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POWRÓT

SPHERE MOVEMENT RESISTANCE IN A SPHERICAL CAP

Key words
Ball-and-sockett joint, movement resistances, hip joint, insert.

Słowa kluczowe
Przegub kulisty, opory ruchu, ortopedia, staw biodrowy, wkładka.

Summary

The paper presents the initial research results of bearing steel sphere oscillatory movement resistance in a spherical cap made of polyamid.The couple was working in the environment of chosen lubricant factors. The constructions of inserts which aim is to absorb the stroke loads and to equal the unit pressures on the co-operating surfaces are shown, too.

INTRODUCTION

The problem of movement resistance of the frictional couple: sphere – spherical cap, concerns the spherical joints used in lots of machine and device kinds. The most frequent, however , the problem is where talking about spherical joints of human body (hip and shoulder joint) as well as their endoprothesis (fig.1).

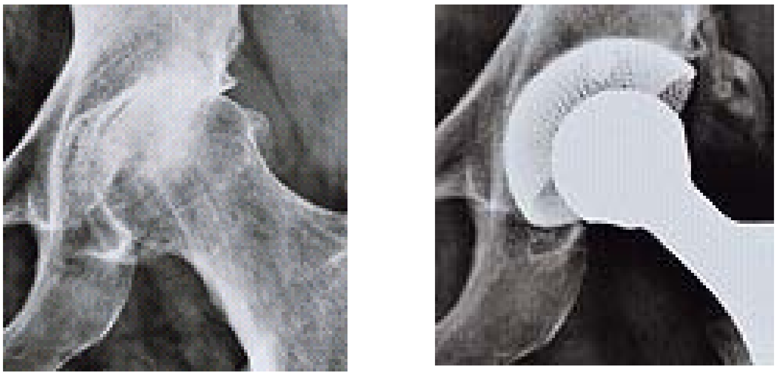

Fig. 1. Biological joint and endoprothesis of hip joint [14]
Rys. 1. Biologiczny i endoproteza stawu biodrowego [14]

The endoprothesa used for medicine are made of various materials creating the frictional couple (pin and sockett)

In spite of using the above mentioned materials, what characterizes endoprothesis is a great friction factor which has the negative influence on tie's durability and an intensive tribological usage of the socket surface in the joint endoprothesis, most often made of plastic [1, 3, 4, 5, 15], causes disadvantageous organism reactions on the used products.

As implies from the above, the problem connected with the improvement of the right work of joint endoprothesis as well as the destroyed by sickness the biological joint is still important [11, 16, 17, 18]. It appears from the progress of both theoretical and experimental works that in some cases the destroyed surfaces of the biological joint could be saved by regeneration and [2] the helping factors can be various inserts and shields [6, 8, 10]. Their usage, if only as the helping factor for moving while operational stiffness of a joint, artrodesis or total, final destruction of a joint and replacing it by endoprothesis, seems to be reasonable. Stated below are the proposals of the spherical cap insert construction solutions, playing the role of the intermediary medium and parting the surfaces of the friction couple.

SPHERICAL JOINT INSERTS

The relative rotational movement of the co-operating couple in biological joints, the head of a hip bone and socket (hip joint), is done mainly by sling.

In some cases there is a need of improving the work of a spherical joint. This improvement can depend on parting the co-operating friction couple by a third element [7, 9], which should

- equalize the pressure in the joint (surface pressure),
- eliminate the sling on the working areas of a joint (lack of friction work),
- dampen and absorb the dynamic loads and strokes,
- diminish the movement resistance.

The elements which fulfills those expectations in the big range are inserts shown below fig. 2.

