Washing Machine Green Design Based on TRIZ/FRT

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Keywords: Washing machine, TRIZ, FRT, Green design.

Abstract. Firstly, the substance-field model is introduced to analyze the functional pattern of the automatic washing machine, FRT (i.e. Future Reality Tree) method is introduced to find the potential conflicts among different components, as much as ten TRIZ solutions are suggested with the help of the contradictory matrix software tools developed by our team. Finally, the innovative solutions are selected, verified and testified. A conceptual model of a solar powered automatic washing machine is suggested with the cooperative TRIZ/FRT method and software tools.

Introduction

Altschuller [1] proposed a method to predict the product technology maturity, based on the mass analysis of patents through around the world. Bingquan He [2] proposed a new prediction technology based on the evolutionary theory method from TRIZ theory, and the feasibility of this method is verified by a design example of a MP3 player. Cheng Jung Yang [3] proposed an integration model of TRIZ, CBR and LCA integration model, which is used for green product design; Wang [4] proposed a kind of technical prediction method based on the review of academic literature as well as patents, and the model is verified and testified. Xiao Chun, Shi [5] uses the technology evolution route and the technology maturity prediction to predict the development direction of the loader technology, and gives the position of the different evolution pattern corresponding to different evolution routes.

The evolution of the washing machine can be divided into three phases: the mechanical age, the semi automation age and the automation era. The automatic washing machine needs no longer man power, during this period, the drum washing machine, the mixing washing machine, and program controlled machine accounted for the vast number of the market. However, there remains many problems, i.e. water, power, detergent consumption, noise, vibration, environmental pollution etc. So an environment friendly product is needed, and developed in this paper. And it is talked about in the following chapters in detail.

Establishment of the Substance-Field Functional Model of a Washing Machine

Automatic washing machine consists of five major subsystems, namely, drive system, washing system, water supply and drainage system, control system, vibration control system. The present automatic washing machine consume large amount of water, electricity and detergent, etc., generate load noises in the washing process, and great vibration in dehydration. According to the existing problems, modern green design of washing machine is required for low noise, energy saving, environmental friendly etc.

In Figure 1, many problems or conflicts could be found to prevent the automatic washing machine to be environmentally friendly. The classified conflicts are summarized as the follows.

(1) Harmful function
Problem 1: High speed rotation of the bucket, caused great noise between the bucket and water, the bucket and the clothes, and the friction between the dehydration bucket and the water bucket etc.
Problem 2: The noise caused by the violent vibration of the motor rotation;
Problem 3: The use of motor vibration damper, impedes the release of heat generated by the motor.
Figure 1. The substance-field model of the automatic washing machine.

(2) Insufficient function
Problem 4: The following installation of the motor vibration damper (vibration damper, vibration spring, etc.), cannot eliminate the vibration completely;
Problem 5: Heating device is to increase the activity of the detergent, reduced the amount of the detergent, but cannot save the detergent completely;
Problem 6: In the drainage pipe installation, the filter is used to reduce the discharge of pollutants in water, reduce the impact on the environment, conducive to the recycling of water, but the filter is insufficient, cannot completely clean the water pollutant;
Problem 7: The installation of vibration damping boom in the four corners of the bucket, which is fixed to the top of the box, is to reduce the vibration of the bucket, but cannot eliminate the bucket body vibration completely.

(3) Excess function
Question 8: The rinsing process consumed too much water from the inlet pipe;
Problem 9: The use of heating device increases the consumption of electricity;
Problem 10: The motor also consumes too much electricity.

Target Recognition by FRT Method
According to the substance-field (S-F for short) analysis of the automatic washing machine, three classes of functions are found, i.e. Harmful function, insufficient function and excess function. The problems within the harmful function can be solved by TRIZ contradiction matrix, while the insufficient and excess functions can be solved by the S-F analysis.

The major diverse coupling effects of the washing machine are summarized as the follows,

1. Dehydration barrel noise vs. damping pad noise,
2. Cooling by the motor vs. the under lead,
3. Tub and motor speed vs. noise, there is also a conflict of No.9- No.31;
4. Noise of motor vs. the heating device precision, there is a conflict No.31- No.29;
5. Amount of detergent vs. reduction of noise, there is a conflict of No.2- No.31;
6. The use the damping pad vs. the heat generated by the motor, it is difficult to distribute, easy to damage the stability of the motor structure,

Based on the TRIZ contradictory matrix, from the corresponding general solutions, the harmful effects could be eliminated, as shown in Table 1.

<table>
<thead>
<tr>
<th>Problem description</th>
<th>TRIZ problem</th>
<th>Conflict s</th>
<th>Principle s</th>
<th>Schemes</th>
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</thead>
<tbody>
<tr>
<td>Problem 1: High speed of the dryer, large noise generated</td>
<td>Speed increased, vs. harmful materials increased</td>
<td>No.9-No.31</td>
<td>2, 24, 35, 21</td>
<td>Solution 1.1: Principle of intermediary 24. The top cover of the washing machine is a sound insulation cover, that is, a sandwich layer is in the middle of the top cover; Solution 1.2: intermediary24, An auxiliary rotary roller is added between the dewatering bucket and the bucket, and the material is silica gel material;</td>
</tr>
<tr>
<td>Problem 2: High speed of the motor, large noise generated</td>
<td>Speed increased, vs. harmful materials increased</td>
<td>No.9-No.31, No.31-No.29</td>
<td>2, 24, 35, 21; 4, 17, 34, 26</td>
<td>Solution 1.3: Principle of intermediary 24, The motor is installed in the tub, installing the damping component between the motor and the tub (spring etc.); Solution 1.4: Principle of change of physical or chemical parameters 35, Adding adjustable vibration damper under electric motor; Solution 1.5: Principle of removal or regeneration of parts 34, brush-less DC motor, brush-less motor, rotating without noise, and the radiation noise of the antenna is reduced.</td>
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<td>Problem 3: Low speed of head distribution</td>
<td>Vibration reduction vs. lower structural stability</td>
<td>No.31-No.13, No.31-No.20</td>
<td>35,40, 27,39; 19,22,18</td>
<td>Solution 1.6: Principle of conversion of harm into benefit 22, The heating device is changed to a heat ex-changer, which is installed on the motor to absorb the heat from the motor, and the heat is used to heat the laundry water.</td>
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As to the excess function problem model, the structure is not ideal, S-F model is used to solve the problem, to improve the existing substance-field model based on the improved method given in table 2. The poor S-F function mode are shown in Figure 2.

