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A Novel Design of Thermos Cup with Thermostat Control based on TRIZ Theory

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Abstract:

Based on TRIZ theory, this work presents a novel methodology for designing thermos cup with thermostat control. In the design processes, this work first presented the system function, system causality chain, and system nine-screen method, then used technical contradiction, physical contradiction and object-field analysis method to obtain the solution to the problems. Finally, the optimal scheme was evaluated and selected by combing various schemes of early analysis and problem solving. The TRIZ theory offers a new idea for the design of thermos cup with thermostat control, and its solution processes also verified the feasibility of the novel design.

***Keywords**: Thermos cup, Thermostat control, TRIZ theory, Innovative design, Functional analysis, Conflict resolution.*

I. INTRODUCTION

Product design needs to be combined with innovative invention theory to develop competitive products to cope with the rapidly changing of market [1]. Combined with design theory, high efficiency breakthrough innovation have entrusted the product with long-term technical advantages and market competitiveness. Nowadays, consumers want each product to have a variety of functions, so that the use of products can be more convenient and efficient. In order to realize the potential of innovative products, a variety of scientific and innovative methods should be adopted in the design process (i.e., linking product design with multidisciplinary design theory purposefully) [2]. On the basis of the above analysis and the application of TRIZ theory, the novel design ideas of thermos cup with thermostat control were put forward. At present, most of the thermos cup on the market can only contain hot water or drinking water at room temperature. Although some thermos cup can hold some hot water to meet the need of constant temperature, most of their products are made of more expensive materials or electronic smart devices added to the cup body to meet the specified requirements [3]. The above problems to the use of products brought great inconvenience. In this context, a new thermos cup with thermostat control is designed to improve its use efficiency. This work first carried on the problem analysis and the problem

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solving to the thermos cup according to the TRIZ method theory flow, and then demonstrated the corresponding design plan conception. By analyzing the optimal solution of the design process to achieve the effect of thermos cup with thermostat control, this study could offer a new perspective for the development and design of other similar products.

II. OVERVIEW OF TRIZ THEORY

TRIZ, an acronym translated Latin to Russian, is a theory of the resolution of invention-related tasks [4]. TRIZ theory dates back to the 1940s. While working as a patent investigator, Archie Schuller read a lot of patent documents, and at work he noticed that there were some basic models for solving problems in seemingly unrelated patents. Every mature patent is solving existing contradictions, and the same principles to solve these contradictions are repeatedly used [5]. In this context, Archie Schuller developed TRIZ theoretical innovation method system after collecting, studying, and refining the patent of massive literature. The system contains a large number of practical innovative methods and tools, which can be used to analyze and solve various complex problems in practice.

III. INVESTIGATION AND ANALYSIS OF EXISTING THERMOS CUPS WITH THERMOSTAT CONTROL

Through the primary product market research, the existing product performance and advantages and disadvantages of various thermos cup with thermostat control were analyzed. In this study, several thermos cup with thermostat control on good sales were selected for comparison, to study the deficiency of existing thermos cup with thermostat control products and the contradiction that needs to be solved urgently, so as to enable novelty, improvement, and optimization of new products [6]. According to this market competition research, two kinds of thermos cup products were selected. The first is to control the temperature by using the new material in the cup; the second is different, mostly relying on the electric energy formed in the discharge process and the water in the cup for heat exchange to achieve the purpose of temperature regulation.

First, the red dot design award of thermos cup products - Rococo production of LKK55℃ cooling cup - was selected for research analysis. This product gets good attention as it is the first thermos cup with adjustable temperature nature. The inner tank of this thermos cup is made of phase change metal between the internal heat conduction layer and the external heat insulation layer of the special material filler. The specific temperature regulation principle is to rely on the phase transition of the aeronautical material used inside the thermos cup. When the cup is connected with hot water, the heat is released to the phase change metal through the inner tank interlayer. This special material absorbs heat quickly and melts, which achieves the purpose of rapidly reducing the hot water temperature. In the process of use,

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when the hot water in the cup is cooled slowly, the phase change metal will solidify and release the heat of the initial absorption hot water to realize the heat preservation effect. In addition to the cold and heat conversion of this single water temperature, the heat can be kept for a long time near the melting point of the phase change metal to achieve the purpose of regulating the water temperature.

