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BIOMECHANICS - TESTING OF MECHANICAL AND UTILITY PROPERTIES OF BOTTLES FOR REDON DRAINAGE

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Abstract: *The article deals with biomechanical research of properties of bottles for Redon drainage, which is used in treatment for removal of unwanted fluids from the human body. Several measurements were made of vacuum, tightness and the amount of drained fluid and also a stress analysis of bottle walls using the finite elements method. The results (operating characteristics, mechanical properties) are important basis for the introduction of the product in normal medical practice. The collected data can be used to deduce the correct use of drains during treatment.*

Keywords: Redon drainage, Measurements, Calculations, Removal of fluids, Mechanical stress.

1. Introduction

Drain is a commonly and widely used medical device for removal of unwanted physiological or pathological fluids from the body (such as blood, lavage fluid, pus, intestinal contents, air etc.), see Fig. 1. There are various types of drainage. Our article deals with the vacuum/suction (i.e. Redon drainage), see the product in Fig. 1b. Redon drainage is a system based on the principle of vacuum extraction of fluid into a collection bottle through a suction tubing with a terminal connection to the drain, which is inserted into the patient body, see references Frydrýšek (2016), Carruthers (2013) and Williams (2003).

Fig. 1: Vacuum drainage: a) application; b) examined Redon vessel.

At the request of the manufacturer of medical devices, our workplace tested a device for extracting air from Redon bottle drains, Fig. 1b. After reaching the desired vacuum in the bottle, the rubber neck is secured with a locking clasp and the Redon bottle is ready for use. The bottle vacuum allows draining of fluids e.g. after a surgery.

In addition to verification of the vacuum device, parameters of the Redon bottles themselves were measured (pressures and the amount of drained fluid), see Figs. 1b to 3. Finally, also the strength and deformation analysis was performed using FEM. The results will serve as an important basis for product recommendation to common medical practice. The collected information also gives an overview of the characteristics of the Redon drainage, which doctors can utilize in improving patient care.

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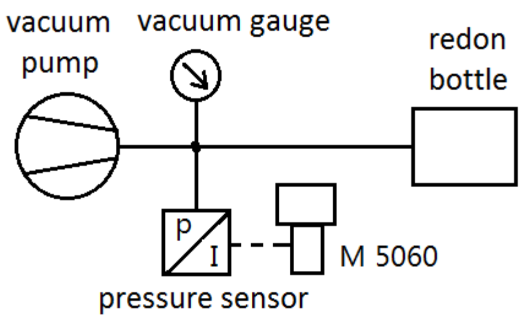

Fig. 2: Measurement of air vacuum during aspiration of a Redon bottle.

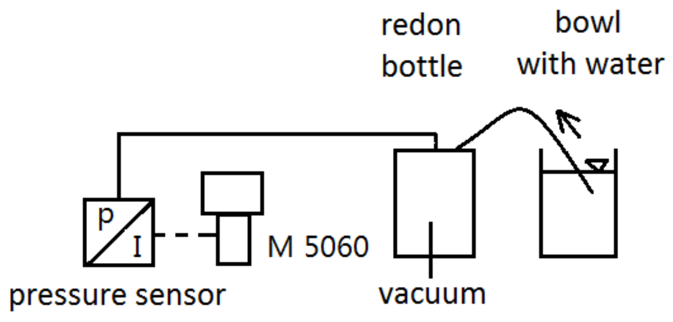

Fig. 3: Measurement of draining of fluid.

2. Measurement

The actual evacuating device is relatively simple; it consists only of a mechanical vacuum pump Busch R5, vacuum gauge and port for connection of the bottle. For measurement of vacuum the PR15 sensor was used, with measurement range –1 to 6 bar and a measurement device M5060, both from Hydrotechnik. Multi-system M5060 is designed to measure pressure, temperature, flow, force, torque, and other variables. According to the manufacturer, the measurement uncertainty is ± 0.15 % of the maximum measured value.

First, the calibration of the vacuum indicator located on the vacuum pump was performed. This was followed by verification of the aspiration rate of air from the bottle of volume 400 ml. The measurement schematic is in Fig. 2.

Fig. 4 shows the measured course of pressure in a bottle of an effective volume 400 ml (the calibrated volume of the bottle, above the max. volume line there is still approx. 50 ml). The aspiration of air started at 1 s and the required vacuum, i.e. min –0.9 bar was reached approx. in 2 s. After this time the bottle can be closed.

