Practical Case Study of Resolving the Physical Contradiction in TRIZ; Super Water-Saving Toilet System Using Flexible Tube

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ABSTRACT

This paper describes the practical case study on finding the innovative conceptual idea of super water-saving toilet system using TRIZ. The physical contradiction in TRIZ with Quality Function Deployment (QFD), is defined for the fixed ceramic S type trap on saving water with preventing the bad smell from septic tank. The concept of flexible tube for saving water in toilet is obtained by using the separation principle in time for resolving the physical contradiction. The consumption of water in the system implemented, is estimated about 3 L comparing with 13 L of that in conventional toilet.

Key words: TRIZ (Theory of Inventive Problem Solving), QFD (Quality Function Deployment), Water Saving Toilet, Flexible Tube, Reliability

1. Introduction

South Korea was recently listed on UN's water short countries, indicating that the water scarcity is now an important social problem. To achieve the dramatic reduction of water consumption, it is necessary to develop the water-saving technologies and activate the relevant industries.

Among various water-saving technologies, the technology for water-saving toilet is highly important because the amount of water consumed for the purpose of flushing in toilet is nearly 27% in home and more than 50% in commercial buildings. In general, the conventional toilet bowel uses 13 L of water for one time use.

In this study, a new technology for water-saving toilet will be introduced by finding the innovative conceptual idea of super water-saving toilet system using TRIZ. The physical contradiction in TRIZ with Quality Function Deployment (QFD), is defined for the fixed ceramic S type trap on saving water with preventing the bad smell from septic tank.

The concept of flexible tube for saving water in toilet is obtained by using the separation principle in time for resolving the physical contradiction.

This toilet employs a flexible tube and a new mechanism, using only 3 L of water, 1/4 of water amount required for the conventional toilet.

The reliability of the real toilet is confirmed in real installation and under severe conditions with acids and 165 thousands repeat tests.

2. Conceptual idea generation using TRIZ and QFD [1~4]

2.1 On finding problem and parameters generating contractions with customer's needs

Practically it is very important, but difficult to find the suitable problem so that TRIZ may suggest with good results. Specially finding the related parameters generating contradictions in TRIZ satisfying customer's needs, is more important in marketing. Of course, the parameters may be found through intensive and sustainable interests in the problem and understanding the cause of the problem.

Using QFD (Quality Function Deployment) relating the customer's needs and design parameters is helpful for finding and conforming the contradictive parameters in TRIZ.

As an example we will explain the conceptual idea generating process on the super water-saving toilet system using TRIZ.

2.2 Structural reason why toilet bowl uses considerable amount of water

As you know, the toilet bowl uses considerable amount of water. So, most people insert bricks to its water tank in order to save water. However, the volume of water saved by such measure is just one liter and such insertion may result in poor flushing effect. The basic operating principle of the toilet bowl is shown in Fig. 1. There is also a slightly modified type called "Siphon Jet", but its basic principle is similar to that in Fig.

1. In addition, there are suction or foam washable toilets mainly used in trains or airplanes. These toilets require a separate power supply and a chemical agent, so they are not suitable for home use.

In general, a toilet bowl consumes about 13 L of water for one time use. The toilet bowl looks clean and has the advantage of preventing bad smells from the septic tank because its water tank is always filled with water. Such advantage is further realized by employing an S-shaped trap containing water in bowl.

However, considerable amount of water is required to make the stool go through such trap with height. Recently, several water-saving toilet bowls or water-saving devices installed inside the water tank have been introduced, resulting in reduction of water consumption to about 6 to 7 L. However, their mechanism is similar to the concept of "inserting bricks" and so, they are not considered to be the ideal solution.

As shown in Fig. 1, the conventional toilet bowl consists of body, drain outlet, and water tank and repeats the procedure of (1) to (5).

