Development to the flexible laser technology for cutting of lamellae

Lyubomir Lazov[1], Hristina Deneva[2]

Abstrct: *Currently, the development of electric vehicles has high global priority on the political agenda. The strict environmental protection targets for exhaust gasses and the new technological approaches force the market progress.*

The report examines innovative production technologies based on the latest laser resources which offer a fast and flexible production for electric motors, generators and transformers of silicon steel sheets. Other major objectives in this line which is discussed in the report are enhanced labour efficiency and substantially reduced rates of energy input per unit of production both of which are feasible only through the application of new innovations such as laser technologies.

Key words: *Laser Cutting, Electrical Steel, Laser Power, Cutting Speed.*

Introduction

From 2011/2012 many established manufacturers bring the first electro mobile the serial vehicles on the market. Parallel is working on the latest generation of lithium-ion batteries with much longer lifetime and capacity. So plan the beginning of the mass market for electric cars in Europe to start possible already from 2015 provided early appropriate conditions, are set.

Status Quo

Viewed in the longer term, the future belongs to the electric cars although that it will take the next 20 years to the moment when they fully are going to dominate on the streets. In the meantime intermediate technologies have been developed that have a purpose to break a trail for electric cars: Mild-, Strong- Plug and hybrid with a small additional internal combustion engine (a petrol or diesel), needed to charge the battery if it is necessary. According to preliminary forecasts until 2020 year the number of electric vehicles in the world will exceed 1 million. As the market share of these cars will be between 10-20%. There are specific views of a number of countries in the international market: the German government foresees to 2020 to move on the streets of the country more than 1 million electric cars, hybrid and full hybrid vehicles, mass production of which started already in 2011. For this purpose the budget planned € 500 million. The Chinese government carried out a test on more than 60 000 cars for the operational capabilities of electric, hybrid and fuel cell vehicles until the end of 2012 in 11 cities in the country. By 2020 the government of Ireland plans 10% of traffic in their country is driven with electric vehicles, and the French government plans to has over 100 000 electric cars on the roads of their country until 2015. In the second half of 2011 South Korean automobile companies started the production of electric cars. The forecast shows its production to exceed 1 million until 2020.

Technical challenges on the verge of the production of electric motors – prototypes

The high number of revolutions on electric motors for electric cars set up fixed technical requirements on the verge of manufacturers of electric motors for electric vehicles [1]. The manufacturers of electric vehicles have to solve a task connected with efficient transmission of energy by the electric motor into a driving energy of car on the road. That task could be achieved by the production of a new construction of lamellae for rotor and stator packages. Through this should be realized much higher revolutions per minute, compared with the electric motors with which reaches speeds up to 5 000 – 8 000 rpm for industrial use.

The most frequently presenting requirements to the electric motors designed for electric cars, are:

- The weight of the electric motor should be as minimal as possible;
- Mechanical stress should not cause increased friction and heat separation;
- The power consumption due to design should be reduced to a minimum;
- Rated power should remain constant over a wide range;
- Acceleration phases of the electric motor must allow a short term overload and ensure a high torque. This means ,that the motor should have a possibility to create a high torque, especially at low rpm;
- For the purpose of energy-saving high efficiency as possible should be achieved. Through possibility to be used simple circuits which supplied minimum losses in the forming of the motor current;
- When traveling downhill, the electric motor must allow speeds of up to one and a half times the maximum speed at the output without damage;
- In order to improve the energy balance of the entire system, a simple way to energy recovery in corresponding phases of operation should be (for example - when braking).
- Auxiliaries (cooling of engine and other units, indoor heating, lighting, etc.), which are powered by electricity should cause the least possible power losses.

The types of electric motors, which can be used to drive electric cars under these requirements targeted accordingly, are:
- DC electric motors;
- AC electric motors.

Technological studies on laser cutting of lamellae with TruLaser 1030 system

We will examine and analyze a production technology based on modern laser technique and which flexibly and quickly leads to the production of lamellae for electric motors, generators and transformers with different construction from electrical steel (fig. 1).

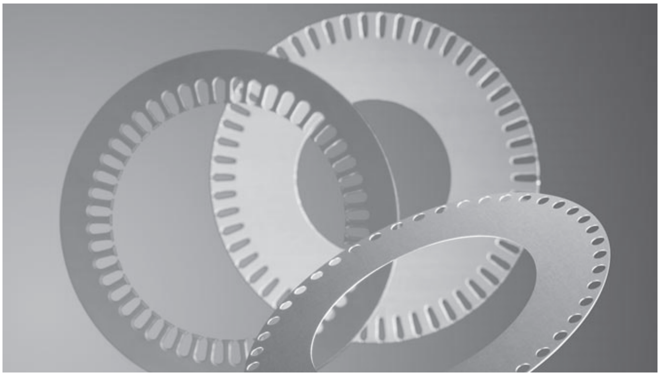

Fig. 1 Lamellae with different geometry (Quelle:Trumpf Lasertechnik)