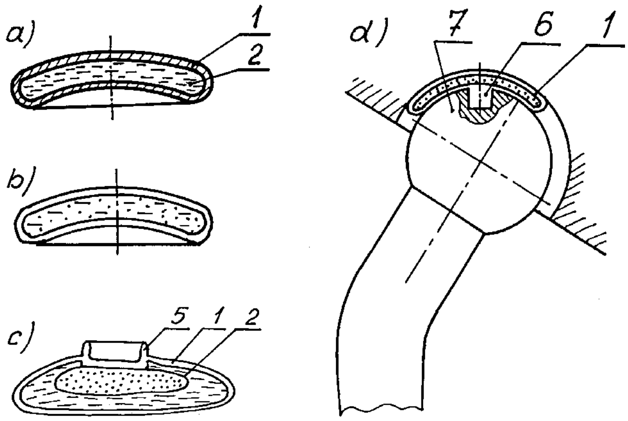

Fig. 2. Inserts [6]
Rys. 2. Wkładki [6]

The insert (fig. 2) has the body of a leak proof and spherical balloon (container) that fills with the portion of a liquid after being tighten. The liquid placed in an insert fulfils the role of lubrication factor where can be the cure in case of ex. insert break. The insert placed between the socket and ball lets for the rotational movement ex 30^o angle. The value of the angle depends on geometry of the insert and the material used where the rotation is made without a sling between the outside surface of the insert and the joint surfaces. The lack of the sling is the result of insert's reeling and playing role of the elastic, rolling element.

The surfaces of the insert deformated by the exterior forces and, caused by them, liquid pressure, stick to the surface of a cap and ball.

AN INFLUENCE OF THE ELASTIC INSERT ON THE DIVISION OF AREAL PRESSURES.

Fig. 3 shows the sample distribution of the areal pressures with the same loads for 2 different material-construction alternatives.

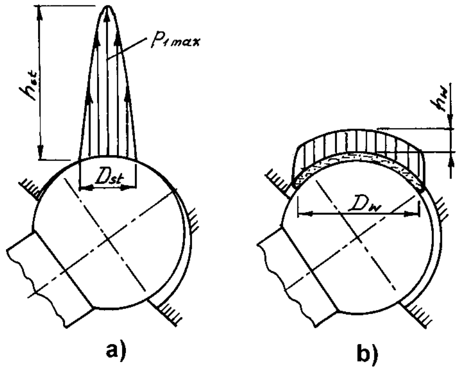

Fig. 3. Sample distribution of unit pressures, a) –ball and cap from the hard material [13], b) - after using an elastic insert
Rys. 3. Przykładowe rozkłady nacisków jednostkowych, a) –kula i czasza z twardego tworzywa, b) -po zastosowaniu elastycznej wkładki

Sample distributions of the unit pressures from fig. 3 show that after using an insert the rapid diminishing of the biggest pressures in the endoprothesis can be expected.

In the insert loaded with a force F it appears the pressure with the following value.

$$p \approx \frac{4 \cdot F}{\pi \cdot d_w^2} \tag{1}$$

where d_w is a projection of the interior diameter of the loaded insert (fig. 4).

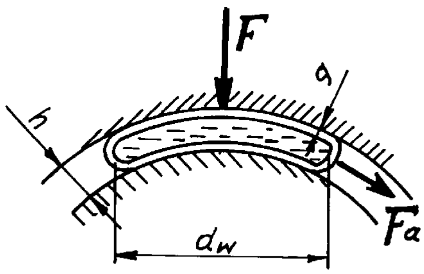

Fig. 4. The load and geometry of elastic insert
Rys. 4. Obciążenie i geometria elastycznej wkładki

The force breaking the insert F_a, in the least useful case , without relation to the friction between the insert's area and the co-operating areas of the ball and cap (pin and socket) the relations can be counted

$$F_a = p \cdot d_w \cdot (h - 2g) \tag{2}$$

replacing 1 to 2 we can get

$$F_a \approx \frac{4}{\pi \cdot d_w} \cdot F \cdot (h - 2g) \tag{3}$$

The pressure breaking the elastic insert container after considering (3) gives

$$\sigma_r = \frac{4 \cdot F \cdot (h - 2g)}{\pi \cdot d_w \cdot S_w} \tag{4}$$

where: S_w -is the area of the cover (shield) cut of the insert

Considering the sample data; F = 1000 N, h = 3 mm, g = 0,5 mm, d_w = 30 mm and with some approximation $S_w \approx$ 35 mm^2, the pressure breaking the elastic container gives σ_r = 2,42 N/mm^2 ≈2,5 MPa.

