

Structure Theory Design of Tennis Service Machine

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Abstract — Tennis service machine is equipment that can assist practitioners serving balls, which uses principle of transfer wheel, between two pinch roller balls to cast. In the paper, internal mechanical structure and ergonomics of related structure of the tennis serve machine have been designed in detail, including storage tank ball, ball funnel, swing system and elevation changes, and discussed by relevant design calculation of its feasibility.

Keywords - tennis ball machine; mechanical structure; theoretical design

I. INTRODUCTION

Foreign tennis service machine starts earlier. Their main functions are to issue a top spin, back spin, side spin, straight ball, and lob, net before ball, ball after field, bottom line of ball, hit ball and stab sideline ball. It fit needs of general practitioners and can meet daily training requirements of athletes. Currently tennis service machine on market a variety of forms, structure is also different. Power to serve their own characteristics, etc., design retains structural features of some of traditional domestic and foreign tennis ball machine, and there are varying degrees of innovation.

II. INTERIOR DESIGN OF TENNIS SERVICE MACHINE

A. Tennis Service Machine Ball Storage Box Design

Role of system is stored tennis and tennis ball supply system at any time as required. It is tennis store where, while it should also be able to tennis ball for successful delivery to funnel stuck phenomenon can not produce action. Based on this feature requires, in storage tank design low ball cap can not be designed in a planar structure [1]. We use it to design a 5° angle with the horizontal conical, and this would resolve stuck problem. The system consists of storage tank ball for ball hopper (with rotation), guide slot and so on.

B. Tennis Service Machine Ball Storage Box Design

It is a key means to serve tennis ball delivery system. For us it is designed to require four openings, funnel from low-power DC motor drive can be rotated. At the same time ball mouth to install a guide groove, so that ball can reach designated location, supply and demand funnel as is shown in Fig. (1).

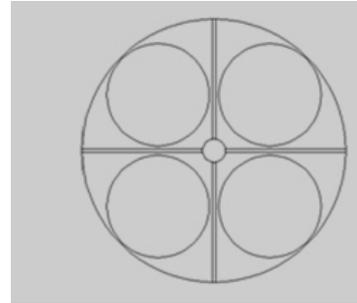


Figure 1. Supply and Demand Funnel

C. Tennis Service Machine Swing System Design

This part is to make tennis obtain a certain angle by a stepping motor and a link mechanism, which issued a sideline ball. According to characteristics of housing structure, design structure is shown in Fig. 2.

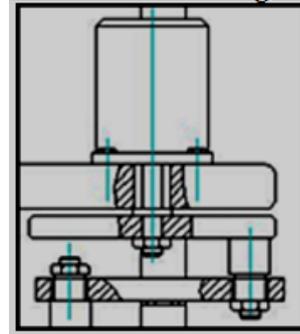


Figure 2 Swing System Working Principle

D. Tennis Service Machine Elevation Changing System Design

This part is to drive screw to make tennis different elevation gain by stepping motor, thereby emitting short balls and long balls. According to role played by its structural features and the cabinet, it will be designed as is shown in Fig. 3.

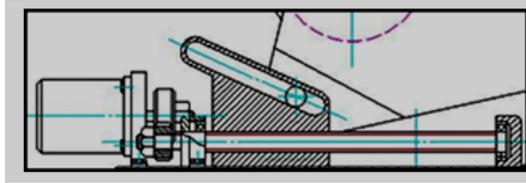


Figure 3. Elevation Changing System Working Principle

IV. CORRELATION CALCULATION OF TENNIS SERVICE MACHINE STRUCTURE DESIGN

A. Design Parameters Standard

Meet the parameters: frequency of 15 times/min; maximum line speed of ball when shot was 34 m/sec; require launch angle between 20° ~ 40° adjustable; power stroke is adjustable; ball inside from transmitter is when fired, claiming their rotation can be achieved: topspin, backspin and so on.

B. Basic Parameters of Tennis Ball

Any tennis, if used by professional tournament, it must meet International Tennis Federation (ITF) standards. All tennis balls have to go through a rigorous testing program in order to determine its characteristics have reached any requirements range. These tests include weight, size, bounce, and the degree of deformation.

