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Fibre laser cutting of polymer tubes for stents manufacturing

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Abstract

Nowadays, stents are the main treatment modality for atherosclerosis. Although metallic stents are effective many concerns still remain. Bioresorbable stents (BRSs) were introduced to overcome these limitations with important advantages. In this paper the authors aim to study the effect of fiber laser cutting over polycaprolactone (PCL), polylactide acid (PLA), and PLA-PCL tubes for stent manufacturing. The effect of Power, Cutting Speed, and Number of Passes over Penetration, Precision, and Dross is presented. Results have shown the difficulty of cut PLA with 1.08 um wavelength lasers, being impossible to achieve a complete penetration both the PLA tubes, as composite tubes. Nevertheless, with PCL tubes, fibre laser has been able to achieve dimensional precisions above than 95.75 %. Fibre laser has been shown to be a profitable tool to manufacture polycaprolactone stents.

Keywords: Fiber Laser, Cutting, Polymers, Tube, Stent

1. Introduction

Nowadays, stents are the main treatment modality for atherosclerosis. Although current stents are effective, many concerns still remain. Recently, bioresorbable stents (BRS) were introduced to overcome these limitations with important advantages: complete bioresorption, mechanical flexibility, etc. Several types of materials are currently been investigated: poly-L-lactic acid (PLLA) and magnesium have been the most promising materials although other polymers suggested as material for bioabsordable stents include polyglycolic acid (PGA) and polycaprolactone (PCL)[1].

The main efforts have been focused on analysing the mechanical and medical considerations of new biodegradable materials. Hideo Tamai et al [2] evaluated the feasibility, safety, and efficacy of the PLLA stent in humans. Fifteen patients electively underwent PLLA Igaki-Tamai stent implantation for coronary artery stenosis with promising results. Venkatraman et al. [3] reported, for the first time, the development of a fully biodegradable polymeric stent

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that can self-expand at body temperatures. Liang et al. [4] designed a biodegradable shape-memory block co-polymers (PCTBV-25) for fast self-expandable stents. The stent made from PCTBV-25 film showed nearly complete self-expansion at 37ºC within only 25 s, which is much better and faster than the best-known self-expandable stents. Vieira et al. [5] studied the evolution of mechanical properties during degradation based on experimental data. The decrease of tensile strength followed the same trend as the decrease of molecular weight.

Although the mechanical and medical properties of the material are important, finding the best manufacture process to this kind of material has to be considered as well. Lasers appear to be the perfect tool for this purpose. Therefore, some authors have been focusing their studies in the laser manufacturing process of polymers. Grabow et al. [6] studied the effect of CO2 laser cutting, and sterilization on Poly-L-Lactide (PLLA). The results showed the dramatic influence of the sterilization procedure on the mechanical properties of the material. Rocio Ortiz et al. [7] examined the picosecond laser ablation of PLLA as a function of laser fluence and degree of crystallinity. Their results revealed the potential of the ultra-fast laser processing technique. Leone et al. [8] employed a 30 W MOPA Q-switched pulsed Yb:YAG to cut Carbon Fibre Reinforced Polymeric Composite (CFRP) thin Sheet. Stepak et al. [1] fabricated a polymer-based biodegradable stent using a CO2 laser. Tamrin et al. [9] determined an optimized set of cutting parameters for CO2 laser for three different thermoplastics employing grey relational analysis.

Although the effect of laser process over different polymers has been studied, nowadays, further studies about the laser cutting process of biodegradable materials are would be helpful to manufacture stents, which expands the laser manufacturing possibilities. The semi-transparent behaviour of most organic polymers at high wavelengths, hinders their manufacturing process with some sort of lasers, making the adaptation of this industry to these new materials costly. This work shows experimentally the feasibility of 1.08 µm wavelength fibre laser to cut polymers, which can open a new market opportunity to laser cutting firms. In this paper the authors aim to study the effect of fiber laser cutting over PCL, PLA, and PLA-PCL tubes for stent manufacturing. The effect of pulse power, cutting speed, and number of passes over complete penetration, dimensional precision, and dross is presented.

2. Material and Method

2.1. Laser Cutting System

Experiments were carried out with a CNC lathe machine. The laser employed was a Fibre Laser Rofin FL x50s that provides: a 1.08 um of wavelength, 26 µs of shorter pulse width, 500 W of maximum power, a higher frequency of 5000 Hz and 1.1 of beam quality with 150 µm of fiber diameter (Fig. 1). The coaxial assist gas nozzle had an exit diameter of 0.5 mm. Pressure air at 0.4 MPa was used for the experiments.

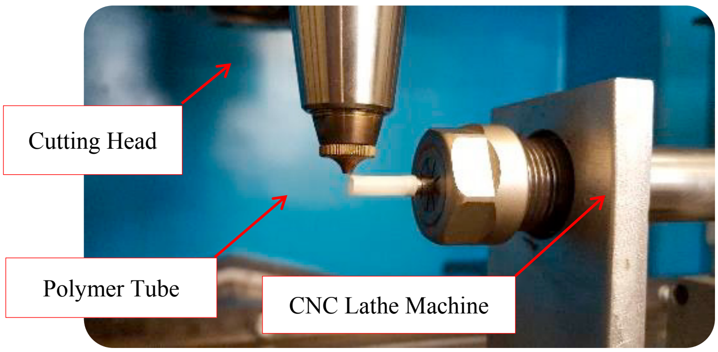

Fig. 1. Laser cutting system

2.2. Materials

Polycaprolactone (PCL) Capa 6500® supplied by Perstorp and Polylactide (PLA) 3251D® supplied by NatureWorks were used as material for the experiments. PCL is a biodegradable polyester with a low melting point