Design and Research of Wrist-Assisted Recovery Robot Hand

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Abstract. With the gradual development of the times, people's material life has been greatly improved. All kinds of sports have become an indispensable part of people's life, but sports are always accompanied by certain risks. People injured by sports show an increasing trend every year. However, it can be found that among many rehabilitation instruments, there is not much research on wrist rehabilitation instruments, which leads to the restoration of bandage splint or plaster fixation in most of the time. These traditional methods have the problems of slow recovery cycle, difficult disassembly and complex replacement. At the same time, most of the wrist rehabilitation instruments that have been developed are large and medium-sized instruments, which can not be carried, can not play a real-time protective role, and can not be well applied to daily life. Therefore, a wearable periodic recovery robot with traditional strap splint, modern transmission and flexible positioning is proposed.

Keywords: Wrist-Assisted Recovery, Robot Hand, Design Research

1. Introduction

Wrist bone concentration areas, in a very small range includes including the near side of the column connected to the radial scaphoid bone, month, triangle bone, peas, bone, and the far side of the column connected to metacarpal trapezium, small Angle, magnum, hook bone bone, the bone distribution closely, also fragile, under strong impact or weight of the dislocated, sprain, easy to fracture and even fracture. Due to the wrist joints for often activity, so long recovery period full recovery is difficult, and now on the market of wrist treatment mostly adopts the traditional splint fixed bandage auxiliary treatment with large and medium-sized physical restoration instruments, these treatments are all more or less there is a certain lack of traditional way recovery has the disassembly difficulty, Replacement of complex problems, auxiliary instruments can not be carried for a long time, can not be moved and other problems.

Auxiliary machine hand wrist recovery treatment, is meant to go to the auxiliary treatment of the injury, hold to, weight and other reasons caused the wrist like navicular bone fractures near etc, through the structure of the machine hand movement to gradually adjust the Angle position, auxiliary and accelerate the rehabilitation of fractures, are fixed at the same time, further to prevent the accident caused by the secondary injury, and at the same time with the effect of fixed treatment equipment physical therapy, so as to strengthen the wrist flexibility and bone strength, play a preventive and protective effect, to achieve a full range of protection treatment for the wrist. At the same time, the exoskeleton design of
the finger part further ensures that the wrist will not be affected by the impact of the finger part and the associated damage, so it is of great significance for the treatment of the wrist. In this study, from the perspective of engineering mechanics, an innovative integrated pneumatic flexible pipe mechanism is proposed, and the pneumatic flexible pipe is used as the main bending way, through the pneumatic three components to pressurize the pneumatic flexible pipe, so as to change the shape. At the same time, this study designed the mechanical exoskeleton shape according to the mechanical principle to protect and wrap the hand in an all-round way. Gear drive and connecting rod drive are adopted to realize the movement of fingers and wrists, so as to strengthen the protection and mobility [1].

2. Exoskeleton design of wrist-assisted recovery robot hand

2.1. Analysis of the degree of freedom of exoskeleton

Exoskeleton of nine spherical pair and three ball pin of vice, are connected by a spring k1 g1 and g2, through practical analysis can find that spring k1 to provide a degree of freedom system, through the organization diagram, as shown in figure 1, can be found in the diagram in total there are 11 lever, contains 16 low rotation vice at the same time, through the calculation of degree of freedom can be, The overall number of degrees of freedom of the exoskeleton is 2. In the practical application of the exoskeleton, the rotating pairs 1 and 13 will be fixed by the pneumatic flexible tube, and the spring K1 will be determined by the thickness of the palm. Therefore, the rotating pairs 1 and 13 and the spring can be further equivalent to obtain a new mechanism diagram, as shown in Figure 2.

According to figure 2 simplify exoskeleton mechanism diagram, can further calculate dof of 4, in the process of actual wear, finger part three knuckles can bend actively, so you can get the agency has three active in brief, because the quantity of active parts diagram is less than the number of degrees of freedom, so motion uncertainty, can be in any movement in the plane [2].

