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THE CONTROL OF THE GEOMETRY OF A BIG JOINT IMPLANT

Damage in the joints may entail deterioration of life quality to a great extent. More than seven hundred thousand big joint (hip-, knee, etc.) prostheses are implanted annually in the world to improve the quality of life, and this number in Hungary amounts to approximately ten thousand. Currently the lifetime of the prosthesis is approximately 10 years [1]. Unfortunately, prosthesis loosens beyond this period, thus replacement is needed. In this paper we present the geometric construction, modelling and Finite Element Analysis of the hip-joint prosthesis.
Keywords: hip joint prosthesis, socket, 3Dmeasurement, reconstruction, Finite Element Method

INTRODUCTION

The hip joint prosthesis (Figure 1) is one of the most complicated big joint prostheses, since it has to ensure a three-dimensional motion. Metal parts (for example, the stem and the sphere head) of hip prostheses are made of either stainless steel or another metal, for example, titanium. The companion piece (for example socket) is made of polythene. The metal sphere head rotates in the polythene companion piece, which is inserted into the hip bone. The polythene has a number of favourable physical and chemical properties, for example, great strength, flexibility and chemical neutrality. However, the prosthesis made of this relatively ductile and resistant material, still wears [4].

Figure 1 – Hip joint prosthesis

1. PARTS OF THE HIP PROSTHESIS

The anatomic hip prosthesis may be cemented and cementless depending on the type of fixation used to hold the implant in place.

Construction:
- socket;
- metal head;
- metal stem of different types.

Basic Materials

The hip-joint stem and head are made of forged, heat treated, cobalt-based, patented special metal alloys, marked BMH-1, protected by a patent, and featuring a chemical composition in compliance with standard ISO 5832-6. The strength characteristics of the tissue-friendly material are the best. The high toughness (impact work), the special texture and chemical composition of the practically unbreakable metal result in the maximum resistance of the hip-joint stems manufactured from this material to the most unfavourable voltage corrosion fatiguing stresses.

The hip-joint socket is made of ultra-high molecular weight polyethylene in compliance with standard ISO 5834-2, and is applied successfully worldwide, on the basis of a procedure in which the material preserves its warranted characteristics.

Stem

The geometry of the stem (Figure 2) is formed in a way that the curved contour line of the stem in the planar section of the plane of bending fully coincides with the cortical contour of the medullary space on the side towards the centre of the body, this way, due to the large contact surface the applied load is transmitted evenly. This is favourable for the use of the bone. The wedging, straight stems are fixed in full length.

Head

The hip-joint head is attached in a self-locked way to the conical neck part of the hip-joint stem (Figure 2).

Socket

There are cams on the outer surface of the sphere to ensure the equal thickness of bone cement. In a special case a serrated-edge version of asymmetric arrangement is also available to increase the support function. The socket is fitted with marker wires at the right angles to enable X-ray check-ups after implantation (Figure 2). The use of bone cement is necessary for the implantation.

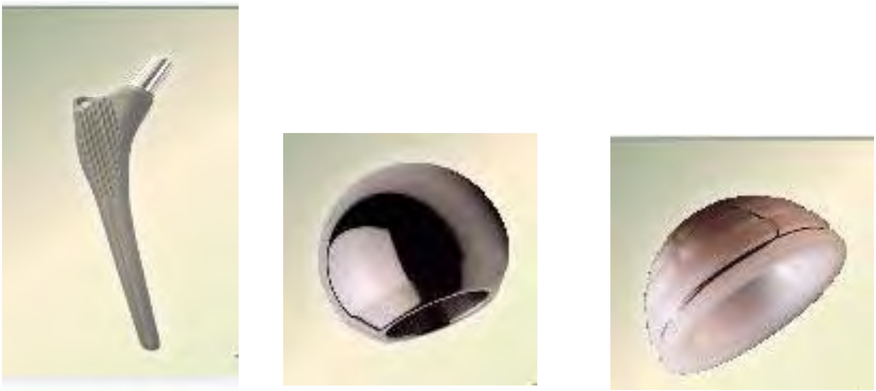

Figure 2 – Stem, Head [3], Socket [3]

The measurement of the socket

We measured with DEA type 3D measuring machine that can be found at the Laboratory of the Department of Production Engineering of the University of Miskolc (Figure 3.).

Figure 3 – 3D measuring machine and measurement of the socket

The measurement happens in the coordinate system defined by the planner and the equipment. It is one of the main characteristics of the CMM that under normal circumstances, it records the features to be examined point by point on the surface of the workpiece.

The concept of the point by point analysis gives the CMM universal usability; thus, all metrological problems that can be described mathematically, can be solved in practice with help of it.

We fixed the measurement data and drew the curves with the help of PC_DMIS software (Figure 4.).

The PC-DMIS expression is the abbreviation of the Dimensional Measuring Interface Standard.

