

DESIGN OF A REMOVABLE CYLINDER WASHING MACHINE STRUCTURE BASED ON TRIZ AND QFD

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Abstract: There are various solutions for the development of cleaning methods for the inner drum of a drum washing machine, in which the design and development of the drum structure is difficult because of its many influencing factors and low efficiency and quality assurance, this paper will be through a questionnaire survey, innovative design for the drum structure of the inner drum of a washing machine, and analyze the correlation of the structural functions of a washing machine through the negative correlation characteristics in the quality house, and build an ideal solution. The paper will analyze the interrelationship of the structural functions of the washing machine through the negative correlation characteristic in the quality house to construct the ideal solution. Secondly, through the TRIZ theory of technical contradictions, physical contradictions to analyze the feasibility of the program, after screening to determine the final program, so as to complete the simple disassembly of the internal drum, so as to complete the user more convenient than the traditional washing machine thorough cleaning and maintenance.

Keywords: Inner drum removable washing machine; Contradiction matrix; TRIZ; QFD

1 PROBLEM DESCRIPTION

1.1 Project Overview

1.1.1 Project source

In modern family life, washing machine has become an indispensable household appliance, its cleaning function is directly related to the user's clothing hygiene and health. However, after using for a period of time, dirt will accumulate inside the washing machine. With the cleaning process, the dirt will fall off and mix into the wrinkles of the clothes, and then pollute the clothes. As shown in Figure 1, Figure 2.



Figure 1 Drum Seal Strip of the Washing Machine



Figure 2 Outer Wall of the Washing Machine Drum**1.1.2 Problem description**

In order to solve the cleaning problem of the washing machine itself and ensure the clean effect of laundry, some washing machines have added the procedure of "self-cleaning" through detergent soaking, heating and repeated spraying to remove the stains of the washing machine itself. However, the clearance effect can not be completely cleaned up.

The best way of cleaning is still to cleaning. As shown in Figure 3:

**Figure 3** Cleaning Effect Diagram of the Washing Machine

This group chooses the creative direction to solve the cleaning problem of washing machine, designed a new washing machine structure, and meet the following limitations:

- ① The manufacturing of the washing machine should not be too complex, and the cost should not exceed a certain proportion of the price of the existing washing machine (this proportion will be understood through the questionnaire);
- ② The washing machine does not need a high cost of the overall disassembly and cleaning method;
- ③ The self-cleaning method of the washing machine should be simple and easy to operate;
- ④ The service performance, reliability and service life of the washing machine itself should not be affected.

1.2 Initial Situation Analysis of Problems**1.2.1 Main problems exist**

The non-disassembly and cleaning of the washing machine can not achieve the purpose of thorough cleaning. The common disassembly methods of mechanical structure can be divided into strike unloading method, pull unloading method, pressure unloading method, temperature difference method and destructive disassembly method. The disassembly method of the washing machine is complex, and the disassembly of the inner bucket needs to be made by professional technical workers to book the door-to-door service. And according to the assembly structure of the unique design of different brands of washing machines, the use of strike and unloading method, through the screwdriver, wrench, flat mouth pliers and other tools, to complete the disassembly. This disassembly cleaning method is difficult to meet the needs of users (see Table 1).

Table 1 Introduction of the Disassembly Method

Technical approach	Disassembly tool	Applicable parts/parts
Knock-off method	Hammers or other heavy objects	Small, medium and large parts/parts
Pull-and-unload method	Dedicated ejector	Disassemble parts that require high accuracy and are not allowed or can not be tapped
Pressure discharge method	Hand presses, hydraulic presses	Status quo simple interference fittings
Temperature difference method	Utilize the thermal expansion and contraction of materials	Larger sizes and hot-loaded parts
Destructive dismantling method	Machine tools such as turning, sawing, drilling, cutting, etc	Fixed connectors, shafts and sleeves have been bitten to each other, and the core value parts have not been preserved and must be destroyed

1.2.2 Current Solutions

After inquiry, the current relatively novel related patents and designs include the following types:

(1)Way to strengthen the water flow cleaning capacity.

According to the author of Beijing industrial and commercial university and other papers, "based on TRIZ ideal solution of automatic washing machine self-cleaning structure innovation design optimization" description, the design is mainly

to improve water valve, in and out of water access components, increase on the automatic washing machine washing machine dehydration tube outer wall and bucket wall self-cleaning function[1].

