THE DESIGN OF BIAXIAL JOINT FOR MOBILE ELECTRONICS WITH THE ANALYSIS ON ARTHROSIS

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Abstract: To bring forward the new form factors is one of the key drivers for future mobile electronic devices. On the other hand, some form factors in nature with evolution process have been the excellent and adaptive. In this paper, we pay attention to the characteristics of arthrosis, researched on the difference between the arthrosis and machine joint. Then the essentials and parameters of the biaxial joint design were introduced. After that a biaxial joint concept for portable electronics based on the bionic principle was proposed. Finally, we provided the statics analysis of the biaxial joint.

1 INTRODUCTION

In recent years, more and more mobile electronic devices have become an improtant part of people's life. One of the key drivers for future electronic mobile devices is to enable drastic change of the physical appearance of mobile terminals with totally new product category possibilities.

The clamshell type electronic mobile device is the most popular type. The joint divided into two parts and the opening angle is general at 160 degree. Obviously, the structure of the joint limits the opening angle. Another problem of this type of communication between two parts is secular fold. So many researches pay attention to the design of rotary joint.

Most of rotary joints only have one axial and two parts of joint turned encircling the axial. Because of the motion intervention, the friction cannot be avoided.

In our research, the design of a biaxial joint based on the bionic principle is introduced. The biaxial joint has two perpendicular axes. Two pairs of apposing movements take place along these axes respectively and circumduction is permitted.

2 THE CHARACTERISTICS OF ARTHROSIS

Locomotor system includes bones, joints and muscles. Each bone is linked with joints. Every arthrosis has some common structures. The typical one is as Figure 1. Compare with the machine joint, the arthrosis have some characteristics:

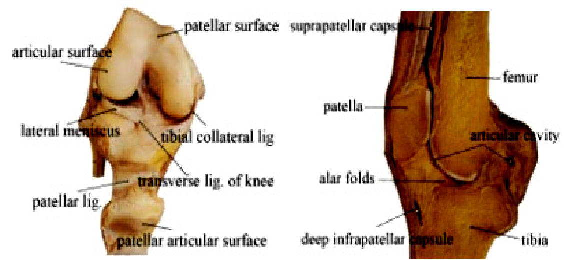

Figure 1: The structures of a typical synovial joint.

The articular surfaces are the smooth surfaces composed by non-standard curve or surfaces.

The articular surfaces indirectly connect with cartilages. The articular discs make joint surfaces fit further with one another, increase stability of joints and absorb large forces of compression and shear.

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The ligaments are the driver of body structures. Usually, one arthrosis connects with one more ligaments. When the arthrosis move, the ligaments around it will cooperated drive the arthrosis to move with a non-repeated track.

3 DESIGN OF THE BIAXIAL JOINT

3.1 The Essentials of the Joint Design

In this project, a bionic joint would be designed for the joint of electronic devices. Therefore some essentials of the main joint design as follow:

While design joints the rolling friction should be selected for decreasing the affect of friction.

Usually the wire is easily failed when folded repeatedly. So the wire should cling on the joint surface to acquire the support. Also the curvature radius of joint should be enlarged at full steam.

As articular discs, some filling would be accepted and it can make joint surfaces fit further with each other, increase stability of joints and absorb the large forces of compression and shear.

Imitate the body drivers, some special drivers should be selected with the small structure and for parallel movement.

3.2 The Surfaces Design of Joint

In body, the hinge joint has two parts, concave and convex, and movement takes place on sagittal plane, e.g., the elbow and ankle. With the analysis on the structures of hinge joint, it is described as Figure 2.

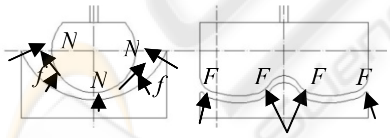


Figure 2: The sketch of hinge joint. The *N* means the support forces, *f* is the frictions, *F* is the transverse forces.

For avoiding the friction, the concave part will be replaced by convex, and the two parts are tangent. See Figure 3 (a). Transverse displacement should also be considered. Simulate the cooperation of the neck and convexity, some keys and slots should be designed. So the joint is showed as Figure 3 (b).

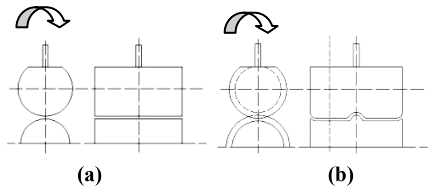


Figure 3: The sketch of joint.(a) joint with double convex, (b) joint with key and slot.

