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Analysis and Reliability of Automated Towel Cabinet Pipeline Key Equipment based on FMECA and FTA

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Abstract

With the improvement of intelligent life and the improvement of living standard, the hygiene and safety of towel machine will become more and more important. As a member of smart home, it is necessary to make high security requirement and reliability analysis because it is usually in a more enclosed bathroom environment. Based on the analysis of the process characteristics of towel machine equipment and the division of assembly line system, the agreed level is determined. The three main equipment units of the intelligent towel machine, namely towel transport and expansion unit, continuous mixing unit for drying and disinfection and drainage unit, are analyzed by the theory method of unit system failure mode, fault effect and hazard analysis. Based on this, the fault tree of transportation unit is analyzed, the main fault source is found, and the design, manufacture and maintenance opinions are put forward.

Keywords

Towel Cabinet Cleaning and Disinfection; Automated Assembly Lines; Reliability; Fault Mode; Fault Impact and Hazard Analysis; Fault Tree Analysis.

1. Introduction

Intelligent devices play a decisive role in the development of manufacturing. With the development of automated technologies such as towel cleaning and disinfection, people have a deeper understanding of the quality and reliability of automated devices. Because people have been pursuing a high quality of life, so the product quality and safety requirements are very high, not only to meet certain technical standards and requirements, but also to have reliability and practicality in a long time, device reliability has gradually become a very important indicator for users. Kadhum A. Abed and others use Fuzzy Hierarchy Comprehensive Evaluation (AHP) to improve equipment performance and reliability in maintenance[1]. Linbo Zhu and others put forward a method to evaluate the operation reliability of equipment based on RVM and PCA fusion characteristics[2]. Ivančan, Jelena and others summarized the fuzzy FMEA risk quantization method based on four fuzzy logic systems[3]. Theyab O. Using fault mode and impact analysis (FMEA)[4], Alamri et al., develop an overall preventive maintenance meter for the entire system, ensuring continuity of production output while maintaining a high level of system reliability and minimizing total maintenance costs; Li Cuiyu and others put forward the T-S fuzzy fault tree analysis method to analyze the reliability of domestic air conditioning and further verify the feasibility and accuracy of the method[5]. Based on the Bayesian Network (BN) which quantitatively calculates the failure probability of complex systems, Aidan Huang and others set up a new risk assessment method using the FMEA for compressor and pump[6]. This kind of special automatic equipment for disinfecting and drying household towels is closely related to people's production and life. While enjoying intelligent convenience, the safety requirement is extremely high. Otherwise, if an accident occurs, it will have serious impact on family or society. Therefore, the reliability design, analysis and evaluation of towel

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washing and disinfecting equipment is very important. Combining FMECA and FTA, this paper firstly analyzes the existence of key equipment on the assembly line of towel cabinet, then analyzes the key equipment in detail, finds the most serious fault and gives the improvement method.

2. About Towel Cabinets Automated Streaming

According to the safety principle, reasonable principle and humanization principle, this design is based on modular design. After researching and reading the literature, the multi-purpose towel cabinet is designed to meet the functional requirements of "transportation and expansion", "storage and drainage" and "drying and disinfection", and automates the whole process through "control system". Compared with other traditional towel cleaning and disinfection methods, it has the advantages of simple process flow, compact equipment and high quality. These four parts are designed individually and then combined to form a complete "production line". Three key modules in the whole production line, towel extension transmission module, continuous blending module for drying and disinfection and drainage blending module, were taken as research objects. The three units constitute the automated towel-cupboard body, as shown in Figure 1.

Figure 1. Automated Towel Cabinet

2.1. Towel Transport Retractable Unit.

According to the overall design concept, the primary purpose of the towel transport unit is to transport the towel directly in front of the user, while cleaning and drying the towel in conjunction with the cleaning and drying disinfection unit. Towel transport components, mainly composed of folding support and high transmission efficiency, bearing capacity of a single row of roller chain, as shown in Figure 2.

