

DEVELOPMENT AND DESIGN OF FOLDABLE BEVERAGE PAPER CUP

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Abstract

To reduce the environmental harm caused by disposable beverage cups, this study takes the green design and development of beverage paper cups as the main research scope, which is carried out in two stages. Firstly, based on the theory of user experience, combined with the semi-structured questionnaire survey, the users' experience in using disposable beverage cups was analyzed. A total of 200 valid questionnaires were obtained to understand the users' expectations for the existing disposable beverage cups, which were mainly functional requirements such as hygiene, convenience of use, and environmental protection. Following the design requirements of product function improvement mentioned above, TRIZ forty invention evaluation rules are used for innovative solutions in line with the evaluation. The second stage is an innovative design. Based on the reduced-plastic design of the beverage paper cup with improved function and easier recycling proposed in the previous stage, the paper cup is continued, retrieved, and analyzed by patent. Finally, a new patent structure design is obtained.

Key Words: TRIZ, beverage cup, new structural design, wisdom

Introduction

According to Taiwan's Environmental Protection Agency, nearly 4 billion disposable beverage cups weighing 47,000 metric tons were consumed annually in 2020. Among them, about 57%

of disposable beverage cups used plastic materials, such as plastic cups and plastic cup covers, and 40% used coated paper, such as disposable beverage cup mouth plastic sealing film, resulting in nearly 97% non-recyclable garbage (Wu, 2022). These plastic materials and plas-

tic sealing film would have a great impact on the environment. As environmental protection becomes more and more important, people are considering using paper cups instead of plastic cups to achieve recyclability and reduce the risk to the environment. However, most commercial paper cups do not have lids, so they are easy to spill the liquid when carrying the paper cups. To avoid the possibility of spilling the liquid, the common solution is to use disposable plastic lids or plastic sealing films to paper cups. Although these methods are convenient, they also disguise the use of plastic products, which increases the difficulty of recycling paper cups and waste resources.

This research proposes implementing green design and TRIZ in order to develop a proposal for a beverage paper cup with improved function to solve the spill problem. A patent search and evaluation are also made to confirm the feasibility and patentability of the production. In addition, the design process of a foldable beverage paper cup is used to illustrate the design process.

Green Design

With the popularization of environmental protection awareness in the world, people pay more and more attention to the environmental protection of product design based on the thinking of environmental sustainability. From the perspective of product development, the way to introduce environmental protection concepts into design is called Green Design or Design for the Environment. In Green Design, the whole cycle process control of products should be imple-

mented to maximize resource utilization and minimize environmental pollution, maximize the value of function and quality, and also minimize the cost (Dorst, 2011). The 4R concept of green design proposed by Burall (1994) focuses on Reduce, Recycle, Reuse, and Regeneration, which is often used as a reference principle in product design to reduce the impact of products on the natural environment from raw material to waste (Giudice et al., 2006). It must be considered throughout the whole process of the production life cycle to save energy, reduce consumption, and reduce pollution in green design (Yuan et al., 2011). The ultimate goal is to improve the impact of a product or system on the Earth's ecology. This study refers to the above green design principles to develop and design beverage paper cups and obtain creative solutions to environmental problems arising from existing beverage paper cups.

This study takes the green design and development of beverage paper cups as the main research direction, and carries on the "development and design of folded beverage paper cup", to propose the design of paper cups with improved function, easy recycling, and new structure, to achieve the structure design of beverage paper cup is simpler, easier to operate and relatively environmental protection than the existing market.

TRIZ

TRIZ is the Russian acronym for Theory of Inventive Problem Solving. It is a method to solve problems for creators or producers when they come up with new products. The TRIZ innovative

design theory was proposed in the former Soviet Union by Altshuller (2002), who had studied over 400,000 patents to

establish 39 engineering parameters (Table 1), 40 inventive principles (Table 2), and a contradiction matrix (Table 3).