ITF tennis standards

Diameter: 6.541 cm -6.858 cm

TABLE I. MOTOR PARAMETERS

Type	gm37-3530	Rated power	30(w)
Rated voltage	12(v)	Rated current	0.50(a)
Rated speed	1250(r/min)	Rated torque	0.7(nm)
Model size	37mm	Output shaft diameter	160mm

E. Squeeze Ball Design and Checking Calculation

According to International Tennis ITF standards, tennis compressive deformation of 0.559 cm -0.737 cm; deformation recovery -1.08 cm to 0.8 cm. Design tennis ball launcher crowded round both to make tennis effective elastic deformation occurs at speed of 10 meters per second ejected, without squeezing bad tennis.

1) selection of squeeze ball type, precision grade and material

a) Material selection.

Related information selected according to squeeze ball round materials are ht350, hardness 250hbs. Hardness difference is 0 [2].

Gray cast iron - organization and mechanical properties of graphite matrix form related. Gray cast iron in the flake graphite substrate serious split in the graphite sharp corners easily lead to stress concentration, so that tensile strength of gray cast iron, ductility and toughness is much lower than steel, but considerable compressive strength and steel, are also commonly used cast iron mechanical properties of worst pieces of cast iron.

Rally: 135 cm -147 cm
Compressive deformation: -0.737 0.559 cm cm
Restore deformation: 0.8 cm -1.08 cm

C. Prop Handicap and Casting Whole Controlling Tennis Ball Velocity

Tennis ball on disc tray, toss a ball under tray below casting whole. When disc toss ball to next port, tennis ball is under casting whole slid along crowded handicap. By tossing disk and driving motor speed it can hold the number of balls per minute under control.

Computing: Design toss disc as an annular groove, groove outside diameter of 26cm, groove inner diameter of 16cm, groove depth of 4.5cm.

Because frequency of serve is to achieve 10-20 times / min, toss disk drive is not speed of motor:

$$v = 2R/60/n = 1.34cm/s$$

$$n = 1/42/v = 56rad/min$$

D. Squeeze Ball Wheel Speed Motor Selection

Due to selected motor, it has speed control function, and because 24v battery-powered, power is not high. Squeeze out enough to drive round tennis ball. Squeeze ball round power formulas reference gear.

Tennis transmitter design speed motor is rated at 30W

So finally select gm37 brush DC motor

Motor parameters are shown in Table 1.

b) Accuracy of selection. Tennis emitter is outdoor general working machine, precision in general, so selection is 7-level precision. (Gb10095--88) [3]

c) According to the design, squeeze ball wheel drive is selected.

d) Expected squeeze ball a rotor diameter of 15-25cm.

2) design according to strength of tooth surface contact

a) determine calculated values in the formula

$$\textcircled{1} \text{ Test } d_1 \geq 3 \sqrt{\frac{2K_t T_1}{\phi_d} \frac{u \pm 1}{u} \left(\frac{Z_E Z_H Z_\epsilon}{\sigma_{HP}} \right)^2}$$

selected load factor $K_t = 1.3$.

$\textcircled{2}$ Compute squeeze ball wheel torque transmission.

$$T_1 = \frac{95.5 \times 10^5 P_1}{n_1} = \frac{95.5 \times 10^5 \times 0.008}{960} = 79.584N \cdot mm \quad (1)$$

$\textcircled{3}$ Affect elasticity coefficient related information materials $Z_E = 189.8MPa^{\frac{1}{2}}$

$\textcircled{4}$ According to tooth surface hardness squeeze ball round fatigue strength limit $\sigma_{Hlim} = 450MPa$

$\textcircled{5}$ Calculate stress cycles

$$n=60nj=60 \times 960 \times (2 \times 8 \times 300)=4.195 \times 10^9 \quad (2)$$

⑥ Take contact fatigue life factor $K_{HN} = 0.85$;

⑦ Calculate contact fatigue allowable stress.