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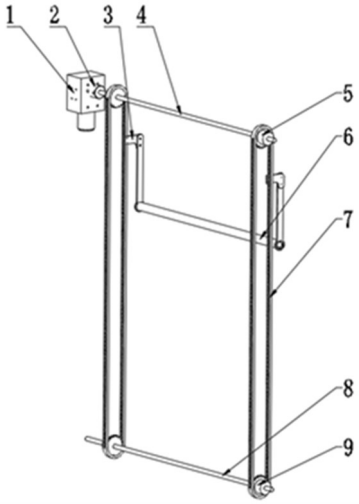

1 decelerating motor 2 coupling 3 folding support 4 active shaft 5 active sprocket 6 airing rod 7 chain 8 active shaft 9 active sprocket

Figure 2. Towel transport schematics

When the user does not need to use a towel, the turbine decelerator locks itself and the towel is suspended from the hanger bar, storing the towel in the towel cabinet. When the user needs to use a towel, the decelerating motor performs a positive reversal, moving the active shaft through the coupler and the active shaft moving the chain, which can move up and down in sync with the chain as shown in Figure 3 because the folding stand is firmly attached to the chain of a single row of roller chains.

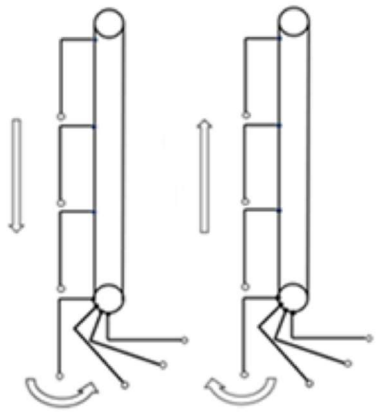

Figure 3. Towel stretch map

2.2. Dry the Sterilizing Unit.

This towel cabinet dryer mainly uses two rounds of drying treatment, the first by extrusion drum for the first dehydration treatment, the second by the transverse fan for the air drying treatment. Two rounds of drying ensure the towels don't grow germs from humidity inside the device. The first round of drying device is shown in Figure 4. The motor is connected to the optical shaft by coupling, on which two pendulum rods are fixed, and the motor rotates and the pendulum rod moves in sync. The moving drum is fixed on the top of the pendulum rod and connected with the pendulum rod by bearing, and can rotate freely. One end of the fixed roller is fixed to the side plate by bearing and the other end is connected to the sprocket below the towel extension device by chain drive through the side plate in the electrical control area.

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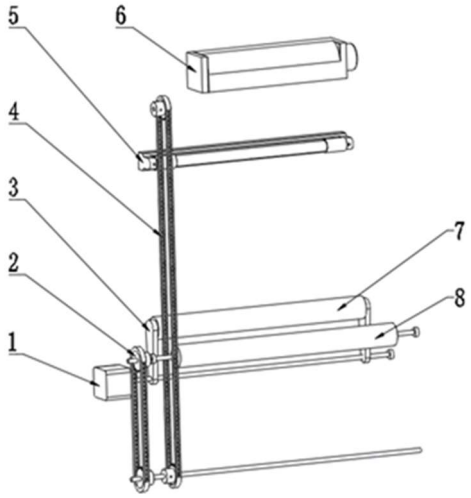
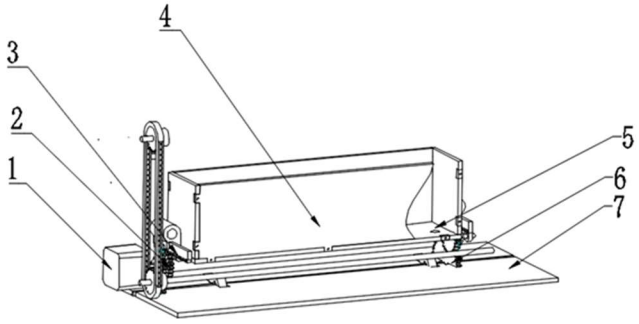


1 motor, 2 sprockets, 3 pendulums, 4 chains, 5 sterilizing lamps, 6 transverse fans, 7 swinging rollers, 8 fixed rollers

Figure 4. Dry Sanitiser

2.3. Drainage Unit.

In order to save the interior space of the multi-purpose towel cabinet and avoid interference between the movement of the fixed drainage device and the towel carrier, the removable cleaning sink is designed as shown in Figure 5. The device consists mainly of stepper motor, double gear, rack and incomplete gear, in which the double gear engages with the partial gear and rack respectively, and the sliding rack is fixed to the sliding bracket supporting the sink, and the incomplete gear is half gear is fixed to the cabinet door, which can be opened and closed at the bottom. After the towel cleaning is complete, make sure the sewage can be discharged quickly and completely by opening a boiling hole at the bottom of the sink to facilitate connection to the pipe to drain the sewage, as shown in Figure 5 below.



