Research and design of a new type of spray washing machine

Liu Dun1, Ruoyu Hu2 and Weigang Zheng1*

1School of Logistics Engineering, Wuhan University of Technology, Wuhan, Hubei, 43000, China
2School of Logistics Engineering, Wuhan University of Technology, Wuhan, Hubei, 43000, China
*Corresponding author’s e-mail: zfeidiso@126.com

Abstract: Considering the universality of washing machines today, washing machines consume a lot of water. In order to reduce the water consumption in the washing process and at the same time achieve the effect of cleaning clothes, a new spray type washing machine is designed. It mainly consists of transportation system, cleaning system and control system. The washing system is designed to perform different tasks for washing machines, washing, rinsing and dewatering, respectively. The new washing machine washes clothes with water spray, washing liquid spray washing, high pressure water mist rinsing residue, sponge roller squeezing dehydration and warm air drying, so that the stains of the clothes are washed and the initial dehumidification is completed. The spray-type new washing machine is completely cleaned by spraying droplets and spraying water mist, which can greatly reduce the water consumption.

1. Introduction
From a national perspective, the popularity of washing machines in China has exceeded 76%, of which the number of towns has exceeded 96% [1]. In the next few years, the growth of demand for washing machines in China will mainly come from: urbanization and rural market for the first time. Demand, as well as renewal demand based on urban market consumption upgrades; the entire washing machine market demand will continue to maintain a moderate growth trend in the next few years. In 2016, China's national water consumption was 605.6 billion cubic meters, and the per capita water consumption was 438 cubic meters, of which about 2.23 cubic meters of water was used to wash clothes using washing machines. The annual water consumption for washing machines in the country reached 3.083 billion cubic meters. Water saving will become the key development direction of the future washing machine. The washing machine industry's target mainly covers three major directions: energy saving, product function and green design. In the technical roadmap for refrigerators, air conditioners, and washing machines compiled by the China Household Electrical Appliances Association, a series of levels of power consumption and water consumption requirements for washing machines have been formulated for power saving and water saving. In terms of product functions, the variety, specifications and shapes of washing machines have been developed for a wide range of people. However, from the laundry mode and the structure, the washing machine is only three types of a pulsator washing machine, a drum type washing machine, and a stirring type washing machine. The pulsator type washing machine is equipped with a pulsator installed in the washing tub, and the motor rotates the pulsator, and picks up the water flow containing the washing powder and the same direction of the dirty clothes to wash the clothes; the drum type washing machine utilizes the horizontal direction. The placed washing tub is continuously rotated, the water flow and the clothes are simultaneously rolled in the tub to wash the clothes, and the
agitating washing machine is now eliminated. In view of the shortage of the existing washing machine, the development direction of the washing machine is large capacity, low noise and low vibration.

Obviously, the existing washing machine is subject to the traditional mode, and it is difficult to achieve the above improvement requirements. Therefore, how to design a new cleaning mode to make the washing machine conform to "large capacity, low noise, low vibration" and save energy and water is imminent.

2. Design plan

2.1 Machine introduction

In order to realize the whole function of the whole machine, the mechanism in the works is modularized to ensure that each mechanism can realize its individual functions, and then the designed functional modules are organically combined and debugged and controlled through a reasonable layout. This ensures that the function of the entire machine can be finally and completely realized. The specific composition of the functional modules is shown in Table 1.

| Module               | Mechanism                              | Function                                      |
|----------------------|----------------------------------------|-----------------------------------------------|
| Transportation       | Separation conveyor                    | Isometric separation of clothing              |
| Transport conveyor   | Transporting clothes into different    |                                               |
| Cleaning module      | Washing box                            | Mixed detergent                               |
|                      | Detergent spray module                 | Remove stains from clothing                   |
|                      | Water mist-steam cleaning module       | Remove residual detergent, disinfection sterilization |
|                      | Dehydration module                     | Initially dehydrated clothes for easy drying  |
| Control module       | STC89c51 microcontroller               | Control mechanism movement                    |
|                      | Console                                | Implement user control of the machine         |

2.2 Workflow

Figure 1. Working flow chart of the whole machine
2.2.1 Transportation system. The transport system controls the movement of the laundry throughout the cleaning process by multi-belt shifting, and the laundry transport process is fully automated through the coordinated operation of the two drive belts and a coordinated conveyor belt.

