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# TESTING THE STRENGTH OF LASER-BONDED ANIMAL INTESTINES

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**Abstract:** *The paper presents the test results of the tensile strength of animal intestines bonded by laser technique. Laboratory studies were carried out on pig intestines using red laser light. The studies were performed according to four different procedures with and without albumin adjuvants*

**Keywords: Animal's intestines, Static tensile test, Influence of temperature, Laser-bonded.**

## 1. Introduction

Natural casing (NC) is part of the small intestinal submucosa (SIS) of the animal, usually pig or sheep's intestine, obtained by mechanically separating it from the intestine. SIS - an acellular, biological extracellular matrix (ECM) - consists mainly of collagen fibers and contains elastin, glycosaminoglycans, proteoglycans (Shi et al., 2013) which preserving the mechanics of the tissue, used in food production, is highly hydrated. The SIS porcine thickness varies from 0.05 mm to 0.22 mm, the surface has a porous microstructure with pores ranging from 20 to 30 µm (Badylak et al., 1989, Nihsen et al., 2008). SIS has a similar structure and biological properties to the skin, therefore it is used as a dressing, tissue scaffold, in the treatment of difficult-to-heal wounds (Badylak et al., 2009).

Laser tissue welding (LTW) is a surgical method for the anastomosis of ruptured tissues including skin and small intestinal tissue (Yang et al., 2011, Huang et al., 2013). In the low-temperature technique, irradiation with laser light induces a localized heating of the tissue and did not exceed the denaturation temperature of fibrillar collagen (i.e. about 65 °C) (Matteini et al., 2007). The mechanism LTW is related to some structural modifications of the non-fibrillar components of the ECM (Matteini et al., 2009, Schober et al., 1986).

A variation of this technique is laser tissue soldering (LTS) using a diode laser and an indocyanine green (ICG) / albumin solder, or bovine serum albumin (BSA) in various concentrations, thanks to which minimal damage to underlying tissue is formed (Cooper et al., 2001). The strength of solder-tissue bonds is dependent on protein concentration (Lauto et al., 1997). LTS technique has been reported in many studies to be much quicker to perform than conventional suture techniques, as well as providing an immediate leak-free closure, with improved histological and mechanical behavior (McNally et al., 1999). Tissue, which is mostly composed of water, strongly absorbs energy and has a penetration depth of about 10 µm for $CO_2$ laser (Thomsen et al., 1987). The argon laser, with moderate tissue penetration of about 200 µm, successfully welded medium and large-sized arteries and created vein – artery anastomoses (White et al., 1986).

The analysis of the joining process used in mathematical models indicates many important physical and

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biological parameters that determine its course. Effective integration of mathematical modeling with laser solder operation can potentially reduce the overall number and duration of experimental trials and potentially lead to improved outcomes for tissue repair by minimizing healthy tissue damage (Mushaben et al., 2018).

## 1. Laboratory tests

The tests were carried out by the following four procedures described in detail below. The main aim of the research was to check the connection strength between laser-bonded intestines. A further goal of this researches was the empirical determination of the connection parameters. The tests were carried out with different values of the laser power (relative to the maximum power of 50 W), beam feed speed, and without and with adhesive substances (albumin 50 % and 100 %).

### 2.1. Procedure no. 1

- cutting two pieces of the casing, about 10 cm long each,
- placing the first intestine on the glass tube (see Fig. 1),
- placing the second intestine on the glass tube, in a way that one overlaps the other (see Fig. 1),
- heating the overlap area by a red laser beam by the following diagram (see Fig. 2a),
- carrying out a test of breaking the connection and its evaluation with the measurement of the force carried out.

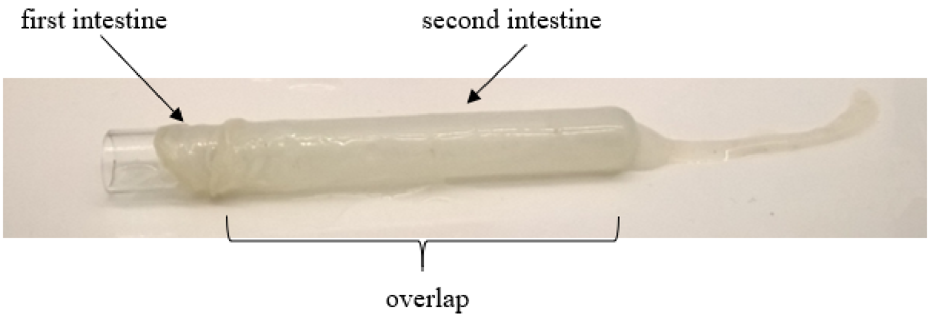


*Fig. 1: Intestines over the glass tube.*

### 2.2. Procedure no. 2 ÷ 4

The next procedures were carried out similarly to procedure no.1. In the comparison with the first procedure, and additionally was used albumin solution (covering between the intestines) and heating the overlap area by a red laser beam by the following diagrams, shown in Fig. 2.