TEST STATION FOR ASSESSING THE RESISTANCE OF MOVEMENTS IN THE JOINT

The basic task of an insert is eliminating the friction force which causes lack of usage in the co-operating areas. Because of that the above mentioned lack seems to be crucial. In case of the work of an elastic insert based on the rolling between moving areas three phases of work can be observed;

- the phase of rolling an insert in case of the lack of insert's diafragma's longtitude (for the geometrical dimensions as above, the angle of such a move is about 30)
- the phase of rolling an insert with the diafragma's longtitude (the rolling angle is >30)
- the phase of sliding the exterior surface of an insert relating to the ball and cap usrface.

The most advantageous form of co-operation of an insert in the spherical joint is the rolling phase with the small longtitudes of insert's diafragma resulting from acting the forces F_a (fig. 4).

The resistance of movement in the rolling-sliding friction as observed in the spherical joint are difficult to assess. To the initial assessment the idea of using the pendulum where a sphere makes the oscillatory movements relating to the spherical cap.

A bearing steel ball was used in the polyamide cap. To asses the friction factors for the couple of materials and the chosen friction factors the device shown on fig. 5 was used.

Fig. 5. Test rig for the evaluation of oscillating coefficient of rolling friction
Rys. 5. Stanowisko badawcze do oceny współczynnika oscylacyjnego tarcia tocznego

To the pendulum the potential energy E_p was used by such an amplitude to gain the given height of lifting h of the centre of mass gravity of the pendulum m.

The given potential energy value gives.

$$E_p = m \cdot g \cdot h \tag{5}$$

where: m –pendulum mass,
g –earth acceleration,
h –lift height.

In the contact between the bearing steel ball and the co-operating spherical polyamide cap PA6 and the given friction factor from the very first amplitude of the pendulum that appears the spread of a given potential energy. Its total spread is the friction work. It can be approximately assigned till the moment of the pendulum stop, from the relation:

$$L_T = T \cdot S = m \cdot g \cdot \mu_z \cdot i \cdot s_s \tag{6}$$

where: T –friction force,
S –total friction way,
μ_z –substitutional coefficient of the movement resistance,
i –the number of the single amplitudes of the pendulum,

s_s –average way of the single, relative contact movement between the ball and

the co-operating spherical cap.

From the comparison of the relation (5) and (6) for the oscillatory, summary, rolling and sliding movement the substitutional friction coefficient can be indicated.

$$\mu_z = \frac{h}{i \cdot s_s} \tag{7}$$

From the geometry of the pendulum (fig6) the angle of the first deflection φ implies

$$\varphi = \arccos\frac{l-h}{l} \tag{8}$$

where: φ - the angle of the first pendulum deflection in grades,

l – pendulum length [mm],

h –the hight of lifting the pendulum mass m mm.

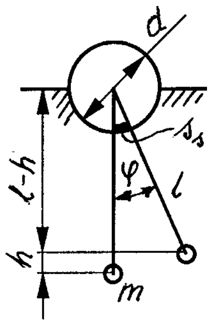

Fig. 6. Scheme of rest orientation of pendulum and after the first oscillation
Rys. 6. Schemat położenia spoczynkowego wahadła i po pierwszym wychyleniu

The average way of the relative movement in the contact between the ball and co-operating element can be sufficiently assigned from the proportion $\pi d/360 = s_z/\varphi$ and then

$$s_z = \frac{\varphi}{360} \cdot \pi \cdot d \tag{9}$$

Replacing (8) and (9) to pattern (7) we can gain the relation for counting the replacing ball with the diameter d oscillatory movement resistance coefficient in the spherical cap depending from the length of the pendulum l, initial angle of the deflation φ^o and the number of waves i in the following

$$\mu_z = \frac{h}{i \cdot \pi \cdot d} \cdot \frac{360}{\arccos \frac{l-h}{l}} \qquad (10)$$

The geometrical dimensions of the used pendulum were: the length of the pendulum l=603 mm, the height of lifting the centre of gravity of the pendulum h=16 mm with the first wave, the bearing steel ball diameter ϕ30 mm, the diameter of the polyamide spherical cap ϕ31 mm. The pendulum with those dimensions shows 77 single waves per minute that is about 38 periods.

