony tea cup equipment. The solution not only improves the efficiency of tea brewing, but also ensures the quality of tea soup and the experience of traditional tea ceremony through careful design. Ultimately, the feasibility and effectiveness of the proposed scheme are verified through kinematic analysis, prototype testing and user experience evaluation. This study is of great practical significance for the modernization and transformation of the traditional tea ceremony, and also provides a reference for the automation of other traditional processes.

2. Analysis of the Steps of Traditional Tea Ceremony Brewing of Design Needs

2.1 Culture and Practice of the Traditional Art of Tea Making.

The traditional Chinese tea ceremony is a deeply cultural way of drinking tea, which is not only a process of preparing a beverage, but also a cultural art that combines philosophy, etiquette and aesthetics. The art of making tea has been developed over thousands of years in Chinese history, forming a complete set of rituals and techniques. The core of this art is to enhance the sensory experience of drinking tea through delicate steps and rituals, while conveying the cultural values of respect, harmony and tranquility.

2.2 Cultural andTechnical Requirements for the Steps of Making Tea.

The process of making tea usually consists of four steps: blanching, brewing, aroma shaking and tea tasting, each of which has its own unique cultural significance and technical requirements [8]. Scalding is not only to clean the tea utensils, but also a kind of preheating, which symbolizes respect and anticipation for the tea tasting process that is about to begin. Brewing tea is the core of the whole tea ceremony, which requires the tea master to have precise control over the temperature of the water, the brewing time and the ratio of the tea leaves to the water to ensure that the color, aroma and taste of the tea are optimally displayed. Shaking is done by shaking the tea cup to make the tea broth in full contact with the air, releasing the aroma of the tea leaves as well as regulating the temperature of the tea broth. Tea tasting is the climax of the tea ceremony, which is not only a tasting of the flavor of the tea broth, but also a kind of spiritual enjoyment and enlightenment.

2.3 Nine-screen Method Analysis.

In order to better understand the steps of the traditional tea ceremony and to provide directions for the optimization of the design, we use the "nine-screen method" in TRIZ to conduct a system analysis. The nine-screen method is a tool for comprehensively analyzing a system, which reveals the inherent contradictions and potential directions for improvement by considering the performance of the system at different times and at different scales [9]. As shown in Fig. 1, we analyze the steps of traditional tea ceremony as the current technical system, and analyze the past, present and future states of the subsystems and supersystems of the current technical system respectively.

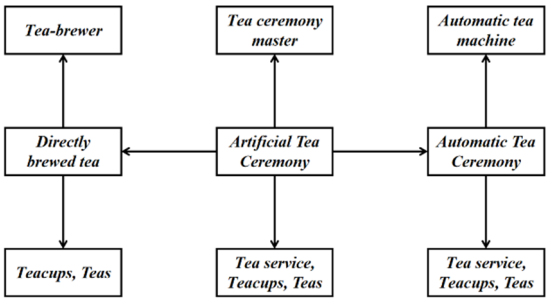


Fig. 1 Analysis of the nine-screen method

In the nine-screen analysis method, the exploration of the tea art of making tea can be analyzed in depth from multiple dimensions. First, in terms of time scale, the evolution of tea ceremony tea-making needs to be examined from the perspective of historical development in the research process, analyzing the origin, development and modern performance of each step. Second, the consideration of spatial scale involves the adaptability of the steps of tea making in different environments. Whether it is a home, a teahouse or a public place, the process of making tea needs to be adapted to specific environmental conditions to ensure the quality of the tea and the drinking experience. Within the system, the research process needs to analyze the internal working mechanisms of the tea brewing steps. This includes details such as the control of the water flow when blanching the vessel and the adjustment of the water temperature when brewing the tea, which together determine the final taste and quality of the tea. The examination of the external part of the system focuses on the interaction between the tea-making steps of the tea ceremony and the external environment. External factors such as the material of the tea utensils and the quality of the water have a significant impact on the tea brewing process. At the system-supersystem level, researchers examine the tea ceremony tea-making in the context of broader cultural and social activities, analyzing its role and influence in cultural exchange and social interaction. Research at the detail level focuses on the specific operational skills in the steps of tea brewing, such as the turning of the wrist when shaking the incense. These details have a decisive impact on the final quality of tea. The overall level requires the researcher to look at the process of tea brewing from a macroscopic point of view, focusing on its smoothness and coordination. The analysis of energy conversion involves the transfer and conversion of heat energy in the process of tea brewing. The researcher needs to consider how to optimize the tea brewing process and improve the quality of tea by controlling the conversion of thermal energy. Finally, the consideration of information conversion focuses on the information transfer during the tea brewing process, especially the non-verbal communication between the tea master and the guests. This communication includes not only the tea master's introduction and presentation of the tea, but also the cultural and emotional information conveyed through the act of tea brewing. Through the nine-screen analysis method can be multi-dimensional, multi-level academic research on tea ceremony tea brewing technology, a more comprehensive understanding of the connotation and value of tea ceremony tea brewing, to provide academic support for the inheritance and development of tea culture.