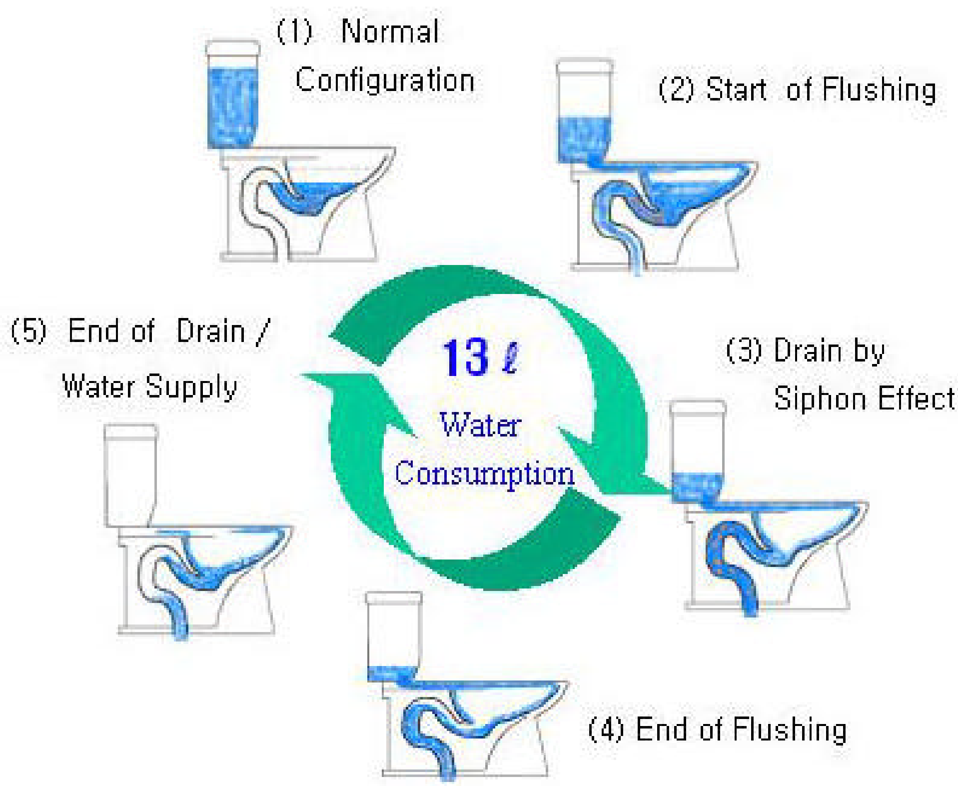


Fig. 1 Operating Method of Conventional Toilet Bowls.

Accordingly, it is necessary to make a new toilet bowl for effective and efficient water-saving.

2.3 Investigating the customer's needs and major design parameters in toilet system using QFD

When the manufacturer and salesman investigate the customer's needs of toilet system, the followings are listed mainly;

1. Removing the stool
2. Flushing bowl
2. Preventing bad smells from septic tank
4. Saving water for flushing recently in water-shortage era
5. reducing noise when flushing

The needs are related to the major design parameters such as bowl, S trap structure, water tank, the outlet/inlet of bowl and so on.

These relationships are summarized in simple QFD analysis and evaluated by the one major design parameter, S trap structure according to each needs as follows.

For Customer's needs	Design parameters ……	S-trap structure	…………
1. Removing the stool		disappearance	
2. Flushing bowl		disappearance	
3. Preventing bad smells from septic tank		appearance	by water in bowl
4. Saving water for flushing		disappearance	
5. reducing noise when flushing		disappearance	

Table 1. Simple QFD Analysis of Customer's Needs and the Related Design Parameters of Toilet System

So the contradictive requirements such as disappearance and appearance of the S trap structure in toilet, are exposed according to customer's several needs.

2.4 Toilet bowl's drain structure from the perspective of physical contradiction and ideal result in TRIZ [5~8]

The toilet bowl fulfills its intended function of flushing and preventing bad smells from septic tank. However, it has a problem of using considerable amount of water. Therefore, it is necessary to improve the toilet bowl, while maintaining its basic mechanism. Under these considerations, the toilet bowl's problem will be defined.

The toilet bowl has a drain in "S" shape in order to prevent bad smells. Water in the bowl can prevent bad smells. However, considerable amount of water is required to remove the stool. In short, a method to remove the stool with less water is required, while maintaining the "S" shaped drain structure to prevent bad smells.

TRIZ requires that the problem should be described and defined in a simple and plain sentence.

Accordingly, the ideal result and solution for the present problem can be said as follows:

How much water is required for the toilet bowl? About 2.5 L of water is always in the bowl for preventing bad smell from septic tank. If there is an ideal method to remove the stool and flush the toilet bowl with minimal water (0.5 L), total 3 L of water per one flush is required.