![Figure 1. The wrist part of the overall mechanism diagram](image1)

![Figure 2. Simplified mechanism diagram of exoskeleton](image2)
(1) Macro mechanical analysis

Since the main purpose of the exoskeleton is to ensure that the wrist will not be hurt, the innovative design of the wrist exoskeleton into an elliptical arch shape, using the arch principle, to distribute the force as much as possible, so as to reduce the impact of the purpose.

The arch rib is used as the main load-bearing component of the arch bridge, and its bearing characteristics are that the arch rib bears the pressure and the support bears the horizontal thrust. The biggest structural feature of arch bridge type is that when subjected to vertical pressure, the lower side of the common straight beam is pulled while the upper side is pressed. According to the characteristics of the material, as the exoskeleton will adopt 3D printing technology, the material chosen is PLV plastic, whose tensile performance is far lower than the compressive performance. If the rectangular straight beam is changed into an arch, The load on the exoskeleton transmits thrust to the abutment through the arch ring. The abutment will be designed as load-bearing supports, so the abutment on both sides will be thickened to absorb the thrust transmitted by the arch ring. Such a structure can greatly reduce the tensile stress of the lower side of the component, and even make the component does not appear tensile stress, can better ensure the compression bearing capacity of the exoskeleton, improve the bearing capacity of the structure, so as to further avoid the second injury of the wrist. The shape of the wrist exoskeleton is designed according to the arch principle. As shown in figure 3.

![Figure 3. Exoskeleton structure of wrist](image)

(2) Micromechanical analysis

The arch structure of the exoskeleton adopts a semi-elliptical convex arc. It can be found from the force-displacement curve of the effect of the forces acting on the arch and the plane. As shown in figure 4. When the horizontal displacement is the same, both the velocity is zero on the vertical direction at the same time, according to the principle of differential and integral calculus, the arch will work less, so the average force is smaller, so compared with a flat arch in the process of the impact of average pressure will be smaller, so the shape of arch is more suitable for the exoskeleton, thus to avoid secondary injury [3].

![Figure 4. Arch and plane displacement-work curves](image)
2.3. **Modeling of wrist-assisted recovery robot exoskeleton**

To ensure recovery and protection, conceptual put forward the hands and wrists comprehensive package type exoskeleton design train of thought, to make sure the finger part can turn flexibly, in the finger joint using 45 # steel no [4]. M4 screw connection, use the pin fixed good refers to the day after, in order to prevent the knuckles of the wrist flexion with pain, The connecting rod device is designed to be connected between each knuckle to interact with each other when bending, and avoid the injury of excessive bending of the knuckle to the wrist, As shown in figure 5.

In order to ensure that the wrist has a certain range of activity, so the need to control the bending degree through the lower side of the pneumatic flexible tube, through the upper pneumatic flexible tube to control the size between the upper and lower splint, control the wrist and the palm of the range of activity. At the same time in the hand between the wrist and hand ministry to connect by means of gear transmission, wrist front-end is designed to be a 1/4 gear, has a full gear in palm top set, when pneumatic flexible pipe bending wrist 1/4 gear rotates, further palm top gear rotates, because is equipped with pneumatic flexible pipe, Therefore, the upper pneumatic flexible tube has played a self-locking effect of the wrist and palm gear transmission, so that the gear meshing is tight, not loose, to avoid the bad consequences caused by insufficient wrapping of the wrist.

![Figure 5. Exoskeleton linkage diagram](image)

3. **The use of pneumatic flexible pipe**

3.1. **Construction of pneumatic flexible pipe**

Because the splint on the palm and wrist joints between gear connection, so the pneumatic splint on the palm of your hand and wrist joints flexible pipe need to avoid the gear, the two pneumatic flexible pipe is adopted to respectively on both side of the gear, due to the effect of the pneumatic flexible pipe of the upper is to control the overall activities of the palm interval, so the two pneumatic flexible pipe of the upper need exactly the same, In order to ensure that the splint on the left and right parallel and stable balance of the activity space. Because the pneumatic flexible tube is on the upper side, according to the structural characteristics of the sector, the pneumatic flexible tube on the upper side is longer than the pneumatic flexible tube on the lower side, so the length of the two pneumatic flexible tubes is 160mm. With the underside of the pneumatic flexible pipe design structure, because the upper pneumatic flexible pipe is bent, so on flexible pneumatic tube from the cross section of the wall thickness is smaller than the wall thickness, the two sides of the wall thickness should be equal, and so on wall thickness to 2 mm, the wall thickness 8 mm, take 4 mm on each wall thickness, from the point of cross section, the width of 20 mm, The height is 20mm.