Take failure probability of 1%, safety factor $s = 1$,

$$[\sigma_H] = \frac{K_{HN} \sigma_{lim}}{S} = 0.9 \times 600 = 540 MPa$$

b) Calculation[3]

① Calculate squeeze ball pitch diameter d , into the smaller value of $[\sigma_H]$.

$$d \geq 2.323 \sqrt{\frac{KTZ_c(u+1)}{u[\sigma]^2}} = 2.323 \sqrt{\frac{1.3 \times 9.898 \times 10^4}{1}} = 10.92 cm \quad (3)$$

② Calculate peripheral speed v .

$$v = \frac{\pi d n}{60 \times 1000} = 5.49 m/s \quad (4)$$

③ Calculate squeeze ball round width b .

$$b = \phi_d \times d = 1 \times 20.5 = 20.50 mm \quad (5)$$

④ Calculate tooth width and height ratio $\frac{b}{h}$.

$$\frac{b}{h} = \frac{109.2}{20.50} = 5.32 \quad (6)$$

⑤ Calculated load factor

According to $v = 5.49 m/s$, 7-level precision, load factor

$$K = K_A K_v K_{H\alpha} K_{H\beta} = 1 \times 1.12 \times 1 \times 1.432 = 1.594 \quad (7)$$

⑥ Formula of elastic potential energy is transferred into kinetic energy:

$$\frac{1}{2} kx^2 = \frac{1}{2} mv^2 \quad (8)$$

(x is compression amount)

Calculate elasticity of squeeze ball

Elastic coefficient of squeeze ball is selected as follows:

$k=178.3$ n/mm

$$x = \sqrt{\frac{mv^2}{k}} = \sqrt{\frac{0.056 \times 10^2}{178.3}} \approx 6.56 \times 10^{-3} m = 0.656 cm \quad (9)$$

So two round tennis balls squeeze compressive deformation is 0.656cm.

And because tennis under extrusion range is 0.559cm-0.737cm.

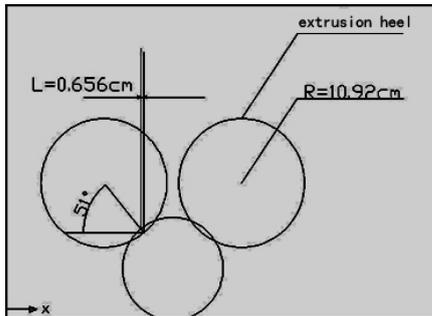


Figure 4 Squeeze Ball Round Radius Design

3) Squeeze ball round radius is designed:

$$R = 178.3 \frac{x}{\cos 51^\circ} \approx 11.68 cm \quad (10)$$

Design (Fig. 4) of gear that meets tooth surface contact fatigue strength, but also meets tooth root bending fatigue strength, and achieve a compact structure, to avoid waste.

V. ERGONOMICS INVOLVED IN TENNIS SERVE MACHINE STRUCTURE DESING

Tennis serve machine is a kind of exercise equipment, and its design to meet requirements of sports equipment, security, stability, reliability and operational suitability. Serve machine for security mainly refers to machine not to harm practitioners; when tennis serve machine balls have a relatively large recoil, stability, reliability is very important. A good product is not only to meet physiological needs of users and psychological needs. In this paper, tennis serve machine appearance, line style, color perception and other visual effects make further consideration. In human-machine relationship product, human is operator, machine is machine. In tennis serve machine-machine relationship, people are practitioners of machine tennis serve machine. Human-machine relationship is shown in Fig. 5.

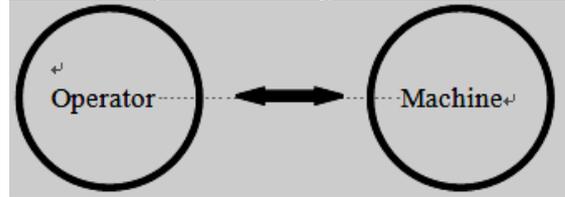


Figure 5. Human-machine relationship

Human in human-machine system is most important, most active part, but also most difficult to control the link. The study of human characteristics is basis of ergonomics. In order to make a variety of design objects and human-related physiological characteristics of people, people in use of the state in a comfortable and appropriate environment, should be fully considered in design of human body in a variety of sizes. Anthropometry is determined by measuring difference in size of various body parts on your body size between individuals and groups for study of human morphology, thereby providing anthropometric data for a variety of industrial design and engineering [4].

Tennis serve machine design, main consideration of human dimension has height, arm length, forearm length, thigh length; high eye tall at shoulder, elbow height range of human activities. The ergonomic design is mainly involved in following aspects of for tennis sport.