(2)Add cleaning tools.

According to the invention patent (invention application no.: 201010160548.4) description, disclosed a flexible particles between the washing machine and method, the washing machine with flexible particles between the inside and outside the bucket, through the regular flow of water through the flexible particles impact and friction washing machine, realize the cleaning between the bucket inside and outside the washing machine. Flexible particle materials can be added to sterilization substances, cleaning between the internal and external buckets at the same time, but also for clothing and (3)washing machine sterilization.

Washing machine that can remove / replace the drum as a whole.

According to the description of the invention patent (invention application number: 201810184251.8), a drum washing machine with a removable washer is disclosed. It can easily take out the washing cylinder from the mouth of the outer cylinder and clean the washing cylinder outside the machine for convenient installation and no need to remove the washing machine.

(4)Non-hole inner drum washing machine.

According to the description of the invention patent (invention application no.: 201410215346.3), a drum washing machine with a non-porous inner cylinder is disclosed, where the washing water is stored in the inner cylinder and there is no water in the outer cylinder, solving the problems of water storage between the inner cylinder and the outer cylinder and the accumulation of dirt between the inner cylinder and the outer cylinder.

(5)The washing machine cleaning the brush

The design of a long handle toothbrush, suitable for cleaning the gap of the drum mouth.

1.2.3 Study objectives

This study aims to explore and propose innovative improvements for the internal cleaning function of washing machines through in-depth analysis of user pain points and needs. The goal is to improve the internal cleaning ability of the washing machines, and enhance the user satisfaction and the market competitiveness of the products.

2 SYSTEMATIC ANALYSIS

2.1 System Analysis

2.1.1 User survey and QFD analysis of drum washing machine

In order to understand users' consumption satisfaction and pain points of drum washing machines, the team made a questionnaire and released it through the "Tencent Questionnaire" to collect data. Survey content includes the basic situation of household washing machine (style, laundry frequency, washing machine capacity), the user view of washing machine since cleaning (use frequency, whether can clean the washing machine), the user view of the pain points of washing machine importance (washing poor, power consumption, noise, complex operation, maintenance difficulties), the user is willing to pay for washing machine additional function project (except mites, intelligent interconnection, drying function, self-cleaning function), etc.

After the recovery and analysis of the questionnaire, we can understand that the main usage of users is the frequency of once every 3 days, the average duration is about 60 minutes, and the service life of most washing machines is more than 5 years. In terms of satisfaction, the use of special functions (such as mite removal, sterilization) are not satisfied with the cleanliness and service life of the washing machine. Users pay more attention to the problem of self-cleaning first, and the problem of mobile convenience. In the cleaning method, the proportion of asking special personnel to dismantle and clean is low, 20 and 20.6% and 23.4% respectively. Based on the analysis and realistic scenarios, the needs of users are derived, created as shown in Figure 4.

