Acta Technica *62*, No. 3B/2017, 361–370

Mechanical design and research of automatic cleaning device for duck heads[1]

Hao Ding[2,3], Lixin Zhao[2,3,4], Canzheng Xia[2,3], Tiantian Zhou[2,3], Ximei Huang[2,3]

Abstract. The study is mainly focused on the mechanical structure of the automatic cleaning device for duck heads. Based on the traditional cleaning device, the mechanical part of the automatic cleaning device is redesigned and improved. First, the Solidworks software system is utilized to design the three-dimensional simulation of the device, which consists of immersion and cleaning boxes in separating structure; the bubbling device, the spraying device, the water circulation device and the water level detection device are added. The opening and closing of the inlet and drain pumps are controlled by the results obtained from comparing the current water level with its initial value that measured by water level sensors. According to the time of the water inlet and outlet from the boxes, the resistance of the conveyor belt, the percentage of cleaning efficiency and so on, the final production of a cleaning prototype has been produced through the theoretical design and analysis; the micro controller is the core of the automatic control system operated on the prototype. The results demonstrate that the overall mechanical design of automatic cleaning prototype for duck heads can cooperate with the micro controller to control the system, and achieve automatic cleaning duck for heads in a full process. Cleaning effect can fully meet the expected target and requirements of qualified products.

Key words. SolidWorks, mechanical structure, immersion, cleaning, water circulation, microcontroller.

[1]1This research was supported by the National Natural Science Foundation of Shandong Province in China (ZR2012CM040), Shandong Provincial Key Research and Development Project (2015GGH311001) and the modern agriculture intelligent equipment research and development project of Shandong Agricultural University.

[2]College of Mechanical and Electronic Engineering, Shandong Agricultural University, Tai'an, 271018, China

[3]Shandong Provincial Key Laboratory of Horticultural Machineries and Equipments, Tai'an, Shandong, 271018, China

[4]Corresponding author: e-mail xlding103@163.com

1. Introduction

In China, duck head is one of the most favorite food in public, while the treatment of duck heads cleaning is dominated by traditional practices. It is generally overturned and cleaned by human force stirring between two cleaning boxes, and shook ceaselessly in a container up and down by changing water for several times. The study aims to solve several major problems existing in duck head cleaning, a new type of duck head cleaning device was designed with the following improvements. First, optimize the cleaning device, and divide it into two independent boxes of soaking and cleaning to avoid water reflow pollution; second, set up the bubbling device, the spray device, the water cycle device and the water level detection device. Bubbles generated by the bubbling device can make duck heads keep turning on the conveyor belt of immersion box, and be soaked more thoroughly; what is more, the spraying device can make the soaked duck heads get further cleaning treatment, with the automatically flipping mechanical structure, the bottom of duck heads gets cleaned by self-flipping. The water circulation device added in box keep water disturbing to avoid the turbid water to wash the subsequent duck heads incompletely or cause secondary pollution. The water level sensor replaces the operator's sensory prediction, measures the level of the water in the box more accurately, and avoids the situation that the water level is insufficient or too high during the cleaning process [1–3].

2. Scheme design and working principle

The cleaning device mainly consists of the storage box, immersion box, cleaning box, conveyor belt, bubbling device, spraying device, collecting bucket, water circulation device, and so on [4–6]. The whole architecture is shown in Fig. 1.

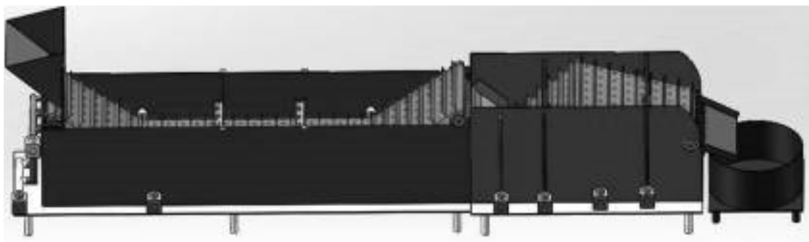

Fig. 1. Device architecture on 3D simulation design

When the device starts, the inlet pipe gate will be turned on until the water reaches the specified level, then it will stop automatically. All the process is controlled by micro controller which is the core of the automatic control system. Duck heads are placed in storage box and evenly distributed on the conveyor belt by virtue of the partition plate in the storage box. The motor drives the conveyor belt to move longitudinally, on which the duck heads move forward to immersion cleaning box. Bubbles washed and cleaned duck heads, which were generated by the

