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DESIGN OF AUTOMATIC VIBRATING CHAIR WITH ECCENTRIC-AND-PITMAN FOR PROLONGED SEDENTARY ACTIVITIES

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Abstract. Sedentary behavior has become one of main inducted cause of physical decline. The pressure of modern life has further increased more working or studying time at home or office, contributing to the growing population of sedentary people furthermore. Prolonged sitting will affect people's physical health, injuring our muscles, and causing physical discomfort. Seriously, it will lead to death. The purpose of this paper is to design a small convenient automatic vibrative chair for sedentary groups, which are driven by eccentric-and-pitman drive system, producing vibration and body movement to relieve physical problems. Double diamond design thinking method was used to find out the health problems including sedentariness and isolation. As a solution, design of the vibrative automatic chair was set as the theme of this study. The automatic vibrative chair was designed with biomimetic method, combining with industrial design principles and mechanical theories throughout structural design. The vibrating performance of the chair was verified using simulation method by adopting SolidWorks software.

Keywords: *Automatic vibrative furniture, chair design, eccentric-and-pitman, sedentariness, post-pandemic era.*

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1. Introducion

Sitting is one of the most common actions of human body (Harrison *et al*., 1999). Many people worldwide engage in sedentary lifestyles. Working and studying takes up most of our time and people were forced to restrict their movement so that outdoor activities has been substituted by prolonged sitting. There are quite a lot of careers involved with long time sitting or even overtime sitting such as school students, factory workers and office staffs. However, sedentary lifestyles still have a major impact on the overall health of the global population. Sedentary lifestyle related health problems have rapidly increased in recent years (Underwood & Sims, 2019). There is an evident relationship between lack of physical activity (sedentary behavior) and healthy problems

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such as obesity, metabolic syndrome, aging with diminished immune and viral defenses (Lim & Pranata, 2020), hypertension (Pardee *et al*., 2007), adverse metabolic markers (Ekelund *et al*., 2006), poorer mental health (Primack *et al*., 2009), body discomfort, pain and even injury, particularly to the neck and shoulders and lower back (Chen *et al*., 2021). Sedentary behaviour is associated with deleterious health outcomes, which differ from those which can be attributed to lack of moderate or vigorous physical activity (Tremblay *et al*., 2010). Furthermore, some researchers have found the health problem that sedentary behavior can deteriorate the existed diseases of human being (Owen *et al*., 2010). Ricci (2022) also reported that insufficient physical activity, that is, prolonged sedentary behavior, has a detrimental effect on health, but people do not know the worst result of insufficient physical activity in terms of sedentariness related to death. Physical inactivity is the fourth leading risk factor for global mortality, accounting for 6% of global mortality (Ricci *et al*., 2020). The scientific report has put forward a conclusion that an energy expenditure of ≤1.5 metabolic equivalents while in a sitting (Diamond & Byrd, 2020). As a result, sedentary sitting is extensive and unavoidable and it is of great significance to come up with a chair which can relieve the negative effect of sedentary sitting.

Whole-body vibration (WBV) was introduced in the late 1990s and over the past decade (Milanese *et al*., 2018) such vibrational experiment depends on vibration Intensity. Human's feeling on different vibrations may vary from vibration intensity. The intensity of vibration varies according to the vibration frequency or the number of oscillations per second. Vibration intensity is commonly measured in hertz (Hz). In the literature, Salimath & Tuljapure (2023) conducted research that vibrative chair with a frequency of 5 Hz & amplitude of 7.5 mm helps people reducing insomnia and fatigue, which may improve sleepers' health. Du et al. (2018) examined that reducing whole body vibrations help reduce discomfort and maintain vigilance, which may improve drivers' health and also reduce the risk of truck collisions. Zhang et al. (2018) investigated the effects of whole body vibrations of 4–7 Hz for 60 min delivered through the car seat, which helps drivers increased sympathetic activation avoiding the sleepiness. Kim et al. (2013) focused on the design of the special chair which the vibration transfer characteristic of a foaming sponge seat. Christopher (2009) investigated the effects of a vibration chair for patients with Parkinson disease (PD) on vibratory therapy, patients with daily 30-minute sessions in the automated vibratory chair were more comfortable and slept better after a training. The result is that below 10 Hz frequency vibration is only for avoiding sleepiness, and it is far from enough if vibration chair increases additional function demand, for example, the requirement of weight loss on different frequency regulation. In order to experience a better feeling such as relaxed body muscles, alleviated physical discomfort and reduced body weight, some studies have investigated whole-body vibration through experimental tests and provided with common vibrative standards. During WBV, the subject stands or exercises on a platform, which vibrates at set frequencies (typically between 15 and 70 Hz) and amplitudes (typically between 1 and 10 mm) (Milanese *et al*., 2018). Gonzaga (2022) pointed out that most vibration trainers operate in a limited range of 15 Hz to 30 Hz, while some are within 30 Hz to 50 Hz. The vibration frequency must also be kept at a low intensity, although increasing the vibration intensity is possible only for a limited time (Gonzaga, 2022). The recommended time for using a vibration facility to exercise is 15 to 30 minutes per session, with 2 to 4 sessions per week (Gonzaga, 2022). Furthermore, the similar experiment including vibration of human subjects designed by Mohajer et al. (2017), vibration on the seat cushion for 65 kg human subject. The results suggested that the design of vibration chair should have variable vibration functional setting limited range in 15-30 hertz and the amount of bearded 65 kg weight. Additionally, the vibrational regulations rely on the design of the mechanical device. Therefore, it is critical to design the vibration through mechanical device such as Pivotal Oscillation, Lateral Oscillation, Linear Vibration, Complex Motion and Solenoid Oscillation. Related studies experience a series of vibrative design in healthcare technique. (1) Pivotal Oscillation, which moves like a sea-saw. Its upper platform oscillates around a fixed center pivot axis. (2) Lateral Oscillation, a 4-bar device, which is designed to produce left-right lateral oscillation. (3) Linear Vibration, it moves mainly in the vertical direction, with modest horizontal movement. (4) Complex Motion including eccentric-and-pitman drive, which combines planar 4-bar device (s) and eccentric wheel device to generate a complex motion pattern. (5) Solenoid Oscillation is an actuator suitable for generating reciprocating movement for vibration (Gonzaga, 2022). All the five kinds of vibration devices can generate a certain vibration respectively. Considering the stability of the vibrative chair, Complex Motion was used in this study.

