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Effect of moisture content of paper material on laser cutting

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Abstract

Laser technology has been used in industrial processes for several decades. The most advanced development and implementation took place in laser welding and cutting of metals in automotive and ship building industries. However, there is high potential to apply laser processing to other materials in various industrial fields. One of these potential fields could be paper industry to fulfill the demand for high quality, fast and reliable cutting technology. Difficulties in industrial application of laser cutting for paper industry are associated to lack of basic information, awareness of technology and its application possibilities.

Nowadays possibilities of using laser cutting for paper materials are widened and high automation level of equipment has made this technology more interesting for manufacturing processes. Promising area of laser cutting application at paper making machines is longitudinal cutting of paper web (edge trimming). There are few locations at a paper making machine where edge trimming is usually done: wet press section, calender or rewinder. Paper web is characterized with different moisture content at different points of the paper making machine.

The objective of this study was to investigate the effect of moisture content of paper material on laser cutting parameters. Effect of moisture content on cellulose fibers, laser absorption and energy needed for cutting is described as well. Laser cutting tests were carried out using CO_2 laser.

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Keywords: laser cutting; paper material; cellulose; edge trimming; energy

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1. Introduction

The laser cutting process of paper, as with most wood-based materials, is a thermochemical decomposition process. The principle of laser cutting process applied to paper material is shown in Figure 1 (Piili, 2009).

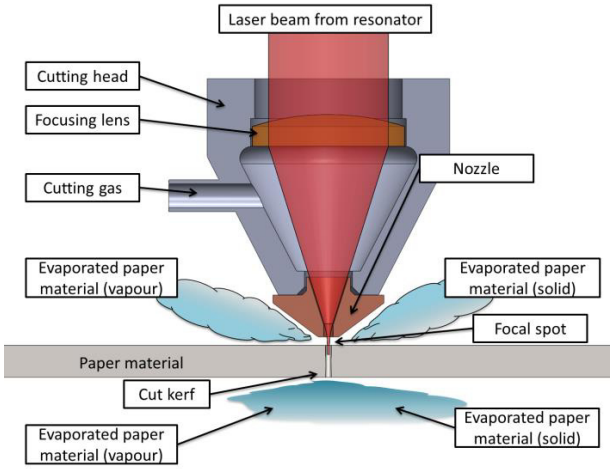

Fig. 1. The principle of laser cutting of paper. (Piili, 2009)

Nomenclature

E_l	cutting energy per unit length [J m^{-1}]	δ	thickness of paper material [m]
P	laser power [W]	R	radius of laser beam [m]
v	cutting speed [m s^{-1}]	C_p	specific heat of paper material [J kg^{-1} K^{-1}]
Cp_1	specific heat capacity of paper material [J kg^{-1} K^{-1}]	Cp_2	specific heat capacity of water [J kg^{-1} K^{-1}]
ρ	density of paper material [kg m^{-3}]		
w_1	mass fracture of paper material [kg]	w_2	mass fracture of water [kg]
ΔT_d	(= T_d - T_a, T_d = degradation temperature, T_a = ambient temperature) [K]		

As can be seen from Fig. 1, cutting process of paper with laser is considered as vaporization cutting. When the laser beam reaches the surface of the work piece it heats up the material to its evaporation temperature and causes the material to sublimate. (Piili 2009)

The energy from the laser beam interacts with the paper material to break chemical bonds and thus disrupt the structure of the material. When cutting a material such as paper, cardboard or pulp, this degradation process has the effect of reducing the large cellulose molecules down to their elemental constituent, which are carbon, hydrogen and oxygen. (Piili 2009) Thus, laser cutting imply low possible health hazard that could be caused by the fumed chemical compounds or the compounds that stay on the cut surface. However, there are not enough studies made on this topic.

Laser light significantly differs from ordinary light by its unique characteristics. Laser light has the photons of same frequency, wavelength and phase. In comparison to ordinary light, laser beams are highly directional, have high power density and better focusing characteristics. This enables the laser beam to be used for material processing. Moreover, different laser types generate the beam with different properties (Dubey and Yadava 2008).

2. Interaction of light and paper material

Laser cutting process can be considered as a thermochemical decomposition process. However, decomposition process takes place when laser radiation is absorbed by the paper material, i.e. the paper material is in interaction with