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OPTIMIZATION OF PARAMETERS OF ORTHOPEDIC REHABILITATION PRODUCTS USING COMPUTER SIMULATION

Solomin A.V.
c.ph.-m.s., as.prof.
ORCID: 0000-0002-5226-8813
National Technical University of Ukraine «Igor Sikorsky Kyiv Politechnic Institute», Kyiv, Peremohy Ave., 37, 03056
Getun G.V.
c.t.s., prof.
ORCID: 0000-0002-3317-3456
Kyiv National University of Construction and Architecture, Kyiv, Povitroflotsky Ave., 31, 03680
Ahmed Mohamed Sabri Khairy Ibrahim
National Technical University of Ukraine «Igor Sikorsky Kyiv Politechnic Institute», Kyiv, Peremohy Ave., 37, 03056

Abstract. *The rationale for the relevance of software tools for mathematical modeling of the functioning of rehabilitation engineering products, in particular orthopedic products, is presented.*

A computer model of an orthopedic supinator was implemented in the ANSYS environment, which lays the foundations of an engineering approach to the design of such rehabilitation tools.

Key words: *supinator, rehabilitation engineering, computer model, ANSYS.*

Introduction.

The tasks of development and design of orthopedic products are now becoming very relevant. However, specific features of shape of such products complicate application of traditional methods of engineering analysis regarding their functioning. At the same time, the need for such analysis is obvious, because with a suboptimal choice of elastic parameters and strength of structures, not a therapeutic, but a harmful effect of rehabilitation products can be observed, or dangerous situations may arise during their operation.

This can be clearly explained on the example of an orthopedic instep, which in order to perform rehabilitative functions in flat feet must be elastic in all phases of the patient's gait. Otherwise, the effect of its use will be negative. At the same time, patients differ greatly in their weight, leg size, and the nature of their pathologies. Currently, the technologies for manufacturing rehabilitation products for such patients are based on the accumulated experience of practitioners without any engineering rationale.

Workbench ANSYS is best suited for solving relevant engineering analysis problems, which provides the ability to create parameterized computer models and further study the influence of various parameters on product characteristics.

The ANSYS computer simulation environment was created for engineering analysis of complex structures in various industries, and primarily in construction and mechanical engineering. But the technologies of this environment turned out to be extremely versatile and effective, which is promising for use in many related industries.

Currently, rehabilitation engineering tasks require improvement in terms of the mathematical apparatus used, as they are still based more on practical experience than on engineering calculations.

The advantages of mathematical modeling of processes occurring in rehabilitation engineering products are obvious and outline the prospects for their improvement and optimization.

Main text

The purpose of the work is to develop a technology for optimizing parameters of orthopedic rehabilitation means using computer modeling in the ANSYS environment for engineering analysis of mechanical phenomena of elastic deformations under loads.

The proposed technology is demonstrated on the example of an orthopedic insole, but can be generalized to other orthopedic rehabilitation products.

It is known that for the purpose of complex correction of various forms of foot deformities, inserted orthopedic insoles, supinators of various shapes and functional purposes are used. The main function of insoles is mechanical lifting of the inner arch of the foot and its support during movement and standing. Medical indications for the use of insoles-supinators are static deformations, flat feet, flattening of the front parts of the feet (transverse flat feet). The use of hard correctors (metal, plastic, cork, a mixture of cork crumbs with nitro varnish) is contraindicated, because they do not have elasticity and cause damage to deformed feet. Elastic correctors, along with the supporting function, perform a constant massage that strengthens the musculo-ligamentous apparatus of the foot. Among the available materials, the most effective is foamed polyethylene, which is easily molded and has such properties as elasticity, flexibility, hygroscopicity, thermal insulation [1]. An important advantage of this material is the possibility of changing its mechanical properties during production by controlling the foaming conditions

In terms of structure, the real rehabilitation insole is quite complex and has several different elements depending on the type of deformation of patient's foot. But these elements are quite similar to each other in their drop-like shape and differ in size, height of rise and location on the plane of foot. Therefore, the task of initial stage of computer modeling was formulated as an engineering analysis of deformations of such a typical droplet-shaped element. It should be noted that in some cases of simplest deformations of the foot, for example, only longitudinal flat feet, such an element fully reproduces the function of instep. In other situations, the supinator has several similar elements.

The maximum degree of its deflection should serve as an indicator of correctness of the instep design, because this parameter is responsible for supporting the arch of the foot. That is, in the case of significant deformation up to disappearance of elasticity of the product, its rehabilitation function will be reduced. Therefore, the main numerical result of the computer model study should be the maximum degree of deflection.

