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Design and Analysis of Poultry Evisceration Manipulator Mechanism

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Abstract:

To solve the related problems of poultry slaughtering in evisceration, a set of device was designed for accurate evisceration of poultry in the assembly line. By grasping the viscera with the designed manipulator, the purpose of separating viscera from carcass can be achieved, and the corresponding finite element analysis and experiments have been done. It can realize the evisceration of different kinds of poultry viscera, and the evisceration of the same kind of poultry viscera with different body shapes and viscera sizes; and ensure the integrity of poultry viscera and poultry carcass, then reduce the viscera damage rate in the evisceration process and increase the production efficiency and quality.

Keywords*: Evisceration manipulator, Three-dimensional modeling, Finite element analysis.*

I. INTRODUCTION

At present, the existing poultry evisceration equipment can no longer meet the high quality demand of the market, and the requirement of consistency of poultry body shape has caused difficulties for the existing evisceration equipment. Therefore, the poultry evisceration work for food has become the latest and urgent problem to be solved. Internal organs of poultry include poultry organs and body fat, such as chicken gizzard, chicken liver and chicken heart. Automatic evisceration devices are used in the evisceration area of large poultry slaughtering line, and evisceration manipulator is used to clean the bore, which can improve the production efficiency of the line [1-3].

In addition, due to the lack of observation and attention, there is a certain risk of pollution in evisceration. At present, China's breeding scale is expanding, and related technologies have made great progress. Poultry automatic evisceration technology has been improved, and the demand for poultry evisceration machinery in the economic market is increasing. In the existing poultry slaughtering production line, the evisceration operation area generally adopts the following process: hoisting the thigh joint of poultry, opening a vent at the anus, and performing internal evisceration with mechanical jaws to pull out all the internal organs of poultry. This way is commonly used to finish the evisceration work in

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the current poultry slaughtering production line. Although this method is efficient and fast, there are many problems and contradictions. For example, this kind of evisceration method is more violent than manual cleaning, especially damaging the surface of poultry viscera and the inner wall of poultry carcass. In Chinese diet, the consumption of poultry viscera is particularly common, and the damage of viscera not only affects the taste of eating, but also affects the quality of sales. In addition, the whole-in-out evisceration method has strict requirements on the shapes and sizes of different poultry and the internal organs of the same kind of poultry. The poultry produced by existing production lines have basically the same size, and it is impossible to eviscerate the internal organs with different shapes and sizes on the same production line. The fixed evisceration method also leads to a lot of damage and adhesion in the internal organs evisceration work [4-5].

In this paper, we design a manipulator that can automatically identify and eviscerate viscera. This manipulator can solve the problem of eviscerating viscera of poultry with different shapes. This paper will build a 3D model in the 3D design software, carry out motion simulation and finite element analysis, and then optimize and improve it for the next steps.

II. MECHANISM DESIGN OF EVISCERATION MANIPULATOR

There are system complexity, parameter setting, external environment and other real-time uncertainties in the operation of poultry evisceration manipulator. There are many uncertain factors in the three-dimensional modeling work of the evisceration manipulator. It is necessary to set the running track of the evisceration manipulator in the actual running environment for different production objects [6].

Poultry evisceration manipulator consists of six servo motors controlled by the central control system, which can realize the six-degree-of-freedom movement of poultry evisceration manipulator. The poultry evisceration manipulator is mainly composed of end execution, parts drive system, poultry evisceration manipulator control system, position detection and feedback system, etc. The relationship among these systems is shown in Fig 1.

