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Design and Research on Household Food Slicer

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Abstract: The research purpose is to design a mini type household food slicer to slice the root vegetables. The study elaborates on the design of each part of the slicer, including selecting electric motor and V belt, the design of V belt pulley, shaft, elevating mechanism and blade, to introduce the main structure and operating principles of the slicer, based on which the conclusion has been reached.

Keywords: Blade, food, root vegetables, slicer

INTRODUCTION

The slicing technology has already been developed mature abroad in 1970s, in the mid-eighties most of the slicers can process monocrystal with large diameter up to 125 mm (5 inches), like the horizontal inside diameter slicing machine manufactured by Mayer Bbu Geyer company in Switzerland which can slice materials with the maximum diameter up to $\phi 304.8$ mm (12 inches). In the following one or two years in the mid-eighties, the slicing technology has experienced its peak of development, many of the automatic multi-function slicers have been commercialized (Xie, 1996).

As to the structure of the slicer, it can be divided into horizontal type and vertical type (Zhou, 2003), which depends on its principal shaft supported by the air bearing or rolling bearing. There're inside diameter slicer, outside diameter slicer, single-blade slicer and multi-blade slicer and the former one is more popular. In the mid-1980s, wire saw, a cutting machine which has a unique design and is totally different from the traditional slicing technology, has come to the semiconductor market quietly, which uses a steel wire to coil the four guide wheels to form hundreds of saw bands. When they operate in a high speed, the silicon carbide will be taken to the machine to produce the effect of cutting. Its advantages are to cause less kerf, small deviation, even cut surface, big quantity and less costs. Its application in the market has created a new chapter for the cutting technology in the 21st century (Huang *et al.*, 1996).

The function of the slicer has been very complete, composite and the way of slicing is diverse. The comb shape cutting machine in 1980s is not new anymore, which has been replaced by the cutting and rotating one, surface grinding one and the one with an air cushion which can prevent the blade from bending and distorting, which can repair and maintain the blade automatically (Jiang, 2011). The chip material can roll and grind by itself while cutting, which can reduce the

bending of the monocrystal. In recent years, Tokyo Precision Corporation in Japan has developed and produced a processing system, which combines the steps of loading monocrystal into machine, slicing, transmitting slices, dismantling graphite bearing pad, chamfering, scrubbing, inspection, sorting and storage etc, to realize the full-automation for processing by connecting many equipments and devices of many kinds according to the technological working flow (Liang, 2003).

The main purpose of the research is to design a small-sized household food slicer to slice the root vegetables. Its body, material inlet, blade, material outlet, baffle plate, manual elevator work together and the materials are processed by the material inlet and material outlet. It's characterized by small volume, high processing efficiency, good uniformity, stability and safety.

MATERIALS AND METHODS

Selection of an electric motor: It's a good choice to use Y series motor which has an international interchangeability, can prevent the dust, iron scurf and some other foreign substance intruding into the interior and is B class insulation. It requires the temperature of working environment can't exceed $+40^{\circ}\text{C}$, the relative humidity can't exceed 95%, the altitude can't be above 1000 m, the rated voltage shall be 380v and the frequency shall be 50 Hz, which only applies to the mechanical machine without special requirement (Jiang and Du, 2012).

The model number of the motor is Y90S-6 according to the Mechanical Design Manual. It can be placed on the left or the bottom of the shelf. See the following parameter: The motor is the Y series three-phase asynchronous motor, as shown in Table 1.

Table 1: Selection of the motor

Model no.	Power rating/kw	Full load speed (r/min)	Locked rotor torque Rated torque	Peak torque Rated torque	Efficiency
Y90S-6	0.75	910	1.5	2.2	0.70

Selection of V belt: The narrow V belt uses synthetic fiber rope or steel wire as its bearing bed. Compared with the ordinary V belt, when they have the same thickness, its width is 30% less. The narrow V belt's transmission power is stronger than the ordinary one's, which allows high speed and bending frequency, has a shorter transmission center distance and is suitable for the transmission of high power and compactness-required structure. The outstanding character of household slicer is light and handy, so the narrow V belt is chosen in its design.