On the market, there are also other similar thermos cup, including Fuguang brand 55℃ thermos cup, JIAI thermos cup, etc. [7]. The basic functions of these thermos cup products are largely same with the basic principles of that of Rococo Company. They are made by using the principle of rapid endothermic cooling of phase change materials thermos cup the interlayer, and slowly exothermic heat preservation after the material endothermic.

The second type of thermos cup with thermostat control is a product that has its own heating function or adjusts the temperature by relying on a matching heating component. The water in the cup is heated by ordinary resistance wire or by electromagnetic waves generated by the electrification of the cup seat.

Through the investigation and analysis, it is concluded that the existing products of the same function have their own advantages and disadvantages. The advantage of thermos cup with thermostat control competitive is mainly reflected in its own heating function and the way to maintain temperature. Thermos cups that use the electrically assisted heating category require the use of a power supply, subject to the use environment. Of these, the 55℃ thermos cup uses new materials to keep the water temperature to 55℃ to reach the appropriate temperature for human drinking, but at the same time, its cost deficiency also makes the shortcomings of this product clear at a glance. In this context, this paper developed a novel design method of adjustable temperature cup products using TRIZ theory based on the existing problems found in the previous research. According to this method, a thermos cup with thermostat control with reasonable price and convenient use is demonstrated for designing.

IV. NOVEL DESIGN METHODOLOGIES BASED ON TRIZ THEORY

4.1 Problem Statement and Analysis

Thermos cup is essential supplies in our life. The insulation principle of ordinary thermos cup is to minimize the heat loss of water, so as to achieve the effect of heat preservation. During the use of thermos cup, we will also encounter problems related to heat preservation. The boiling water in the cup cannot be drunk immediately because the temperature is too high. We can only wait until the temperature of the water drops slowly before drinking. This creates a very inconvenient use problem, so that the advantages of the product into disadvantages and pain points. In this context, the TRIZ theory was used to analyze the initial problem, in order to solve the problem that the hot water cannot be drunk in form of warm water immediately in conventional thermos cups. The innovative design of traditional thermos cup should meet the following limitations: 1) Design and manufacture of the thermos cup with thermostat control should not be too complicated and the cost should not be too high; 2) The thermos cup with thermostat control should not be used with environmental restrictions too strictly; 3) The thermos cup with thermostat control should respect the traditional operation mode without changing the use manners too much.

4.1.1 System function analysis

Function refers to the behavior or action when a component changes or maintains a parameter of another group [8]. In TRIZ theory, function is an abstract expression of the specific working ability of a product or technical system, and any product has its specific function.

Function is the reason for the existence of product, and product is the essence carrier of function [9]. The main purpose of the system function analysis is to decompose the existing system, determine the main functions provided by the technical system, and clarify the useful functions of each component and its contribution to the functions of the system to which it belongs. Accordingly, the function model diagram of drawing component is established by disassembly analysis.

According to the system function analysis process, the main thermos cup of this study was analyzed as an independent system with complete functions. The technical system includes stainless steel shell, inner tank, plastic cup cover, key, rubber ring, spring, and super system includes water dispenser, hot kettle, and use crowd. Among them, the main technical system includes the system action object system component [10]. The super system component refers to the external factor which causes the influence to the system. For example, in the research, the water dispenser, hot water kettle and crowd belong to the super system component.

Accordingly, thermos cup interaction matrix in the system is established in Table I, in which the analysis of the interaction of each component is clearly expressed. The unit with “+” means that it is possible to act, and the follow-up needs to analyze the specific role of each component. The unit with “-” indicates that the two have no effect and will no longer be considered in subsequent analysis.