1 stepper motor, 2 double gears, 3 rack, 4 sink, 5 drain holes, 6 incomplete gears, 7 cabinet bottoms

Figure 5. Sketch diagram for cleaning sink

3. Towel Cabinet FMECA

The general process of FMECA is to first define the scope of analysis, draw the reliability block diagram of the system, determine the fault mode and then carry out fault cause and fault impact analysis. At the same time, the fault detection method and corrective measures are analyzed, and finally the key parts or weak parts of the system are identified by qualitative analysis or quantitative analysis.

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3.1. Level of Engagement

When using FMECA for hardware selection, the product structure is layered at the hardware level. According to the actual situation of the above design [7], the agreed level of the towel cabinet assembly line system in this article is shown in Figure 6.

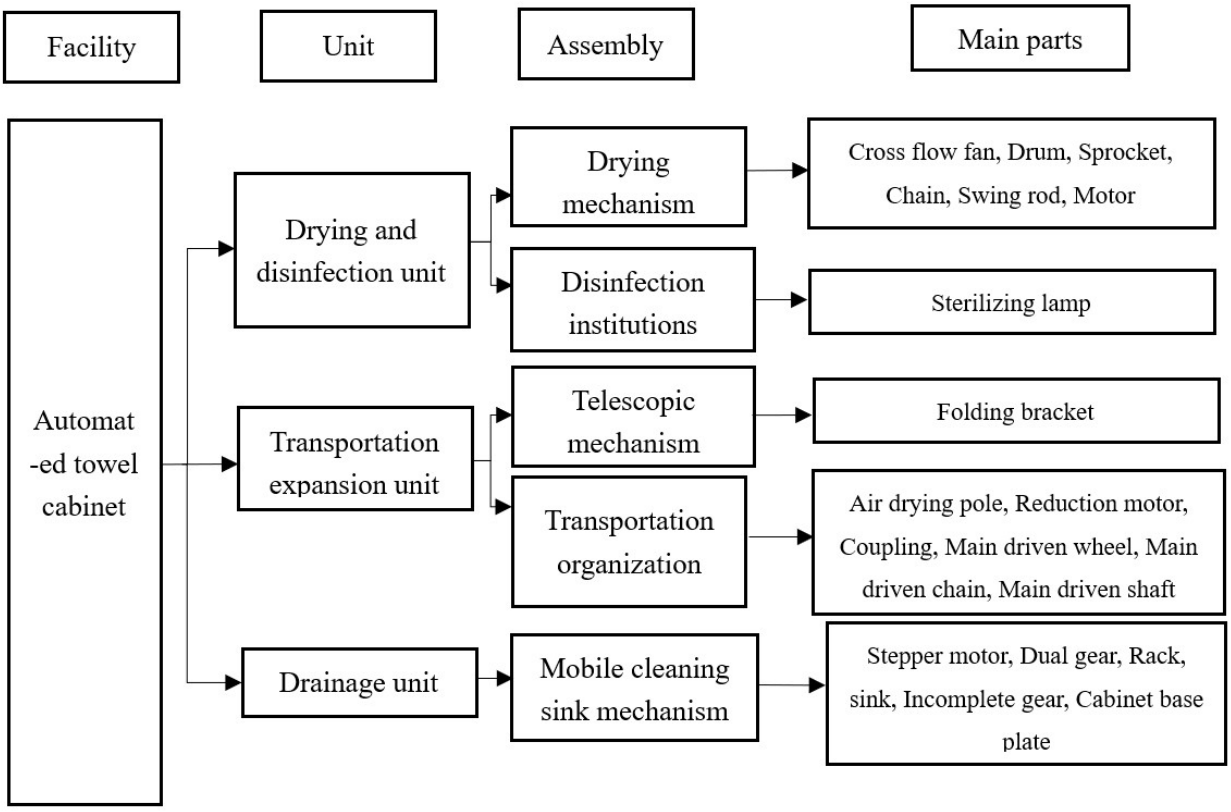

Figure 6. Automated towel cabinet assembly line system engagement level

3.2. FMECA for Automated Towel Machines

This article takes the transportation organization as an example to carry on the FMECA step by step analysis.

1) Fault source parts, fault pattern analysis. Fault source parts mainly include the decelerating motor of the transportation organization, the airing rod, the coupling and the main slave drive chain, the main slave drive wheel and the main slave drive shaft. The main faults of the transportation organization are: 1 decelerating motor overload and tripping; 2 Main and secondary wheels jammed, tooth wear and bearing failure; 3. Curvature and fracture of drying rod; 4 Chain sprocket cooperation is not good, appear jump chain and so on phenomenon; Too much noise in chain operation; 5 coupling has broken shaft, oil leak.