The laser technology studied by us does not have this high-performance technology that possesses the punch technology, but it is highly effective in the production of prototypes and small series. Its specific peculiarity is that the new developments of products shorten the time by the ideas born in the construction office to test the final product. Advantages that the new innovative technology integrates in itself, are:

- rapidity and flexibility to production of new products;
- satisfied of market needs of customers (SMEs) needing of small series;

- flexible production of conical rotor and stator packages that with punching approach for mass production is not cost effective;
- Easy integration into production lines requiring high automation of the cutting process through packaging to the final product (fig. 2).

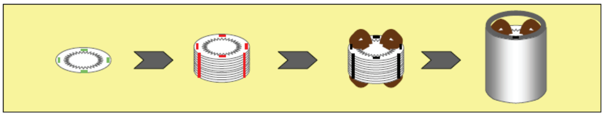

Fig. 2: Technological linkwork to the production of electric motors

Fig. 3 Fiber laser on Trumpf firm Tru-Fiber 300 (Quelle:Trumpf Lasertechnik)

Many companies to the market offer various laser sources and systems for laser cutting. But to realize a good industrial implementation it is required specialized preliminary studies on the technological process for concrete material and construction of the lamella [2,3,4,5,6]. A successful example in solving to the problem of lamellae cutting has shown by Trumpf Lasertechnik using its new Fiber laser Tru-Fiber 300 (power to 300 W) (fig. 3). Working in basic mode and beam quality $M^2 \leq 1{,}1$ the research team has achieved cuts with width 20 – 70 µm. The study made by us, examines the possibilities for flexible and high quality cutting of thin lamellae. A number of factors affecting on the technological process are dealt and summarized on figure 4. Analyzing them and linking them with the basic technological cutting parameters as power of laser radiation and cutting speed, lead to optimization of the process. For example: the obtaining of clean cut edges of the lamella without burrs is a prerequisite for the subsequent operation – packaging without formation of air gabs, which will deteriorate the quality of the final product. Of significant important for the treatment quality is the size of heat affected zone in the vicinity of the cutting edge. It is desirable the HAZ to have small sizes as order not to alter the magnetic properties of the material, which in its turn would have deteriorate the operational characteristics of the electric motor.

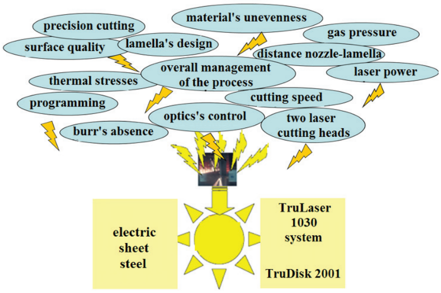

Fig. 4 Factors affected on the technological process

In our study on the process of laser cutting through melt have been used samples by electrical sheet steel of three marks M250-35A, M330-50A, M530-50A and laser technological system TruLaser 1030 (fig. 5) [7].

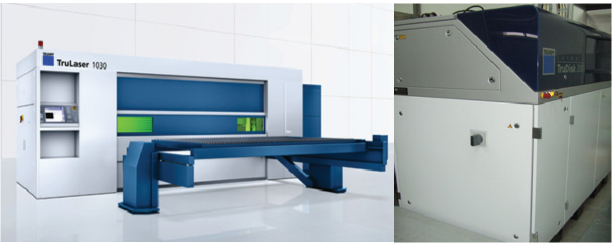

Fig. 5 An industrial laser system for cutting TruLaser1030 (left) and laser source TruDisk 2001 (right)) [7]

The system is involved a disk laser TruDisk 2001 with an active medium of Yb:YAG and wavelength λ = 1,03 μm (Table1).

Table 1 Technological characteristics of laser system

Parameters \ Laser system	TruLaser 1030 and TruDisk 2001
Active medium	Yb:YAG
Wavelength λ (μm)	1,03
Maximal average power *P* (kW)	2
Frequency of the impulses v (kHz)	20
Duration of the impulses τ (ns)	300
Beam quality *BPP* (mm.mrad)	4
Minimal diameter of working area d_0 (μm)	190
Max. speed v (m/min)	60
Laser stability at nominal power	±1%
Focal length of the optical system (mm)	200
Gas (N_2) nozzle (mm)	1,7

In our experimental study has been analyzed the influence that laser power *P* (respectively power density q_s) and cutting speed v (resp. reaction time t) exerted on the geometry and quality of the cut (fig.6, fig.7). Structural changes in the areas of mechanical impact and thermal influence have been observed with optical and metallographic methods (fig.8).