bubbling device at the bottom of the immersion box; during the cleaning process, the residue would be made available by the filter. Duck heads entered the spray cleaning box through the connecting plate and the skateboard after the first soaked cleaning, then, they would be soaked in a moment in the bottom of spray cleaning box, that conveyed upwards by the belt in groups. In the ascending phase, the first spray cleaning began to carry out until the duck heads were on the highest point, while the improved design of the mechanical structure makes the top and bottom of duck heads exchange by rolling, the second spray cleaning was mainly for the other side of duck heads; at last, the clean duck heads would go to the drying collection bucket through a rear plate [7–8].

3. Research and design of the key mechanical parts

In order to avoid the problem of the extrusion of the duck heads and irregularly arranged on the conveyor belt, the storage box needs to design to be different levels of the partition according to the length, width and height of duck heads, so that the transmission of duck heads is not squeezed and overlapped. In addition, the spacing between the bottom and the conveyor belt is very small, it must be satisfied that only when the same batch of duck heads was transported by the conveyor belt, the next batch of duck heads would fall into the bottom of storage box and wait for the transport of the conveyor without dropping out [9–11]. According to statistics of the average shape of the duck heads, the results of length, width and height are 105 mm, 35 mm and 35 mm, the weight is 110 g, as a result, it was confirmed that the gap between the conveyor and the storage box is not more than 10 mm.

The number of the partitions inside the storage box besides the length, height and spacing of them are calculated and designed based on the average size of the duck heads. As is shown in Fig. 2, the height of the storage box is 600 mm, the spacing between adjacent partitions is 60 mm, the width of the separator is 10 mm; the height of the low partition is 40 mm, and the length is 80 mm; the height of the high partition is 80 mm, and the length is 110 mm; the angle between the rear panel of the storage box and the horizontal plane is 160 degrees.

