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Ultrafast pulse Lasers Jump to industrial Macro Applications

Martin Griebel, Walter Lutze, Jürgen Weißer, Jan Langebach

(JENOPTIK Automatisierungstechnik GmbH, Konrad-Zuse-Straße 6, 07745 Jena, Germany)

[a]*First affiliation, Address, City and Postcode, Country*

[b]*Second affiliation, Address, City and Postcode, Country*

Abstract

Ultrafast Lasers have been proven for several micro applications, e.g. stent cutting, for many years. Within its development of applications Jenoptik has started to use ultrafast lasers in macro applications in the automotive industry. The JenLas D2.fs-lasers with power output control via AOM is an ideal tool for closed loop controlled material processing. Jenoptik enhanced his well established sensor controlled laser weakening process for airbag covers to a new level. The patented process enables new materials using this kind of technology. One of the most sensitive cover materials is genuine leather. As a natural product it is extremely inhomogeneous and sensitive for any type of thermal load. The combination of femtosecond pulse ablation and closed loop control by multiple sensor array opens the door to a new quality level of defined weakening. Due to the fact, that the beam is directed by scanning equipment the process can be split in multiple cycles additionally reducing the local energy input. The development used the 5W model as well as the latest 10W release of JenLas D2.fs and achieved amazing processing speeds which directly fulfilled the requirements of the automotive industry. Having in mind that the average cycle time of automotive processes is about 60s, trials had been done of processing weakening lines in genuine leather of 1.2mm thickness. Parameters had been about 15 cycles with 300mm/s respectively resulting in an average speed of 20mm/s and a cycle time even below 60s. First samples had already given into functional and aging tests and passed successfully.

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1. Main text

The femtosecond laser is already an established instrument for various micro applications ranging from medical engineering and precision finishing in machine-tool building to semiconductor industry. However, it is not often found in typical macro applications in established industries such as the automotive industry.

Jenoptik with its Lasers & Material Processing division is both manufacturer and user of this type of laser. The Lasers business unit develops and produces 5-Watt and 10-Watt femtosecond lasers while the Material Processing business unit uses these lasers in machine tools.
The automotive related application described below was already developed 15 years ago and, equipped with a CO_2 laser tool, it was introduced into the industry for a wide range of applications. The goal is to create a succession of individual laser drill blind holes which form an invisible tear seam in single-layer or multi-layer materials serving as a cover for an airbag. Typical customers for this type of machine are companies in the automotive industry, both as manufacturers and with the established suppliers.
Due to its wavelength, the CO2 laser is perfectly suited for most of the plastic materials used. However it comes up against limiting factors caused by the thermal load when particularly delicate trim materials such as genuine leather are to be processed. Up until now, there has been no satisfying solution for this, resulting in this type of laser not being used in series production.

The method described in patent EP 0 827802 B1 is based on the measurement of the small transmitted portion of the laser radiation as the beam penetrates the composite material. The recorded signals are used, according to the penetration depth, to control the laser process precisely in order to reach the predefined residual wall thickness, resulting in a high-quality weakening with a clearly defined tearing resistance and no visibility on the A-surface.
The corresponding machine type JENOPTIK VOTAN® A is already being used by all reputable manufacturers and is popular world-wide.

However, the thermal input is too high for temperature-sensitive decoration materials such as leather, leading to negative side effects. The generated exhaust gas inflates the fiber structure, causing the delicate collagen fibers to stiffen and expand along the cutting contour. Because of this, the processed leather shows a visible bulge and is noticeably thicker and harder along the processing line.

In order to address these negative effects and reduce them to an acceptable level, the heat input and the heat-affected zone arising from the laser process have to be reduced considerably.

It is exactly for these requirements that the femtosecond laser is perfectly suited. Material is removed by ultrashort pulses with very high peak-intensity while the adjacent material is not heated up significantly. Jenoptik takes advantage of this effect when using the new process variant for material processing.

A scanner cyclically directs the laser beam along the contour to be processed on the leather part, gaining in depth cycle by cycle.
Opposite the beam exit side, there is a sensor array that monitors the scanner's working range, captures the process for each processing point, and stops the process when the desired residual wall thickness has been reached.