2) Fault cause and effect. The overload of decelerating motor is mainly caused by no overload alarm of motor. The result of this fault is excessive mechanical load, and the biggest characteristic of overload is the heat of motor. The tripping is caused by the motor jamming, which may cause the transport agency to shut down, thus causing the entire crew to shut down. The main subtraction wheel jammed due to the failure of assembly, which may cause the towel transportation to be interrupted; The low efficiency is mainly due to gear pitting and slow transmission efficiency. The bending deformation of the drying rod is caused by the lack of hardness of the used material, and the effect of failure is mainly reflected in the unsightly appearance and the danger of cracking. The main reason of 4 jump chain is that the chain may be worn out and the pitch elongated. The noise is too much because the sprocket chain is not the same. Too loose or too small a chain; Inadequate lubrication; Chain and sprocket wear; Or

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chain pitch is too big, sprocket chain does not cooperate well to be able to start the transport function, production will stall. The main reason why the 5-coupling is broken is that the bearing clearance and bevel gear clearance are not adjusted well during the assembly process, and the correct engagement cannot be ensured. Failure to adjust and replace bearings in time for wear and tear. The reason of the oil leak is that the sealing performance is poor, the sealing performance deteriorates, the oil leak reduces its transmission torque, which makes it difficult to start.

3) The severity of the malfunction. Overloading and tripping of decelerating motor, jamming and abrasion of primary and secondary gears and improper equipment will cause the whole unit to stagnate or not work properly, and the malfunction is very bad. Gear spotting results in low efficiency, large bending deformation, coupling leakage and chain noise, which may result in lower rigidity of failure. Chain jumper and coupler rupture, will also cause the filling can not be completed properly, the degree of failure is bad.

4) Occurrence Probability Ranking (OPR). On the whole dry bending deformation, the work efficiency is not enough noise high severity small failure, the probability ratio is larger; The probability of major faults such as overload of motor, damage of chain structure of sprocket and failure of coupling to start is relatively small. The failure rate of airing rod is between the above two types.

5) The undetectability of malfunctions. The failure of the unit parts is relatively undetectable and easy to be detected except for the failure of the main and secondary moving wheel, the bending deformation of the airing rod and the undetectability of the coupling oil leak.

6) Risk Priority Number(RPN). It is necessary to improve sprocket spotting efficiency and sprocket chain assembly inefficiency. The faults of motor, airing rod and coupling also need to be considered in the analysis of such faults. Based on the above analysis, a FMECA table of transport expansion units can be given in table 1.

Table 1. Transport body FMECA

Possible faulty equipment	Possible faulty parts	Failure mode	Severity	Fault cause	failure effect	failure rate	Undetectable measure	Hazard degree
Transportation organization	electrical machinery	overload	7	Excessive mechanical load	Motor heating	4	4	112
		tripping operation	7	Motor jamming	Transmission stop	4	3	84
	gear	seizing	5	Improper assembly	Transport stopped	4	7	140
		Insufficient work efficiency	3	Gear pitting	Reduced sprocket efficiency	5	7	105
	Airing pole	Bending deformation	2	Improper material selection	Unattractive	3	5	30
		fracture	4	mechanical failure	Towel drop	5	4	80
	chain	chain jumping	6	Chain wear	Transportation stagnation	4	3	72
		High noise	2	Insufficient lubrication	noise pollution	3	3	18
	coupling	broken shaft	6	bearing wear	Stop rotating	4	3	84
		Oil leakage	3	Poor sealing	Difficulty in starting	5	6	90
telescopic mechanism	Folding bracket	deformation	3	Mechanical design defects	Inaccurate positioning	3	5	45

Similarly to the FMECA of the transport expansion unit, the FMECA tables of the drying and disinfection unit and the drainage unit can be given as shown in tables 2 and 3.

