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# Biomechanical analysis of stent – oesophagus system

W. Kajzer, M. Kaczmarek, J. Marciniak

Institute of Engineering Materials and Biomaterials, Silesian University of Technology,
ul. Konarskiego 18a, 44-100 Gliwice, Poland

**Abstract:** The paper presents the biomechanical analysis of a stent – oesophagus system. In particular, stresses and strains for the esophageal stent (Z-type) reflecting its implantation technique were calculated. The obtained results are the basis for the optimization of the geometrical features of the stent and mechanical properties of the metallic biomaterial.

**Keywords**: Biomaterials, Esophageal stent, Finite element method

## 1. INTRODUCTION

The aim of the work was the biomechanical analysis of the given geometrical form of the esophageal stent used in a digestive system treatment. A three dimensional model of the stent implanted into the oesophagus and the mechanical parameters of the stent were used to evaluate the relationship between the stent and the oesophagus tissue [1-3]. The performed analysis concerned the stresses and strains distribution in the elements of the modeled system. The research connected with the experimental verification enables to work out the physical model taking into consideration the physiological conditions of a human. The obtained results are the basis for the optimization of the geometrical and material features of the stents and at the same time they allow to set the conditions useful for the implantation technique.

## 2. METHODS

### 2.1. Geometrical model of the stent – oesophagus system

In order to carry out the biomechanical analysis with the use of the finite element method a geometrical model of the esophageal stent was worked out. The following parameters were set [4]: the length of the stent l = 120 mm, the length of the reflux valve $l_z$ = 80 mm, the diameter of the stent wire $d_d$ = 0,37 mm, the thickness of the plastic layer g = 0,3 mm, the diameter of the stent in the distal part $d_1$ = 25 mm, the diameter of the stent in the middle part $d_2$ = 18 mm. These stents are made of the austenitic stainless steel. The stent was covered with the plastic layer.

In order to analyze the stent – oesophagus system a geometrical model of the oesophagus was also worked out. The model of the oesophagus was in the form of the thin-walled pipe of the following parameters [5]: the inner diameter $d_{wn}$ = 24 mm, the thickness of the wall $g_{sp}$ = 3 mm, the length of the oesophagus $l_p$ = 40 mm.

The length of the esophagus model was equal to the single segment of the stent increased in both directions of 10 mm.

### 2.2. Discrete model of the stent – oesophagus system

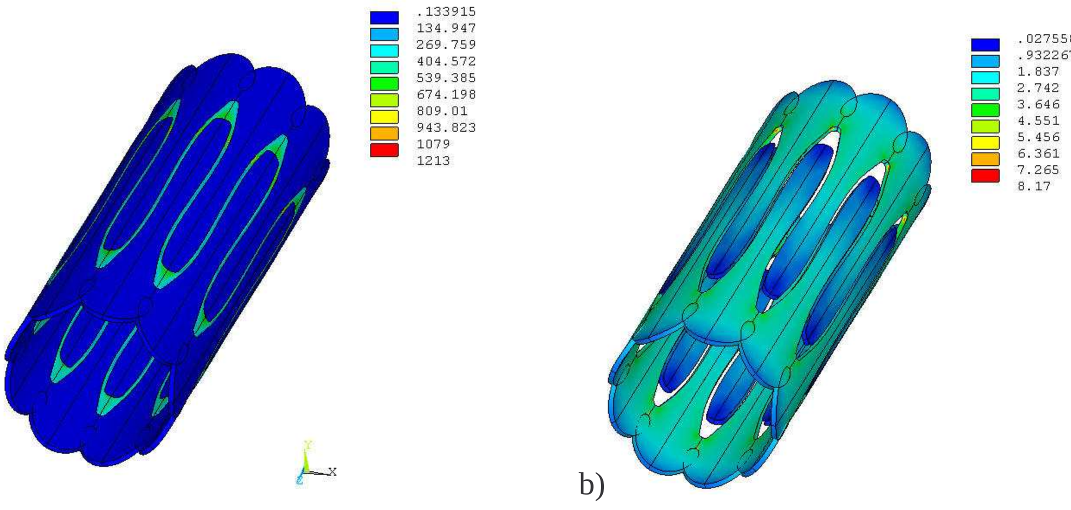
In order to perform the finite element analysis a meshing of the geometrical model of the implant was done. The SOLID95 finite element was used. This element allows to take into consideration a physical nonlinearities and large displacements. Due to the repeatability of the structure the calculations were carried out for the single segment of the stent (distal part). In the analysis the two stages were applied. The first stage was a clamping of the stent up to the diameter which allows to insert the stent into the oesophagus. The second stage was a slow expansion of the stent up to the initial diameter, a contact between the stent and the oesophagus and then the elastic work of the stent with the oesophagus. The simulation of the clamping and the expansion was performed in the displacemental manner.