A. Model Design of Tennis Serve Machine

Product model design should meet aesthetic taste of people currently possible to guide and improve aesthetic awareness through compelling public good design maximum. Serve machine exterior design for a bold breakthrough in pursuit of streamlined import other design elements. In a circular arc instead of a straight line, pay attention to appearance and smooth shape, giving a clean and beautiful and durable feel. Combination of arcs and straight has smooth lines, concise, very dynamic vitality and joy of life [5]. Tennis serve machine overall sense and style must have unity, and whole line style harmony is most important aspect

to achieve a unified effect. First, subject line should be coordinated, and it constitutes a large Tennis serve machine broadly consistent linear geometry of outline and should constitute main part of the curve, secondary site should be smooth transition.

Since device of type emitted tennis for all types of spin, practitioners can be corrected in next for a spin on weaknesses. It can be targeted to strengthen practitioners then spin technology. Meanwhile, an injury to reduce practitioners need for a high degree of device will be enough. Practitioners in ready position when ball and stop bits feet of natural open shoulder width, knees slightly bent, feet off ground, focus falls on front foot palm, beat about head with a high waist and pointing at each other, two foot kept gently beating or body shaking slightly, his eyes tightly watching tennis serve machine tee height, orientation, etc., so design practitioners tennis serve machine main consideration when standing in space. When people standing space depends not only on body size, but also on body to maintain balance while standing flat minor balancing act and muscle relaxation foot unchanged, in order to maintain a balance must be limited to upper body and arms can reach space. Under this condition, it is standing space of human scale [6]. Standing human activity space is shown in Fig. 6.

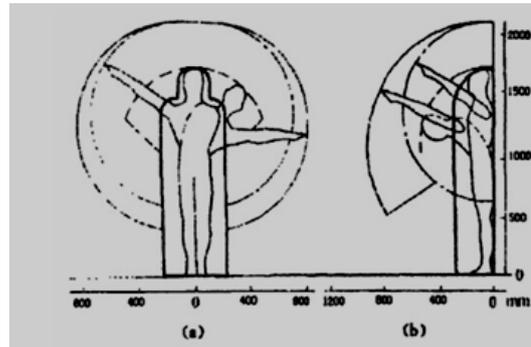


Figure 6 Standing Human Activity Space

Ergonomics uses anthropometric data percentile to represent human dimension level [7]. Due to space as possible to adapt to vast majority of people use a high percentile should be designed based on human dimension. Tennis serve machine emitted a rebound after landing, and bend grip practitioners, in order to make people comfortable, choose 50th percentile data. P50 represents 50% of population figure dimensions are smaller than this value, while 50% of population size is larger than body. Tennis is a life-long training exercise, the design of tennis serve machine to 18 to 60 year-old male body size data-oriented features, and specific data is shown in Table 2 below.

TABLE II. 50TH PERCENTILE HUMAN DIMENSION OF 18 TO 60 YEARS' OLD MALE

UNIT: MM

Height	Uparm length	Shoulder width	Forearm length	Thigh length	Leg length	Elbow height
1678	333	375	237	465	369	1024

Tennis serve machine launch exports from ground height 200mm. In general, when people standing working, more comfortable working height than standing elbow height 10 to 50mm, elbow press P50 standing body height calculation operations, Tennis serve machine is across field, and net distance is 2m. Then practitioners can stand 1.2m after a tennis ball to placement of tennis center, within a radius of 900mm range, to find best ball position to prevent causing bodily injury.

Install two casters on tennis serve machine base, and it is easy to carry. Appearance of tennis serve machine is mainly P50 consider lifting body posture. Tennis serve machine can prevent fatigue caused by people, and its maximum width is determined to 684mm, less than width of car trunk, easy to put into a car trunk, while meeting people stoop lift machine maximum width. Men in one hand bend posture maximum output is 16Kg, but after taking into account practitioners finished practicing tennis, physical exertion, so total weight of tennis serve machine is less than 25Kg, and it can use less dense material composites. Prevent a comeback hit tennis serve machine to generate momentum, resulting in its instability and locking device.

B. Exterior Color Design of Tennis Serve Machine

As one of product appearance main elements, color is aesthetic and decorative, meaningful and symbolic semiotics. Color products are from human visual perception and physiological stimuli, and resulting experience and physiology association [8] [9]. As another element of

product design modeling, color is irreplaceable way to convey information and one of the most attractive design tools. Color can make appearance of proper landscaping, and good product color design can be more landscaping improve appearance quality, allow operator to feel happy and joyful and improve work efficiency [6]. Use of bright colors, it is colorful, bold and has strong visual impact. Focus on artistic interest compound interest personalized products to meet spiritual needs of modern and individual performance.