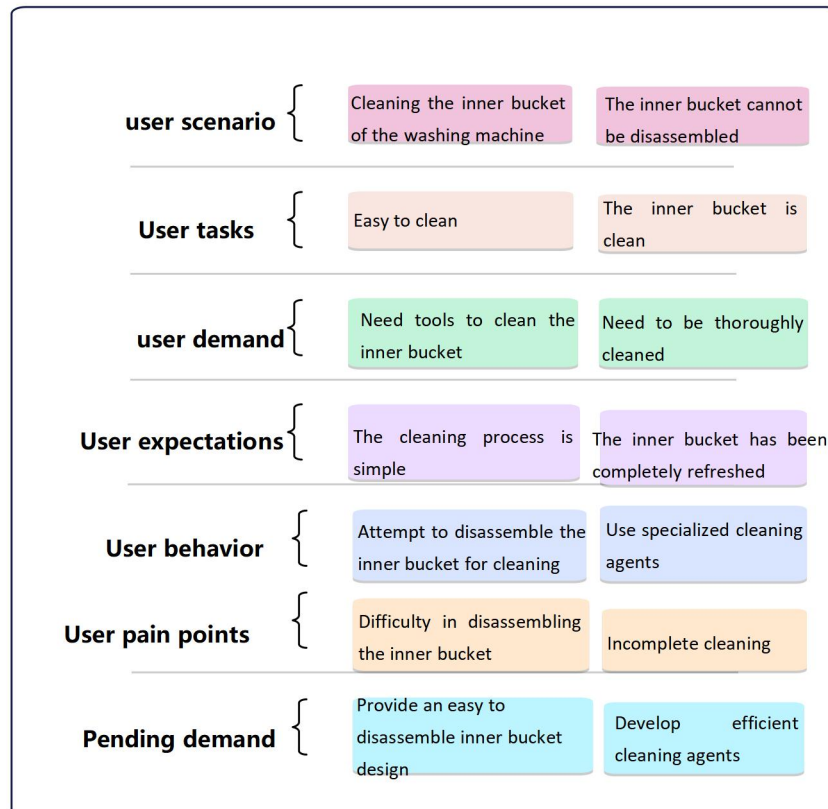


Figure 4 User Story Diagram of Cleaning the Bucket inside the Washing Machine

According to the variance test and T test results, there is no significant difference in the average price of the washing machine for consumers who choose to manually remove the inner cylinder of the washing machine. For the consumers who choose to manually remove the inner cylinder of the washing machine, the average price of the washing machine receiving the cleaning is CHY2707.17, and the standard deviation is 1403.392. Among the consumers who consider the manual disassembly, the average price of the washing machine that accepts the removable inner cylinder is 2CHY558.82, and the standard deviation is 1309.608. We considered no significant difference in the mean of acceptable price between the two groups of users.

According to the user survey results of washing machine and the product structure and function requirements of drum washing machine, QFD design is conducted, as shown in Figure 5. After analysis, the team found that there is a positive correlation between the technical characteristics, such as shock absorption and weight, sealing parts and sealing rust treatment; there is also a negative correlation between the technical characteristics; the vibration will be increased in order to strengthen the washing effect. For energy conservation and environmental protection, consumers and society require water saving and electricity saving, the drum washing machine can use relatively little water to achieve the purpose of environmental protection, but will increase the washing time and reduce customer satisfaction on the other hand. The washing machine in low temperature environment will reduce the solubility of the detergent, so the heating function, adding the drying function, resulting in the deterioration of "energy saving" characteristics; the service life and safety of the washing machine, the machine structure requires good integrity, the assembly way to ensure the tight seal, to achieve waterproof, vibration prevention, insulation and other properties, on the other hand, in order to disassemble, washing machine box, drum, piping system, circuit control system, should be removed, tested and replaced.

Among them, the pain point that is difficult to completely clean is the goal of this study, which requires the structural design and assembly design of the purpose of future maintenance and disassembly, and the convenience of maintenance window and disassembly tools to be considered in advance. The improvement of maintainability has a negative impact on the performance of rust prevention and insulation. The design of opening the window will destroy the integrity of the box and the drum. The existence of this contradiction requires further analysis using TRIZ related theory.