2.2.2 Cleaning system. The washing system is designed to perform different tasks for washing machines, washing, rinsing and dewatering, respectively. The new washing machine washes the clothes with water spray, washing liquid spray washing, high-pressure water mist washing residue, sponge roller extrusion dehydration and warm air drying, so that the stains of the clothes are washed and the initial dehumidification is completed.

2.2.3 Control system. The whole machine is used by STC89c51 as the main control chip to complete the movement control and timing control of the conveyor belt; the longitudinal movement control and direction control of the nozzle; the up and down movement of the sponge roller and the extrusion mechanism of the sponge roller. Energy is provided by an external power source.

2.3 Delivery mechanism
Fixing a plurality of hooks on the conveyor belt so that each hook is separated by a certain distance, the clothes are hung on the clothes hook and slowly move with the conveyor belt, and are transported to a designated position to complete the corresponding work flow. During the one-way rotation of the conveyor belt, multiple pieces of clothing can complete all the washing processes, which improves the efficiency of the machine operation and simplifies the internal structural design.

2.4 Cleaning module
The cleaning module is divided into three parts: detergent-water mixture washing, water mist-steam washing and dehydration drying.
2.4.1 Washing liquid mixture washing

Considering the high density of the laundry liquid, the water droplets between the water flow and the water mist are provided with the washing liquid, and the mixed liquid mixed by the washing box is evenly sprayed onto the surface of the laundry by the spraying device, and the surface area of the water drops is much larger than the water flow. The laundry liquid is sufficiently contacted with the dirt to make the washing more sufficient. Moreover, the stain on the clothes is mainly oily substance, and the water droplets with the laundry liquid are sprayed, so that the surface area of the O/W emulsion droplet formed by the contact of the laundry liquid and the stain increases, which is hundreds of times larger than the water flow cleaning, thereby becoming even less. Stable and easy to fall off. Through the second stage of high-pressure water mist-steam flushing, instead of the manual cleaning process, the O/W emulsion droplets are easily detached, which not only ensures the original cleaning effect, but also reduces the damage to the laundry during the cleaning process [2]. Due to the relative reduction in the amount of liquid used in the main body washing (only about 20 to 30% of the pulsating liquid amount), the contact affinity reaction between the detergent and the dirt is enhanced. Even if the relative concentration of the washing liquid is increased by three times, the amount of the washing liquid is saved by 40% compared with the large amount of water, and the high concentration of the washing liquid is required to enhance the chemical detergency [3]. Because this mode realizes the rubbing effect between the layers of the clothes, the granular washing powder can be grounded between the layers of the clothes, so that it can be quickly melted to exert its performance, and the washing liquid inside and outside the agglomerated clothes is sufficiently frequent. Exchange, thus giving full play to the potential of the chemical detergency of the detergent on the dirt on the clothes. At the same time, the device also uses the charged spray technology to make the washing liquid more fully and evenly sprayed on the clothes: the charged spray means that the liquid forms a droplet under the action of mechanical force or aerodynamic force, and is corona, inductive or contacted. The charge is charged to form a two-phase flow of the electro-hydraulic fluid. The charged spray is widely used in the fields of pesticide spraying, electrostatic spraying and exhaust gas particle removal because of its small particle size, uniform spatial dispersion and good deposition characteristics on the target.