To create a 3D computer model of instep, the authors used powerful capabilities of ANSYS Workbench modeling toolkit and corresponding forms from the work [1].

The geometric model was created based on sketches of intersections of the

modeling object. First, sketches of two cross-sections of the instep were reproduced using splines of curves: on the inner part of foot in the shape of the pattern from the work [1], and on the outer part in a shape close to a straight line at the base of the sole. The 3D model of droplet-like element of the instep was obtained by drawing technology along two sections (Skin / Loft). When parametrizing model, the dimensions are first set for an averaged patient, and the typical parameters of material polyethylene foam (modulus of elasticity, Poisson's ratio, specific density, etc.) are also set, as well as the averaged load from above in the form of vertical pressure. In the future, all these numerical values of quantities are parameterized, that is, they are given names and the possibility of changes during analysis of the completed model.

The finite element mesh parameters for numerical analysis are left at default. The model with superimposed grid is shown in Figure 1.

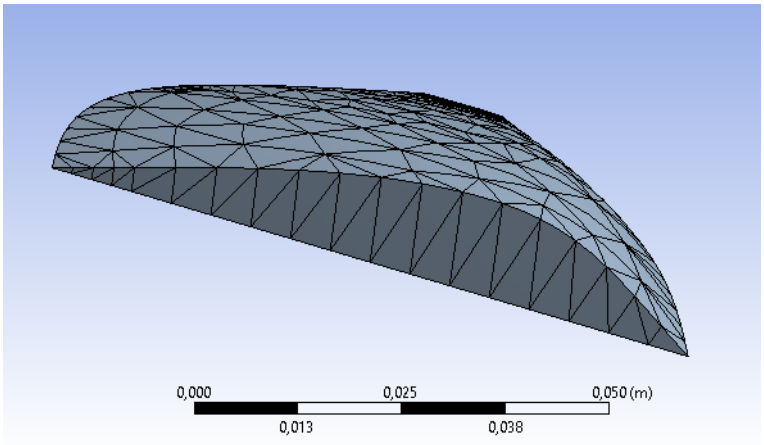

Figure 1 – 3D model of an instep element with an overlaid finite element mesh

After calculations by ANSYS processor of the correspondingly created model, the results of stresses, deformations and other parameters of grid nodes of the model are obtained, which can be further displayed in a user-friendly form. These can be appropriate tables, graphs, charts. For processing and presenting the results of calculations in a convenient form in ANSYS environment, there is a special powerful post-processing module that provides the possibility of additional processing of results through user-entered formulas and code fragments or standard library functions.

For example, one of the options for presenting results of calculations in the form of a deformations diagram along the plane of instep element is shown in Figure 2.

The insole parameters for the average patient and material are chosen: length 0.08m, width 0.06m, height in the undeformed state 0.012m, material density 7850kg/m3, Young's modulus 300000Pa, Poisson's ratio 0.42.

Here, the degree of deformation in corresponding points of the plane of instep element is indicated by color or intensity of gray. As you can see, the value of maximum deformation is highlighted on diagram. At the same time, it is clear that the deformation depends on many factors, such as dimensions of instep element, material parameters, the patient's weight, the size of his foot, and so on.

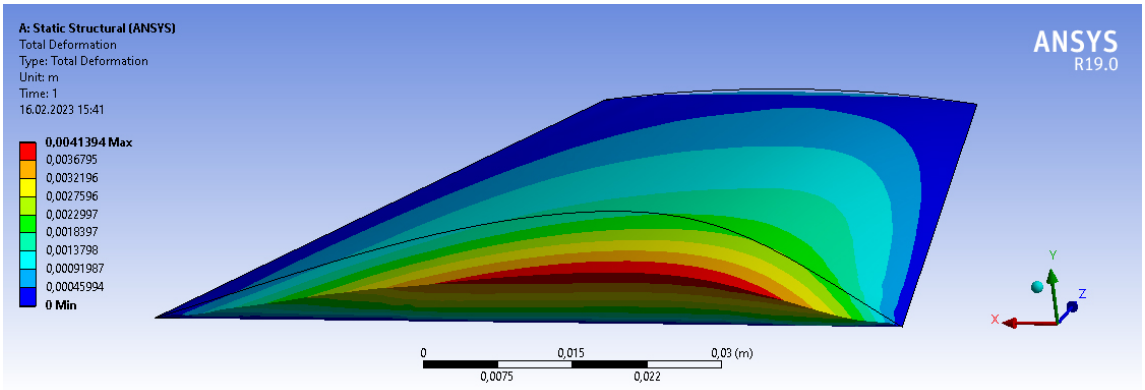

Figure 2 – Presentation of results in the form of a deformations diagram in the instep element