Vibration facility is essential for sedentary health. Therefore, this paper focusses on research on creative design of a convenient automatic vibrative chair. This automatic vibrative chair is designed by using double diamond design thinking method and eccentric and pitman drive is adopted to generate abrasive movement function driven by electric motors. The chair is designed for sedentary people, light and portable, which can relax body muscles, alleviate physical discomfort and reduce body weight through vibration.

2. Design methodology

Double diamond design thinking method (Gustafsson, 2019; Tschimmel, 2012) was developed in 2005 as a simple graphical way of describing the design process (Council, 2015; Gustafsson, 2019). The Double Diamond design process is a widely taught and applied in the process of design. It was created following a study of 11 large corporations and their internal design processes. This research method is very practical in industrial design.

2.1. Design framework

Double diamond design thinking method was composed of four parts including discovering, defining, developing and delivering. In other words, a more detailed definition, the whole process consists of identifying the problem, defining the theme, exploring and developing the concept and finally evaluating.

In this research, firstly, we should investigate the problems in the current situation of the increased number of sedentary people (Liao *et al.*, 2022), while this habit of sedentary sitting itself would cause a lot of health problems. The objective of the research is to design the automatic mechanization, portability, beauty of chair. Secondly, the theme of designing a vibrative automatic chair was set for consuming that it would be a solution to the problems caused by sedentary sitting. Thirdly, ideation of chair design was conducted in several aspects. The appearance design is based on the biomimetic design, where the shape is imitated as flowers in nature. The flower’s stalk and bud look elegant and light. The ball of chair imitates the bud of flower, the chair’s legs imitate the stalk. The interior structure is to be completed with theories of industrial design and mechanical engineering design to realize reasonable selection of components and arrangement of inner space as well as adoption of structural materials. Among all interior structures, eccentric-and-pitman drive is the core structural component to realize the function of activating vibrative movement so as to relax muscles and relieve body discomfort. All the chair structure can be verified by model creating and movement simulation with help of industrial design software SolidWorks. Thirdly, the process of chair design is conducted, followed by design optimization, 3-D model creating and vibrative movement simulation. The simulation sets the input intensity at about 65kg body weight, with the upper and lower iron plate of $30 * 30cm$. The vibration displacement, velocity and frequency data of the chair are the output parameters showing the vibrative performance of the chair. Finally, the feedback will be test in simplified vibrative cushion, randomly selected eight experimenters were participated in this experimentation (As is shown in Fig 1).