2.4 Optimization of Design Requirements.

Based on the analysis of the nine-screen method, we summarize the following optimized design requirements:

Automated Scalding System: Develop a system that automatically controls water temperature and rinsing time to ensure that the tea set is clean and preheated; Precisely controlled steeping mechanism: Design a mechanism that can precisely control the water temperature, volume and steeping time to suit different types of tea; Dynamic shaking device: Innovate a mechanical device that can simulate the manual shaking action to fully release the aroma of the tea leaves; User-interactive tea tasting experience: design a system that facilitates the user to access and taste the tea broth, while retaining the ritualistic feel of manual operation; Integration of culture and aesthetics: Integrate the cultural

elements of the traditional tea ceremony into the automation design to maintain the aesthetic experience of the tea-making process.

3. Problem Solving with TRIZ Tools

3.1 Analysis and Resolution of Technical Contradictions.

Technical contradiction is a common problem in engineering design, which occurs when the improvement of one parameter leads to the deterioration of another. In the design of automatic tea ceremony tea cup equipment, we may encounter the following technical contradictions, as shown in Table 1:

Paradox 1: Increasing the water temperature to speed up preheating during the scald step may result in damage to the teacup material.

Paradox 2: In the tea brewing step, in order to improve the efficiency of tea brewing, increasing the amount of water may reduce the concentration of tea and affect the taste.

Table 1 Contradiction Matrix

Improvement parameters Deterioration parameters	Suitability
Material damage	15,10,2,3

To address these contradictions, we can use the Contradiction Matrix in TRIZ to find solutions. The Contradiction Matrix is a tool that pairs the improvement and deterioration of engineering parameters and provides the corresponding inventive principles [10].

Solution 1: For the contradiction of the ironing step, we use the corresponding inventive principle "preaction" in the contradiction matrix. By designing a temperature control system, the system is able to stop heating automatically after reaching the preset temperature, thus avoiding damage to the tea cups.

Solution 2: To address the contradiction of the tea brewing steps, we adopted the principle of "dynamic characterization". We designed a tea brewing mechanism with variable water volume, allowing the user to adjust the water volume and brewing time according to the type of tea and personal taste.

3.2 Physical Contradiction Analysis and Resolution.

A physical contradiction is when the same parameter within a system has opposite needs under different conditions. For example, in the aroma shaking step, the teacup needs to be both fixed and movable in order to be shaken.

Paradox: Teacups need to be rotated freely to release the aroma when shaking, while they need to be secured to avoid pouring during steeping and other steps.

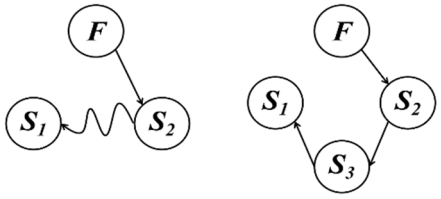
We can use the principle of separation of physical contradictions in TRIZ to solve this problem. Separation principles include spatial separation, temporal separation, and conditional separation.

Solution: Adopt the time separation principle and design a switchable fix/release mechanism. During the aroma shaking step, the user can easily release the teacup and let it rotate freely; during other steps, the teacup is stably fixed in place.

3.3 Physical Field Model Analysis and Solution.

The object-field model is a model used in TRIZ to describe the interaction between substances and fields in a system. In Automatic Tea Ceremony Teacup Equipment, the Object Field Model can help us to analyze and optimize the interaction between the teacup and the environment.

The problem is obtained as shown in Fig. 2a, during the tea tasting step, the S1 user's hand needs to be in direct contact with the S2 teacup, which requires that the teacup maintains a certain temperature while the external temperature is suitable for handholding.



(a) (b)

Fig. 2 Object field modeling

By constructing object-field models, we can identify substances (e.g., teacups) and fields (e.g., thermal fields) in a system and analyze the interactions between them.The solution is obtained by designing a teacup with S3 thermally insulating material, which can effectively insulate and maintain the temperature of the tea broth while making the external temperature suitable for handholding. In addition, a temperature feedback system can be introduced to automatically adjust the distribution of the thermal field through the analysis of the physical field model to adapt to different usage scenarios.