![Figure 2. Poor S-F function model.](image)

The major problems are excessive use of water and energy. Excessive motor energy consumption has too many impacts on the accuracy and quantity of the products. The fewer the part numbers, the less power consumption that needed, but it leads to a decrease in the stability of the structure, so the technical conflicts No.26- No.13 is identified.

The more powerful the motor is, the high energy consumption that needed, so technical conflicts No.21- No.22 is identified.

Heating device results in heat consumption, which affects the measurement accuracy and the level of automation of the machine, so there is a contradiction No.2 vs. No.28, and No.28 vs. No.32.

The number of the components will affect the stability of the product structure, so the contradiction of No.13 - No.26 is identified. So the excess function problem model is shown in table 2.
Table 2. Elimination of the excess effects.

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<td>Problem 8: Too much power consumption of motor</td>
<td>Less parts of the motor, vs. stability of the structure, vs. power consumption.</td>
<td>No.26-No.13, No.21-No.22</td>
<td>15,2,17,40; 10,35,38;</td>
<td>Solution 2.1: Principle of separation 2, Washing machine and body-building equipment connection; Solution 2.2: Principle of preliminary action 10, Fitness electric dual purpose washing machine, you can manually laundry, and then electric washing, saving electric energy.</td>
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<tr>
<td>Problem 9: Too much power consumption of heating devices</td>
<td>Power vs. energy consumption</td>
<td>No.21-No.22</td>
<td>10,35,38;</td>
<td>Solution 2.3: Principle of preliminary action 10, Use hot water in the solar water heater to wash and reduce the power consumption of the heating device; Solution 2.4: Principle of preliminary action 10, Washing machine and kitchen utensils integrated use of heat generated by heating the washing water preheating;</td>
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<tr>
<td>Problem 10: Too much water consumption</td>
<td>water use vs. the accuracy of the testing device vs. manufacturing base.</td>
<td>No.2-No.28, No.28-No.32</td>
<td>18,26,28; 6,35,25,18</td>
<td>Solution 2.5: Principle of replacing mechanical system 28, Using photoelectric sensor instead of spring weight measuring device; Solution 2.6: principal of universality 6, The washing machine drain pipe is connected with the water supply device of the toilet, and the sewage is used for flushing the toilet seat;</td>
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</table>

Green Conflicts Identification and Design Example

FRT method is used to decide whether there is a conflict between environment and the solution, three solutions are used as the FRT “scheme injections”, i.e. Solution obtained from the process of elimination of the adverse effects, excess effects and insufficient effects.

![Future reality tree of the washing machine.](image-url)
To eliminate the harmful effects, six kinds of schemes are proposed, which are used for innovative “solution injections”, and the future reality tree of the machine is shown in figure 3.

"Injection schemes” are used to eliminate the harmful effects, some problems are transformed into TRIZ conflicts, represented by the green engineering parameters, and then solve the problem by using the contradictory matrix. For example, the "injection 2.1”, namely the scheme 2.1, although can effectively reduce the noise, but the increased use of insulating materials, reduced the efficiency of the material recovery, deteriorate the contradictory parameters in TRIZ.

The 3D conceptual model of the solar washing machine is shown in Figure 4, the installation of solar panels can be removed on one side of the washing machine, and the solar energy plate can rotate freely by one shaft and the box to absorb solar energy more effectively.

Figure 4. The out shape of the solar automatic washing machine.

The solar washing machine has one solar panel, energy is saved in one suitable story battery, which supply energy for driving motor. A pulley structure is connected with the drum, where clothes are put inside. Though it is a just conceptual model, the major parts are testified by FEM software, as in figure 5.

Figure 5. FEM analysis of the supporter of the solar automatic washing machine.
Summary

The substance-field model is introduced to analyze the functional pattern of the automatic washing machine. Future Reality Tree method is used to find potential conflicts in the machine. Three typical problems are classified, ten conflicts among different components are summarized. By the introduction of the TRIZ methodology, the corresponding ten solutions are suggested with the help of the contradictory matrix software tools developed by our team [6]. A conceptual solar powered automatic washing machine is therefore suggested, major parts are testified by FEM software. And the model is to be developed with the cooperative TRIZ/FRT method and CAD/CAM/CAE tools.

Acknowledgment

The above-mentioned research work is supported by the Chinese NSFC, 61272017, P.R. China, and the Science,Technology and Innovation Commission of ShenZhen Municipality, and the Key Laboratory of High-efficiency and Clean Mechanical Manufacture at Shandong University, Ministry of Education.

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