Table 1. 39 Engineering parameters of TRIZ

No.	Engineering parameter	No.	Engineering parameter
1	Weight of M	21	Power
2	Weight of non-M	22	Waste of energy
3	Length of M	23	Waste of substance
4	Length of non-M	24	Loss of information
5	Area of M	25	Waste of time
6	Area of non-M	26	Amount of substance
7	Volume of M	27	Reliability
8	Volume of non-M	28	Accuracy of measurement
9	Speed	29	Accuracy of manufacture
10	Force	30	Harmful factors acting on object
11	Tension/Pressure	31	Harmful side effects
12	Shape	32	Manufacturability
13	Stability of object	33	Convenience of use
14	Strength	34	Reparability
15	Durability of M	35	Adaptability
16	Durability of non-M	36	Complexity of device
17	Temperature	37	Complexity of control
18	Brightness	38	Level of automation
19	Energy spent by M	39	Productivity
20	Energy spent by non-M		

Ps. M=moving object

Table 2. 40 Principles of TRIZ

No.	Principle	No.	Principle
1	Segmentation	21	Skipping
2	Taking out	22	Blessing in disguise
3	Local quality	23	Feedback
4	Asymmetry	24	Intermediary
5	Merging	25	Self-service
6	Universality	26	Copying
7	Nested doll	27	Cheap short-living object
8	Anti-weight	28	Mechanics substitution
9	Preliminary anti-action	29	Pneumatics and hydraulics
10	Preliminary action	30	Flexible shells and thin films
11	Beforehand cushioning	31	Porous materials
12	Equipotentiality	32	Color changes
13	The other way round	33	Homogeneity

14	Spheroidality-curvature	34	Discarding and recovering
15	Dynamics	35	Parameter change
16	Partial or excessive cations	36	Phase transition
17	Another dimension	37	Thermal expansion
18	Mechanical vibration	38	Strong oxidants
19	Periodic action	39	Inert atmosphere
20	Continuity of useful action	40	Composite materials

Table 3. TRIZ contradiction matrix (Partial)

Worsening Feature	1. Weighty of moving object	2. Weight of stationary object	3. Length of moving object	... 39. Productivity
Improving Feature				
1. Weight of moving object			15,8 29,34	35,3 24,37
2. Weight of non-moving object				1,28 15,35
3. Length of moving object	8,15 29,34			14,4 28,29
..				
37. Complexity of control	27,26 28,13	5,13 28,1	26	3,27 29,18
38 Level of automation	28,26 18,35	28,26 35,10	26	35,13
39 Productivity	35,26 24,37	28,27 15,3	18,4 28,38	35,38

By using the TRIZ method, the designers can effectively solve the contradiction of system problems and improve product design. The first step for a designer to use the TRIZ method is to find the contradictory characteristics in the product's system. The next step is to match the meaning of each contradiction with two appropriate parameters from the 39 engineering parameters. Then the designers confirm these two parameters of contradiction in the contradiction ma-

trix, they would finally choose 3 or 4 of the most frequently used solutions from the 40 principles for solving a design problem. Deng et al. (2011) applied a contradiction matrix and 40 inventive principles to improve the functionality of hangers. The universal design principles were considered during the hanger innovation. Chia et al. (2015) applied the theory of inventive problem-solving to propose a new approach to new service designs. It integrated TRIZ problem-

solving tools and its knowledge base to offer a new TRIZ-based approach to address this weakness in service design with two case studies. Lee et al. (2020) applied an integrated TRIZ method to problem-solving during product development and studied a case of the smart-phone original design manufacturer (ODM) industry. They classified and summarized the problems often encountered during the development process by interviewing experts. Then these problems were matched with suitable engineering parameters from the concept of the contradiction matrix in TRIZ and found possible solutions referring to the principles of 40 inventions.

The contradiction matrix is used to solve the problem of conflicting engineering characteristics in the system. When we want to improve one engineering characteristic, we can analyze and predict that it will cause deterioration in other engineering characteristics. At this time, there is a technical conflict between the two engineering characteristics, and we can use the contradiction matrix to get 40 innovative rules to solve problems. However, if we only know how to improve a certain engineering characteristic and cannot predict whether it will cause the deterioration of another engineering characteristic, then we cannot use the contradiction matrix to solve the problem. Liu et al. (2003) proposed the innovation rule corresponding to a single engineering characteristic to solve the problem of unpredictable deterioration of engineering characteristics, the innovation rule table corresponding to a single engineering characteristic for a single problem of improving engineering characteristics is shown in Table 4. Liu

and Chuang (2009) used the TRIZ method and brainstorming to set up an innovative problem-solving process. The corresponding 39 engineering parameters were found with the help of Brain Storming, and then the contradiction matrix or the inventive principle corresponding with a single engineering parameter was applied to achieve 40 inventive principles. They studied a case of the stick as an example to adopt the inventive process to improve the design of a stick according to its drawbacks.