## 3. RESULTS

### 3.1. The analysis of the stent – oesophagus system

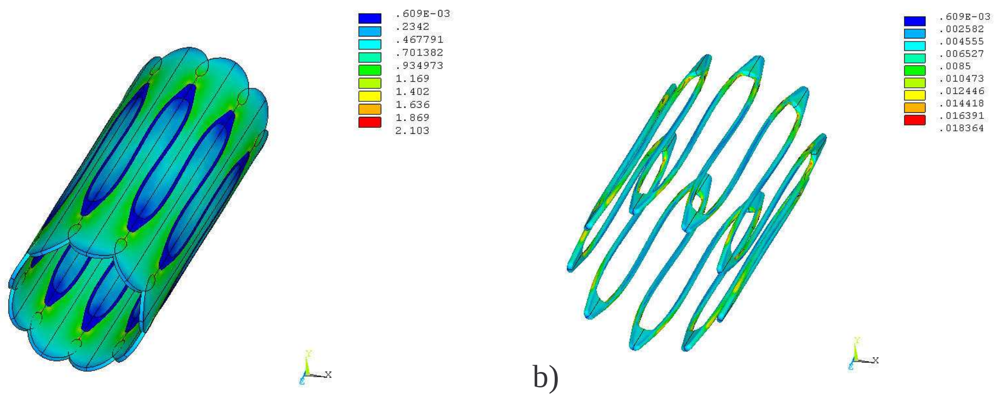
#### 3.1.1. The first stage - clamping of the stent up to the diameter which enables to insert the stent into the oesophagus

The stresses and strains in the elements of the esophageal stent for the given radial displacement equal to 7,5 mm were presented in fig. 5 and 6. The aim of the idea of the radial displacement was the diameter reduction of the distal part of the stent of 15 mm. It allowed to implant the stent into the oesophagus. The obtained stresses were in the range 0 ÷ 1213 MPa – fig. 1 and reached the maximum values in the bent regions of the stent. The stresses distribution for the plastic layer were presented in fig. 5b. the stresses were in the range 0 ÷ 8 MPa. The analysis of the model has shown that the strains were in the range 0 ÷ 201 % – fig. 6a. The highest strains were localized in the plastic layer bordered on the metallic segment in the bent region. The strains distribution for the metallic segment was presented in the fig. 2b. The maximum values were equal to 1%.




a) b)

Figure 1. Stresses distribution in the esophageal stent [MPa], the radial displacement – 7,5 mm: a) the stent, b) the plastic layer

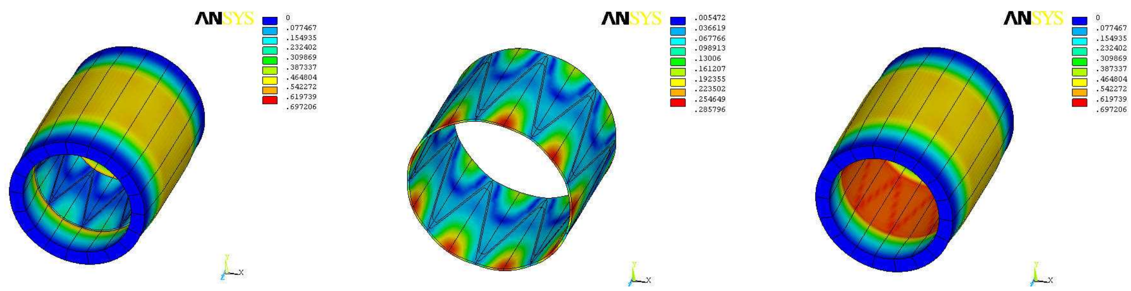



a) b)

Figure 2. Stresses distribution in the esophageal stent [MPa], the radial displacement – 7,5 mm: a) the stent, b) the plastic layer