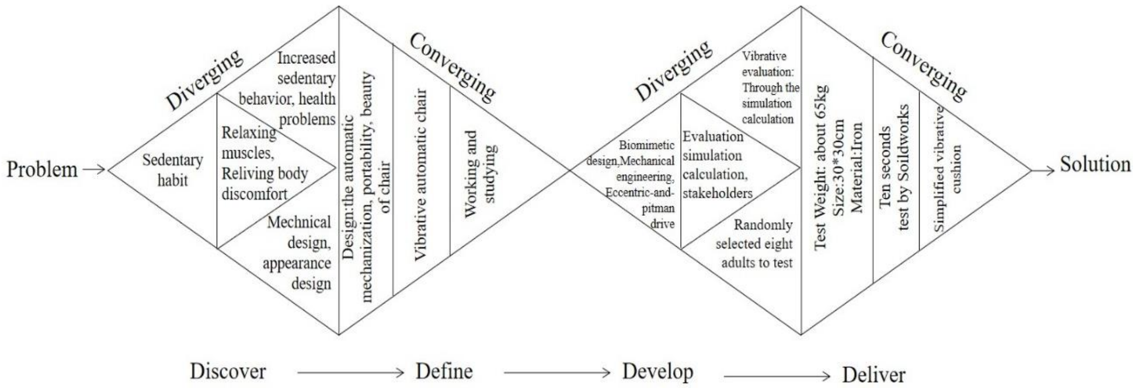


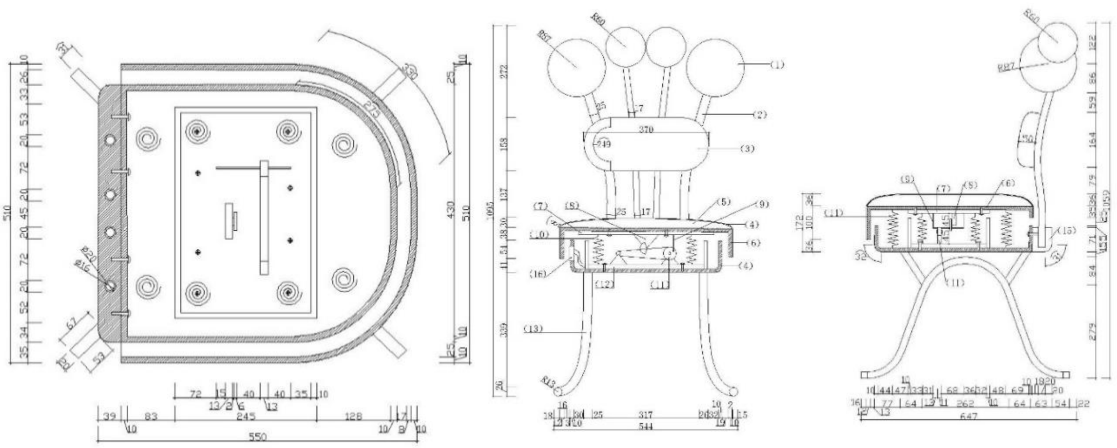
Figure 1. The overall structure of double diamond design thinking method
Source: Jie Deng, 2023

Small convenient vibrative chair is designed to achieve physical movement through motor vibration, mainly for sedentary groups. The ideation is an important aspect of furniture design. The inspiration of appearance design is derived from the shape of natural flowers based on the study of bionics (Junior & Guanabara, 2005).

Considering the demand for industrial production, transportation as well as maintenance, the chair was designed to be detachable. As a result, all parts of a chair are easy to be assembled and extremely convenient for mass production. The back of the chair is to use metal material with one-time bent molding technology. The curve of back is designed to adopt the principle of human engineering linked with the characteristics of the spine. Soft cushion is designed to be installed on the back of a chair on the spine and neck part, which is not only beautiful but also considerably comfortable. The shell of the chair is shaped by one-time plastic molding or 3D printing technology, which is also with soft cushion attached to the surface to increase comfort. The chair consists of upper and lower layers of plastic plate. The internal structure is equipped with a vibration box and connected with an electric plug which is designed for connecting with external power supply. To strengthen the chair, the bottom of the chair is added with a metal panel. The base of the chair is made of a metal material with one-time bent molding technology which is easy to install and remove (Fig 2). Traditional vibration equipment usually needs special environment and tools to fabricate, of which the volume is sometimes large. Besides, commonly classified chairs, which do usually provide limited functions like sitting and rest, could not meet special needs of sedentary groups who are lack of exercise. On the contrary, the vibrative chair studied in this paper is designed to be portable and is combined with both functions of the ordinary sitting and body relaxation by vibrating movement.

2.2. Design construction

The construction design of the vibrative chair in this research was conducted by software CAD and Blender. CAD-based software system can manage the entire design process by simulating and analyzing the optimal positions of the measurement system (Germani *et al*., 2010). Chair construction drawings were drawn in top view, front view and side view by using software cad. After coming up with a construction drawing of a chair by CAD, software blender was used to build the image of the product.



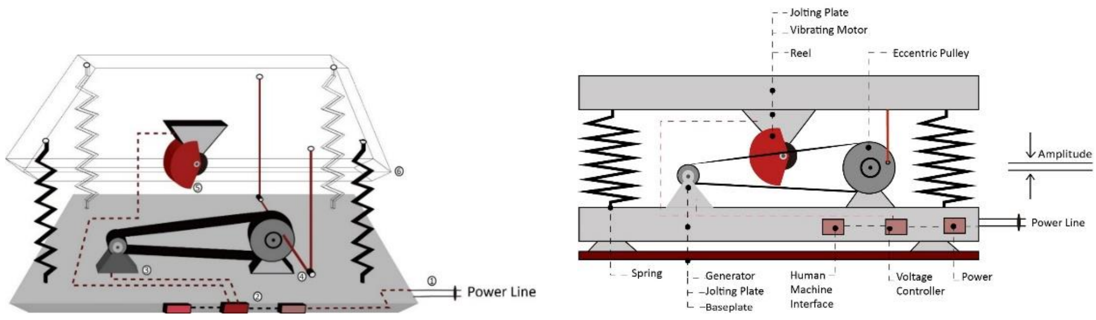
a. The top view b. The front view c. The side view