As the analysis before, the curvature radius should be enlarged. So the section of the joint part can be designed as demisemi circularity. So the biaxial joint structure is described as Figure 4.

Figure 4: The sketch of final biaxial joint structure.

3.3 The Design of Medium in Joint

For the fit and stable of the structure of synovial joints, there are other structures inside the joint, such as articular cartilages.

See the sagittal section of temporomandibular joint in Figure 5 (a), the articular disc suit on the surfaces of two joint parts.

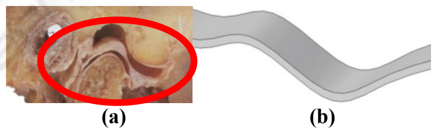


Figure 5: (a) The sagittal section of temporomandibular joint. (b) The sketch of connective band.

Simulate the structure and function of the articular disc, a connective band is design as Figure 5 (b). It is suited on the surfaces of two joint parts.

For keeping balance, three bands from different directions interlude the joint cavity. See Figure 6.

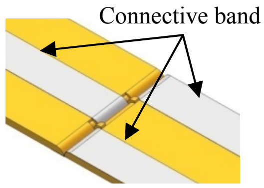


Figure 6: The biaxial joint with connective band.

3.4 The Design of the Joint Driver

In the movement of articular, muscles drive the joint. They compress and elongate to change the direction between two attachments on the different bones. The greatest excellence of using muscle drivers in joint is the minimal volume. In this research, artificial muscles would be selected as joint drivers.

In the biaxial joint, one part would turn around the other back and forth. Therefore two couples of drivers should be emplaced on the double side of the joint.

For balance, they should be distributed symmetrically. In this design, the turn range of the joint can be from 0 to 360 degree. See Figure 7.

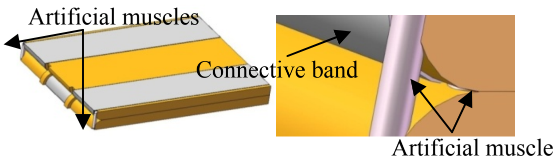


Figure 7: The biaxial joint with artificial muscles.

4 STATICS ANALYSIS OF THE BIO-JOINT

In this paper, because of the tangent motion between two joint surfaces, the slip resistance can be ignored.

Predigesting the joint structure, the joint surfaces with connective band can be modelled as Figure 8.

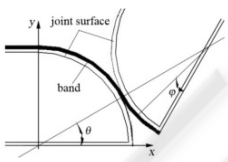


Figure 8: The model of the system.

4.1 The Motion Track

If we establish the coordinate at one of the circles, the other one rotated on its surfaces. So the motion track equation of discretionary point on the moving circle can be founded as

$$X=2R\cos\theta-R\sin(\pi/2-2\theta+\varphi) \quad (1)$$

$$Y=2R\sin\theta-R\cos(\pi/2-2\theta+\varphi) \quad (2)$$

Here φ is the angle between the point on the joint surface and underside of the joint.

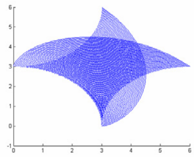


Figure 9: The motion track of the joint.

When the φ changed from 0 to $\pi/2$, we draw one track with every 0.25π degree. And the tracks are described as Figure 9 in area *XY*.

4.2 The Forces of the System

For ensuring the reliability of connection of two joint surfaces, beforehand force *F* would be added on the bands. The forces are showed in Figure 10.

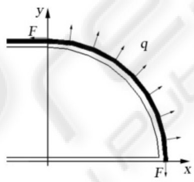


Figure 10: The sketch of the forces on system.

Here, *F* is the beforehand force, *q* is the forces density. So the force on arc with the length as $Rd\theta$ is $f=qRd\theta$.

The component of forces on the axial X and Y is

$$f_x=qRd\theta\cdot\sin\theta,\ f_y=qRd\theta\cdot\cos\theta \quad (3)$$

According to the principle of forces balance, it can be described as

$$F=\int_0^{\pi/2} qR\sin\theta d\theta \quad (4)$$

Then

$$q=F/R \quad (5)$$

4.3 The Stress

4.3.1 Stress on the Band

As it described before, in this design the fix up of joint is realized by some connective bands. So the bands are the primary force suffering object. With the repeatedly folding, it should be laid-back and wearing. Thereby the integrality and reliability of structure would be destroyed. So in this part, the stress of connective band would be analyzed.

Firstly, the normal stress for the beforehand forces can be

$$\sigma_{bF}=F/A_b \quad (6)$$

Here, A_b is the section area of connective band.