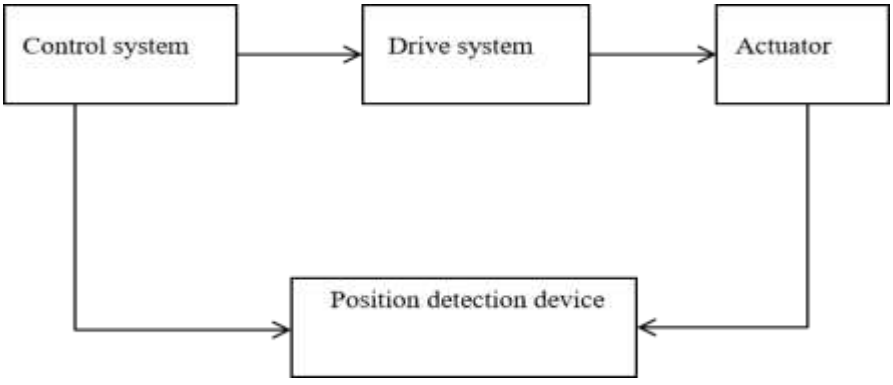

Fig 1: Manipulator operation control system

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The evisceration manipulator cooperates to complete the expected action. The mechanical arm of poultry evisceration manipulator consists of base, bending arm, wrist arm and revolving arm. After the central control system sends out the operation command and characteristic signal of the manipulator, all parts of the manipulator of the poultry evisceration manipulator cooperate with each other, and work together to complete the predetermined actions of the system, namely, clamping of the end actuator, rotation of the revolving arm, pitching of the bending arm, pitching of the wrist arm, swinging left and right, and slewing of the base. The degrees of freedom are shown in Fig 2.

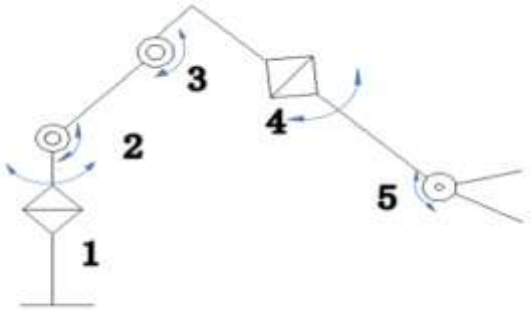
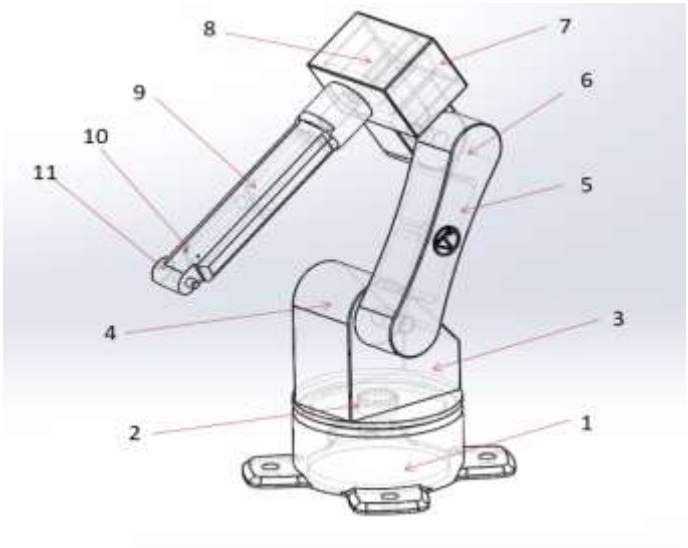


Fig 2: Schematic diagram of mechanical structure of six-degree-of-freedom manipulator

The manipulator bears a small load, but its environment is characterized by humidity and serious oil stain. While meeting such requirements, the manipulator can operate normally. The mechanical structure of the manipulator includes foundation, foundation base, bending arm, wrist arm and revolving arm, as shown in Fig 3.



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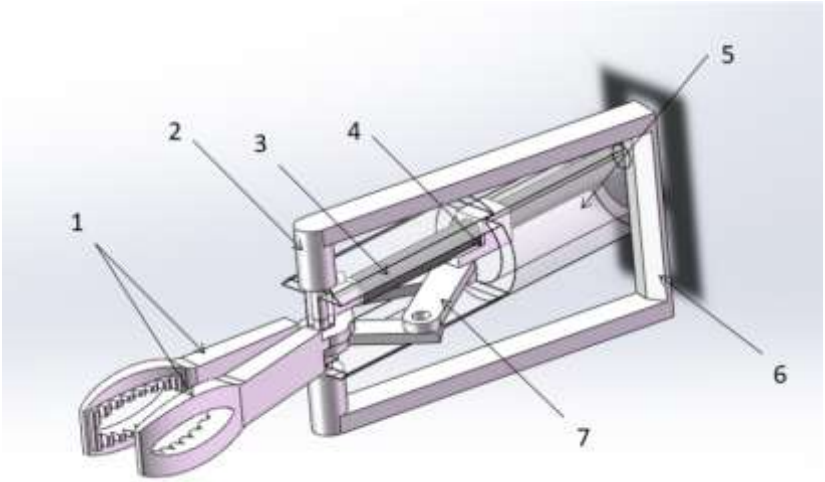
1. Foundation 2. Foundation base servo motor 3. Foundation base 4. Bending arm servo motor 5. Bending arm 6. Wrist arm servo motor 7. Wrist arm 8. Revolving arm servo motor 9. Revolving arm 10. Industrial camera mounting hole 11. Mechanical gripper servo motor

Fig 3: Main structure of manipulator

The clamping method is a two-piece concave jaw structure, which is similar to the tissue forceps used by surgeons. By comparing the chicken viscera, the working environment of the manipulator is the same. The end actuator consists of mechanical gripper and cutting mechanism, as shown in Fig 4.