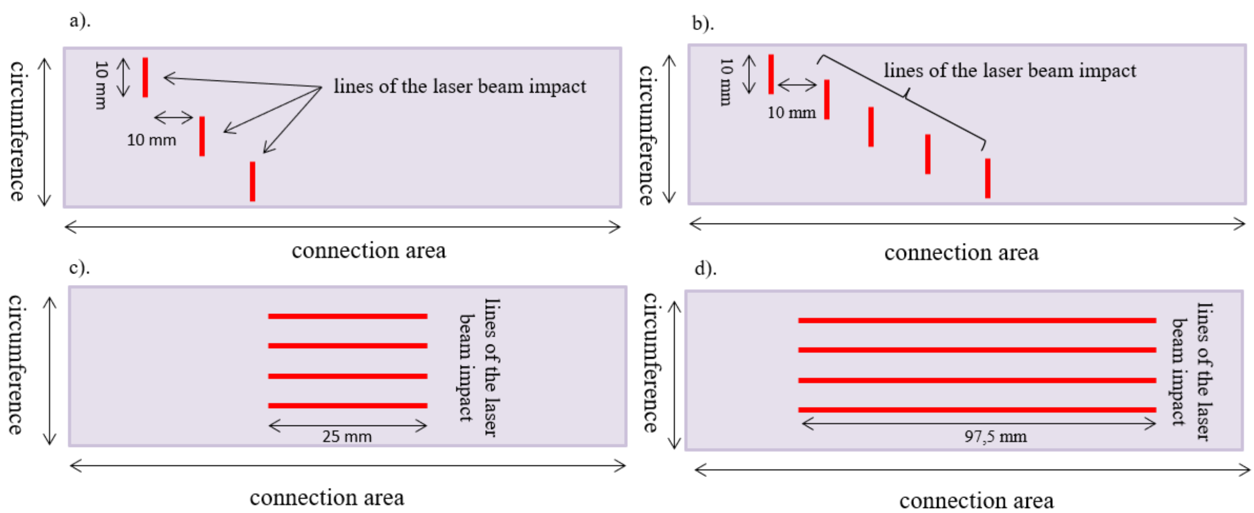


*Fig. 2: The location of the lines of laser beam impact on the casings in the connection area for a) procedure no. 1; b) procedure no. 2; c) procedure no. 3; d) procedure no. 4.*

The obtained results for the above procedures were collectively presented in Tab. 1.

*Tab. 1: The results of laboratory tests according to procedures no.1, 2, 3, and no. 4.*

| | Procedure 1 | | | Procedure 2 | | | Procedure 3 | | | Procedure 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Laser power [%] | 15 | 15 | 15 | 15 | 15 | 15 | 11 | 11 | 11 | 11 | 11 | 11 |
| Laser speed [mm/s] | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 |
| Connection force [N] | 5.1 | 5.4 | 4.7 | 10.4 | 2.9 | 12.3 | 11.6 | 11.2 | 9.8 | 13.1 | 24.1 | 15.5 |
| Adhesive substance [%] | No | No | No | 50 albumin | 50 albumin | 50 albumin | 50 albumin | 50 albumin | 50 albumin | 100 albumin | 100 albumin | 100 albumin |

## 3. Conclusions

- The use of a red laser by the following procedure no. 1 allows for obtaining the bond strength despite the lack of a bonding substance.
- During the implementation of connecting casings according to procedures 1 ÷ 4, the temperature value (250 °C) was not exceeded in the place of the laser beam impact (Fig. 3).

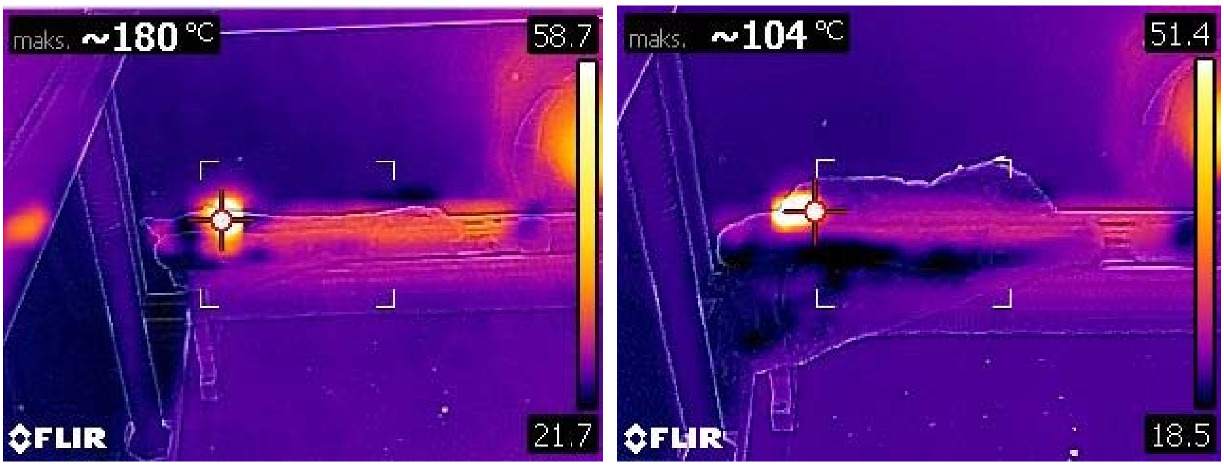


*Fig. 3: Thermal images of the zone of the connection made with the red laser.*

- The phenomenon of strong intestinal contraction was observed under the influence of the laser beam, therefore it is necessary to apply mechanical pressure on the edges of the joined intestines.
- The use of mechanical pressure increases the strength of the connection by 3 ÷ 4 times, which results from the results presented in the 1, compiling the results of the tests carried out by the following procedure no. 2.
- Reducing the laser power and the laser speed results in less intestinal contraction, even in the absence of mechanical pressure.
- Based on laboratory tests carried out by the following procedures no. 1, 2, and 3, it was found that the water in the area between the interconnected intestines was justified initially, and therefore another method of applying the adhering substance (albumin in powder form) was proposed. By using the

method of blowing powdered albumin, the effect of partial binding of water in the area between the joined intestines was obtained.

- The mechanism of connecting tissues with laser light is not yet well understood to decide whether protein coagulation or other modifications taking place in the ECM determine its quality. NC supplemented with protein substances such as albumin allows testing hypotheses regarding this process.

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