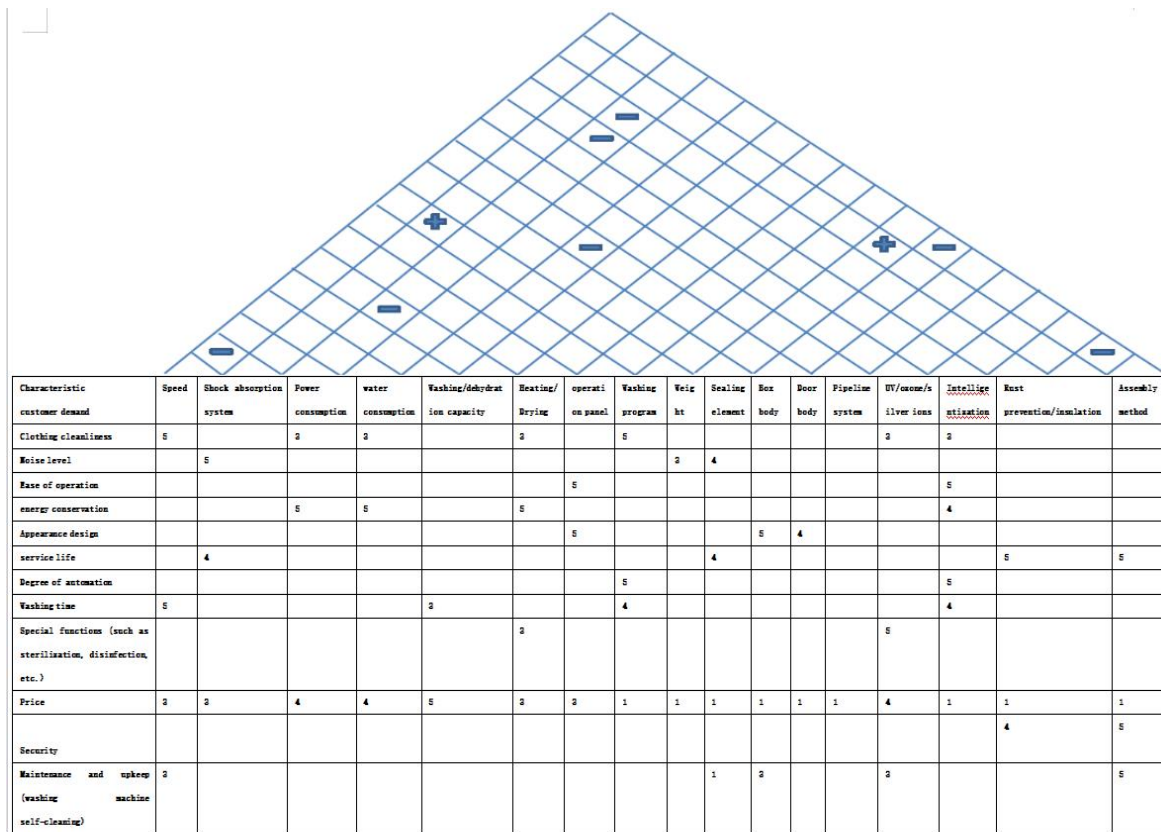


Figure 5 Analysis Diagram of Drum Washing Machine

2.1.2 Final ideal solution (see Table 2)

Table 2 Final Ideal Solution Analysis Table

Question	Analyze the results
The end goal of the design?	The washing machine can be thoroughly cleaned. The outside of the drum can be cleaned without disassembly as a whole.
Idealize the end result?	The structure of the washing machine is not complicated and the cost does not increase.
What are the obstacles to achieving the ideal solution?	The washing machine is operated in a tightened and sealed state. The disassembly of the washing machine requires specialized tools and personnel.
What is the result of this disorder?	The structure and assembly of the washing machine box and drum are simplified.
What are the conditions for not having such an obstacle?	Electricity, air, intelligent systems.

3 USE THE TRIZ TOOL TO SOLVE PROBLEMS

3.1 The TRIZ Tool

3.1.1 Analysis of technical contradictions

In order to increase the cleaning convenience of the washing machine (maintainability), the improvement of the washing machine mechanism, whether it is to increase the window, or expand the gap, or split the drum, will affect the reliability of the washing machine, constitute the technical contradiction between the two parameters.

The improved parameters were maintainability and the deteriorated parameters were reliability. The principle of the invention is found by the contradiction matrix table (see Table 3):

Table 3 Contradiction matrix Table 1

Improved parameters	reliability
Maintainability	11、10、1、16

Principle 11: Pre-prevention principle. For systems with high risk and high cost failure, prepare and compensate in advance to improve the reliability of the system.

Principle 10: Pre-action principle. Act in advance to improve effectiveness and safety and make things simpler before procedures occur.

Principle 1: segmentation principle. Divide an object into separate parts; divide it into easy assembly (or combination) and disassembly; increase the degree of the object segmentation.

Principle 16: deficiency or excessive principle. The desired result is achieved with more or less quantities in situations where controlled precise quantities cannot be achieved.

We use the invention principle 1 (segmentation principle) to open the window or split in the drum wall, so that the cleaning tool can be cleaned or the parts can be removed.

The second step is to consider that opening the window or splitting will destroy the integrity of the drum and reduce the strength of the drum. In order to increase the intensity, the window area will reduce (deteriorate), forming the contradiction between the intensity of the object and the area of the moving object.

The improved parameter is the intensity of the object, and the deteriorated parameter is the area of the moving object. The invention principle is obtained from the contradiction matrix table (see Table 4):

Table 4 Contradiction matrix Table 2

Improved parameters	deterioration of parameters	The area of the moving object
The strength of the object		3、34、40、29

Principle 3: local characteristics principle — make different parts of the object should have different functions;

Principle 34: Self-abandonment and regeneration principle. This is the combination of self-abandonment and regeneration. Once a useful function is completed, remove it from the system immediately, or regenerate it immediately for reuse.