2.4.2 Water mist - steam washing

The water mist-steam cleaning system adopts the water mist-steam mixed flow cleaning to completely replace the original water flow cleaning method [4]: the water vapor-water mist flow is blown out by the air flow pressure, and the contact area of the water molecules with the clothes is effectively increased. To make the cleaning more thorough, the water mist can completely remove the detergent and stain residue from the clothes, the water vapor can care for the clothes, fully extend the fibers of the clothes, increase the elasticity of the clothes, accelerate the process of removing the stains, and sterilize. And it does not cause damage to the clothes. The new cleaning method saves 60%-80% of water compared to the traditional water flow cleaning method; the time required for water mist cleaning is shorter, and it is more efficient than the repeated cleaning of water flow.
2.5 sponge extrusion water absorption device
After the washing task is completed, the clothes fixed on the conveyor belt enter the set between the two squeeze sponge rollers with the conveyor belt, and the rollers move up and down along the clothes, and the water in the clothes is initially sucked by mechanical squeezing by using the good water absorption of the sponge. In addition, this can not only make the clothes flat, but also greatly reduce the energy consumed by the subsequent air-drying clothes. After the extrusion of one piece of laundry is completed, the moisture on the sponge is squeezed by rotating and rotating, so that the sponge roller can continue to work repeatedly [5].

Figure 5. Squeeze water absorption module

2.6 Washing box
In order to prevent the user from adding excessive detergent, a special washing box is set, and the volume measurement scheme is adopted by changing the manner of uninterrupted flow metering of the pump head by the pump motor. By setting the standard amount per unit volume, when the detergent is added, the amount of addition is controlled by the number of unit volumes discharged by the control device[6]. The piston pump is selected as the injection component, and the precise flow control is realized by controlling the number of round trips of the piston. The washing liquid mixing device provided by the machine premixes the water and washing liquid to an optimum ratio which is set in the system in advance, and heats it to the optimum washing temperature of about 35 °C to enhance the washing effect of the detergent [7].

3. Conclusion
The new spray-type washing machine uses a new water mist cleaning technology to design a new laundry cleaning mode, and has been rationally deployed according to the simulation test results. The whole machine model was built by solidworks 3D modeling software. The dynamics and statics simulations were carried out by Adams and ansys, which proved its feasibility. The washing machine mechanism is relatively simple, and the raw materials used are relatively common in the market, so the cost is low. It has the characteristics of water saving and low noise. It reduces excess energy consumption during use and greatly reduces operating costs. It can be seen that it has considerable economic benefits.

References
[1] Q, J., W, Z.W. (2001) Vibration model and dynamic characteristics analysis of top-mounted wave-wheel washing machine [J]. Vibration and Shock,20(4):77-80.
[2] H, L., Q, J. (2008) Drop simulation analysis of washing machine transport packaging [J]. Packaging Engineering, 29(4): 61-62.
[3] Zhao, X., Zhao, S.Y. (2001) Study on the external liquid washing mode under optimal liquid supply and analysis of various potentials. Journal of Northwest University of Light Industry,19:54-58.
[4] Zhang, L.G., Zhu, X.Y., Hu, G., Li, Y.F., Yuan, S.Q. (2018) Experimental Research on the Hydraulic Performance of Low-Pressure Atomization Nozzle. China Rural Water and Hydropower,10:109-113.
[5] Zuo, Y.Y., Shen, X.M., Liu, H.B. (2007) Finite Element and Experimental Modal Analysis of
Drum Washing Machine Case. Mechanical Design and Manufacturing, 6:99-101.

[6] Ban, Y., Zhou, W., Zhou, F.C., W, L.D., Zhou, C.H. (2014) Research on Automatic Add Detergent Technology for Washing Machine. In: 2014 China Household Appliance Technology Conference. Zhe Jiang, pp.381-385.

[7] Farkas, J., Peter, H., Christian, P., et al. (2011) Characterization of the effluent from a nanosilver producing washing machine[J]. Environment International, 37(6): 1057-1062.