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TABLE I. Thermos cup interaction matrix

Assemblies	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
A		+	+	+	-	+	+	+	-
B	+		+	-	+	-	-	-	-
C	-	+		-	+	-	-	-	-
D	+	-	+		-	+	+	+	-
E	-	+	+	-		-	-	-	-
F	+	+	-	+	-		+	-	-
G	+	+	-	-	-	+		+	-
H	+	+	-	+	-	-	+		-
I	-	-	+	-	-	-	-	-	

* A = bowl cover; B = inner cap; C = inner tank; D = incrustation; E = rubber band; F = mechanical spring; G = button; H = hand; I = kettle.

Then, the functional model table was established, as shown in Table II. By using the function model form, we can analyze and identify the specific functions between the original and understand the function of each original thermos cup. The functional carriers, specific functions, functional objects, parameters and properties of the engineering system are systematically recorded in Table II.

TABLE II. Interactions among the assemblies

Numbering	**Functional carriers**	**Function**	**Functional object**	**Parameters**	**Properties**
1	A	Protecting B	B	Thread rotating connection	Insufficient benefits
2	B	Bracing B	B	Thread rotating connection	Insufficient benefits
3	D	Bracing A	A	Bayonet joint	Sufficient benefits

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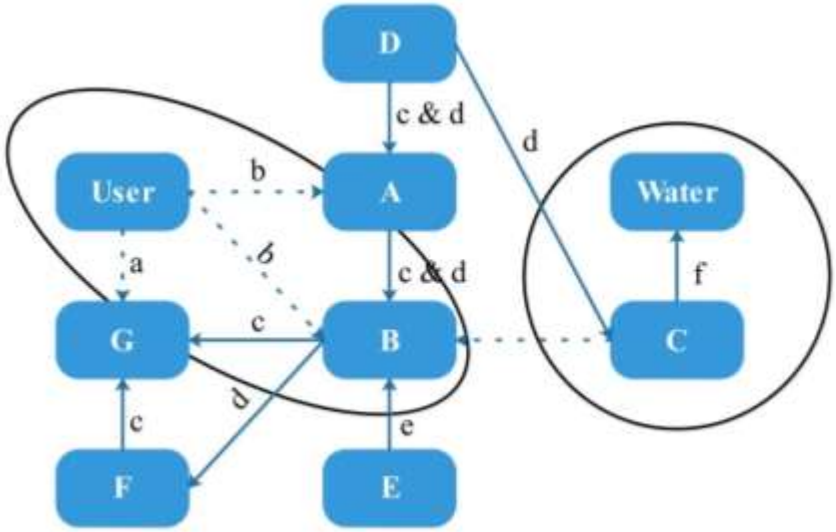
4	E	Sealing B bottom	B	Location	Insufficient benefits
5	F	Bracing G	G	Location	Sufficient benefits
6	C	Water storage	Water	Location	Sufficient benefits
7	H	Taking the cup	D	Location	Sufficient benefits
8	H	Revolving A	A	Location	Insufficient benefits
9	H	Pressing G	G	Location	Insufficient benefits
10	H	Revolving B	B	Location	Insufficient benefits
11	C	Bracing G	G	Location	Sufficient benefits
12	C	Protecting F	F	Location	Sufficient benefits
13	D	Protecting C	C	Interval with one layer	Sufficient benefits

At the beginning of the problem based design, the first is the function analysis [11]. The purpose of functional analysis is to analyze systems, subsystems and components from the perspective of completing thermos cup functions rather than manufacturing thermos cup technology. Above part has completed the cutting process, which is to study whether each function of the thermos cup is necessary. If necessary, other parts of the system can replace it to complete the corresponding function.

According to the above functional analysis, Table II is graphically converted into Fig. 1 for indicating the the functional model of thermos cup. Through the function model diagram, we can clearly understand the function of each function unit and the function of the unit acting on the unit, especially the unit with special problems, as shown in Fig. 1. The simple analysis model diagram conceptualized the design idea, removed some unnecessary structure, thus making the thermos cup structure more concise and simpler. Then, by changing the way of opening B and A, the operation would be simplified, such as the open mode of G.



* A = bowl cover; B = inner cap; C = inner tank; D = incrustation; E = rubber band; F = mechanical spring; G = button; H = hand; I = kettle.

a = button executor; b = turninging open; c = supporting; d = protection; e = seal; f = storage.