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Table 2. Drying Sterilization Unit FMECA

Possible faulty equipment	Possible faulty parts	Failure mode	Severity	Fault cause	failure effect	failure rate	Undetectable measure	Hazard degree
Drying mechanism	cross flow fan	Fan blade vibration	2	Loose axle fit	noise pollution	3	4	24
		High bearing temperature	5	Deterioration of lubricants	Severe vibration of bearing box	4	2	40
	roller	vibrate	3	Loose fixture	Increased vibration	5	4	60
		wear and tear	3	Improper assembly	Low extrusion efficiency	7	3	63
	sprocket	seizing	7	Improper assembly	Transmission stop	4	3	84
		Insufficient work efficiency	3	Gear pitting	Reduced sprocket efficiency	5	7	105
	chain	chain jumping	6	Chain wear	Transmission stagnation	4	3	72
		High noise	2	Insufficient lubrication	noise pollution	3	3	18
	swing link	seizing	5	Improper assembly	Composite motion stop	4	3	60
	electrical machinery	overload	7	Excessive mechanical load	Motor heating	4	4	112
		tripping operation	7	Motor jamming	Transmission stop	4	3	84
Disinfection institutions	sterilizing lamp	Working current too high	7	short circuit	Exploding lamp	4	2	56

Table 3. Drain unit FMECA

Possible faulty equipment	Possible faulty parts	Failure mode	Severity	Fault cause	failure effect	failure rate	Undetectable measure	Hazard degree
Drainage unit	stepping motor	overload	7	Excessive mechanical load	Motor heating	4	4	112
		tripping operation	7	Motor jamming	Transmission stop	4	3	84
	rack	Insufficient work efficiency	3	Rack wear	Low transmission efficiency	4	7	84
	water channel	Insufficient tightness	5	Low coordination of sink board	water leakage	2	3	30
	incomplete gear	seizing	7	Improper assembly	Tank shutdown	4	3	84
		Insufficient work efficiency	3	Gear pitting	Reduced transmission efficiency	4	6	72

3.3. Identification of Key Equipment

FMECA analysis of the three devices was performed as described above, with the sum of the hazards, the mean hazards and the maximum hazards shown in Table 4. It can be seen from table 4 that the firming unit is a key equipment with high hazard value and high risk, so further FTA evaluation should be made.

Table 4. Hazard Analysis by Equipment

Facility	Sum of hazards	Average hazard level	Maximum hazard value
Transportation expansion unit	860	78	140
Drying and disinfection unit	778	64.8	112
Drainage unit	466	77	112

4. Transport Module FTA

FTA is a top-down approach to fault analysis. This method is often used for system reliability, stability, security, and risk assessment. Fault tree analysis helps designers and maintainers examine failures and refine technical solutions.

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4.1. Analysis of Transport Unit Fault Tree

All parts of the cementing unit may fail, and the main causes of failure can be summed up into two main categories, one is inadequate assembly, the other is mechanical, parts damaged, and different components of the cause of their failure.

1) Fold bracket: Fold bracket structure is simple, the main cause of failure is mechanical design defect.

2) Causes of motor failure may be: motor internal combustion, motor external damage, motor assembly, etc.. The main causes of internal burnout of motor are internal damage and component burnout, and the main causes of component burnout can be divided into component circuit short circuit and oversupply current. The external damage of the motor is mainly caused by the damage of the motor housing and the damage of the output components.

3) Gear: the cause of gear malfunction may be pitting of gear, improper assembly and so on.

4) Couplings: the failure of couplings may be due to broken shafts, oil leaks, improper assembly.

5) Airing rod: The failure of the airing rod is due to fatigue and bending deformation. Based on the above analysis, a fault tree of solid refueling unit is constructed as shown in Figure 7.