Figure 2. Automatic vibrative chair and construction. (1) - Neck Cushion (Spinal Mat); (2) - Metal Back Chair; (3) - Waist Cushion (Backrest); (4) - Fabric Cushion; (5) - Spongy Cushion (Soft fabric); (6) - Chair cover; (7) - Vibration plate; (8) - Eccentric Wheel; (9) - Transmission Bar; (10) - Spring; (11) - Crank Pulley; (12) - Motor Mounting Base; (13) - Chair Foot; (14) - Chair Internal Spring; (15) - Chair Back Embedded unit; (16) - Control panel.
Source: Jie Deng, 2023

Similar to a small vibrating vehicle chair, of which the main technique includes an internal motorized vibrative device (D'Amore & Qiu,2021) which is connective with mechanical engineering approach to design product (La Rocca & Van Tooren, 2007), the convenient vibrative chair in this study also adopts the internal motorized vibrative devices. The mechanical and electrical driven devices were installed inside the chair and four internal springs were used to support the chair. Transmission mechanism adopted connecting rod gearing mechanism, eccentric wheel and springs to acquire the vibrating function. The vibration of the chair could be adjusted by the extension and withdrawing movement of springs connected with rod gearing mechanism. Eccentric wheel was used to strengthen the vibration effectiveness. As a result, the vibrative chair was facilitated with two sets of vibration mechanisms devices which functioned cooperatively to realize reliable vibrative movement. The vibrative chair could be adjusted with the vibration frequency and intensity selectively according to the user's need.

2.2.1. Eccentric-and-pitman drive optimization

The vibration principle of the chair is explained as following. The vibration plate is connected with the base by four springs and the middle position of the vibration plate installs an eccentric wheel which was driven by an internal motor inside to produce a high-speed vibration for the vibration plate. The base of the chair is equipped with a motor belt drive device producing another vibrating movement source for the chair, the following wheel of which was connected with a transmission rod near the outer side. The other end of the rod is hinged with the vibration plate. These four parts constitute a crank-link mechanism. The belt pulley moves as the crank passing through the belt after the motor, by which the vibration plate is driven up and down. The vibration plate acquires the high-frequency vibration under the dual functions of the eccentric wheel and the motor belt drive device and the combined vibration is finally transmitted to the human body from the chair (Fig. 3).



a. Three-dimensional image b. The elevation

Figure 3. Eccentric-and-pitman drive
Source: Jie Deng, 2023

2.2.2. Design of link drive mechanism

Hypothesized capacity of the convenient chair is to carry a person of *65Kg* weight and overcome the inertia force due to drive vibration. As a result, the vibration process requires the transmission mechanism to have a great load capacity. The link drive mechanism is considered as the main transmission structure to achieve up and down vibration. Schematic diagram of link gearing mechanism illustrates that the mechanism is mainly composed of crank *1*, connecting the rod *2*, chair vibration plate *3* and frame *AB*. In order to maintain continuous vibration, it is required that the transmission mechanism must contain a crank *1*, which can be realized by a pulley in the belt drive. To generate crank *1* in the transmission mechanism, the size relationship of the four structures should satisfy the principle of rod length (Fig. 3). Combined with the appearance and size requirements of the chair, the following formulas should be satisfied.

$$
\begin{gathered}
L_1 < L_2 < L_{AB} < L_3 \\
L_1 + L_3 < L_2 + L_{AB} \\
L_1 + L_2 < H_{(1-1)}
\end{gathered}
\qquad (1)
$$

where, L_1 is the length of crank *1*, L_2 is the length of link *2*, L_3 is the length of chair vibration plate, L_{AB} is the length of the frame and H is the height of a chair. Note: There should be a large medium link transmission mechanism. The detailed design process of the connecting rod mechanism can be designed as follows, see in Figure 4.

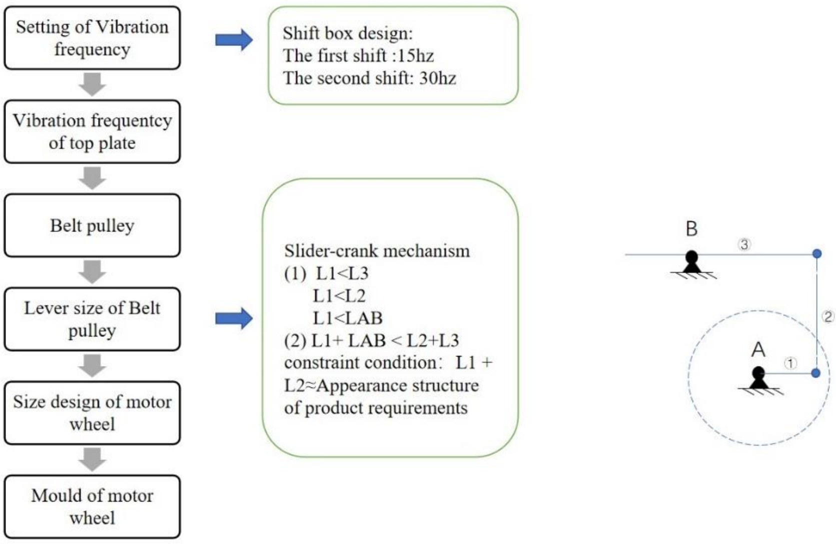


Figure 4. Schematic diagram of link gearing mechanism
Source: Jie Deng, 2023

2.2.3. Design of eccentric wheel vibration mechanism

In order to acquire vibration with high frequency and proper amplitude, the eccentric wheel vibration mechanism connecting with rod transmission vibration mechanism was set in the middle position of internal space of chair. This eccentric wheel vibration mechanism is shown in Figure 5.