Principle 40: Principles of composite materials. Changing the uniform material structure into composite structures to obtain new properties or functions.

Principle 29: Air pressure and hydraulic structure principle. Using air pressure or hydraulic pressure to replace the components or functions of the system often enhances the reliability and controllability of the system.

We use the invention principle 3 (local characteristic principle), so that the different parts of the object should have different functions.

According to the innovative principle found out in the above contradiction matrix, and combined with the requirements of the inner barrel disassembly design of the drum washing machine, the "1 division" and "3 local quality principle" are determined to be in line with the innovation direction of the design through the specific analysis.

3.1.2 Analysis of physical contradiction and separation principle

The more functions the drum washing machine needs to meet, its structure will be more complex, which conflicts with the design requirements of simple washing machine structure and easy to manufacture. Therefore, TRIZ's conflict theory analysis shows that the conflict is a physical conflict and can be directly used to solve[2].

The core idea of solving this physical contradiction in TRIZ theory is to use the separation method to separate the mutually exclusive requirements of a certain characteristic of the research object and meet them separately[3]. In TRIZ theory, the separation principle is used to solve the physical contradictions. The separation parties are divided into four principles: spatial separation, temporal separation, conditional separation, and integral and partial separation. In this design, the spatial separation square and the condition separation are selected (see Table 5).

Table 5 Table of Correspondence between Spatial and Conditional Separation and 40 Invention Principles

	Spatial separation
The corresponding principle of invention	1.Segmentation principle 2.Principle of extraction 3.Principle of local mass 17.Principle of spatial dimensionality change 13.Principle of reverse action 14.The principle of curvature addition 7.Nesting principle 30.Flexible shell or film principle 4.Add the principle of asymmetry 24.With the help of the intermediary principle 26.Replication principle

The spatial separation method corresponds to the 40 inventions, as shown in Table 5. The principles related to mechanical structure design are selected from the invention principle corresponding to the spatial separation principle: 1.

Separation principle; 2. extraction principle; 3. local mass principle; 17. spatial dimension change principle; 13. reverse action principle; 14. curvature increase principle; 7. nested principle; 30. flexible shell or film principle; 4. increased asymmetry principle; 24. assisted agent principle; 26. replication principle. Through the selection of principles, we choose 1. segmentation principle; 3. local quality principle, the following to explain these principles.

The segmentation principle is the first principle in the invention principle of TRIZ, which divides a system into multiple parts in a virtual way or in a real way, so as to decompose (separate, separate, extract) or merge (combine, integrate, combine) a beneficial or harmful system attribute. In most cases, multiple parts of the separation are reorganized (or integrated) to present certain new functions and (or) eliminate harmful effects. With the improvement of the segmentation degree, the technical system gradually develops to the micro level. Its guidelines are: divide an object into multiple separate parts; divide it into parts that are easy to assemble (or combine) and dismantle; and increase the degree of object segmentation[4].

Therefore, in view of the conflict of the drum washing machine, the separation principle of whole and part can be used to divide the cleaning function of the washing machine into independent working content one by one, so as to reduce the difficulty of innovative design[5]. In order to realize the total function of cleaning the outer wall of the inner cylinder of the drum washing machine, the drum of the washing machine can be divided by the principle of separating the whole and the part into several independent parts to achieve. Use the mechanical structure and related modeling knowledge to design the components that can realize each function, and finally get a set of feasible solutions that can meet the needs[6].

4 DETERMINATION OF THE TECHNICAL SCHEME

In the process of this design, the group discussed and analyzed various schemes for cleaning the drum and the outer wall with simple and feasible methods without increasing the cost.

Scheme 1: Rapid disassembly structure of rear plane / side plate of washing machine

This scheme is initially generated according to the idea of dismantling the washing machine, which makes the disassembly process more convenient. Without passing special tools and personnel, it only needs to simply open the side of the wall, open a large enough window, and extend into the cleaning tools, so as to achieve the purpose of cleaning[7].

The advantage of this scheme is that it has little impact on the original structure of the washing machine and does not increase the cost. However, the disadvantage is the size of the window selection, which will increase the risk of leakage, and then produce leakage danger; too small window will produce the cleaning tools can not contact more area, the cleaning purpose can not be realized.