1. Gripper 2. Slitting drive motor 3. Screw 4. Sliding nut 5. Housing 6. Slitting knife 7. Connecting rod

Fig 4: End actuator

The vent supporting device consists of four parts: lifting support frame, drive motor, vent supporting gripper and vent supporting slide rail. The vent supporting device is located between the manipulator and the assembly line, which is used to spread the opened poultry to expose the internal organs and facilitate the identification of industrial cameras. The operating principle of the vent supporting device is evolved from hyperbola in mathematics. The structure diagram of the vent supporting device is shown in Fig 5 [7].

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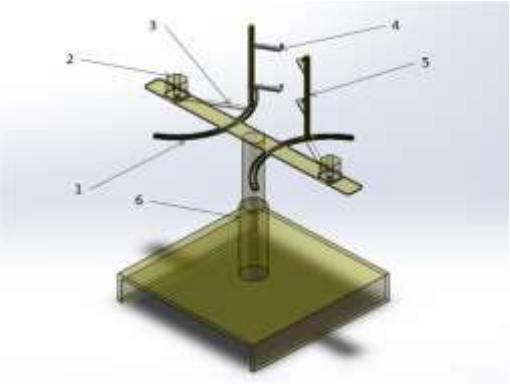

1. Double-arc slide rail 2. Motor 3. Connecting rod 4. Supporting jaw 5. Column 6. Lifting bracket
Fig 5: vent supporting device

The three modules of the evisceration manipulator are respectively the modeling of the poultry evisceration manipulator arm, the modeling of the end actuator of the poultry evisceration manipulator arm and the modeling of the auxiliary vent supporting device of the poultry evisceration manipulator arm [8].

The mechanical arm part of the poultry evisceration manipulator consists of a foundation, a foundation base, a bending arm, a wrist arm and a revolving arm, which is driven by a servo motor. This part is the operating part of the poultry evisceration manipulator, and drives the end actuator to work cyclically and periodically between the assembly line and the viscera conveying table. The end actuator part of the poultry evisceration manipulator consists of a mechanical gripper, a connecting rod, a screw nut and a shell, which is driven by a servo motor. This part is the actuator part of the poultry evisceration manipulator. After the nut is driven by a screw, it is converted into a linear motion, and then the connecting rod mechanism is driven to open and close the mechanical gripper and grab the internal organs. The auxiliary vent supporting device part of poultry vent cleaning manipulator consists of hydraulic lifting platform, sliding track, connecting rod and vent supporting gripper. It is driven by servo motor and hydraulic device. This part is an auxiliary part of poultry evisceration manipulator, and the supporting gripper column makes hyperbolic motion along the arc sliding track to drive the supporting gripper to open the poultry vent. Through this series of modeling, after assembly, the main functions, such as vent supporting, evisceration, separation of adhered tissues and viscera placement. The general assembly drawing is shown in Fig 6.

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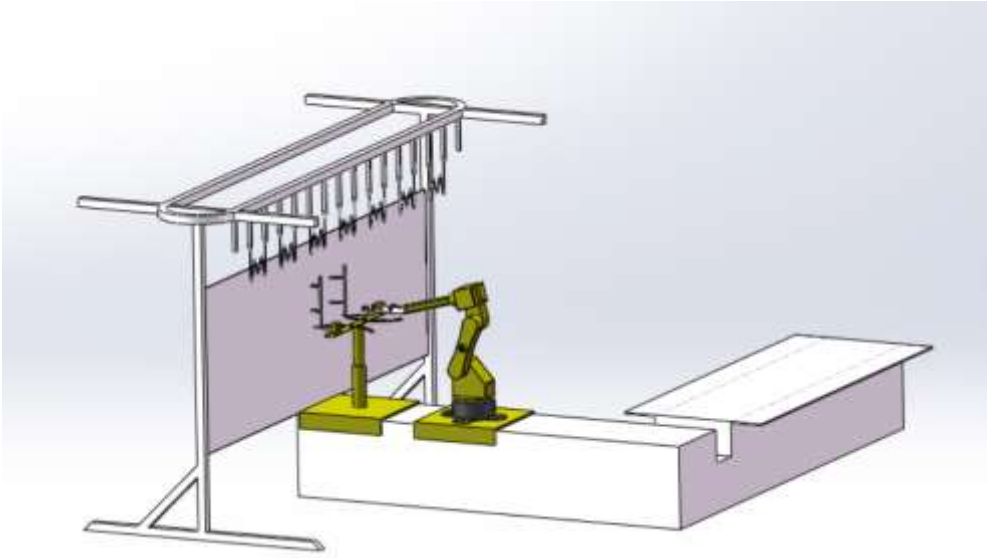