Patent Search

Through searching related technical patents of beverage paper cups with cup lids and cups, it is found that there are 3 patents of invention patent announcement No. I756112, I756700, I462859, and 2 patents of new patent announcement No. M629241, and M615015, which are listed in Table 4 and Table 5. After analysis and conclusion, the above-mentioned patent achievements are different from the operation mode and means applied in this research. Therefore, the "Development and design of folded beverage paper cup" developed in this research should be an innovative technological achievement used in beverage paper cups.

Research Method

The process of this study consists of seven steps, namely, the establishment of thematic research topics, literature discussion and data collection, survey methods and execution, analysis, and summary of investigation results, innovative design ideas, verification and testing of design results, and conclusions.

Table 4. Table for single engineering parameter and inventive principles (Partial)

Level of Principles	A1(more than 10 times)	A2(8~9 times)	B(6~7times)	C(4~5times)
Engineering Parameters				
1. Weight of moving object	35		18.28.26. 27.31.34	02.03.10.29 01.08.19.36.40
..				
26. Amount of substance	35.03 29	18	10.14	27.28.40 02.15.31
..				
33 Convenience of use	01.13	02	18.28.32 34.15.25 35	16.17
..				
39 Productivity	35,10 28	01		16.20.27.30.04 40.05.25.21.31 36

Table 5. Patent retrieval of beverage paper cups

Item	Announcement number	Patent Name
1	I756112	Rotation Foldable Cup
2	I756700	Beverage Packaging Container and Container Cover Assembly
3	I462859	A Disposable Cup Lid and a Convenient Tea-Making Set

Survey Methods And Implementation

See Figure. 1 below for details. Following the above, the relevant execution contents are explained in terms of the investigation method and execution, analysis and conclusion of the investigation results, and innovative design concept.

This study is mainly conducted by questionnaire survey, with a total of 200 questionnaires. The main purpose of this study is to understand and analyze the recycling methods, attitudes, and experiences of general users toward disposable beverage paper cups. In terms of the investigation, the semi-structured