4. Automatic tea ceremony tea cup equipment design

4.1 Structural Design of the Automatic Iron

The core of the design of the automatic iron is to realize the uniform preheating and sterilization of tea cups. The module adopts planetary gear rotation system, three tea cups are installed on the same tray, through the rotation of the planetary gear to drive the tray rotation, simulating the artificial ironing of the "Guan Gong patrol" action, as shown in Fig. 3. The cups are fixed with a spring-clip mechanism, which not only ensures the stability of the ironing process, but also makes it easy for the user to remove the cups during the tea-tasting steps.

4.2 Automatic Tea-making Mechanism Design

The key to the design of the automatic tea-making mechanism lies in the simulation of the "phoenix's three nods" pouring action and the precise control of the position of the teacups. The mechanism is realized by a fixed-point pourer, which can be fine-tuned in three dimensions to ensure that the hot water is accurately poured into the teacup. The teacups are secured in place with spring-loaded clips to ensure stability during the pouring process.

4.3 Design of Automatic Incense Shaking Mechanism

The automatic aroma shaking mechanism is designed to enable the tea cup to be shaken 360° around to fully release the tea aroma. The mechanism consists of rocker arm and planetary gear on the tray, and the end of the rocker arm is equipped with a cup fixing buckle. Through the rotation of the planetary gear, drive the rocking arm for bidirectional shaking, to realize the tea cup all-round shaking incense, as shown in Fig. 4. In order to achieve a more complex shaking trajectory, the drive of the rocker arm using bevel gears and planetary gear linkage, to achieve the overall 360 ° synchronized shaking.

Fig. 3 Pallet rotation mechanism

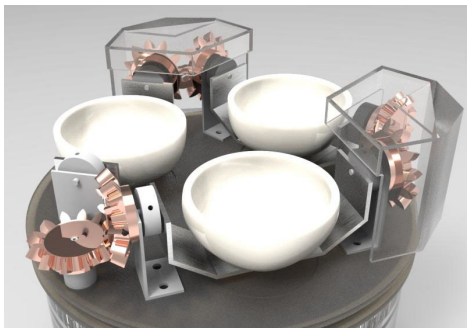


Fig. 4 Automatic fragrance shaking mechanism

4.4 Tasting Process Design

Although the tea tasting process cannot be automated, the device is designed with a simple cup release mechanism. The user simply presses the spring-loaded clasp and the cup is easily removed for tea tasting. This design preserves the interactive nature of the tea ceremony and improves the user-friendliness of the device.

4.5 Overall Structural Design of the Equipment

The overall structure of the automatic tea ceremony tea cup equipment is designed with modularity and compactness in mind. The blancher, tea brewing and aroma shaking modules are all integrated inside the equipment and coordinated through a centralized control system, as shown in Fig. 5. The casing of the equipment is made of food-grade materials to ensure safety and durability in use.

Fig. 5 Automatic Tea Ceremony Teacup Equipment

5. Summary

In this study, we used the "Nine Screen Method" of TRIZ theory to conduct a comprehensive systematic analysis of the fully automated tea ceremony tea cup equipment, and proposed innovative automation design solutions for the key steps of blanching, brewing and shaking. Through the application of technical contradiction, physical contradiction and physical field model, we successfully solved the technical problems encountered during the automated tea brewing process, and ensured that the quality of the tea soup and the traditional tea ceremony experience were preserved. We have designed an automated blancher that simulates the traditional blancher process by using a planetary gear system to achieve uniform rotation of the teacups; a precise tea brewing mechanism that simulates the tea brewing action of the "phoenix with three nods of the head" by accurately controlling the amount of water and the temperature; a dynamic aroma shaking mechanism that optimizes the release of the aroma by using the rocker arm and the gears to link up to achieve an all-round shaking of the teacups; and an easy release mechanism for the teacups. The user-friendly design of the tea cup releasing mechanism to maintain the sense of ritual when tasting tea. The development of fully automatic tea cup equipment is an innovative attempt to integrate traditional tea ceremony with modern technology, which not only improves the quality of life, but also opens up a new path for the inheritance and innovation of traditional tea ceremony. With the continuous progress of technology, we look forward to more innovative products combining traditional culture and

modern technology in the future, so that the traditional art can show new vitality and charm in the modern society.

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