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Determination of material characteristics of polyethylene

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Abstract – The contribution deals with mechanical properties of polyethylene used for production of tibial plateau of knee joint endoprosthesis. The influence of temperature on modulus of elasticity in tension is determined and property model with respect to visco-elastic properties is assigned to the material using cyclic test. The methodology of proposed model parameters determination comes from Laplace transform of activation force and response. The goal is to find input data and material model further usable in computational modeling using finite element method.

The paper deals with mechanical properties of the polyethylene plate, which are used in total replacement of the knee joint. The mechanical quantities describing the characteristics of contact of two bodies (development of contact pressure, contact surface area) can be effectively determined by using computational modeling.

The reason why the computational modeling was used is the fact that the foregoing mechanical quantities cannot be acquired directly by experiment, although the use of experimental modeling is an integral part of the realized complex solution of the problem concerning abrasion of endoprosthesis elements.

Determination of mechanical properties

The goal was to determine a change of the elastic modulus value of polyethylene samples, in traction at a changed temperature. The measurement was carried out at the normal temperature of 20°C and the human body temperature of 37°C. The samples for test were manufactured from polyethylene components of tibial plateaus used for knee joint replacement, provided by Saint Ann's University Hospital in Brno. Rectangular samples of crosswise section were cut of tibial plateaus with respect to the maximum use of the material. The total number of cut-out samples was 12 (6 for each temperature) and average dimensions of crosswise sections were: width 9.2 mm, thickness 6.0 mm. The tension test was carried out on the test machine ZWICK Z 020 – TND.

It was proved statistically that the body temperature has an effect on the elastic modulus value. With temperature increase from 20°C to 37°C the elastic modulus values decrease from 690 MPa (standard deviation 29 MPa) to 617 MPa (standard deviation 17 MPa). The statistical processing was performed in the MINITAB 15.

Determination of visco-elastic properties

The visco-elastic properties of materials are manifested with stiffness and damping effects. One of possibilities of experimental determination of these effects is the use of universal test equipment. A test sample is made from the given material and submitted to a slow loading cycle. The mathematic model of the given material is assigned and respective constants, characterizing the visco-elastic properties of the given material, are determined on the basis of the shape of quotients of Laplace images of load and response. The theoretic bases of the methodology are provided under [1] and [2].

The test sample was made from a worn polyethylene plateau and was submitted to a cyclic tensile test. Maxwell's model (spring and damper are connected in series) was assigned accordance with the shape of quotients of Laplace's figures of load and response. The parameters of the model were determined from Laplace's figures too (stiffness k = 10940 $N.mm^{-1}$, damping b = 292400 $N.mm.s^{-1}$)

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