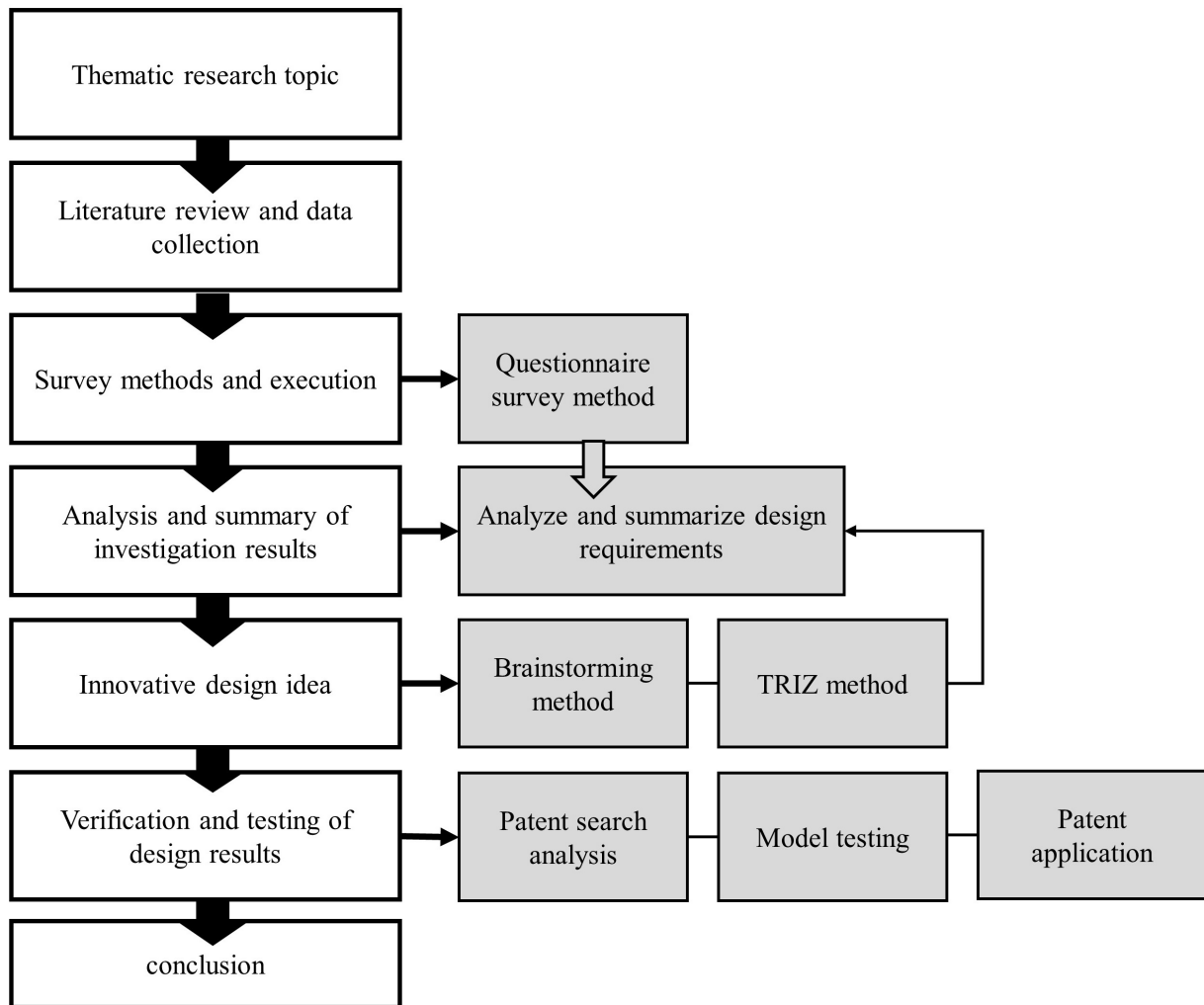


Figure 1. Research flow chart

interview questionnaire was issued in this study. The outline of the questionnaire is shown in Table 7. The subjects were those with experience in using beverage paper cups. There were 200 valid respondents (103 males and 97 females). The subjects gave feedback based on their personal experience, and the research team continued to analyze and summarize the questionnaire results.

Analysis And Conclusion Of Investigation Results

In this study, 100% of the subjects had experience in using and recycling beverage paper cups. The main reasons to use paper drink cups were lightness (80%), accessibility (89%), and low cost (95%). In item 3, inconvenience

Table 6. Patent retrieval of new beverage paper cups.

Item	Announcement number	Patent Name
1	M629241	Paper Cup Lid and Paper Cup Combination
2	M615015	Paper Container

Table 7. Contents of the questionnaire on the use experience of beverage paper cup

Item	Contents of question
1	Have experience in using beverage paper cups
2	Reasons to use paper drink cups
3	Inconvenience of beverage paper cup recycling
4	Desired improvement of beverage paper cup

of beverage paper cup recycling, 90% of users had problems with the existing beverage paper cup-related devices, the main terms included cup sealing film is not easy to separate (91%), difficult to clean (82%), and waste of plastic cup lid (80%) and so on. In terms of desired improvement of beverage paper cups, users mainly expressed their views on reducing the use of plastic products (such as lids and seals) (90%), easier recycling (87%), and hygienic (85%). The above statistical results for the use experience of beverage paper cups can be summarized as not easy to recycle, a waste of resources, and problems of hygiene. From the above conclusions, we can have the two research directions as reduce and recycle.