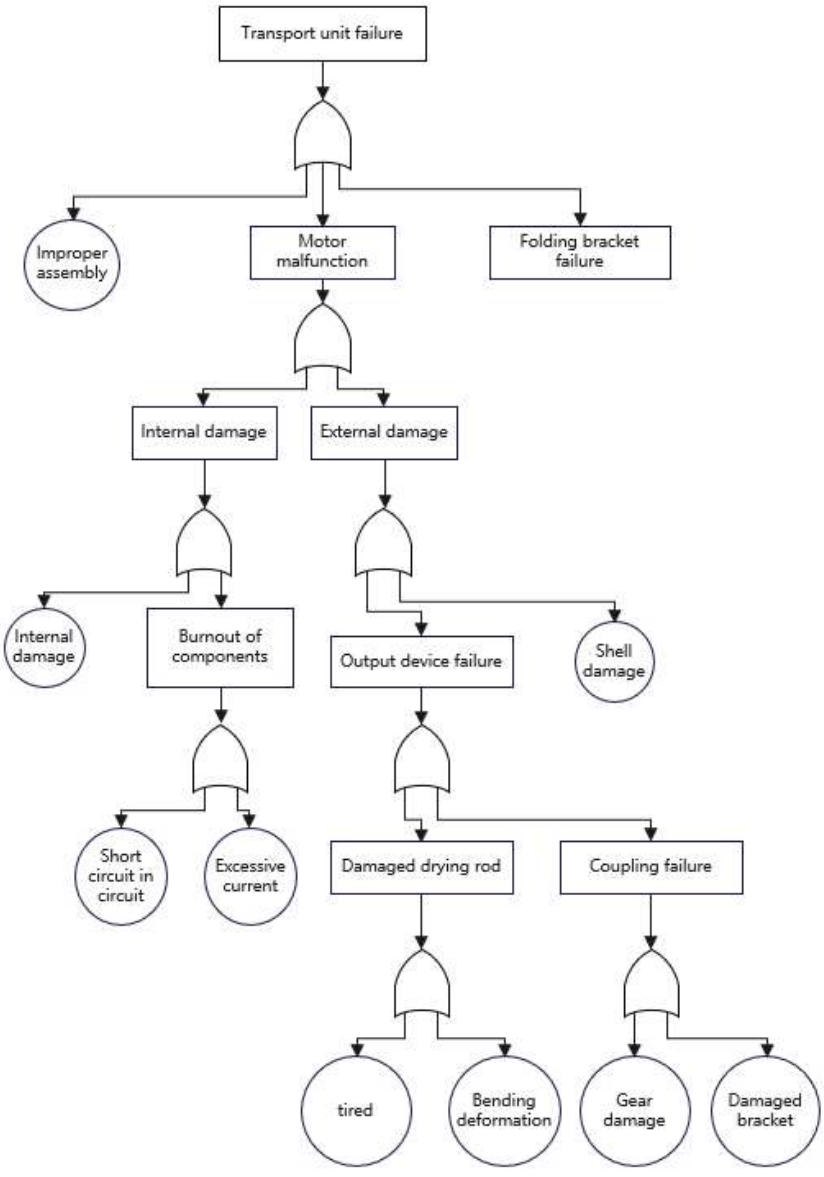

Figure 7. Fault tree of solid refueling

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4.2. Fault Tree Results Analysis

As can be seen from Figure 7, the main faults of the transport unit can be divided into component faults and circuit failures.

1) Parts malfunction. Airing rod, continuously rotating worn parts, transmission units, main connectors and couplings, the main forms of such parts are wear and tear, fatigue and plastic deformation, are the key failure parts that cause safety accidents.

2) Others mainly involve folding stents. The folding bracket is an important link to maintain the normal operation of this production line and plays a vital role in ensuring the quality of the product. When the folding scaffolding breaks down during use, it will affect the transportation of the product and affect the overall product quality.

4.3. Improvement Measures

The following improvements can be made to address the more prominent problems with the transport unit:

1) Emphasis is placed on upgrading key parts and electrical components and ensuring that there are sufficient spare parts for more vulnerable parts.

2) In this production line, the shell can effectively prevent oil pollution and dust pollution, as well as accidental collisions during workpiece transport, but it needs to be inspected and adjusted regularly.

3) Some parts need to be improved in terms of structure, material and strength, such as airing rod, folding bracket to be combined with towel cabinet size and shape characteristics for structural improvement and size adjustment, the utility model increases its design strength and structural stability, thus avoiding equipment malfunction and the consequent consequences.

4) Periodically downtime maintenance equipment, because fixture loosening caused parts to loosen should pay special attention to adjustment and fixing.

5) Wash regularly to prevent corrosion due to incomplete cleaning.

6) To set up an immediate and efficient fault feedback mechanism, under the premise of strengthening the technical training of production line operators, carry out daily maintenance and timely overhaul of equipment, so as to promote the reliability of equipment, and avoid operator error resulting in malfunction.

5. Conclusion

In this paper, the reliability of automatic assembly line of towel machine is analyzed by combining FMECA and FTA. Based on the FMECA method, the transport unit is considered to be the key equipment in the system from two aspects of fault cause and fault hazard, which is used as the core equipment on the towel machine assembly line. According to the article, we must ensure the parts have sufficient strength, make strict equipment maintenance plan and cleaning plan every day, implement strict reliability management in the production process and use, carry out targeted system design and reliability management, and promote the reliability of the whole production system.

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