LASER CUTTING MACHINES FOR 3-D THIN SHEET PARTS

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Abstract. *Laser cutting machines are used for precise contour cutting thin sheet. In industrial application nowadays various types and construction of laser cutting machines can be met. For contour cutting 3-D thin sheet parts laser cutting machines with rotation movements and laser robots are used. Laser generates the light beam, that presents a tool in working process. Application of laser cutting machines made possible good quality of products, flexibility of production and enlargement of economy.*

Keywords: cutting, laser, optical system, injection

1. Introduction

The production of laser cutting machines began thirty years ago. The progress was very fast and at present time every year over 3000 laser cutting machines are installed in the world. Laser cutting is one of the largest applications of lasers in metal working industry. It is based on vaporize the material in a very small area by focused laser beam. Process characteristics are: uses a high energy beam of coherent light; beam is focused on an small spot on the work piece by a lens; focused beam melts, vaporizes, or combusts material; molten material is ejected out from the melt area by pressurized gas jet. Laser cutting is the high speed cutting with a narrow kerf width that results in superior and enhanced quality, higher accuracy and greater flexibility. In fig. 1 schematic is shown the laser cutting.

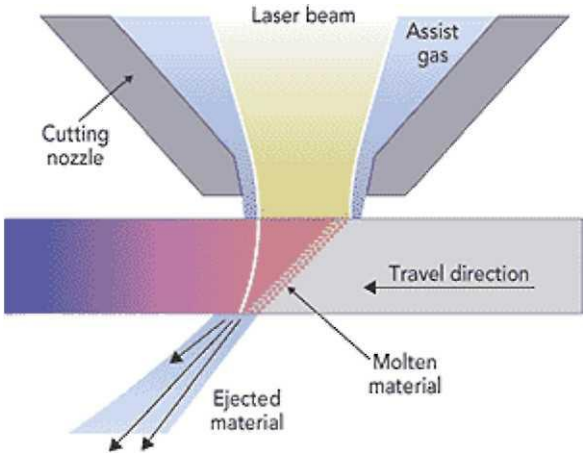

Fig. 1*: Laser cutting*

By combining the laser beam and the machine providing motion, in addition to the applied numerically controlled system, it is possible to provide for a continual sheet cutting along the predetermined contour. The laser beam can cut very hard or abrasive materials. Cutting with lasers is a very cost effective process with low operating and maintenance costs and maximum flexibility. Nowadays in industrial application various types and construction of laser machines for contour cutting thin sheet can be met.

2. Laser cutting machines

Laser machines for contour cutting thin sheet present the product of high technology. They are composed of: laser, beam guiding, cutting head, coordinate table, system for energy supply and control unit. In fig. 2 is shown the basic configuration of laser cutting machine.

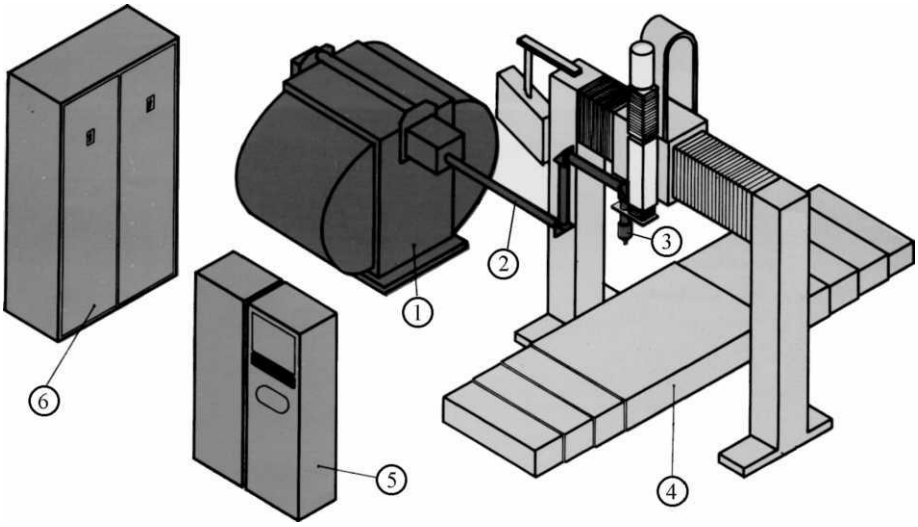

***Fig. 2**: The basic configuration of laser cutting machine:*
1-laser, 2-beam guiding, 3-cutting head, 4-coordinate table, 5-control unit, 6-system for energy suply

Laser, the optical quantum generator, generates the light beam, that presents a tool in working process. By optical system in cutting head the laser beam is focused in diameter from 0,2 mm with the power density over 10^8 W/cm^2. Since our desire is to remove the evaporated and molten material from the affected zone as soon as possible, the laser cutting is performed with a coaxial assist gas. The gas blowing increases the feed rate for as much as 40 %. Cutting process along contour is realized with the movement of laser beam or workpiece. Machine for movements is an accordance with necessity's of laser machine. For variety of work laser machine have a support tables who can be supplied: a simple cutting grid, a cutting table with transportable and removable pallets and a change-over table.