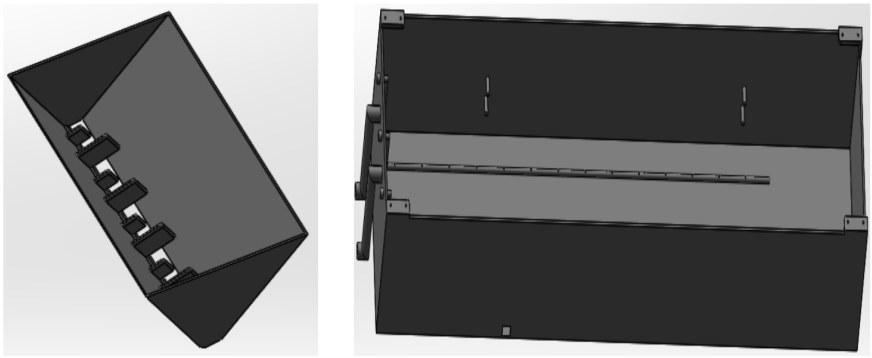

Fig. 2. Storage box–left and immersion box–right

3.1. Design of soaking structure

3.1.1. Determination of immersion box and conveyor belt The remaining blood in duck heads will only be cleaned out after soaking a sufficient time. While the duck heads in the transmission and soaking process can be rolled, there is a bubbling device set in the bottom of the soaking box; the length, material, cross-sectional area and shape of the bubbling device will make a difference on the rolling stability and uniformity during soaking. There is a distance from the bubbling device to the conveyor belt, the collision between the bubble and duck heads occurred, then the duck heads had tumbling of themselves when the bubbles got out from the holes of the conveyor belt; it allows the duck heads to be fully soaked to achieve the purpose and requirements of preliminary cleaning. Considered livestock slaughter is a stream of operations, and the production will be great sometimes. The conveyor belt will be accelerated or decelerated with the movement of the main chain but not allowed to affect the quality of duck heads cleaning. The parameters chosen for this study are based on the maximum amount of duck heads delivered per batch of the conveyor belt - the maximum soaking time required for six duck heads; it has a certain chance to ensure the duck heads roll as enough as possible and get enough soaking time, which can guarantee the uniformity of cleaning. The length, height and width size of the prototype box are 3000 mm, 620 mm and 710 mm; the material of the box is zinc plate.

The width of the conveyor belt is 600 mm in design, there are some baffles with height of 51 mm and width of 5 mm evenly set on the surface of the belt to separate different batches of duck heads; the holes are evenly distributed between the baffles with a diameter of 20 mm, as a result, each batch of duck heads can be fulfilled soaked and flushed by the bubbles, the immersion conveyor is shown in Fig. 3.

3.1.2. Selection of the inlet pump and air pump in bubbling device The volume of the box is given by formula

$$V = S \times H = W \times L \times H\,, \tag{1}$$

where V is the volume of the box, S is its bottom area, H is the height of the box, W is its width and L is its length.

The wall thickness is 20 mm, the length $L_1 = L - 20 = 2980\,\text{mm}$, the width $W_1 = W - 20 = 680\,\text{mm}$, the bottom thickness is 10 mm, and the height of $H_1 = H - 10 = 610\,\text{mm}$. The internal volume is given as

$$V_1 = W_1 \times L_1 \times H_1 = 1.254385\,\text{m}^3\,. \tag{2}$$

The height level of cleaning water required is 2/3 of the total height, the actual volume of water is

$$V_{actual} = 2/3V_1 = 0.836188\,\text{m}^3\,. \tag{3}$$

In the actual process of water injection, the immersion box is injected by two water pumps at the same time. The time between adjacent two groups of ducks is

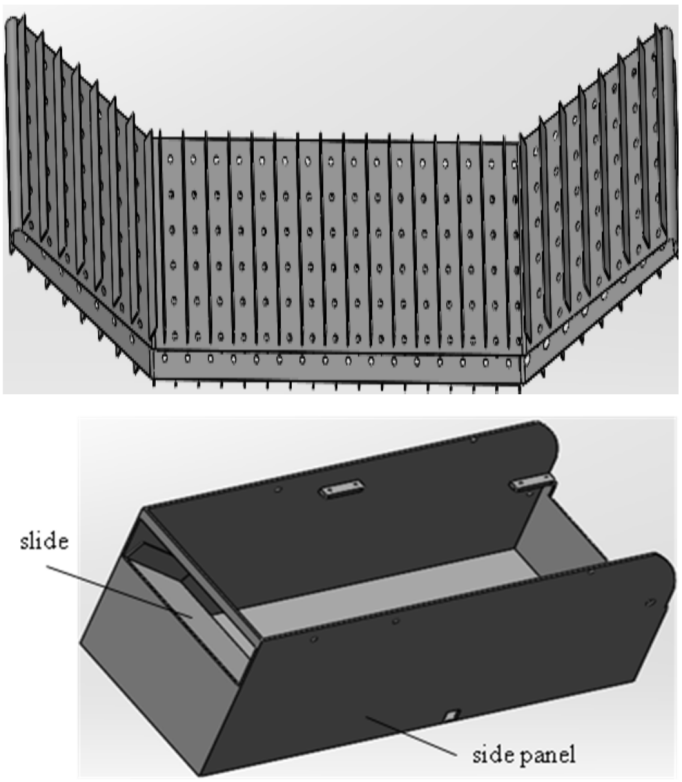

Fig. 3. Top–immersion conveyor belt, bottom–cleaning box

6 min at least. In accordance with the minimum time to calculate the requirements of the box, its volume is 836.188 l, the parameters are shown as follows: the length is 3000 mm, the width is 700 mm, the height is 620 mm, the wall thickness is 10 mm. The selection of the jet pump in actual application is illustrated in Fig. 6, left part.