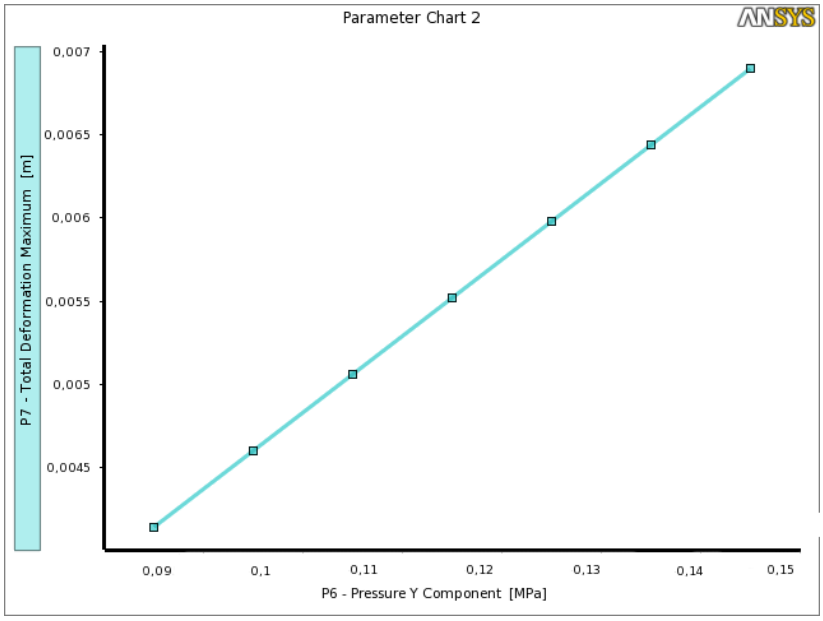

Figure 3 – Graph of dependence of the maximum deformation on the load (pressure on surface of the instep)

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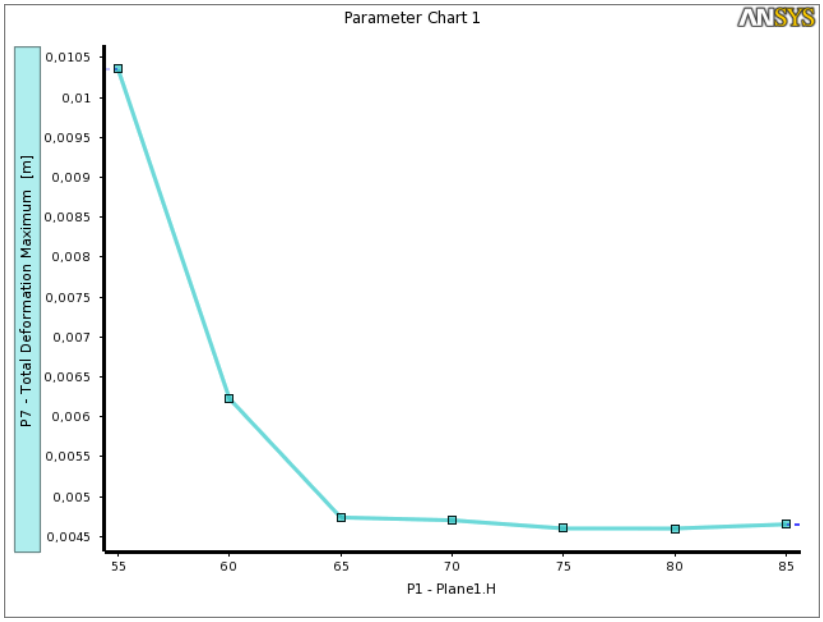

Figure 4 – Graph of dependence of the maximum deformation on the length of the instep

Parameterization of the model provides an opportunity to study dependencies between its target characteristics and independent parameters. As an example, in the graphs of Figure 3 and Figure 4 are shown the obtained dependences of maximum deformation on the load (pressure on the surface) and on the length of instep. The pressure is related to the patient's weight, and the length is related to the size of his foot.

As can be seen from the graphs, based on results of modeling the stress and deformation processes in rehabilitation product, it is possible to optimize the parameters of rehabilitation products depending on patient's characteristics.

Summary and conclusions.

The use of ANSYS environment is promising in solving the problems of rehabilitation engineering, where practical experience of specialists, rather than exact mathematical calculations, dominates so far. The paper shows possibility of building a model and engineering analysis of the functioning of different complex orthopedic products.

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