In industrial application nowadays various types and construction of laser cutting machines can be met. It depends on, first of all, what method is used to realize a relative movement between the laser beam and a workpiece. The form and the configuration of laser cutting machine depend on form and dimension of workpiece as well as on demanded precision and working quality. Possible variants of laser cutting machines are presented in fig. 3. By contour cutting 2-D thin sheet parts the use of machines with X-Y table coordinate is effective and real when CNC control unit is used for control. It is often a multy-axis mechanical system which permits linear movements. The CNC is claimed to be superior to types conventionally used in the manufacture of machine tools. It is up to 10 times quicker, compensates for overrun errors, adapts the programmed laser power to the processing speed, controls the cutting gas pressure and the laser parameters. CNC laser-cutting machine offers an optimal solution to cut all kinds of sheet materials economically.

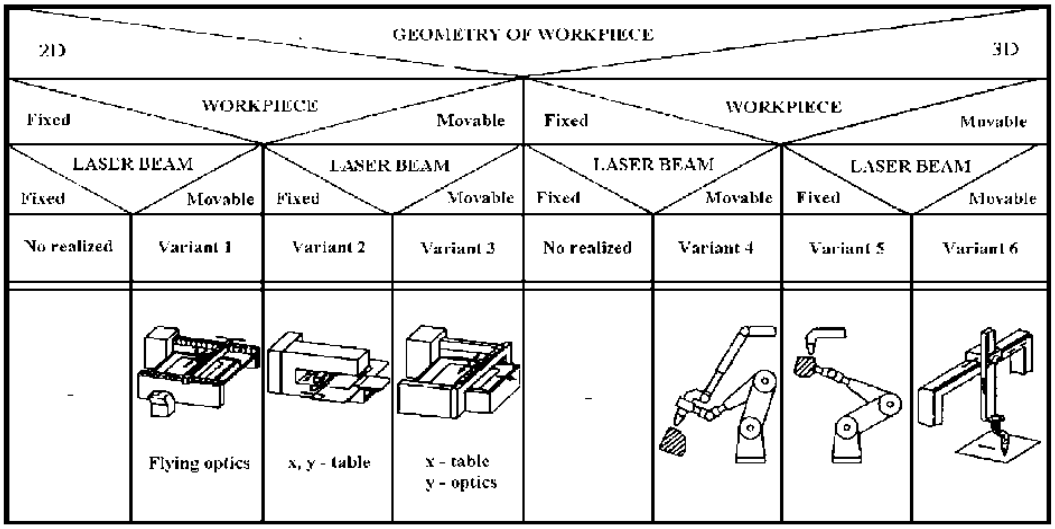

***Fig. 3**: Variants of laser cutting machines*

For contour cutting 3-D thin sheet parts, rotation movements are added to laser cutting machines. Rotation movements are realized by rotation of cutting head or by rotation workpiece by added devices on worktable, fig. 4.