### 3.1.2. The second stage – slow expansion of the stent up to the initial diameter, the contact between the stent and the oesophagus and the elastic work of the stent with the oesophagus

In the next steps the geometrical features of the stent during the expansion in the oesophagus were analyzed. The expansion was realized with the use of the radial displacement, up to the total expansion of the stent. The stresses, the strains and the displacements in the stent – oesophagus system were presented in the fig. 3 – 5. The analysis has shown that the radial displacements, after the total expansion of the stent, were in the range 0 ÷ 0,69 mm (fig. 3a). The maximum radial displacements in the stent were equal to 0,2 mm (fig. 3b) and in the oesophagus were 0,69 mm (fig. 3c). The stresses were in the range 0 ÷ 247 MPa (fig. 4a and 4b) and the maximum values were localized in the bent region of the metallic segment. The stresses distribution in the oesophagus was in the range 0 ÷ 2,6 MPa - fig. 4c. The strains were in the range 0 ÷ 27 % - fig. 5a and 5b. The highest strains for the layer were localized at the ends of the analyzed segment. Figure 5c shows the strain distribution in the oesophagus.




a) b) c)

Figure 3. Radial displacements [mm] during the work of the system: a) the stent – oesophagus system, b) the stent, c) the oesophagus

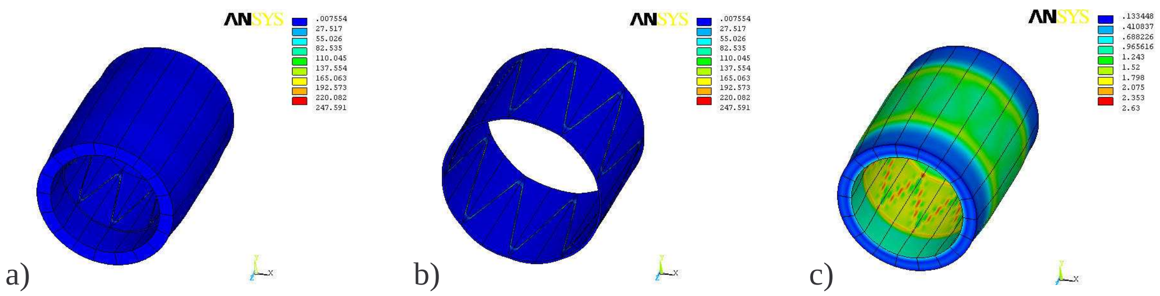



Figure 4. Stresses distribution [MPa] during the work of the system: a) the stent – oesophagus system, b) the stent, c) the oesophagus

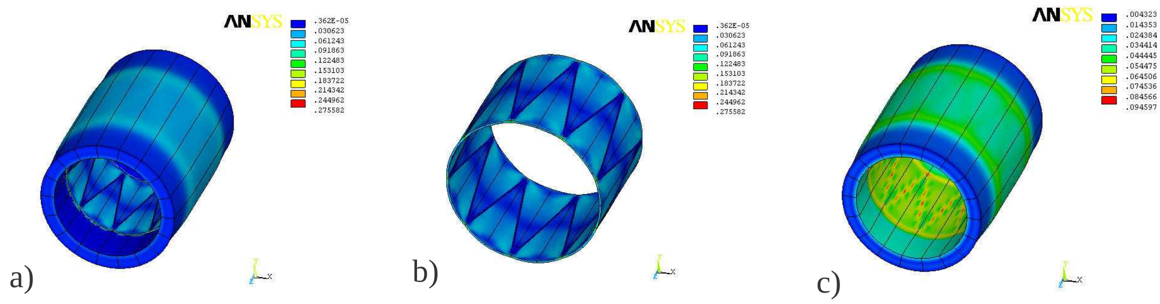



Figure 5. Strains distribution [x100%] during the work of the system: a) the stent – oesophagus system, b) the stent, c) the oesophagus

## 4. SUMMARY

The numerical analysis of the esophageal stent – oesophagus system was performed. The analysis took into consideration the conditions caused by the narrowing of the oesophagus lumen resulting from the progressive malignant disease. The implantation operation was connected with the initial clamping of the stent. The clamping ensured the implantation of the stent into the appropriate site in the oesophagus. The calculated values of the stresses and the strains in the elements of the esophageal stent are the basis for the optimization of the geometrical features of the stent and mechanical properties of the metallic biomaterial.

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