Innovative Design Idea

In the stage of innovative design development and revision, we apply the brainstorming method to discuss the innovative idea for these two topic of re-

duce and recycle. Then convert the design requirements obtained from the discussion of Brain Storming to the 39 engineering parameters corresponding to TRIZ, and check whether there are any contradictory relationships between these engineering parameters. If there is a conflicting relationship, use the conflict matrix table; if there is no conflicting relationship, use a single project parameter innovation rule table. Then use the obtained 40 innovation rules and sub-rules to design a new beverage paper cup, and apply for a new patent after patent search and analysis.

Folded Beverage Paper Cup Design Development

The design of this study is based on the user's expectation of the beverage paper cup, including easy recycling, resource waste, sanitation, ease of use, recycling, and environmental protection. It is oriented towards the design project of reducing and recycling. After a heated

discussion in the brainstorming group and enthusiastic input of opinions, the design project for reducing and recycling was gained. The design function for reducing is that paper is the only material to reduce the use of plastic materials and waste resources, and the design function for recycling is that integrated design and single material composition make it easier to recycle.

Then, the design project items obtained by the brainstorming method were converted into TRIZ's 39 engineering parameters. From the first design requirement: paper is the only material to reduce the use of plastic materials and waste resources, the engineering parameter to be improved is converted to No. 26 Amount of substance. From the second design requirement: integrated design and single material composition make it easier to recycle, the engineering parameter to be improved is converted into number 33 Convenience of use. Because the two engineering characteristics to be improved cannot predict the engineering characteristics to be avoided, the contradiction matrix table in Table 3 is not used but a single engineering parameter and inventive principles in Table 4 are used instead. From Table 4, it can be seen that if you want to improve the engineering parameters No. 26 Amount of substance, the 40 innovation rules appear more than 10 times, including No. 35 Parameter change, No. 03 Local quality, No. 29 Pneumatics and hydraulics, and that appear 8 to 9 times is No. 18 Mechanical vibration. If we want to improve the engineering parameter number 33 Convenience of use, the 40 innovation rules that appear more than 10 times are No. 01 Segmentation, No. 13 The

other way round, and that appear 8 to 9 times is No. 02 Taking out. We choose the 40 innovation rules No. 03 Local quality and No. 01 Segmentation as the innovation method to design the beverage paper cup. Therefore, using these two innovative rules and sub-innovation rules, as Table 7, to guide the thinking and design of the beverage paper cup, the innovative invention design description is as follows: (1) No. 01 Segmentation: In order to achieve the purpose of increasing split area, the structure of folded beverage paper cup created in this topic includes the cup body and at least one cover piece (the cover part is connected to the top of the cup body) as shown in Fig. 3 and Fig. 4, and there are broken lines between the cover piece and the cup body (No. 3 in Figure 3). When it is used, it contains the drinking supplies inside the cup, and folds the cover inward along the folding line to make the lid out, which can prevent spilling the drinking supplies in the cup when it is moved, and also effectively prevent dust and foreign matter from falling into the cup. (2) No. 03 Local quality: Applying this principle as a consideration of reduction, this design replaced the original use of plastic sealing film and lids through the integrated structure design of the paper cup with its own lids, as shown in Fig. 5. The usage situation is shown in Fig. 6 below to achieve the benefit of easier recycling.

Conclusion

In summary, an integrated structure design combining a paper cup and lid is proposed in this study. The structure includes a folded beverage cup with a cup body and at least one lid piece. It