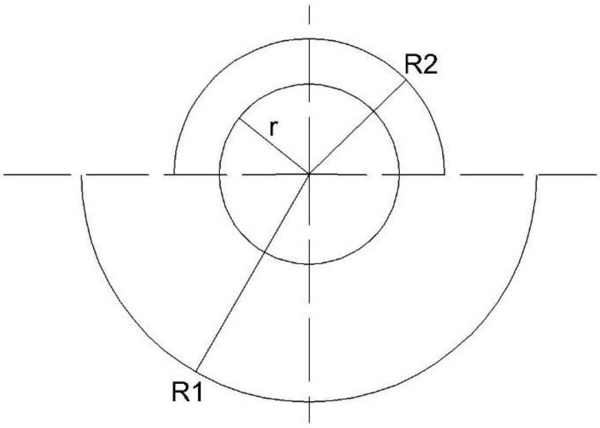


Figure 5. Semicircular eccentric wheel mechanism
Source: Jie Deng, 2023

Eccentric wheel adopts semicircular eccentric wheel mechanism, which is to be manufactured by carbon structural steel. In the figure 5, R_1 is the external radius of the semicircular eccentric wheel, R_2 is the external radius of the installation shaft of the semicircular eccentric wheel, *r* is the radius of the installation shaft of the eccentric wheel, and the axial length of the eccentric wheel is L. The chair vibrates under the action of the vibrating eccentric wheel and the vibration frequency *f* is determined by the speed of the eccentric wheel.

$$f = n/60. \quad (2)$$

Here *n* is the speed of the eccentric wheel, and the speed of the *DC* motor is set as n=100 *rps*（rounds per second. Eccentric wheel vibration mechanism should be able to vibrate the chair and the seated human body when working alone at high frequency. The centrifugal force *F* of the eccentric wheel part should overcome the gravitational sum *G* of the chair and the seated human body, resulted in $F > G$. When the eccentric wheel rotates, the centrifugal force would be generated. And the centrifugal sum force *F* is the difference of centrifugal F_1 of the larger semicircle and the centrifugal force F_2 of the smaller semicircle.

$$F = F_1 - F_2 \quad (3)$$
$$F_1 = m_1\omega^2 r_{1\ barycenter}$$
$$F_2 = m_2\omega^2 r_{2\ barycenter}$$

where, m_1 and m_2 are respectively the quality of the big and small semicircles of the eccentric wheel. $r_{1\ barycenter}$ and $r_{2\ barycenter}$ are the radiuses from the center of gravity of the larger and smaller semicircles of the eccentric wheel to the center of the circle. *ω* is the angular velocity of the eccentric wheel.

$$m_1 = 1/2\,\pi R_1^2 L\mu, \quad m_2 = 1/2\,\pi R_2^2 L\mu \quad (4)$$
$$r_{1\,barycenter} = 4R_1/3\pi, \quad r_{2\,barycenter} = 4R_2/3\pi$$
$$\omega = 2\pi n.$$

Then,

$$F = 8/3\,\pi^2(R_1^3 - R_2^3)L\mu n^2$$

To meet the requirements of appearance structural design, parameters of eccentric wheel mechanism follow $R_1 = 0.025m, R_2 = 0.005m, L = 0.1m, \mu = 7\,800\ kg/m^3$ and $G = 1500N$. Calculated $F\ is\ 3178.7N$. Therefore, $F > G$ is satisfied, meaning the designed eccentric wheel mechanism could vibrate the human body.

3. Result

3.1. Analysis Method by Simulation

SolidWorks software is used to test and analyze the effectiveness of product design, which can provide real-time feedback (Popa & Popa, 2017). Models will behave differently when design changes occur (Planchard, 2017).

In this paper, internal vibrative structure of automatic vibrative chair was simplified in order to simulate vibration by SolidWorks. Firstly, simplified models of different structural parts of the chair were created and the whole three-dimensional model of the chair was assembled in the SolidWorks environment. Secondly, COSMOS Motion Module of SolidWorks was plugged in simulation analysis and the output results are characteristic motion curve of displacement and speed of vibrative plate as well as energy consumption curve of the motor.

3.2. Output and Analysis of Simulation

Simplified SolidWorks model of chair, the SolidWorks simulation model of the vibrative chair is shown in Fig 6. It can be shown that the chair can achieve very good combined reciprocating motion in a vertical direction.