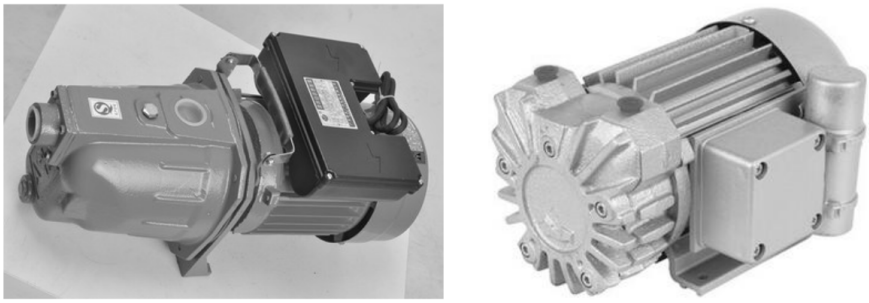

Fig. 4. Left–jet pump, right–air drum device

The purified air is compressed and then blown into water from the bottom

through the bubbling tube, in the depth of the water it produces bubbles with a definite pressure and rises rapidly to the surface of the water. The bubbling device uses a high pressure circulating pump to generate high pressure air flow. Bubbles can be generated through a bubbling pipe arranged in the matrix at the bottom of the box in water and carry out an impulsive cleaning of objects.

In the overall design, three slots structure is placed in the bubbling device with a same group of gas sources, while the exhaust holes are arranged in a matrix. It has the advantages of low investment in equipment, evenly distributed bubbles, good cleaning effect. The performance of the blower parameters and the requirements of the design are consistent, that the G75 model blower is shown in Fig. 4, right part.

3.2. Design of cleaning structure

The main task of cleaning box is to wash the blood on the surface of duck heads, so the bubbling device can be omitted, while adding a water circulation device and two spraying devices, the internal structure of the box has also been changed, the box is shown in Fig. 3, right part. In the connection to the immersion box, in order to allow duck heads to transport successfully by conveyor belt of the cleaning device, the side boards are added on both sides, which can prevent the duck heads dropping from the slide.

The device can make duck heads roll automatically while overstepping the highest point transported by the conveyor belt using physical principles. There is a sprinkler installed for cleaning the top of duck heads in the ascending phase of the conveyor belt, and there is another sprinkler installed for cleaning the bottom of duck heads in the descending phase, thus the duck heads will get cleaning in all directions. The sewage will outflow from both sides of the conveyor belt or the holes on the surface of the conveyor belt, but not follow the conveyor belt down towards the next row of duck heads needed cleaning, which can avoid secondary pollution, the conveyor belt is shown in Fig. 5, left part.

The baffles on the conveyor belt is used to separate the batches of duck heads, and there are some small round holes evenly distributed between two baffles, which is easy to make the water spraying over duck heads fall into the box below in time.

4. Results and discussion

The preliminary design of the mechanical part of the prototype is shown in Fig. 5, right part, the automatic control system was designed for hardware and software next step, and the control device will be installed later in the prototype for testing.

4.1. Experiment of prototype

The test contains the following four aspects, including the separation of duck heads in storage box, uniformity of duck heads, the bubbling device in immersion box and cleaning test in the spraying device [12–14]. It is mainly evaluated from five aspects showed below:

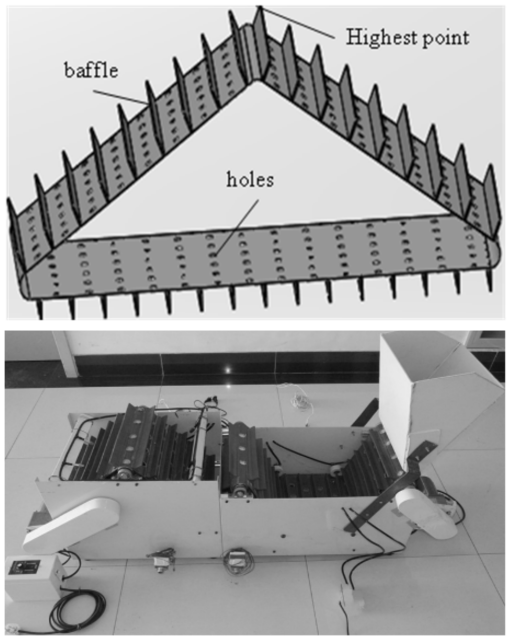

Fig. 5. Top–cleaning conveyor belt, right–actual structure of the prototype

a) The number of duck heads out from the conveyor belt is stable.
b) The number of duck heads per row is similar.
c) Soaking time in each group of duck heads when they were cleaning is the same.
d) The quality of the duck heads after cleaning is in line with the requirements.
e) The surface damage rate of duck heads is to meet the requirements.

There are repetitious tests performed with a large number of duck heads, Fig. 6 shows the pictures took during the tests.

4.2. Analysis of results

As a result of the test, there are a few following conclusions:

a) When the speed of conveyor reaches a certain value, the objects falling into the storage box will not be squeezed and heaped up.

b) Most of the duck heads can be evenly distributed over the conveyor belt beside few curled ones, and they will be blocked by the filter when passing through the filter device, so that it is easy to go through the conveyor slot.

c) Bubbles generated by the bubbling device can pass through the holes on the surface of the conveyor belt and directly impact the surface of duck heads, which will produce considerable momentum to make the duck heads roll forward while being soaked as long as the air pressure is large enough.

d) Spraying device can clean each row of the objects four times in high-intensity according to the preset function; the immersion and cleaning time of duck heads for

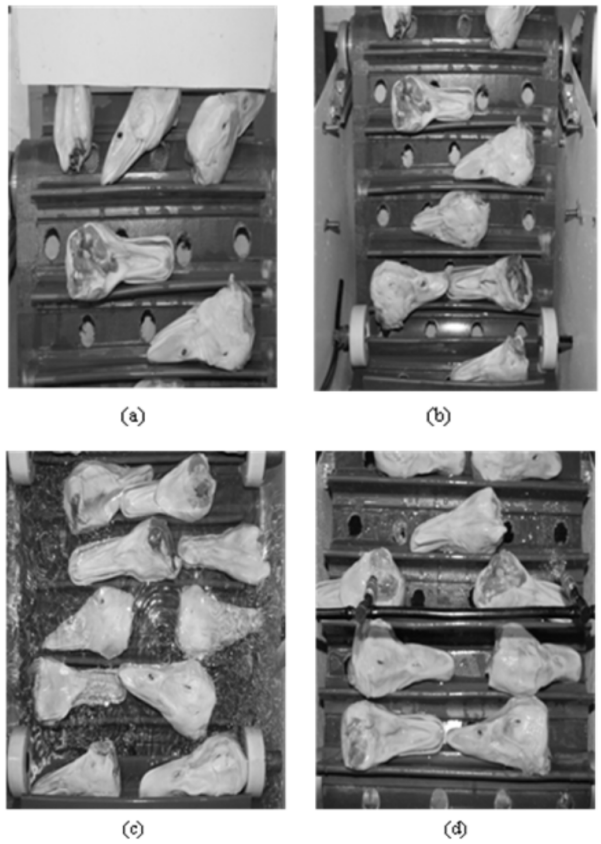

Fig. 6. Repetitious tests of prototype of (a) the separation of duck heads in storage box; (b) uniformity of duck heads; (c) the bubbling device in immersion box; (d) cleaning test in spray device

each batch is roughly the same.

e) Qualified rate is up to 98 percent after the above series of cleaning process, in addition to minor injuries from the cutting machine to the storage box, the cleaning device throughout work will not have negative impacts on duck heads.

The statistical data demonstrates that the process is improved by 10–30 % in terms of capacity, qualified rate of cleaning increases by more than 3 %, the fresh-water used in cleaning per time can be saved by 10–20 %, at the same time, it can save two labor costs to the process at least.