Fig 6: Assembly drawing of evisceration manipulator

III. ANALYSIS

The analysis of the evisceration manipulator is finite element analysis, which is carried out by ANSYS and SolidWorks Simulation. The finite element analysis object of the poultry evisceration manipulator consists of four important parts of the evisceration manipulator, namely, the manipulator foundation, the manipulator revolving arm, the mechanical gripper of the end actuator, and the vent supporting gripper of the vent supporting device [9].

The manipulator gripper is the end actuator of this design task. The two hinges of the mechanical gripper are fixed, and the external load mainly comes from the reaction force when gripping the object. According to the clamping force set by the visceral pressure characteristic curve before, the gripper is statically analyzed. The force is set to be 10N. The material is 316 stainless steel, and the force point is located in the visceral clamping area of the gripper. The set data is input into the software, and the results are shown in Fig 7 and Fig 8.

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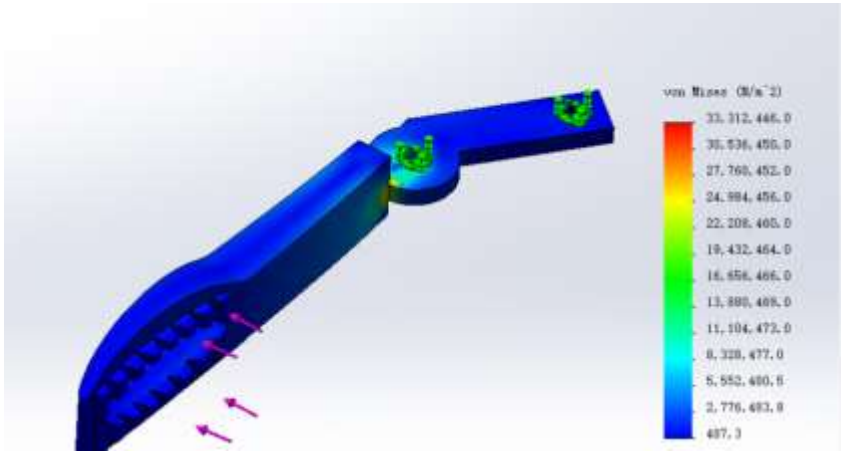

Fig 7: Gripper stress

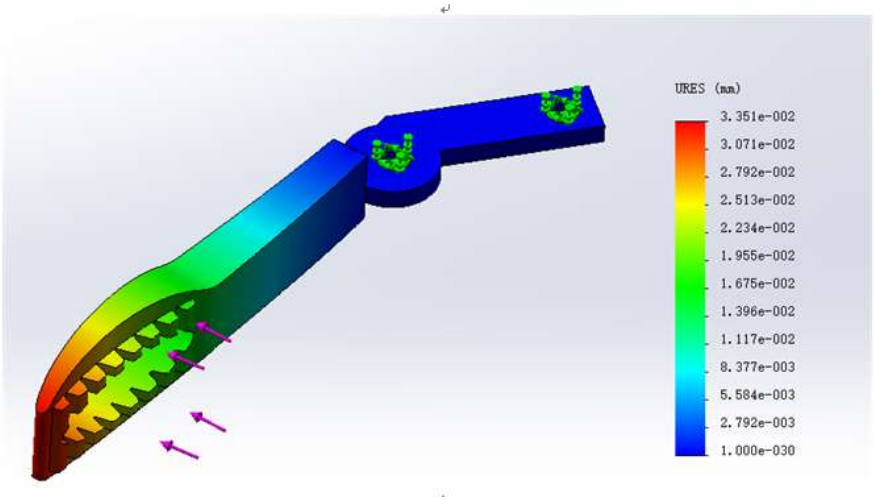

Fig 8: Gripper displacement

Seen from the stress diagram, the maximum stress of the gripper is at the joint between the gripper and the hinge. The maximum stress is 33312446N/m^2, and the yield force of 316 stainless steel material is 170000000N/m^2; seen from the displacement diagram, the maximum displacement of the gripper is located at the position where the gripper grips the viscera,, and the maximum displacement is 3.351x10-2mm, which is relatively small. The gripper design meets the requirements.