What is the most ideal method? The "S" shaped trap is required to prevent bad smells from the septic tank, but this structure has to be removed when flushing the stool in order to save the water. In other words, the trap structure has to appear and disappear.

So the S-trap structure is the parameter of physical contradiction in TRIZ. The physical contradiction is generated when different needs have to be satisfied at the same time.

The typical solution for resolving physical contradiction is "to separate such contradictory factor in time and space."

Based on the ideal solution for the present problem, the physical contradiction can be defined as follows:

"The trap structure is required to prevent bad smells and it has to be removed to flush the stool with less water."

This physical contradiction's control parameter, S-trap structure can be separated in time. In other words, the time requiring such trap structure and not requiring it can be clearly identified. On the basis of such ideal solution, the following results were obtained.

The toilet bowl's drain outlet has a trap structure, but it loses such structure when flushing the stool. Once the flushing is completed, it recovers the trap structure again.

In this way, the physical contradiction can be overcome by time-based separation, which provides a clue to solve the present problem.

Fig. 2 is a schematic diagram of a new water-saving toilet bowl realized by applying the ideal solution. The new water-saving toilet bowl can be implemented by body and flexible tube and repeats the procedure of (1) to (3).

In this structure, the trap structure's presence or absence in connection with the flushing operation is successfully realized.

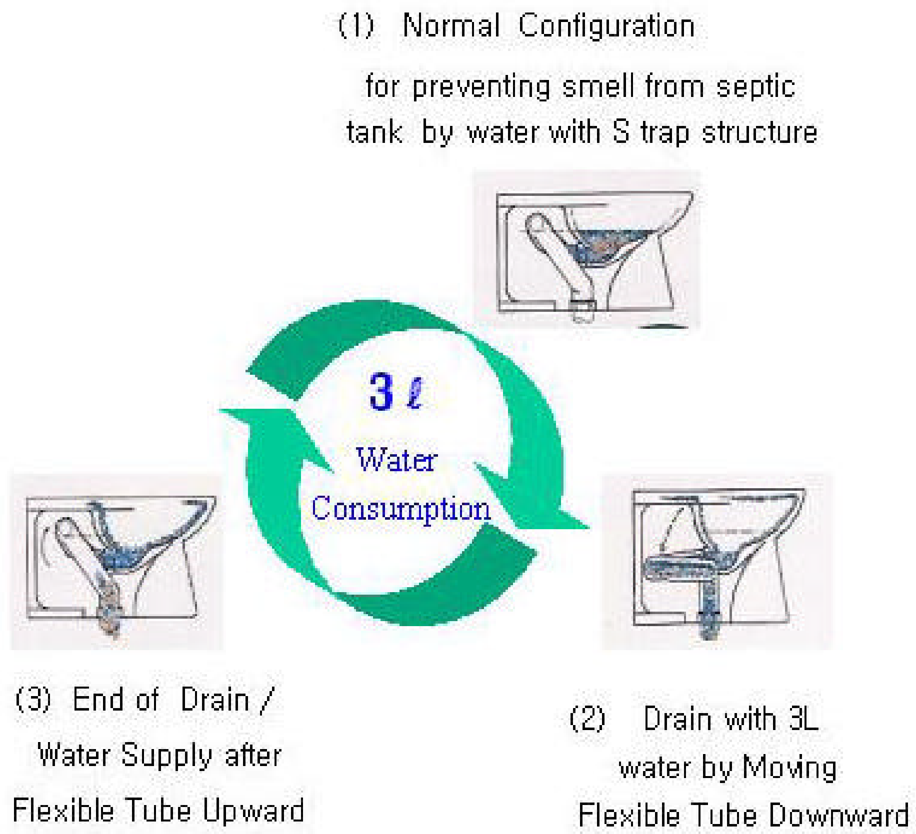
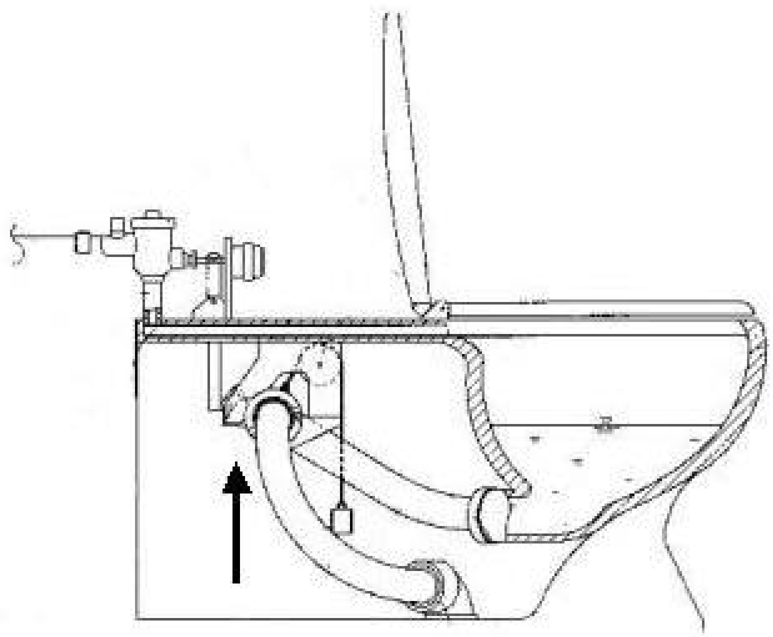