Then, the normal stress for bending moment is

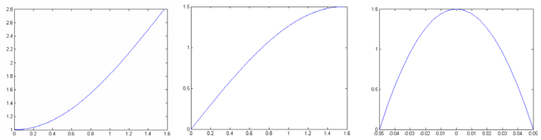
$$\sigma_{bM}=My/I_{bz} \quad (7)$$

Here, y is the direction between the point and central on section. And $M=F(R-R\cos\theta)$ is the bending moment on the section, $I_{bz}=\int_{A_b} y^2 dA_b$ is the moment of inertia for axial z.

So the whole normal stress on connective band can be described as

$$\sigma_b=\sigma_{bF}+\sigma_{bM}=F/A_b+My/I_{bz} \quad (8)$$

The maximal normal stress on connective band is at the point when $y=y_{max}$. It changed with θ can be described as Figure 11 (a).



(a) **(b)** **(c)**

Figure 11: The maximal stress on connective band. (a) Normal stress changed with θ, (b) Shear stress changed with θ, (c) The τ_b change with y.

At the same time, the shear stress at y on section can be showed as

$$\tau_b=3F_{bs}(1-4y^2/h_b^2)/2bh_b \quad (9)$$

Here, h_b is the thickness of band, b is the breadth of it, and $F_{bs}=F\sin\theta$ is the shearing force on the section.

In Figure 11 (b) the curve of maximal shear stress changed with θ is described.

A maximum of F_{bs} when $\theta=\pi/2$ can be get. So the τ_b with such F_{bs} can be described as Figure 11 (c). The maximum of τ_b can be found when y=0.

4.3.2 Stress on the Joint Surface

Because of the no direct touch between two joint surfaces, the joint surface gets the press form connective bands only when it turned. See Figure 12. Due to the radial press with the forces density q, the axial loads is F, so the normal stress from the press on the joint surface is

$$\sigma_{jF}=qR/A_j=F/A_j \quad (10)$$

Here, A_j is the section area of joint surface.

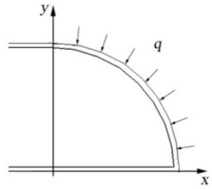


Figure 12: The sketch of the forces on joint surface.

Then, the normal stress for bending moment on the joint surface is

$$\sigma_{jM}=My/I_{jz} \quad (11)$$

Here, y is the direction between the point and central on section. And $M=\int_0^\theta qR^2\sin(\theta-\varphi)d\varphi$ is the bending moment on the section, $I_{jz}=\int_{A_j} y^2 dA_j$ is the moment of inertia for axial z.

So the whole normal stress on joint surface is

$$\sigma_j=-\sigma_{jF}+\sigma_{jM}=-F/A_j+My/I_{jz} \quad (12)$$

The maximal normal stress on joint surface is at the point when $y=y_{max}$. It changed with θ can be described as Figure 13.

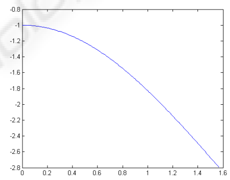


Figure 13: The maximal normal stress changed with θ.

Also, the shear stress is existed on the joint surface. The shear stress at y on section can be showed as

$$\tau_j=3F_{js}(1-4y^2/h_j^2)/2bh_j \quad (13)$$

Here, h_j is the thickness of joint, and $F_{js}=\int_0^\theta qR\cos(\theta-\varphi)d\varphi$ is the shearing force.

So we can get a similar curve as Figure 12, the maximal shear stress changed with y is described.

4.4 The results

In this design, when one surface round on another, although the point on one changed his track direction after it pass the tangency part, but due to the tangent point track is arc, the move is smooth.

Based on the forces analysis, there's no slip resistance between two surfaces. It's the virtue of such design, because it defence the energy wasting and surfaces wearing; and at the same time, it is a shortcoming, because it can not stop at any part with friction. But here we bring out the driver of artificial muscle, the orientation is ensured.

When selecting the material of connective band, only if the allowed stress is larger than maximal one gained before, reliable structure can be accepted.

5 CONCLUSIONS

As one of the most important part of electronic mobile devices, the design of joint catches the great attention of researchs. One of the key drivers for the devices is to enable drastic change of the physical appearance of mobile terminals with totally new product category possibilities. In this paper, some characteristics of the arthrosis are analyzed. And we bring out a biaxial joint for electronic mobile devices based on the bionic principle. At last, the statics of such biaxial joint is analyzed.

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