Working coefficient $K_A = 1.0$ (Mechanical Design Manual, form 12-1-67). Transmission power $P = 0.75$ KW, design power of the synchronous belt $P_d = K_A P = 0.75 \times 1.5$ KW = 0.75 kW. Efficiency of the transmission belt = 0.9, efficiency of the shaft transmission = $0.75 \times 0.9 = 0.7$ kW:

- **Transmission ratio:** Rotational Speed of principal shaft = Rotational Speed of big pulley = 425 r/min

Rotational Speed of motor = Rotational Speed of small pulley = 910 r/min

$$\text{Transmission ratio } i = \frac{n_1}{n_2} = \frac{910}{425} = 2.14$$

- **Selection of the small pulley's diameter:** Rotational Speed of small pulley $n_1 = 910$ r/min. The dimension of the pulley's diameter is calculated by the speed reducing ratio, which is designed according to the working rotational speed and motor's rotational speed. Working Rotational Speed/Motor's Rotational Speed = Driven Pulley's Diameter/Driving Pulley's Diameter $\times 0.98$ (sliding coefficient)
 - Initial small pulley's datum diameter $dd_1 \geq (dd)_{\min}$, $(dd)_{\min} = 90$ mm
 $dd_1 = 140$ mm shall be chosen according to Mechanical Design Manual, form 14.1-8
 - Checking belt speed:

$$V_1 = \frac{\pi d_1 n_1}{60 \times 1000} = \frac{3.14 \times 140 \times 910}{60 \times 1000} = 6.67 \text{ m/s}$$

Small Pulley's Rotational Speed $5 < V_1 < 25$ m/s

- Calculation of the Big Pulley's datum diameter:

$$dd_2 = i dd_1 = 2.14 \times 140 = 299.6 \text{ mm}$$

- Calculating the center distance a and choose the narrow V belt's datum length L_d

- According to the overall dimension's restrictive condition or the required center distance of the transmission belt, based on formula (8-20), the initial center distance is a_0 :

$$0.7 (dd_1 + dd_2) \leq a_0 \leq 2 (dd_1 + dd_2)$$

$$307.72 \leq a_0 \leq 879.2$$

Finalizing the center distance $a_0 = 400$ mm.

- **Calculation of the relevant belt's length L_{d0} :**

$$L_{d0} \approx 2a_0 + \frac{\pi}{2} (dd_1 + dd_2)$$

$$\approx 800 + 690.2 + 15.9$$

$$\approx 1506.1 \text{ mm}$$

The belt's datum length L_d is chosen from form 8-2 1600 mm.

- **Calculation of the center distance a and its fluctuation range:** Transmission's actual center distance is approximate to:

$$a = (L_d - L_{d0}) / 2 + a_0 = (1600 - 1506.1) / 2 + 400 = 447 \text{ mm}$$

Considering the manufacture error of the pulley, belt's length error, elasticity of the belt and the need of supplementing the tension because of the loose belt, the fluctuation range of the center distance is normally given as the following:

$$a_{\min} = a - 0.015 L_d = 447 - 0.015 \times 1600 = 423$$

$$a_{\max} = a + 0.03 L_d = 447 + 0.03 \times 1600 = 495$$

- **Checking the wrap angle α_1 on the small pulley:** The wrap angle α_1 on the small pulley is smaller than the wrap angle α_2 on the big pulley and the total friction force of the small pulley is relatively less than the big pulley's, so sliding can only happen to the small pulley. In order to improve the transmission working ability, the following formula should be used:

$$\alpha_1 \approx 180^\circ - (dd_2 - dd_1) / a \approx 90^\circ$$

$$\approx 180^\circ - (299.6 - 140) / 447 = 159.5^\circ$$

- **Finalizing the number of the belts:** In order to make each V belt bears strength evenly, the number of the belts should not be too many, normally less than 10, or else, the belt with larger cross-sectional area shall be chosen to reduce the number. Here the number of the belts is $z = 2$.

- **Calculation of belt's initial pulling force F₀:** Considering the influence of the centrifugal force and wrap angle, the minimum initial pulling force of each V belt shall be:

$$(F_0)_{\min} = 500 \times (2.5 - K\alpha) \times P_{ca} / K\alpha \times z \times v + qv^2 = 500 \times (2.5 - 0.925) \times 0.825 / 0.925 \times 2 \times 6.67 + 0.1 \times 6.667 = 53 \text{ N}$$

The actual initial pulling force of the belt shall be larger than 53 N.