Fig 1: The functional model of thermos cup

4.1.2 System causality chain analysis

According to the above functional model, the conflict area directly related to the model is determined according to the problem representation (looking for the design pain point), and the next design process is carried out by using the system causality analysis in the TRIZ theory. Based on the causality of development and change, the so-called system causality is to analyze the relationship between the main contradiction and the secondary contradiction (internal and external) of the system development and change [12].

This causality analysis is also called fault tree analysis [13]. In the process of analyzing and thermos cup each unit, we found out a series of causality relations between the root cause and the result, which constitute a number of causality chain relations. First of all, the main purpose of this causality chain analysis is to find out the root cause of the problem [14] to find the "weak point" to solve the problem, and finally to find the starting point for solving the problem. The causality chain analysis diagram is shown in Fig. 2.

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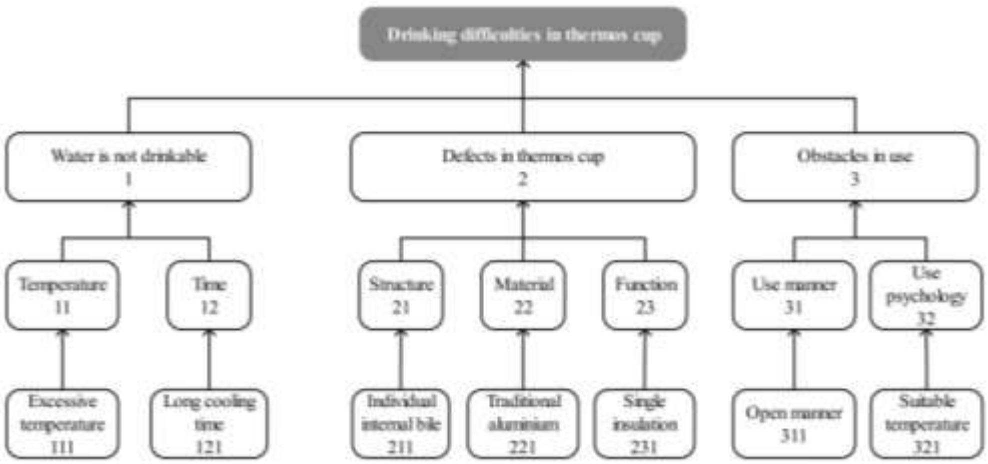

Fig 2: Causality chain analysis

From the existing problems found, (i.e., excessive temperature, long cooling time, single insulation inner tank, single insulation, open mode, and suitable temperature), the direct causes of the first layer of logic were listed. Each cause and result of the first layer discovery problem were connected with each other by arrow. The arrow points to the corresponding result from the direct cause, and the whole is constructed into a complete causal chain. As a result of these direct reasons, the above steps are carried out in this cycle, and the reasons were indemnified as temperature, time, structure, material, function, use manner, and use psychology.

The key issues were identified as 121, 111+211, 211, 221, 21+231, 21+311, 21+321, 211+311, 23+221. The thermos cup single inner tank directly led to the stable temperature of the water in the cup, and the single heat preservation also led to the problem that the water temperature in the thermos cup is too high and the drinking is difficult. Thus, simple analysis of causality chain can be obtained that the problem can be solved from the aspects of thermos cup structure, inner tank material, cooling time of water and so on.

4.1.3 System nine-screen analysis

System nine-screen or multi-screen method represents the systematic thinking in TRIZ theory [15]. It is to consider the overall situation, for which the requirement is not only to consider the current situation, but also to consider their changes in the system level and time. When addressing the problem of thermos cup temperature adjustment, static images of innovative or existing designs are usually generated in the mind, and images that change from past to present and future in the nine-screen method would become

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dynamic images. Nine-screen method, also called system operator, is specific method for processing dynamic images [16]. The most common multi-screen method consists of nine screens with two coordinate axes. The vertical is the system level, which includes subsystems, systems and super-systems. The horizontal is time, focusing on thermos cup past, present and future. The time line set thermos cup with thermostat control as the divergence of thinking to retrospect the conventional thermos cup of the past and the intelligent thermos cup in the future.