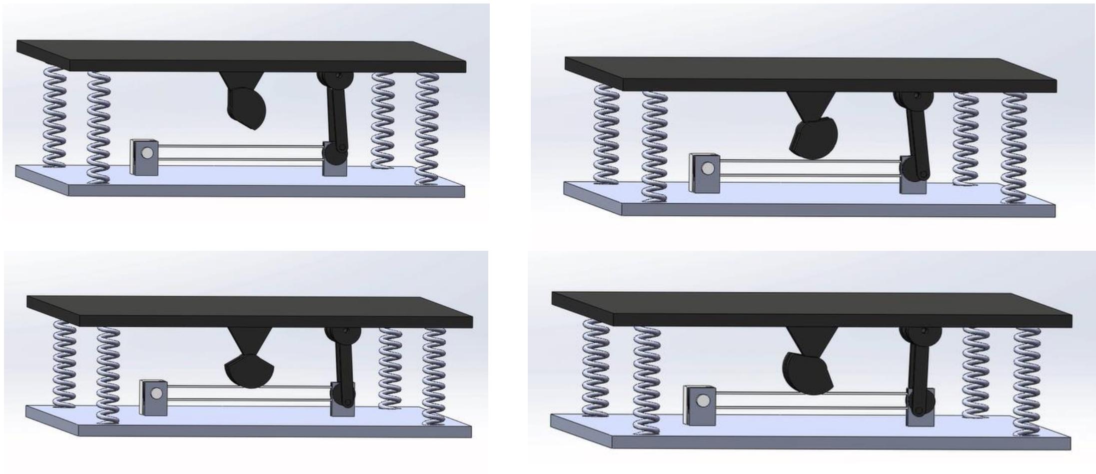


Figure 6. SolidWorks Simulation calculation
Source: Jie Deng, 2023

Simulated motion curves were put forward, shown as in Fig 7. The motion curves included curves of displacement, speed and motor energy consumption related to time under vibrative motion driven by an eccentric wheel and crank connecting rod mechanism together. The displacement curve shows that the chair could achieve reciprocated vibration with the maximum amplitude of 2mm and vibration cycle of 0.6s, which can satisfy the vibrative need of the human body within the bearable range. The speed curve shows that the maximum vibrative velocity of chair is 79mm/s. The motor energy consumption curves show that the total average consumption power of two eccentric wheels is less than 70 w. As a result, the vibrative chair is energy-saving. Motion curve is the reflection of the motion characteristic of vibrative chair. Adjustment of parameters such as motor speed or physical parameters of eccentric wheel can change the motion characteristics of the vibrative chair, which is corresponding to different motion curves. The corresponding relationship between adjustment of parameters and motion curves can be used to optimize vibration characteristic design of the chair.

The first step is to establish the corresponding mathematical model which is expressed by the theoretical formula with parameters related to physical parameters of vibrative chair such as wheel speed and rod length. Secondly, the COSMOS Motion module in SolidWorks is used to simulate the vibration motion process of the chair under the combined condition of the two vibrating mechanisms. The motion curves will be generated and the motion characteristics will be analyzed. Finally, physical parameters of vibrative chair such as motor speed or parameters of eccentric wheel can be adjusted to optimize the vibrative curve, satisfying the requirement of apparent design and customer needs to the maximum degree.

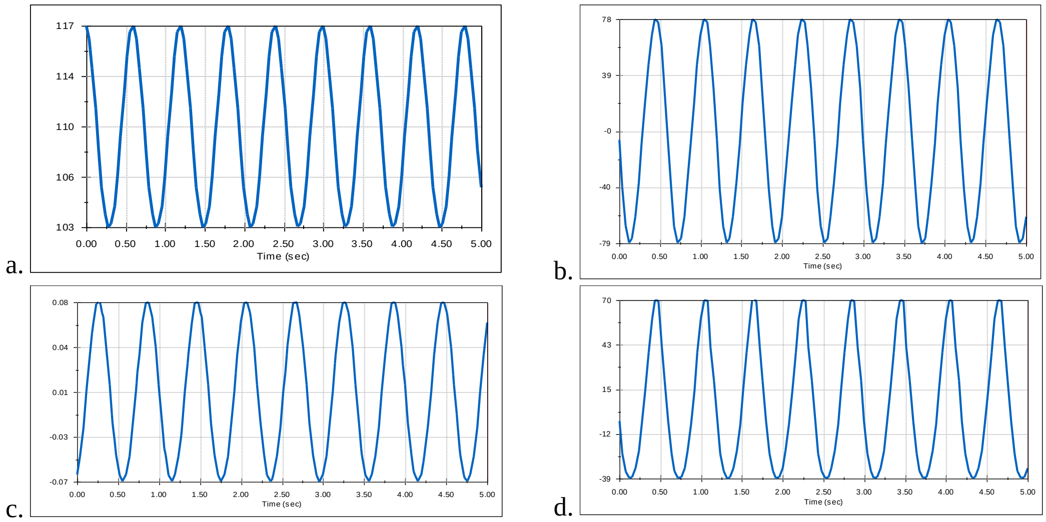


Figure 7. Motion Curve Results of Simulation
a. Displacement of Vibrating Plate Related to Lower Plate – Amplitude is about 2mm.
b. Vibrating Velocity of Vibrating Plate-Amplitude is about 79mm/sec.
c. Energy Consumption of Upper Eccentric Wheel.
d. Energy Consumption of Lower Eccentric Wheel.
Source: Jie Deng, 2023

4. Evaluation: vibrative chair

The design evaluation randomly invited eight adults to test the vibrative chair and provided feedback on this research's design process and implementations. The eight adults had the same habits in prolonged sedentary activities while working or studying. The researcher recorded the feedback.