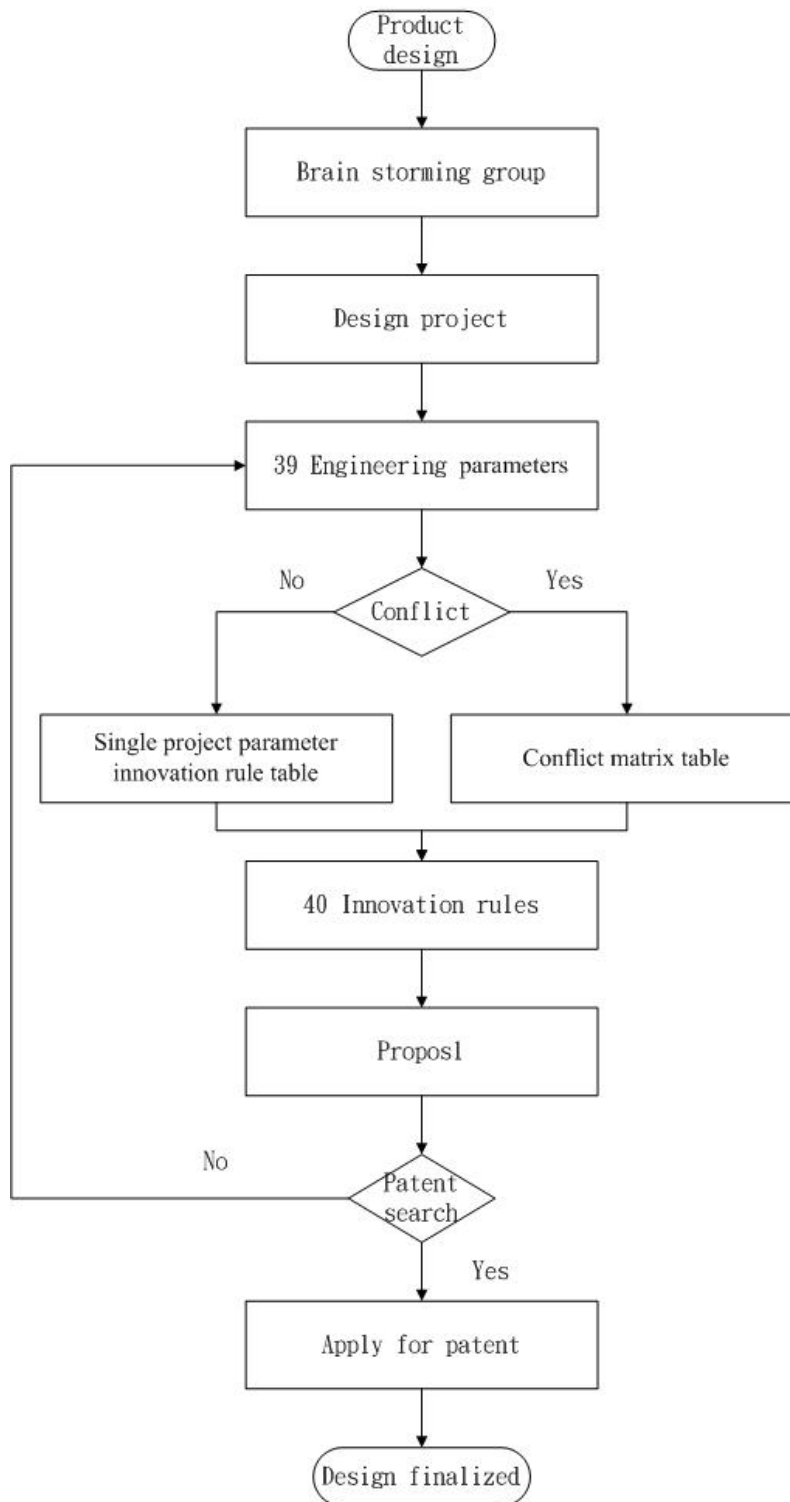


Figure 2. TRIZ product design flow chart

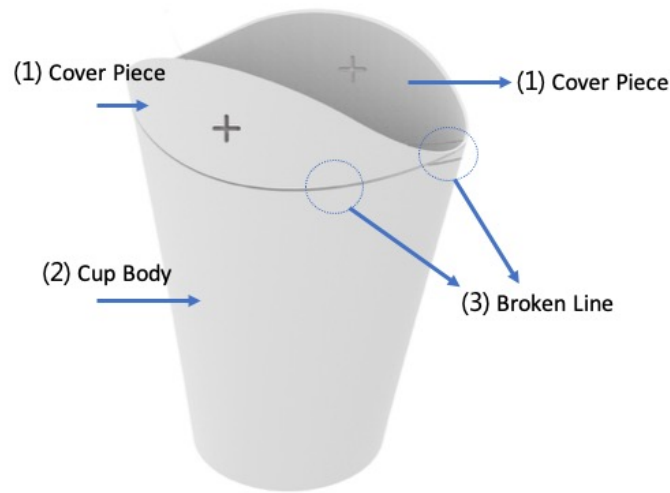


Figure 3. Structure design of folded paper cup (1)