Scheme 2: Expand the front door of the washing machine

This scheme is based on the idea of washing the inner cylinder brush of the washing machine, that the reason why cleaning is not convenient is that the gap is too small, by magnifying the gap and improving the cleaning brush, you can be more convenient in the case without disassembly[8].

After discussion, it is believed that this method has some problems such as affecting the sealing effect and sacrificing the inner cylinder space (and use space), and it cannot guarantee that all the outer and outer walls of the inner cylinder can be completely cleaned[9].

Scheme 3: Opening of the inner wall of the washing machine drum

This scheme is to combine the two ideas of cleaning from the outer opening and the brush, open the "window" in the inside of the drum, open from the inner wall, and extend the cleaning tool. Carry on the cleaning of the outer wall of the inner wall and the outer wall by using the curve Angle of the cleaning brush[10].

The technical focus of this scheme is in the size and number of window sizes. The number of Windows, small size, it is difficult to clean all the position, the expansion of the window, will affect the structural strength of the drum.

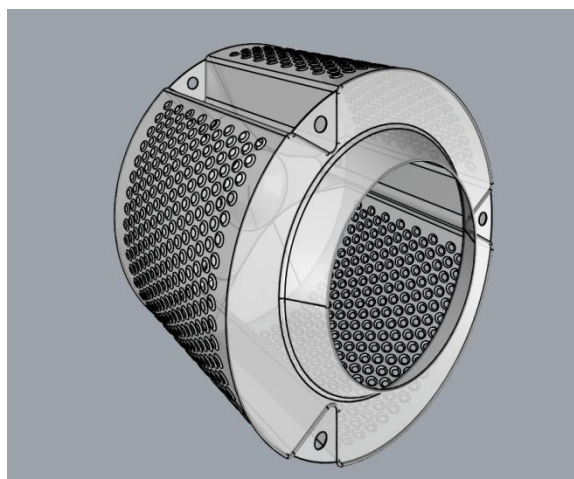


Figure 6 Design Drawing of the Removable Washing Machine Drum

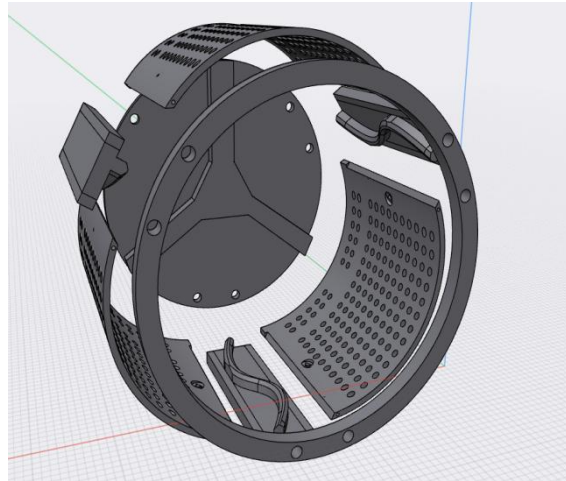


Figure 7 Schematic Diagram of the Drum Parts of the Removable Washing Machine

As shown in Figure 6 and Figure 7 is the drum structure of the washing machine. The washing machine in this design adopts the innovative easy disassembly design, which enables users to easily assemble and assemble the inner drum of the washing machine at home, eliminating the complexity and inconvenience of the traditional professional disassembly method[11]. To achieve this, we have made significant improvements to the internal structure of the washing machine, so that the inner drum will no longer use the overall stainless steel plate design, but is optimized into three distinct uneven plates, reinforcement and bottom plate.

In designing the engagement mode of these components, we introduce the protruding and concave lock and buckle mechanism. This is also used as an error-proof feature to ensure the user's intuitive operation in the disassembly process, reducing the possibility of misoperation, and also guarantee the accuracy of disassembly and assembly. This intuitive and easy to understand design can reduce the risk of error during use.

Despite the ease of easy disassembly design, we recognize that it may bring challenges to the sealing and waterproof performance of washing machines[12]. For this reason, we believe that the washing machine needs to use waterproof and anti-rust steel, so that it can not only improve the durability of the bucket in the washing machine, but also effectively resist rust and wear, to ensure that the washing machine can maintain the best performance in all kinds of environments.

COMPETING INTERESTS

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