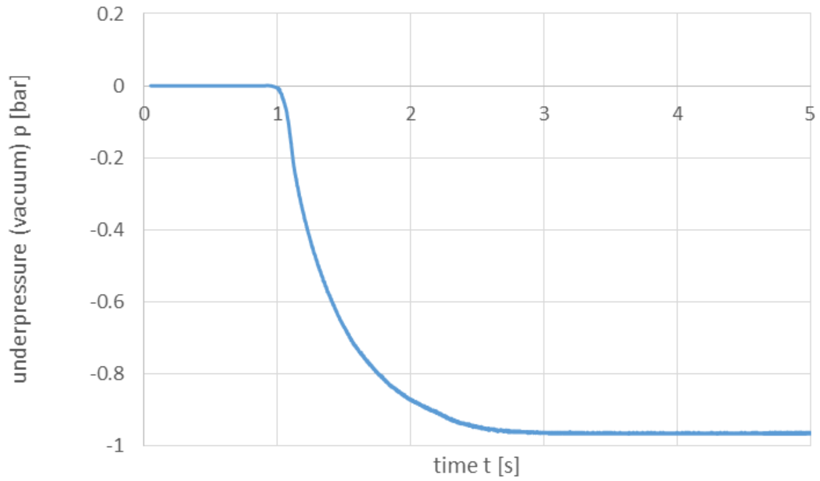

Fig. 4: Measurement - course of air vacuum during aspiration.

Another measurement was to determine the changes in vacuum, depending on the amount of drained liquid. During the measurements the bottle was connected through a tube to a pressure sensor, and through a second tube, after the release of the clasp, water was drained into the bottle, see diagram in Fig. 3. During filling of the bottle the vacuum has been recorded, and the value of the volume of drained liquid was read from the scale on the bottle. Measurements were performed on two bottles. From the course of pressure in Fig. 5 it is evident that after the effective volume 400 ml is filled, the remaining vacuum in the bottle is min. –0.8 bar.

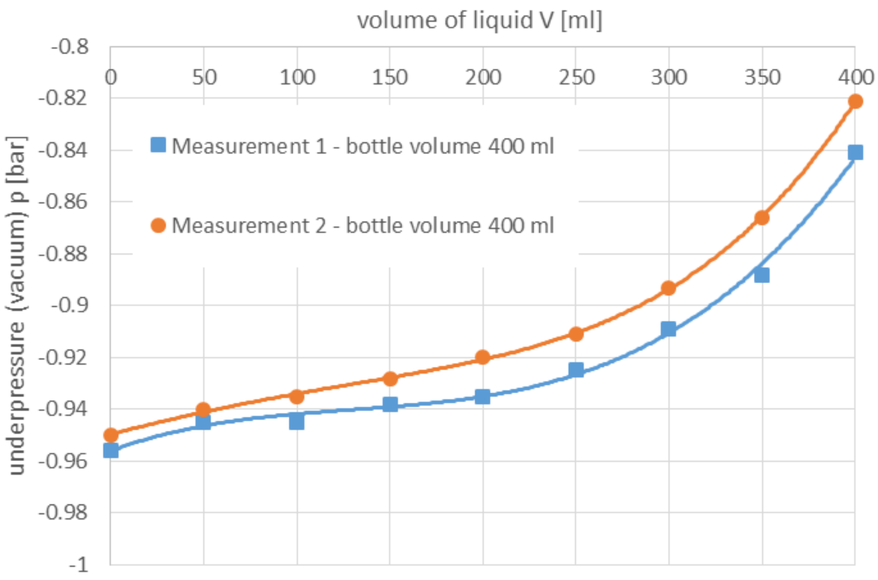

Fig. 5: Two measurement records - course of pressure during drainage.

The next measurement verified the amount (level) of vacuum in bottles ready for shipment. 10 samples of 200 ml and 10 samples of 400 ml were examined. Results are shown in Tab. 1.

Tab. 1: Vacuum in Redon bottles ready for use.

measurement	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**mean**
bottles 400 ml	-0.898	-0.888	-0.878	-0.888	-0.895	-0.892	-0.878	-0.898	-0.885	-0.868	**-0.8868**
bottles 200 ml	-0.777	-0.75	-0.777	-0.754	-0.757	-0.744	-0.761	-0.758	-0.761	-0.785	**-0.7624**

Apart from the above measurements, also e.g. tightness of the bottles, tightness of clasps for closing bottles, tightness of hose connections were determined.

3. Finite Element Analysis of Redon bottles

The subject of the FEM calculation was verification of the strength of the collection vacuum Redon bottle when comparing various shape versions (imperfections) that are commonly encountered during the production process. The vessel is made of hard PVC. The vacuum in the bottle is 0.9 bar.

The measurements of randomly selected bottles and the adopted simplifications showed 8 variants of simple geometries of symmetrical vessels (plane strain formulation), see Fig. 6. Variants 7 and 8 correspond to the bottle with a notch (extremely damaged bottle). The bottle material is considered isotropic and homogeneous. Finally, the calculations of deflections and stresses were performed, see e.g. Fig. 7.