- **Calculation of the force F_p in belt transmission:** In order to design the bearing of the pulley, the force F_p imposed on the shaft in belt transmission needs to be calculated:

$$F_p = 2zF_0 \sin \alpha / 2 = 213 \text{ N}$$

Design of V pulley: The wheel hub of the pulley is normally connected by key. The main requirements towards pulley are light in weight, good workmanship, even distributed mass and the groove face that is in contact with the ordinary V-belt should be bright and clean to reduce the wear of the belt. As to forging and welding the pulley, the internal stress needs to be small.

According to the size of the diameter, the frequently-used pulley's structures include type S: solid pulley (used for the small-sized one), type P: plate pulley (used for the small and medium-sized one), type H: orifice plate pulley (used for the pulley with bigger size) and type E: pulley with oval wheel arms (used for the large-sized pulley). Because the angle between the two sides of the ordinary V-belt is 40°, in order to adapt the distortion of the cross-sectional area and the decrease of wedge angle when the V belt bends on the pulley, so the groove angle f of the ordinary V belt is stipulate as 32°, 34°, 36°, 38° (as per the type and diameter of the belt).

The four commonly-used structures are solid type, plate type, orifice plate type and wheel arms type. When the datum diameter is $dd \leq 2.5d$ (d is shaft's diameter, the unit is mm), the solid type can be used. When it's $2.5d \leq dd \leq 300$ mm, the plate type is normally adopted. When it's $D_1 - d_1 \geq 100$ mm, the orifice plate type is normally used. The wheel arms type is normally adopted when it's $dd > 300$ mm. The design of the pulley's structure mainly depends on the pulley's datum diameter, as per belt's type and number to calculate the width of the wheel flange, as per belt's type to calculate the dimension of the wheel's groove. So small pulley D = 108 mm will take the solid type and big pulley D = 272 mm will take the plate type. Small pulley's width $L_1 = (1.5 \sim 2) \times d = 2 \times 16 = 32$ mm. Big pulley's width $L_2 = (1.5 \sim 2) \times d = 2 \times 45 = 90$ mm.

Design of the shaft: The design of the shaft's structure depends on the following several aspects: the

configuration, fastening, assembling and disassembling of components in the shaft and the workmanship of the shaft:

- **Draw up a component-assembly scheme:** Predetermine the principal components' assembly direction, sequence and interrelation. Lock ring and bearing are on the shaft successively. The ring of the bearing is used to locate the direction of shaft, which is suitable to fix the components at the end of shaft and can bear stronger axial force.

- The fixation of the components on the shaft can be divided into two directions: The fixation of the shaft's direction: the transmission of torque and motion, which can use pinch fit (bearing inner ring). The fixation of the shaft's direction: to avoid the axial movement which is produced when the components are working, the round nuts can be used.

The shaft's end part shall have a 45° chamfer to make it centering during installation, which can prevent the sharp edge cutting hands.

- **Material of shaft:** The roughcast of shaft is normally made from round steel or forgings. The shaft is often working under alternative stress, so the requirement for material is as the following: high strength, good rigidity, small sensitivity of stress concentration, anti-fatigue, easy to process and some of the shafts have a high standard for its surface. Medium carbon steel 35 or 45 and alloy steel 20 or 40 Cr etc., are mainly the materials of shafts. The most frequently used one is 45 steel which has a higher comprehensive mechanical performance, so the 45 steel is used in this design.

- **Definition of shaft shoulder:** On the shaft only the sleeve and bearing are installed, the shoulder is used to locate. If the shoulder is used, it'll make the diameter of the shaft increase. And because of the sudden change of cross section, the stress concentration will be caused at the shoulder area. In addition, too many shaft shoulders are not good for processing, so shoulder location is usually used when the axial force is stronger. Positioning of the shaft shoulder's height is normally used $h = (0.07 \sim 0.1) d$, d is the diameter of the shaft which matches the component. The positioning shoulder height of rolling bearing must be lower than the height of bearing inner ring's section to make it easy to dismantle bearings. The height of the shaft shoulder can consult the Manual for the installation dimension of bearings.