Tennis serve machine is a sport equipment, where its color is simple, more simple there will be more eye-catching color, the stronger the overall sense. Body tone tennis serve machine is determined to be red because red belongs to warm colors, people will have lively, happy, excited feelings arousing the enthusiasm of practitioners play, delaying fatigue and mental fatigue sportswear. With use of yellow and red to increase interest of practitioners.

C. Security Design of Tennis Serve Machine

Security is human survival, life and development eternal theme. Security refers not causing injury, occupational disease, condition, or death caused by equipment or property damage, or harm and conditions [6]. Tennis serve machine design should also consider security issues.

Tennis is a public place, staff more mixed. In addition to tennis practitioners, there may be other bystanders. In this case, Tennis serve machine not only serves function, but also pays attention to prevent others from across machine, causing unnecessary harm. Its surface marked by a symbol

danger signs place; in addition, occasionally touching tennis machine problems also appear to strike back, which also requires its shell should have certain strength of material. If machine noise interferes with practitioners and others, it should avoid tennis serve machines emit excessive noise, causing environmental pollution. Therefore, to deal with major institutions Tennis serve machine reinforcing bars were carried isolation rubber or cork base, reduced machine vibration and reduce noise; sound absorbing materials and insulation materials sound absorption structure, set in machine surface to prevent direct transmission of noise.

D. Tennis Serve Machine Control Panel Design

For design of control panel it should consider human factor, color distribution shape, and position of region to arrange keys, in order to give practitioners most convenient experience, start from practitioners to use habits, so each built in control layout on panel as more reasonable and easier usage.

Overall shape of o main control panel and associated staffing structure, both to ensure omanpower to cover most of ocontrol panel, key design can not be too small, so that o operation becomes inconvenient. Taking into account o different size of o staff, on the basis of ergonomics at size popularity of measured statistical processing, indicating size of index position in crowd with a percentile, control panel can use the first 50 percentile data as basic dimensions. Hand muscles distribution is shown in Fig. 7.

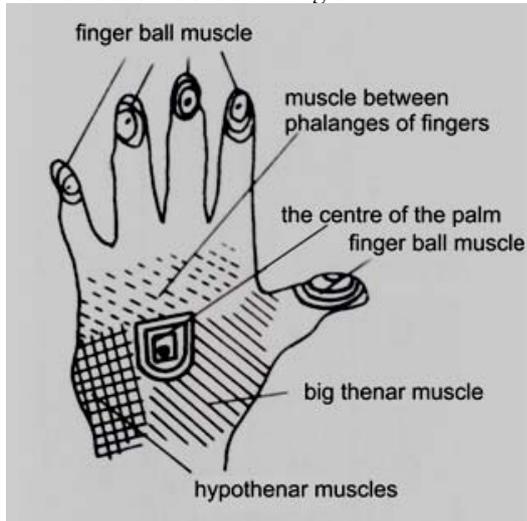


Figure 7. Distribution of Manpower Muscle

Main form of buttons and size of finger muscles is urging finger size. First, thumb button design size 95th percentile of muscle size as basic design data, according to people's daily habits, hand equipment (such as when wearing gloves) and psychological demands correction, can be used to produce results data. According to fingertip force applied map, select oval button shape; button rounded edges to avoid partial processing sharp force; spacing between keys with thumb finger width of design basis, so as not to touch adjacent keys bit principle[10]; key arrangement is designed to meet

people's cognitive habits, operating practices[11]. Use different colors to distinguish different keys.

VI. CONCLUSIONS

In the paper, design principles, overall structure and ergonomics of tennis service machine have been studied totally. Various parts of tennis service machine were calculated and checked, although this is more complicated, more precise and accurate calculations can select desired components, and ensure machine running in good condition, to avoid some problems caused by wearing, and even damage, so that it can extend machine life[12]. From size of various components of stiffness to motor power, speed has carried out detailed research, calculation and check. It will manufacture and carry a lot of good work in this field tennis service machine in industry can be more widely used[13]

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