In the vent supporting device, the vent supporting gripper is the end actuator, and the external load of the vent supporting gripper mainly comes from the reaction force when pulling the sternum of poultry. The vent supporting gripper is made of 316 stainless steel. Static analysis is carried out on the vent

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supporting gripper. The force is set to 100N, and the force point is located at the groove of the brace claw. After entering the set data into the software, the results are obtained as shown in Fig 9 and Fig 10.

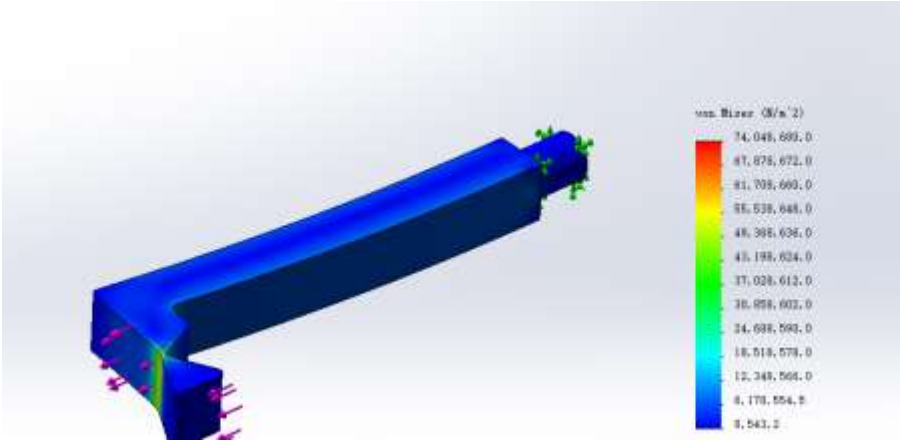

Fig 9: Stress of vent supporting jaw

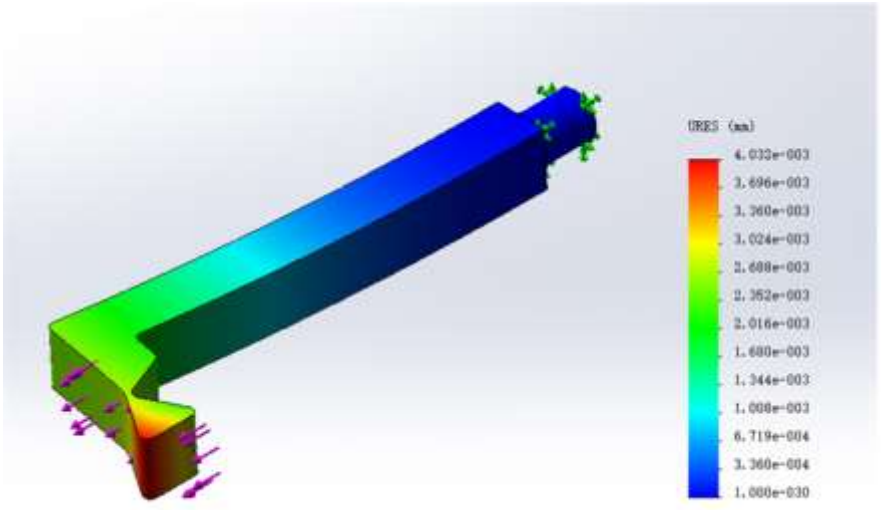

Fig 10: Displacement of vent supporting gripper

As can be seen from the stress diagram, the maximum stress of the vent supporting gripper is at the vent supporting gripper and hinge groove. The maximum stress is 74048680N/m^2, and the yield force of 316 stainless steel material is 170000000N/m^2; the the displacement diagram shows that the maximum displacement of the vent supporting gripper is located at the groove. The maximum displacement is 4.32x10^{-3}mm, which is small. The vent supporting design meets the requirements.

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IV. CONCLUSIONS

In this paper, according to the current situation of poultry production line, the mechanism design and analysis of poultry evisceration manipulator are carried out. The designed poultry evisceration manipulator can accurately remove poultry viscera, and the corresponding mechanical analysis and simulation experiments are carried out on the designed product. The poultry evisceration manipulator can greatly promoted China's economy and increased productivity. As the labor cost has become an important cost of production nowadays, the cost of manual cleaning cannot make ends meet compared with production and sales; uninterrupted operation of evisceration manipulator has low operating cost and high production efficiency, and ensures the quality of production and processing, which greatly reduces the production cost.

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