4.1. Experimental process of vibrative chair

In this research, the function of the vibrative chair was to test in SolidWorks and the engineer's technical design was adequate. The limitation of products is the cost saving and this product did not get any funding to support production. However, the researcher used the simplified vibrative cushion, which has the same function as the vibrative chair, to test and get feedback from the experimenters (Fig. 8). The feedback feels like an actual chair and the experimenters will feel the vibration through the seat cushion.

The dimension of the test chair is $420cm * 500cm * 900cm$, and the dimension of the simplified vibrative cushion is $35 * 38 * 10cm$ (length, width and height).

4.1.1. Description of experimental procedure

Firstly, the simplified vibrative cushion is to put on the office chair and the distance of the tested chair behind the wall is 1000mm. Secondly, the experimental subjects respectively experience the test of the vibration process through the cushion and the researcher takes photos and records the whole experimental process. At the end, eight adults will share their feelings and summarize the experimental situation after the experimental subjects have completed the record (Fig. 8).

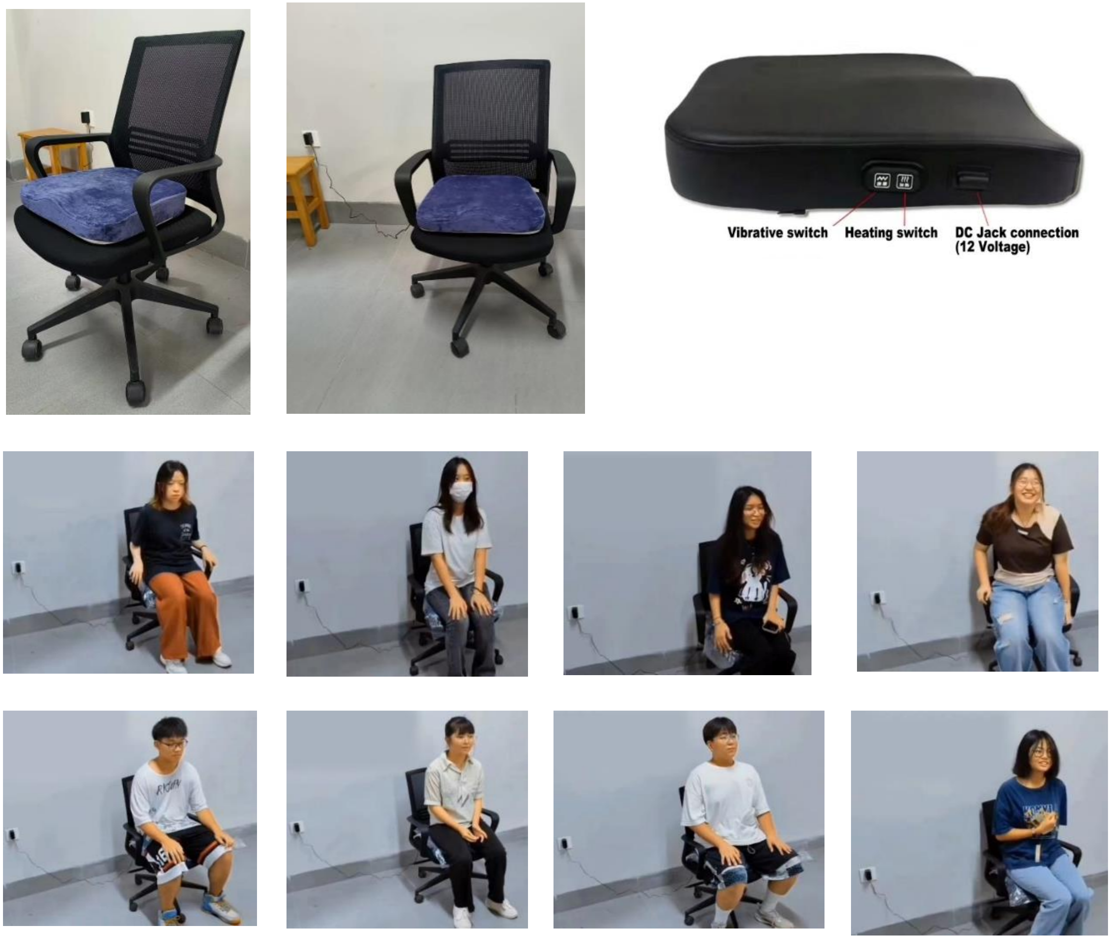


Figure 8. The vibrative experimental process
Source: Jie Deng, 2023

4.1.2. Summary feedback

Compared with the ordinary chair, the vibrative chair makes people more comfortable and relaxed. The feedback of the majority is that it can solve the discomfort and fatigue caused by sitting for a long time. The ergonomic design improves the sitting problem and is more humane (Table 1). Keywords in this feedback will include comfort, relaxation, convenience, pleasant, humanity and reducing fatigue.