Two kinds of pneumatic flexible pipe molds were designed using 3D printing technology. Silastic rubber liquid was injected into the two molds respectively to wait for cooling. After cooling, three
pneumatic flexible pipes were taken out to complete the design and production of pneumatic flexible pipe.

3.2. Sealing of pneumatic flexible pipe
Flexible pneumatic tube after filling in the gas would be separate and pneumatic components, in order to ensure the flexible pneumatic tube pressure must be and not happen the phenomenon such as leakage, therefore need to seal of pneumatic flexible pipe, and the pneumatic flexible pipe is not a one-time items, so the structure of the inflatable deflated to adopt and repeatable to seal flexible pneumatic tube, Therefore, related to the structure of the bicycle tire, decided to use the valve mouth to seal, through the valve mouth to control the pressure change in the tube. Valve in the pneumatic flexible pipe is used as the air interface and the vent valve, and keep the air will not leak, and USES a copper valve, valve body is equipped with work like a one-way valve core, compressed air inflated inner tube can not free air leakage, to ensure that the function of the pneumatic flexible pipe.

4. Carriage and use of physiotherapy institutions
Will be attached to the lower part of the wrist exoskeleton, As shown in figure 6. Electric therapy pulse massage piece placed inside the exoskeleton and wrist skin can be directly in contact, the middle power supply and control unit will be used in the embedded method, at the bottom of the wrist exoskeleton flow set aside the core unit place, from the inside to the outside to install electric therapy pulse massage piece, at the same time to ensure that the massage piece can better adhere to the wrist skin, Therefore, an elastic band will be added between the massage piece and the wrist exoskeleton, so that the pulse massage piece of electric therapy is completely attached to the elastic band, and when the hand is covered with the exoskeleton, due to the effect of the elastic band, the massage piece will be more closely attached to the skin, so as to play the best auxiliary effect.

![Electric pulse massage tablet carrying picture](Image)

**Figure 6.** Electric pulse massage tablet carrying picture

5. Conclusion
Through experimental analysis assisted recovery machine hand wrist can well protect the effect, at the same time due to the structural characteristics of flexible pneumatic pipe making machine hand have very strong maneuverability, can replace the traditional well bind treatment, and further makes up for the stationary wrist recovery therapy apparatus bulky move difficult problem, there is a strong market and development space, and has a high ductility, More auxiliary recovery and application modules can be extended to achieve more rich functions. Therefore, in conclusion, wrist assisted recovery robot hand can be said to be a wrist treatment instrument with high integration, strong development, wide application and excellent effect. It plays an auxiliary protective role for the wrist from all aspects, and therefore has great significance for the treatment of the wrist.

References
[1] Chen Zhimei, Zeng Jun, Cheng Qinhe, Fang Liu Juan. Application of self - made integrated wrist
fixation band in anesthesia recovery room [J]. Journal of Nursing, 2010, 25(06): 74.

[2] Zhao Yaohong, Xia Hao, Wang Ziqian, Li Ruiqin. Function design and appearance design of wrist rehabilitation robot [J]. Packaging engineering, 2019, 40(08): 118-122.

[3] Du Yanchen, Guan Zhenxing, Zhang Gang. A novel wrist nursing rehabilitation device [J]. Advances in biomedical engineering, 2018, 39 (03): 138-140+150.

[4] Huang Lei, Sun Zhongsheng, Liu Yuanfeng. A wrist motion rehabilitation device based on pneumatic flexible actuator [J]. Machinery manufacturing and automation, 2016, 45 (06): 216-219.