4. Conclusions

From experiments (pressure measurement and measurement of the quantity of drained fluid) and stress analysis (calculations of deflections and stress) it is evident that the disposable Redon bottles are properly designed and can be used in conventional medical practice.

Knowledge gained from measuring of fluid drainage is important finding for physicians and serves to improve the patient care.

Acknowledgments

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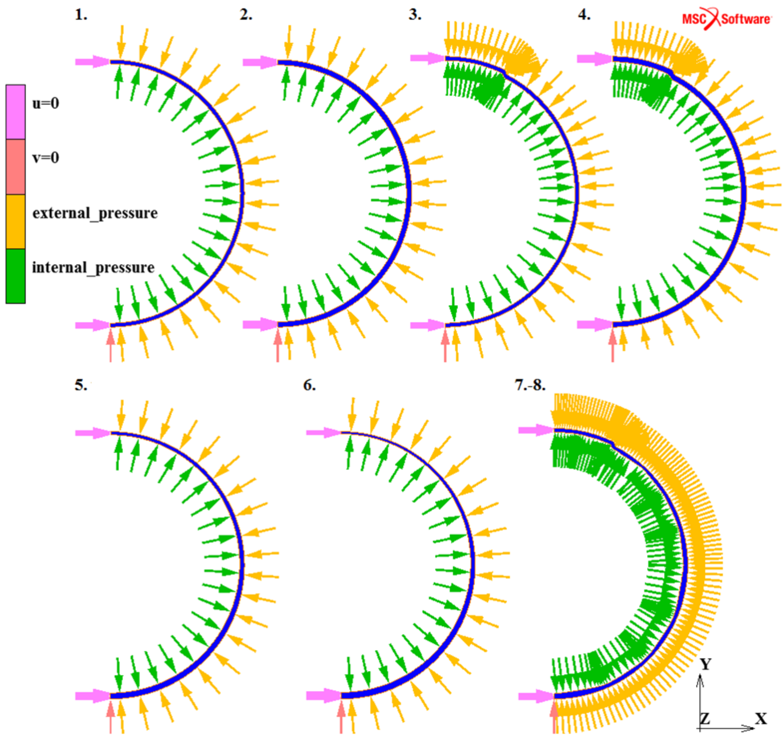

Fig. 6: FEM - Variants of Redon bottle calculations (plain strain, planar symmetry and boundary conditions, SW MSC.MARC/MENTAT).

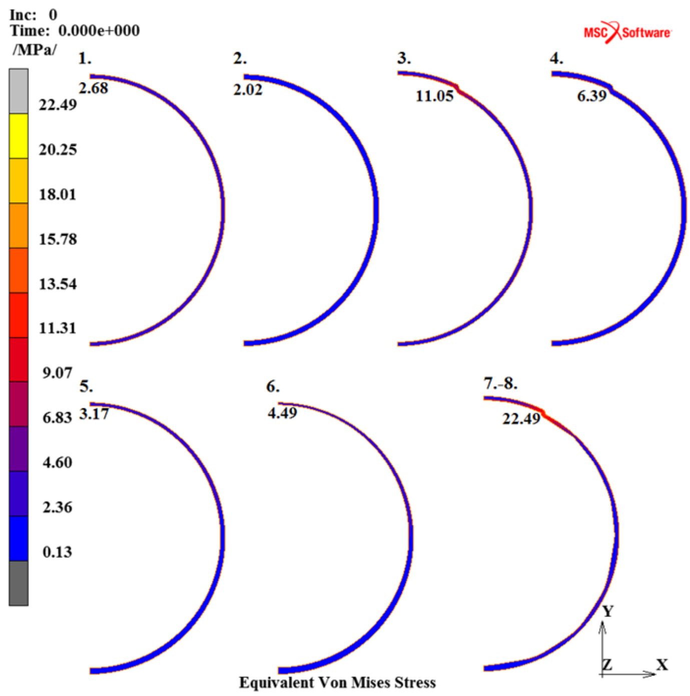

Fig. 7: FEM - Variants of Redon bottle calculations (Equivalent von Mises Stress).

References

Carruthers, K.H., Eisemann, B.S., Lamp, S. and Kocak, E. (2013) Optimizing the closed suction surgical drainage system, Plast Surg Nurs, 2013, 33(1), pp. 38-42.

Frydrýšek, K. and Dvořák, L. (2016) Redon bottles - Calculation and Measure Report, 218, 5, pp. 1-35.

Williams, J., Toews, D. and Prince M. (2003) Survey of the use of suction drains in head and neck surgery and analysis of their biomechanical properties, J. Otolaryngol 2003, 32(1), pp.16-22.