- **Definition of shaft's length:** In order to make the components which have pinch fit with the shaft easy to assemble, the pressure inlet end of the related shaft segment shall be tapered, or different dimension tolerance can be used on two parts of the same shaft segment. When the length of shaft is

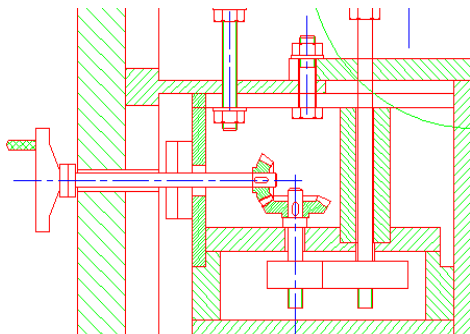


Fig. 1: Elevating system

defined, try to make the structure compact and at the same time make sure the components have space for assembly and adjustment. The length of each segment of the shaft is mainly decided by the axial dimension of the part where each component working with the shaft and the necessary space of the adjacent component (Fan and Chen, 1994).

Design of the elevating system: The slicer's elevator system consists of hand wheel, hand wheel shaft, a pair of bevel gears, transmission shaft, a pair of transmission gears, transmission screw and clip shaft sleeve. Hand wheel and one end of the hand wheel shaft are fixed together and the other end of it is fixed and linked together with a bevel gear. The other bevel gear is fastened on the top of a transmission shaft and its bottom is fixed and connected with a transmission gear. The other transmission gear is fixed together with the bottom of the transmission screw. And the pair of the bevel gears and the pair of the transmission gears mesh respectively, as shown in Fig. 1.

The elevating system can make the slices processed by the slicer have even thickness, neat cut surface, more accurate and convenient to adjust the thickness. When it's working, the rotation of the hand wheel will drive the hand wheel shaft turn around the horizontal axis. The transmission shaft turns around the vertical axis through the transmission of a pair of bevel gears (West and Deng, 2010). The transmission gear transmits the rotation to the transmission screw whose rotation makes it have up-and-down movement with the clip shaft sleeve, in this way; the operating clip fastened on the top of it moves upward to get one slicing thickness. Then the whole device moves horizontally to make the blade slice the material on the clip horizontally. Because the blade is fixed on the blade rest which cannot move in the process of slicing, the slices have even thickness. The shaft group used in the structure can rotate the clip sleeve after the work piece finishes moving specified distance (slicing thickness) upward, the shaft moves horizontally through the transmission of the gear and gear sleeve. Get the clip sleeve fully fastened and don't let the work piece have the slightest movement to make sure the quality of the slices.

Design of the blade: The size of the material inlet decides the length of the blade. When it is 82 mm, the length of the blade $L > 82$ mm will be OK. $L = 120$ mm will satisfy the operating requirement.

RESULTS AND DISCUSSION

Main structure: The slicer consists of material inlet system, cutting system, material outlet system and manual elevator system. The material inlet system is very simple; because it's a household slicer which doesn't have a large quantity to slice, the manual feed is used. It not only lowers the costs, but also reduces the size of the slicer (He *et al.*, 2013).

Cutting system: It consists of blade, blade rest, principal shaft and a pair of pulleys. The electric motor transmit the power to the pulley and then to the principal shaft which will rotate the blade adapter and it will drive the blade to do circle movement, so that the materials can be sliced.

Material outlet system: In order to make sure all the slices of the materials come out, the size of the baffle plate shall be a bit bigger than the mouth of the material outlet, which not only can make the materials drop accurately, but also can discharge the material in time.

Elevating system: It can make the slices processed by the slicer have even thickness, neat cut surface, more accurate and convenient to adjust the thickness.

Working principle: Though circle movement of the blade and materials' manual feeding to realize the continuously slicing of material. The electric motor transmits power to the principal shaft through belt and the principal shaft will rotate blade rest, manually feeding the slicer and the material will be sliced.

CONCLUSION

The design of the slicer is in accordance with principles of ergonomics, easy to operate, convenient, safe and high stability. The shape and appearance, which is simple and decent, occupy less space and easy to carry, has greater aesthetic value. The overall structure is concise and reasonable.

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