Fig. 2 Operating Method of New Water-Saving Toilet Bowls.

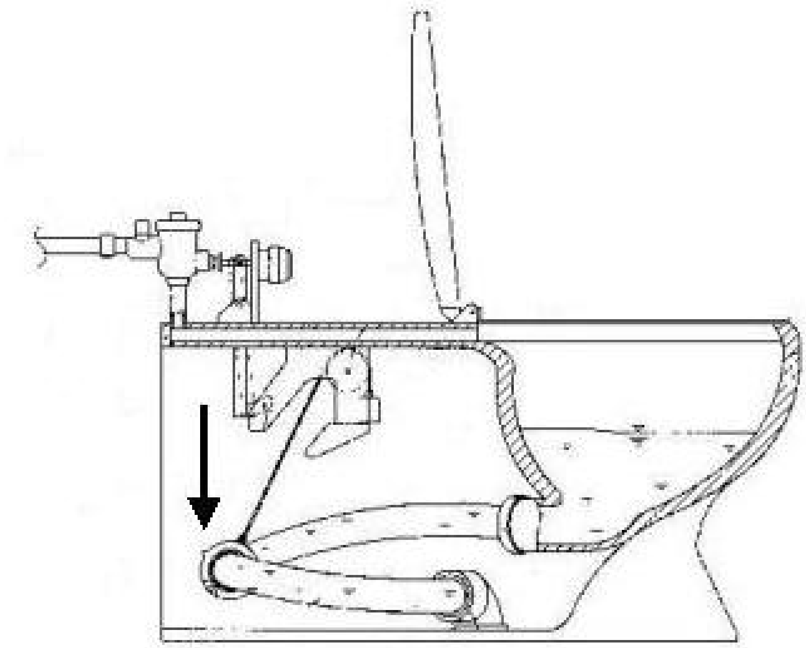
In designing the mechanical mechanism to move the flexible tube structure, the so-called "Modeling with Miniature Dwarfs (MMD)", one of creative problem solving technologies, was applied. This technology allows us to imagine dwarfs working themselves without the use of additional devices. In other words, we can make out a structure operated by dwarfs to accomplish the desirable result.

In this toilet bowl, we can image a structure operating by itself without additional electric pump or motor to lower and raise the flexible tube. The weight of water removes the flexible tube downward and then, a simple mechanical component, such as spring or plummet, helps the flexible tube return to its original position upward.

Hence, the flexible tube is moved upward and downward by only gravity with any other working energy such as electricity.