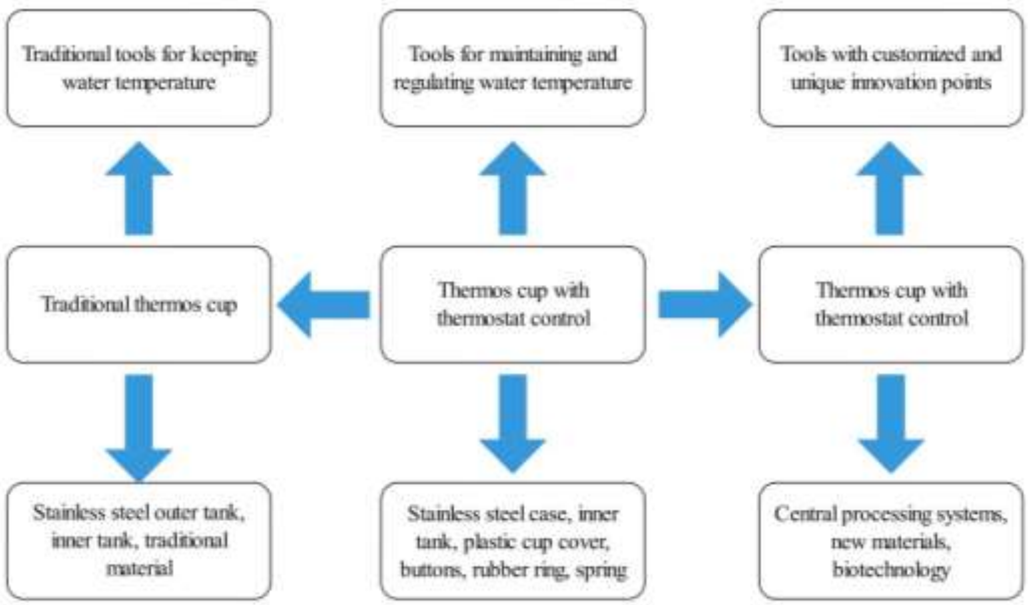

Fig 3: System nine-screen analysis

In contrast with the traditional thermos cup tools to maintain water temperature, the thermos cup with thermostat control of current research is a tool capable of adjusting water temperature. Future intelligent thermos cup will be equipped more advanced materials to achieve the function of intelligent temperature control, as shown in Fig. 3. According to the system nine-screen analysis, the thermos cup with thermostat control design needs to use more mature technology to adjust the water temperature through the cooperation of various structures and parts.

4.2 Solutions to Problems

As mentioned earlier, TRIZ theory holds that contradiction is the core of invention problem [17], but when we face a specific invention problem, contradiction will not appear itself. Contradiction analysis - how to extract the contradictions from the research problems accurately and reasonably, and transform the diversified problems into typical general problem [7]-is expected to work. When solving the problem

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of adjustable temperature cup in this study, the contradiction analysis method is used to explore the corresponding problem.

4.2.1 Using technical contradictions for problem solution

TRIZ theory divides contradictions into two categories; the first is called technical contradiction, and the other corresponding contradiction is called physical contradiction [18]. TRIZ theory summarizes and abstracts 40 invention principles to solve contradictions from a large number of invention schemes. These 40 invention principles are refined based on a large number of feasible contradiction resolution principles and can guide the design and implementation of this thermos cup with thermostat control product.

Through the description and analysis of the second section of this study, the existing technical contradictions are summarized and defined: if the thermos cup can adapt to the requirement of drinking water with different temperatures, it is necessary to increase the volume of inner tank and system components; if the system components increase, the system complexity will increase; if the components are added, the operation of the system will be affected.

Secondly, according to the principle of invention flow, find the contradiction matrix to determine the description of functional engineering parameters. Where, improved parameters are No. 35 applicability and versatility; deteriorated parameters are: No. 33 operability, No. 36 system complexity.