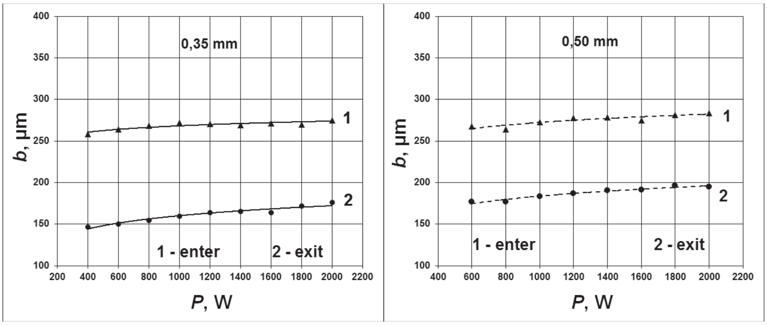

Fig. 6 Graphics on the experimental dependences $b_{enter} = b_{enter}$ (P) and $b_{exit} = b_{exit}$ (P) in laser cutting with speed v = 14 m/min

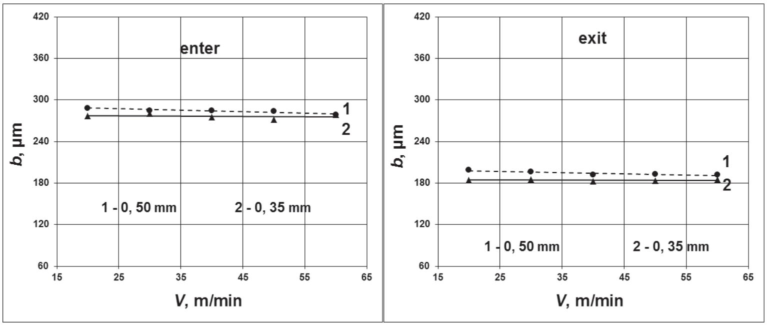

Fig. 7 Graphics of dependences $b_{enter} = b_{enter}$ (v) and $b_{exit} = b_{exit}$ (v) when cutting samples of M250-35A and M530-50A with laser power P = 2 000 W

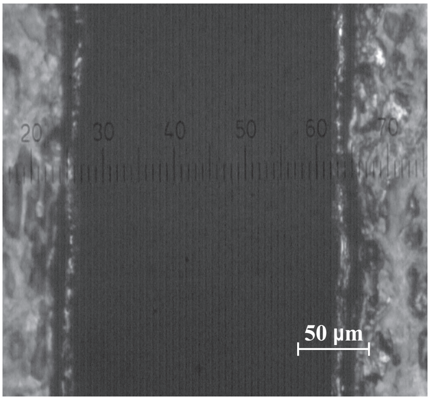

Fig. 8 A section of cut with P = 1 000 W and v = 20 m/min of 0, 50 mm material thickness

The results of the experiments (see fig. 6) show that there is no significant variation in cutting width b as on the enter so and on the exit of the cut when the laser power is changed from 400 W to 2 000 W.

Of the many experimental studies accomplished to investigate the impact of cutting speed *v* on the width *b* and the quality of cut, and grouped into three series in terms of constant laser power *P* = (500, 1000, 2000)W, is found:

- Raising the cutting speed of 20 m/min to 60 m/min did not result in a significant various in the width of the slit as of the enter and the exit (see fig. 7);
- Better quality of the cuts with cutting speed 20 m/min and laser power *P* = 1000 W (fig. 8);
- In the considered range of cutting speeds and power *P* = 500 W is observed the termination of the cutting process by melting the sheet material with a thickness of 0,50 mm.

Conclusion

The quality of the cut filigree contours and the high degree of reproducibility and flexibility of innovative technology evident in near time (future) will impose a total application of laser technology in the production of electric motors for cutting of stator and rotor packages.

Examined in this report conclusions (products) and results found only a small recursion (sight) to major innovative opportunities that laser equipment and technology provide today to the evolving production of electric cars. We assume that they will appear (will provide) and a rich resource for future studies. Expected in the future as a result of this cooperation to be formed new fields of research investigations that will streamline and enforce electric motors to the roads in Europe and the world.

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[1]Lyubomir Kostadinov Lazov Prof. PhD, Faculty of Engineering Rēzeknes Augstskola, Atbrīvošanas aleja 115,Rezekne, Latvia, phone: 0037128327234, phone2: 00359 888869092, e-mail: llazov@abv.bg

[2]Hristina Ivanova Deneva PhD, Faculty of Engineering Rēzeknes Augstskola, Atbrīvošanas aleja 115,Rezekne, Latvia, phone 00359886437355, e-mail: hdeneva@abv.bg

Докладът е рецензиран.