(a) Normal: Up Configuration of the Tube



(b) Drain: Down Configuration of the Tube

Fig. 3 Down & Up Configuration of the Flexible Tube in Water-Saving Toilet

2.5 Design & fabrication

The toilet bowl's ball (a rounded part to contain the stool and water) is made of a sanitary ceramic and the flexible tube is made of a durable and anti-microbial material with resistance to temperature change. In order to use only 3 L of water, a flush valve generally used for urinal is employed. In this way, a new water-saving toilet bowl that does not require a separate electric motor or pump is realized. The flexible tube is lowered by the water weight and then, automatically raised by the weight of the plummet at the opposite side. Further, this product may not require a separate water tank, so its size may be reduced to 2/3 of the conventional toilet bowl. The new water-saving toilet bowl without water tank is best suitable for commercial buildings where the space for toilet is limited. Further, the toilet bowl for home use that employs 3-L water tank, the same flexible tube and operating mechanism is available.

(a) For commercial buildings (3-L toilet with flushing valve)

(b) For home use (3-L toilet with water tank)

Fig 4. Super Water-Saving Toilet System

3. Performance test

3.1 Measurement of water consumption

According to KS (Korea Standard) L 1551 Standards specifying the toilet bowl's flushing performance [9], crumpled paper and aniline dye tests were conducted. In addition, the amount of water used in each test was repeatedly measured. From these tests, it was confirmed that the new toilet bowl uses 3 L of water (±0.5L).

3.2 Measure ment of noise level in the course of flushing

In an apartment building, the noise generated by flushing the toilet bowl at the upper floor is the most important one disturbing the people living in the lower floor. At present, there is no standard relating to the flushing noise level. So, according to a Japanese company's method, microphones were placed at the point (1.5 m above and 1.5 m in front of the toilet bowl) to measure the noise level, while closing the cover of toilet bowl. It is desirable to conduct this test in an anechoic room. However, it was not practical to make such system. So, this measurement was conducted at night with two kinds of toilet bowls, the conventional siphon-type toilet bowl and the new water-saving toilet bowl employing the flexible tube. From this test, the conventional one showed the average noise level of 70 dB, while the new one resulted in the average noise level of 60 dB. In short, the new water-saving toilet bowl generated less noise by about 1/3. The difference of noise level between two toilet bowls could be easily identified even without any device for measuring noise.

4. Reliability test

4.1 Repetitive operation test

The repetitive operation test was conducted by making a pneumatic test device pushing the flushing valve four times in a minute. When compared to a Japanese company's in-house durability criteria of 165,000 times (corresponding to 20-years use), this new water-saving toilet bowl was confirmed to have comparable durability.

4.2 Acid resistance test

The flexible tube coming into contact with the stool and water was soaked in hydrochloric acid, a bleaching agent, and a detergent used in clearing the plugged tube for 6 months to determine the flexible tube's mechanical and physical properties. Except some bleaching by a bleaching agent, the flexible tube did not show any change of its physical properties.

4.3. Fluidity in drainpipe below the toilet bowl

The sloped drainpipe connects the toilet bowl to the septic tank. This drainpipe's diameter is usually 100 mm and its slope degree is 1/50. PVC pipe is generally used, but iron pipe with rough surface is also used.

In the fluidity test, the PVC pipe for the water-saving toilet bowl did not show any plugging. In addition, the water-saving toilet bowls were actually installed at restroom in a subway station to conduct this test. The industrial endoscope was used to observe the change the inside surface of the iron pipe with 30 m in length below the toilet bowl. In this test, there was no obvious scale inside the pipe. In short, the fluidity of stool and water was good in both simulated and actual field tests.

5. Conclusions

In this study, the flexible tube and its operating mechanism using TRIZ, were applied to toilet bowls widely used in households and commercial buildings to dramatically reduce the water consumption from 13 L to 3 L. The new water-saving toilet bowl's performance was also tested. As a result, it is confirmed that this new toilet bowl would be a solution for saving water. In addition, the noise of flushing level is reduced by 1/3 of that in conventional toilet.

From this study on the water-saving toilet bowl employing the flexible tube conceptually, the parameter of physical contradiction in TRIZ is found by intensive investigating the toilet structure with flushing, preventing bad smell from septic tank and saving water for flushing with the related QFD analysis.

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Appendix

The patent on the structure using flexible tube in toilet system was issued in Korea and Singapore. It is accepted as a patent in U.S.A. recently.

In South Korea the TRIZ theory was introduced in 1996 first. These days several companies (such as Samsung, LG Electronics) and universities (such as Korea Polytechnic University) have utilized it to solve various technical problems at the early stage of product development and to apply the results to design products creatively.