Table 1. Summary of feedback and feelings of people in the vibrative chair experiment

Experimen-ters	Summary of opinions
1	The vibrative chair makes us more comfortable sitting, relaxing our muscles and reducing the discomfort caused by sitting too long.
2	The vibrative chair relieves us of the fatigue caused by prolonged sitting.
3	The vibrative chair makes up the soft cushion, providing the ultimate comfort.
4	It is more convenient that the vibration chair allows us to adjust the intensity with different modes according to our preferences and needs.
5	The vibrative chair helps us to improve our sitting posture, which is more humane.
6	The vibrative chair allows me to naturally maintain good posture when I sit down, reducing fatigue.
7	The vibrative chair makes us comfortable and relaxed.
8	The vibrative chair allowed us to improve our sitting posture and relieve the physical discomfort of being sedentary.

Source: Jie Deng, 2023

5. Discussion

The designed philosophy of the chair follows the automated vibrative mechanisms, originally aimed to alleviate physical pain, reducing other existed and potential health problems and preventing deterioration of existed health problems for sedentary people.

The vibrating device in this research, eccentric-and-pitman drive system, is similar and comparable to those presented in lots of previous studies (D'Amore & Qiu, 2021; Goetz, 2009; ISO, 2009; Regterschot *et al*., 2014; Salimath & Tuljapure, 2022; Toward & Griffin, 2011; Walton, 2007; Zhang *et al*., 2015). These previous studies have described and analyzed the design mechanisms and advantages of their vibrative devices. In this study, the design of vibrative chair has not only considered mechanical design, but also incorporated with aesthetic and ergonomics principles. Using computer simulation to evaluate new products, researchers can not only save the cost of experiments but also quickly collect necessary data, which increase efficiency in furniture design. This research has adopted a simulation method using software to validate the vibration characteristics of the vibrative chair and examine the feasibility of its mechanical construction. The simulation results show the simulation method is applicable, which can be used as reference for other furniture designs. Various extensions can be made to the design of the chair on the basis of the design work illustrated already. The vibrative chair can be further designed to use different colors and different materials to meet the varying needs of different customers. The application places can also be extended so that market space of the chair can be enlarged. On the extension design of colors, the vibrative chair can use the most popular colors in each year. In addition to the single color of the most popular colors, combination of several kinds of most popular colors can be used as well as other colors. Different phases, brightness and purity of color can result in different effect on the appearance of vibrative chairs.

Judging by the extension design of materials, shell fabric of the chair can be matched according to the latest furniture fabrics. And metal material to provide enough strength can be substituted by high strength inorganic polymer material. Common furniture fabrics are mainly cotton fabrics, flannelette textiles, linen textiles and blended fabrics. Each different fabric material can give people a different sense of touch and seating experience. Cotton fabric chair, soft texture with good air permeability, can give a person a feeling of comfortable softness. Flannelette chair, smooth and delicate, can provide a person with a sense of mercerization. Linen chair, relative to other materials and having a stronger sense of texture, can make a person sense a simple low-key feeling. Finally, the blended chair, which has a smooth and delicate touch, can make more fashion changes. Focusing on the extension design of application purpose, the application scenarios can be extended to more purpose not only limited to sedentary people. The automatic vibrative chair can not only be used in ordinary families, but also can be used in places where the body needs physical relaxation such as factory resting room, company office and gymnasium as well. The vibrative chair can be even set in the more places such as coffee shop, theme parks and shopping centers to attract more tourists or customers. The appearance design might should be adjusted in order to support the application preference to leisure and entertainment.

On the relevance to industry, the potential application prospect is extensive, which will contribute to furniture and gymnastic instruments industry. The eccentric and pitman drive industry will benefit enormously along with success and wide application of automatic vibrative chair. The design method of automatic vibrative chair in this paper by using double diamond design method and adopting eccentric and pitman drive can also be used as reference for designing other industrial products.

6. Conclusion

Under the circumstance of number and sitting time of sedentary group has increased, this paper has put forward with the idea of designing a vibrative automatic chair driven by an eccentric-and-pitman drive system aimed to care for sedentary people. The idea is acquired by using double diamond thinking design method and the detailed design process is realized by adopting biomimetic design methods as well as industrial design methods. The final design is simulated and verified by SolidWorks software. The vibrative chair is designed to be portable and automatically controlled by switches. The simulation results show the vibrative chair designed for a 65kg person can meet the design target with sound movement characteristic and energy saving properties. The design of vibrative chair can be further extended in various aspects such as colors, materials and application purpose, which can enlarge the application places in return.

The convenient vibrative chair is still in the design process and not fabricated into real object yet. And the actual market response to the promotion of vibrative chair both for the purpose of caring for sedentary people and other purposes such as leisure and entertainment is also unknown. These can be focused on in the following studies, including product feedback from the market will improve our upcoming design.

Data Availability Statement

The datasets of simulation calculation generated during the current study are available in the Mendeley repository, Doi: 10.17632/kprgsr8hyr.2

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