For those geometrical dimensions and the given first wave the substitute resistance coefficient in the oscillatory movement counted depending on (5) and (10) gives approximately

$$\mu_z = \frac{4{,}5}{i} \qquad (11)$$

In the chart 1 the initial results of the ball movements resistance in the oscillatory movement in the polyamide spherical cap researches were placed based on the relation (16) where the contact of the friction couple works in the environment of the chosen lubrication factors. The indicator of the relative movement resistance $k_{\mu z}$ is the quotient of the substitute movement resistance coefficient μ_z or the friction couple with the lubricating factor and the dry work (no 1 in the chart 1).

Chart 1

The substitute coefficient of the resistance with the relative oscillatory movement of the bearing steel ball in the polyamide spherical cap in the environment of the various lubrication factors.

No	Lubrication factor	The number of the single pendulum waves I	The substitute coefficient of the resistance oscillatory movement μ_z	The indicator of the relative movement resistance $k_{\mu z}$
1	Dry work	30	0,15	1,0
2	Paraffin oil	75	0,06	0,40
3	Hipol 15 oil	64	0,07	0,47
4	Liten EPG 0 lubricator	48	0,09	0,60
5	Renolit-Duraplex 6 lubricator	33	0,14	0,93
6	ŁT4S3 lubricator	48	0,09	0,60
7	Water	34	0,13	0,87
8	Water Salt Solution NaCl, 5%	42	0,11	0,73
9	Water Solution with the green soap	64	0,07	0,47
10	Extraction naphtha	36	0,12	0,80
11	Latex insert filled with air	240-590	0,02-0,008	0,13-0,05

FINAL AMENDMENTS

From the initial researches it implies that the substitute resistance coefficients with the oscillatory and relative rotation movement of the ball in the spherical cap. There are a lot of the construction and lubrication material solution nowadays with the various qualities. The presented way of researching let us compare the resistances of the oscillatory movements of the cooperating materials in he various environmental conditions that is after implying different lubrication coefficients.

From the geometry of the insert cooperating with the joint the relative angles of the rotation in the spherical joint can be estimated where the material of the insert is only bended. Those rotation angles do not cause the elastic lengthening of the insert material. The values of those angles relatively to the construction of the insert and the geometrical dimensions of the joints are $\alpha \approx 20^o \div 40^o$ in the cross-section in direction to the motion of the rolling insert (the deflection from the main axis of the joint). The angles bigger than given ones cause, depending on the material's flexibility; the lengthening of the surface or slide of an insert relatively to the surface of the joint.

The above remark shows that quite wide range of the angles of movements eg. in the joint with insert let the work without a slide, should be the positive argument to use it in biological joints. The inserts can fulfil the spectrum of possibilities in the surgeon treatment. The proposed construction of the inserts gives hope for the possibility of their use in the partial endoprothesis too because they cause the equality of the surface pressures, diminish the slides on the working areas, timid the vibrations and absorb the dynamic loads and shocks and diminish the movements' resistances.

The work over the technology of making the inserts for the biological joints concerning the materials with the special resistance strength for bending and the biomedical correlation that is the right range of neutrality, demands a lot of interdisciplinary actions. In the present state of researches in order to solve the construction and technology problems the

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Opory ruchu kuli w czaszy kulistej

Streszczenie

W artykule przedstawiono wstępne wyniki badań oporów ruchu oscylacyjnego kuli ze stali łożyskowej w czaszy kulistej wykonanej z poliamidu. Ta para pracowała w środowisku wybranych czynników smarnych. Pokazano także konstrukcje wkładek, których zadaniem jest amortyzowanie obciążeń udarowych i wyrównywanie nacisków jednostkowych na współpracujących powierzchniach kulistych.