Through referring to the contradiction matrix chart, the possible solution set of this problem is M35-33 = [34, 15, 1, 16] and M35-36 = [29, 15, 28, 37], a total of seven innovation principles. The seven invention principles mentioned above are 1 cutting principle, 15 dynamic principle, 16 insufficient or excessive action principle, 28 replacement mechanical system principle, 29 air pressure or hydraulic principle, 34 discard and regenerate principle and 37 thermal expansion principle.

According to the analysis of the principle solution set obtained from the design requirements, it can be seen that the more suitable invention principle and the design conception based on this principle are as follows.

1) Split principle: some system components of the thermos cup are separated to realize the functional requirements of storing drinking water at different temperatures, and the thermos cup is dissected into a detachable assembly system, which not only increases the adaptability of the system, but also ensures the simplicity required by the system.

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2) Dynamic principle: design some components of the thermos cup (such as C and internal A) into double layers and support the two layers of components to move each other at the same time; add a regulating system and allow the added system to adjust the water flow.

3) The principle of replacing mechanical system: using magnetic field or electric field to replace the mechanical field of existing thermos cup, improving the heat preservation function of thermos cup to improve the temperature regulation function; equipping inner tank with electric field controllable components under the action of electric field to achieve the purpose of heat preservation and water temperature regulation.

4) The principle of deficiency or excess: locally increasing the number of thermos cup water storage components and the number of forms of water storage inner tank; increasing the area of contact between drinking water and external environment in the thermos cup, increasing the heat dissipation area and speed up the cooling rate.

4.2.2 Using physical contradictions for problem solution

Another kind of contradiction contrast with the technical contradiction is the physical contradiction [19], which is defined as the mutually exclusive requirement for the same engineering parameters of the same object or subsystem when realizing a certain function. Generally speaking, behind the technical contradiction often hides the physical contradiction. Physical contradiction is one of the key problems that TRIZ should study and solve.

Firstly, determining the description of physical contradictions:

(Water storage portion) should be (added) to meet (both hot and cold) requirements;

Water storage should be (reduced) to meet (simple structure, easy to process) requirements.

Through the concrete analysis, based on the three separation principles, three design concepts to solve contradictions are obtained as below:

1) The principle of spatial separation: thermos cup with thermostat control is designed with two inner tanks, one for cold water and the other for hot water.

2) The principle of time separation: if the water temperature is appropriate when drinking water is needed, the water temperature is hot when there is no drinking water demand.

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3) The principle of condition separation: providing cold boiled water when hot, hot boiled water when cold.

4.2.3 Using Object-field model for problem solution

An object-field model refers to the need to analyze the structural attribute of each technical system when the two originals interact [20]. The problem description of the object-field model in this study is that the boiling water just connected to the cup cannot be drunk immediately because the temperature is too high and can only be drunk until the temperature of the water drops slowly, which leads to a very inconvenient use problem. The object-field model is shown in Fig. 4.

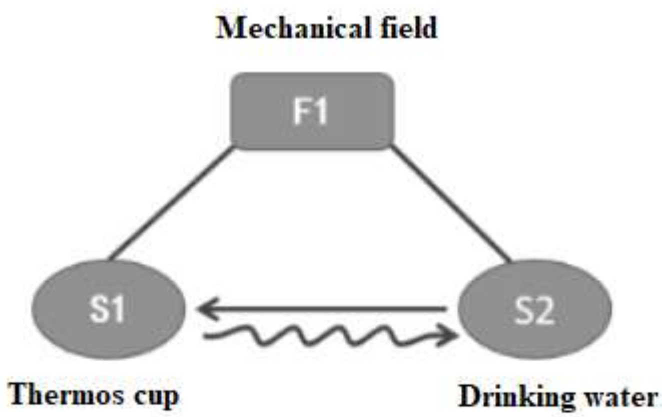

Fig 4: Basic object-field model diagram

Solutions: adding another field (F2) to offset the excessive effect of thermos cup on drinking water temperature control, as shown in Fig. 5.