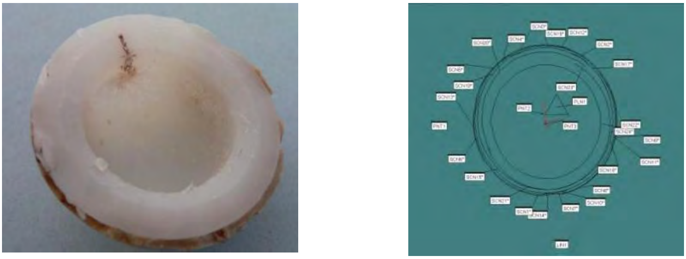

Figure 4 – Picture of the measured socket and graphical representation

The PC-DMIS is a full value geometric measure pack for Windows. This program translates the top level commands into a form that makes it possible to control the Command Measuring Machine. It is an advantage for the user, that he can start the measurement with the familiar drop-down menus, windows, dialogue boxes and icons. The variability of the user's surface of the PC-DMIS simplifies customization, so the user may apply his personal settings in the software, which yields more comfortable and more efficient work

2. RECONTRUCTION OF THE MEASUREMENT POINTS

The reconstruction of the measurement points happened with the help of several types of 3D design software, at which I applied the bases of computer geometry and graphics. For instance I used Hermite – interpolation [2] for the composition of the curves.

Hermite – interpolation

Tertiary Hermite – interpolation not only it to be interpolated points, but we presuppose the tangent vectors for known one in these. Given the p_0 and p_1 point, and t_0 and t_1 tangent vector.

Let us be searching an one like that

$$a(u)= a_0+a_1u+a_2u_2+a_3u_3 \tag{1}$$

curve defined with a third degree polynomial, onto which one

$$a(u) = p_0H_0^3(u) + p_1H_1^3(u) + t_0H_2^3(u) + t_1H_3^3(u) \tag{2}$$

or

$$a(u) = [H_0^3(u)|H_1^3(u)|H_2^3(u)|H_3^3(u)] \begin{bmatrix} p_0 \\ p_1 \\ t_0 \\ t_1 \end{bmatrix} \quad (3)$$

where

$$\begin{aligned} H_0^3(u) &= 2u^3 - 3u^2 + 1 \\ H_1^3(u) &= -2u^3 + 3u^2 \\ H_2^3(u) &= u^3 - 2u^2 + u \\ H_3^3(u) &= u^3 - u^2. \end{aligned} \quad (4)$$

These sketched with the help of Hermite – arcs visible on the figure below (Figure 5).

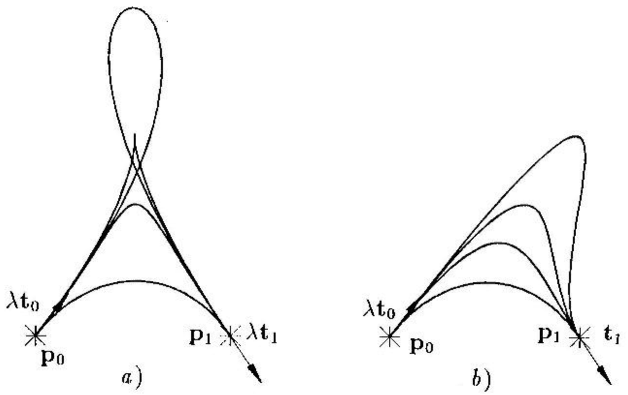

Figure 5 Hermite- arc shapes

We drew and analysed the measured points with CAD software (for example AutoCAD).

Steps:

- entering the measurement points into the software (entering the coordinates into the AutoCAD software);
- drawing the contour lines;
- drawing the Hermite - sheets;
- turning the curves (around the rotation axis) (Figure 6.);
- drawing the differences (Figure 6.)

After the theoretical surface we drew the real surfaces, on which the distortions, bulging and buckling are clearly visible. On the figure below example of the measured socket can be seen (Figure 7).

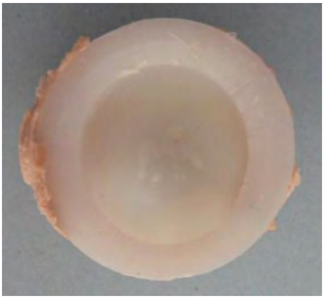
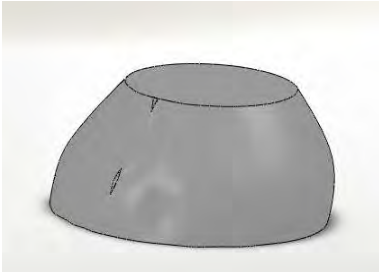

Figure 6 – Drawing the surface and difference of the theoretical and real surface

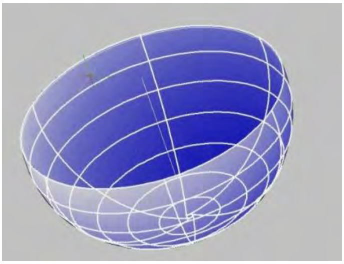
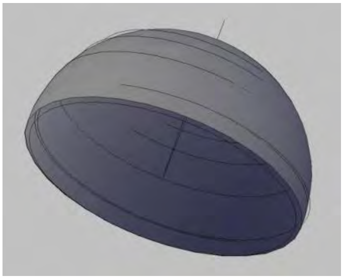

Figure 7 – The measured socket and model of the socket, drawn with the CAD

3. SUMMARY

We presented the elements of the hip-joint prosthesis. Within that however we dealt with the socket in detail. We checked the socket, which is removed from some patient with the help of 3D measuring machine. We covered about the measured data and we reconstructed co-ordinates with the help of different software with computer aided design. From these we received a theoretical surface and the exact and deformed surface.

4. AKNOWLEDGEMENT

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