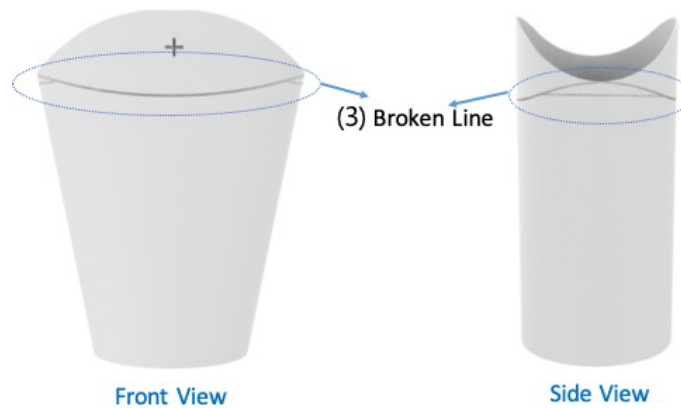


Figure 4. Structure design of folded paper cup (2)

provides an integrated design with a lid, which strengthens the practical value of the paper cup, makes it easier to recycle the plastic reduction design, and reduces the expected benefit of resource waste. It is obvious that this product is a progressive product. The main functional fea-

tures of the design include (1) improving the general paper cup without a lid, thus improving the practicability of the paper cup, (2) reducing the plastic design that is easier to recycle, and (3) reducing the waste of resources, so as to achieve the design purpose of this study. This design

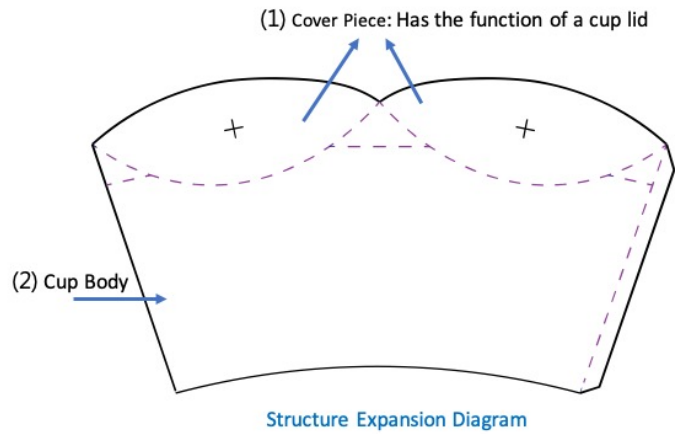


Figure 5. Folded paper cup expansion structure design



Figure 6. Use situation of folded paper cup

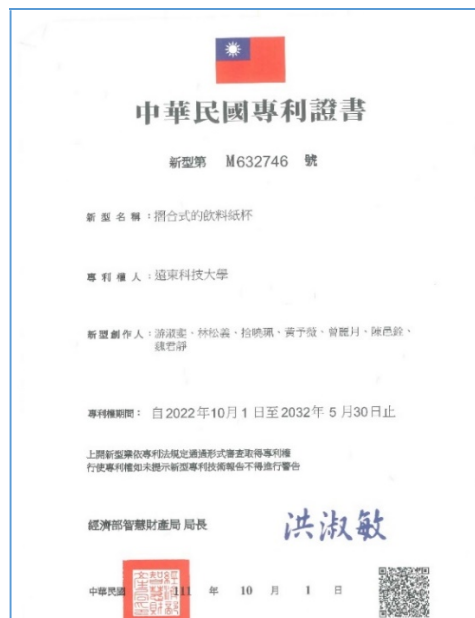


Figure 7. Patent Certificate

by the comparison of patent analysis and the national patent examination and verification procedures, finally obtained a new patent, the certificate number of new M632746, as shown in Figure 7.

It is suggested that future related research can be further extended to the folding design of the cup body. For example, the folding line of the cup body can be used to make the mouth of the cup more easily compressed to the bottom of the cup along the folding line, and the recycling volume can be reduced to a smaller size to further improve the efficiency of resource recovery.

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