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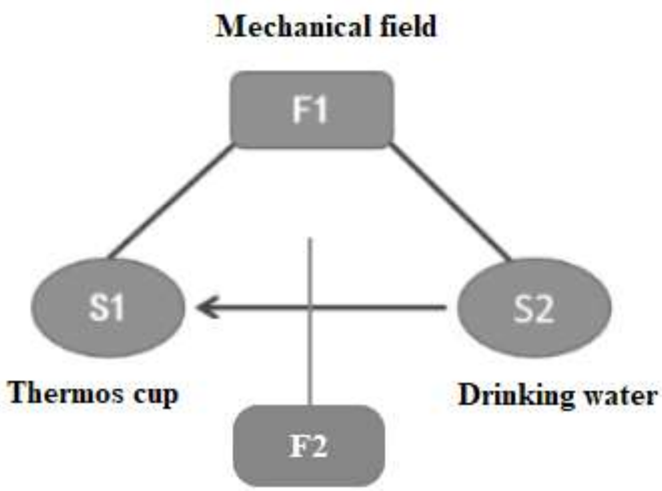

Fig 5: Object-field function model of temperature-regulating function

Design scheme: dividing the inner tank into two parts; one part stores hot water and the other part stores cold water. When drinking, mixing the two to counteract the excessive effect.

4.3 Final Ideal Solution

The final stage of this study is to summarize the conceptual scheme to sort out the various schemes in the process of problem analysis and solution in the early stage of the study, through evaluating the project from the three directions of cost, reliability and difficulty of product realization. According to the best scheme, the model is established by rhino software, and the model file is put into the rendering software for rendering processing, and the final ideal solution effect diagram is obtained. Accordingly, the details of the rotating thermostat are shown in Fig. 6, and the use scenario is shown in Fig. 7.

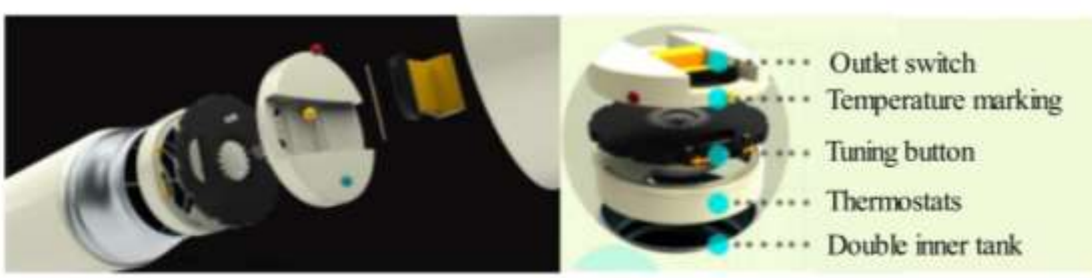

Fig 6: Details of rotating thermostat

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Fig 7: Using scenario diagram

This work designed the above thermos cup with thermostat control by analyzing and solving problems. This work addressed the pain point of ordinary thermos cup that cannot drink hot water immediately at the beginning. Based on the structural design, the inner tank of the thermos cup was divided into two halves. When picking up the water, it need s to take the hot water in one side and the warm water in another side. The specific adjustment mode is that the cup cover was designed through mechanical structure, and thus the rotary knob can adjust the outlet ratio when the pouring out. The TRIZ theory based design makes thermos cup with thermostat control product design easier, and the product structure simplifies the manufacturing costs greatly. Overall, this design is easy to carry and could improve the applicability of the thermos cup.

V. CONCLUSIONS

Based on the research and analysis of the existing similar function thermos cup with thermostat control in the market, this work aims to find out a new product design point. Firstly, three problem description and analysis methods were synthesized to make sufficient thinking divergence for subsequent problem solving. Then, in the problem solving stage, the best solution was obtained by using two kinds of contradiction analysis method and object-field architecture model method. This study abandoned the design idea of the same thermos cup with thermostat control on the market, used the TRIZ theory to creatively design the thermos cup with two inner tanks for containing drinking water with cold and hot temperatures. Finally, the bowl cover mechanical device was used to adjust the water temperature in the cup to achieve the purpose of temperature regulation. This work explored the product innovation scheme according to the design theory process, which is of contribution to the development and research for the same type of products.

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