5. Conclusion

The two-box cleaning device was designed instead of the overall cleaning box with the improvement and perfection of the mechanical structure, while the automatic

control system can achieve the automation and intelligent in duck heads cleaning. There are following aspects of innovation.

a) The use of the storage box to solve the problem for distribution of duck heads on the conveyor belt.

b) Realization of the twice cleaning function in immersion device and spraying device, the water level sensor can be used to control each water-supply switch and adjust the height of the water level in the tank arbitrarily, the whole process of cleaning thereby will realize automation.

c) Duck heads can realize automatically soaking and rolling, thus both sides can be cleaned using bubbling device and angle difference in conveyor belt.

d) Speed of the main chain can be detected in a rotary encoder, combined with the duck heads producing quantity and maximum number cleaned on the belt per row in unit time; automatic control system with micro controller can adjust the cleaning rate and effect in real time.

References

[1] S. M. Henderson, R. L. Perry: *Agricultural process engineering.* Soil Science *79* (1955), 321.

[2] K. G. Rajesh, V. Singh: *Simulation based planning for design of washing machine using h/w & s/w co design.* International Journal on Computer Science & Engineering *2* (2010), No. 8, 2545–2549.

[3] F. B. Olotu, N. O. Oladip, A. J. Farounbi, S. I. Obiakor: *Development of a continuous process multi-crop washing machine.* International Journal of Basic and Applied Sciences *3* (2014), No. 3, 96–100.

[4] S. C. Ding, W. H. Li, S. Z. Yang: *Research on automatic washing machine control system.* Materials Engineering for Advanced Technologies *480–481* (2011), No. 3, 1302–1307.

[5] E. O. Vilen: *Dishwashing machine with integrated recycling system.* Journal of Cleaner Production *5* (1997), No. 1, 143.

[6] K. J. Xiang, B. F. Xu: *The analysis about pollutant index of the wastewater originating from small vehicles washing.* Mechatronics Engineering, Computing and Information Technology *556–562* (2014), No. 1, 833–836.

[7] U. Heise, W. Harbich: *Investigation at a top counter weight of a washing machine.* Journal of the Acoustical Society of America *105* (1999), No. 2, 1191.

[8] A. N. Tidwell, A. R. Gonzales, P. Fenn, B. P. Marks, A. Mauromoustakos: *High pressure washing to remove decayed tissue and improve quality of clingstone peach puree.* Journal of Food Science *62* (1997), No. 1, 131–134.

[9] J. Mendenhall, T. D. Negusse, T. G. Solomon, R. Price: *Design of a vegetable washer for the food service industry.* Foodservice Research International *5* (2006), No. 6, 43–65.

[10] A. Moos, D. D. Steele, D. C. Kirkpatrick, R. Price: *Small-scale mechanical carrot washer for research sample preparation.* Applied Engineering in Agriculture *18* (2002), No. 2, 235–241.

[11] H. O. Wang, Z. C. Hu, F. Wu, S. Cao, H. Xie, T. Zhong: *Design and experiment on ultrasonic-ozone washer for fruits and vegetables.* Transactions of the Chinese Society of Agricultural Machinery *42* (2011), No. 7, 165–169+175.

[12] H. O. Wang, Z. C. Hu, F. Wu, S. Cao, H. Xie, T. Zhong: *Design and experiment on ultrasonic-ozone washer for fruits and vegetables.* AMA, Agricultural Mechanization in Asia, Africa & Latin America *44* (2011), No. 7, 165–169+175.

[13] D. C. P. Ambrose, S. J. K. Annamalai: *Development of a manually operated root crop washer*. African Journal of Agricultural Research *8* (2013), No. 24, 3097–3101.

[14] E. Jayashree, R. Viswanathan: *Design and experiment on ultrasonic-ozone washer for fruits and vegetables*. Studies on mechanical washing of ginger rhizomes *47* (2010), No. 4, 37–40.

Received April 30, 2017