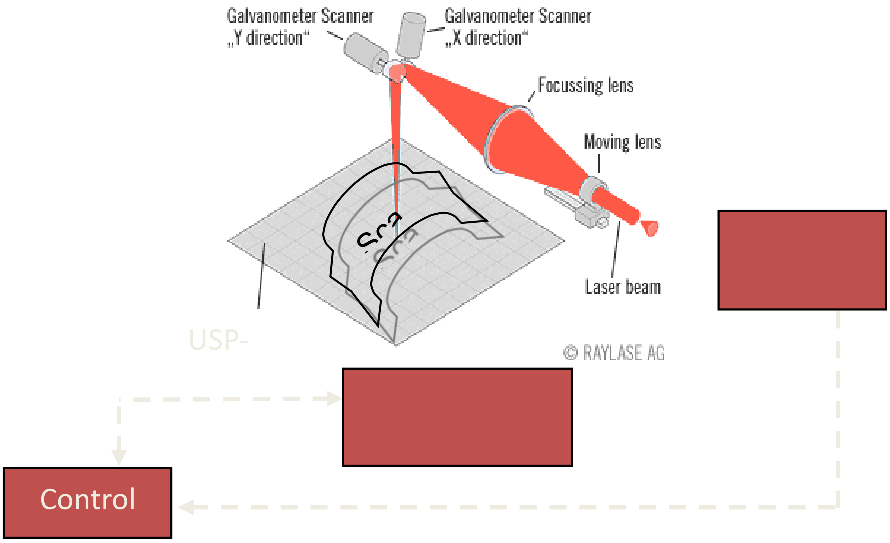

Fig. 1. control prinziple

Typical material thicknesses for leather range from 1 to 1.6 mm. It takes approximately 15 to 20 cycles to reach the desired thickness. Especially in the last cycles, only those processing points where no sensor signal has indicated that the target residual wall thickness has been reached are machined by the laser beam. This method is described in the patent DE 10 2013 104 138 B3 and is being adapted for use in an industrial system at the moment.

Especially high-energy impulses are essential for optimal ablation and successful process control. So it is very advantageous that the in-house 10-Watt infrared-power femtosecond laser JENOPTIK JenLas® femto 10 provides impulses having an especially high energy of up to 60 µJ.

The laser is equipped with a seed oscillator and a regenerative amplifier. This technology is particularly well suited for creating radiation with a high optical quality and pulses with high pulse energies at repetition rates to a few 100 kHz. The disk shape of the laser crystal allows to realize an excellent heat management ba combination with continuous pumping power, resulting in exceptionally stable output for the temporal and spatial pulse shape, powers and amounts of energy.

The pulse-on-demand function which is provided by a fast beam switch is essential for this method because each machining point along the weakening line needs to be addressed separately. As described above, the material is processed in several cycles, and in particular during the last cycles, shortly before the weakening line is completed, the penetration depth is selectively detected by the sensor and stored by the system for each processing point. As a result, the system has detailed information on each processing point - another advantage of this application.

Creating a tear seam in an airbag cover is a safety-related process, which is why the manufacturers insisted that it has to be mandatorily monitored and documented. The direct feedback via the sensor array allows very exact processing operations with a small tolerance. It is also easily possible to document and keep track of every single part over the course of many years of production.

For a successful transition to series application it is important that all the components used have a high industrial reliability. In this regard, the JENOPTIK JenLas® femtosecond laser excels due its long service life. The pump diodes have a service life of more than 20,000 hours and the maintenance work can be scheduled and production downtime avoided.

In additional, the laser has a monolithic frame in which the optical elements are installed. Due to this construction, the system obtains excellent results in vibration tests. In an industrial environment, vibrations often cause problems with overly sensitive laser types.

Another important point for the industrial application is the cycle time. The extremely good focusability of the laser beam allows kerf widths of less than 0.1 mm. Accordingly, the amount of material that is actually vaporized is minimal, permitting production-relevant speeds despite the relatively low average power of approximately 10 to 15 Wattsfor macro applications. The cycle feed rate is 500 to 1000 mm/s, resulting in an expected process time of 25 to 30 seconds for 15 to 20 cycles. Thus, the complete process including loading takes significantly less than 60 seconds, which is the process time requested by the industry.

Due to the extreme high peak-intensity non-linear absorption is caused so that the femtosecond laser can also process a wide range of materials independent of their linear absorption coefficients – another feature making it interesting for mass application. For example, the same procedure may be used not only for genuine leather but also for alternative decorative trim covers such as plastic films, imitation leather appliqués and even textile surfaces.

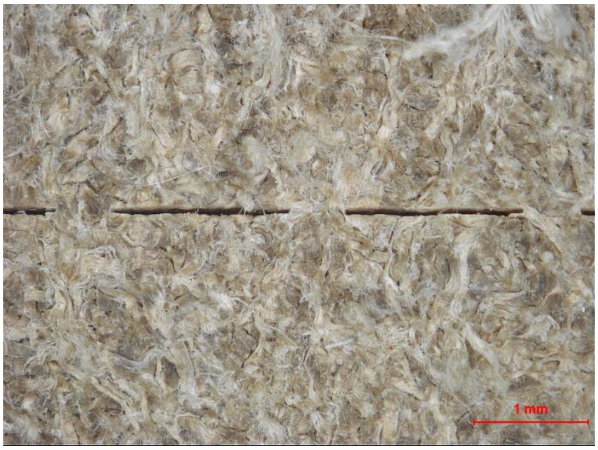

Fig. 2. laser weakening B-side;

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