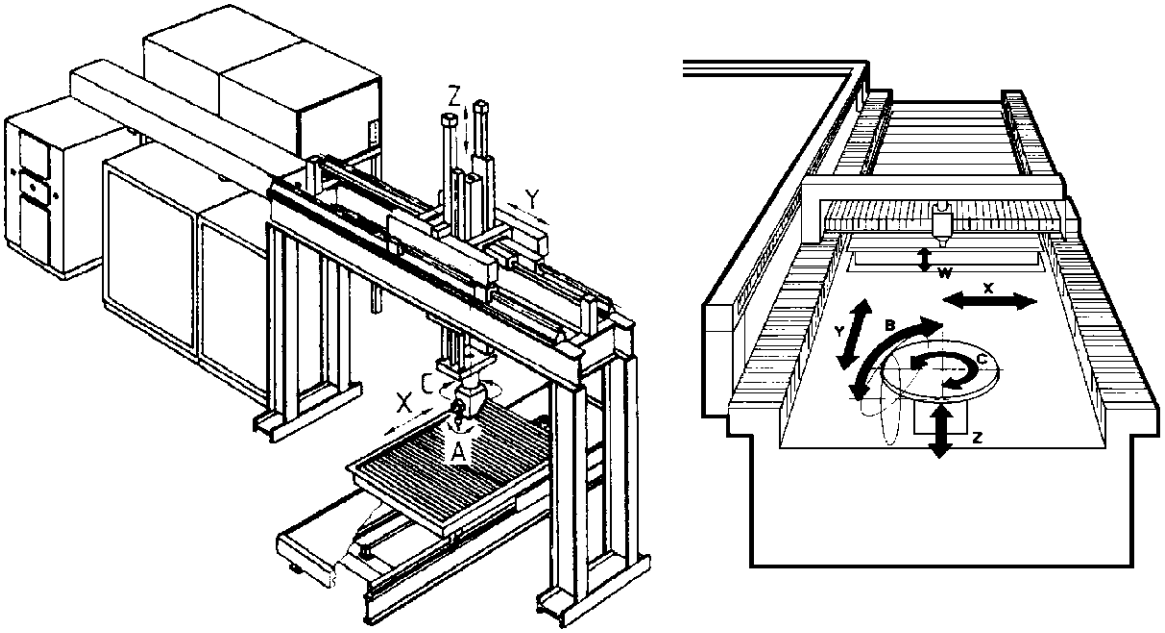

***Fig. 4**: Laser cutting machines for 3-D parts*

Observing the variants of realized laser cutting machines the tendency of principles "flying optics" is evident. The principle is based on spacious, mechanical and automatic movement of optical parts of system for laser beam transmission an deviation and optical system for focusing laser beam by cutting head, which are optically and mechanically connected.

3. Laser robots

Modern laser cutting robots have a totally flying optics architecture. All movements are made by the focusing head and the workpiece remains stationary. Laser robot takes the laser beam along any continuous pre-programmed path in three-dimensional space, then cuts with accuracy, speed and quality. The speed and acceleration on the main axes of the new generation of robotic systems are 60 m/min and 23 m/s^2. Integration of the laser beam guiding in the robot arm structure offers great advantages compared to conventional systems with external laser beam guiding. All limitations of the accessibility to dimensional components are eliminated due to the high movability and the compact design of the slim hand articulation module. Due to the centre outlet of the laser beam on the wrist, the 6th axis of the robot may be omitted, and the free space can be used for passage of the beam. This solution offers the following advantages: compact construction of the robot hand articulation, very good accessibility to 3-dimensional components, favourable work envelope and high degree of freedom of motion, high cutting speeds, high path accuracy and economic price. In fig. 5 is shown the laser robot.

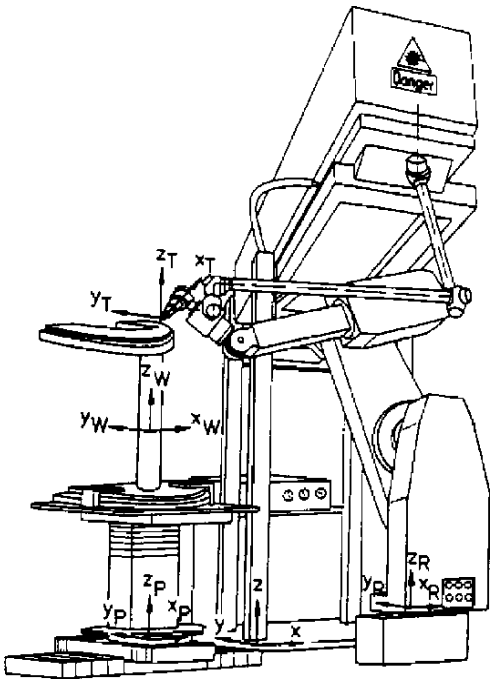

Fig. 5*: Laser robot*

By laser robot it is necessary to adapt the position of the focusing lens to the real position of the workpiece. The robot is fitted with a capacitive sensor on the head for adapt the position and focusing the lens. The sensor is interfaced to the robot control and can read the real position of the workpiece. The robot consequently moves the lens so as to always be correctly in focus. In this way the best quality cut edge is obtained. Laser robot work with automatic programmable laser control and with adaptive focusing head. Sensors of workpieces, sensors of safety and sensors of process increase convenience, reliability and safety of work with laser robots. The need for such high performance is due to the fact that the focused laser beam has a well-defined offset (the focal length) and therefore such dynamics are more to direct the tool than for the actual working phases.

Special software that permits accommodation of coordination laser power with cutting speed are present and desirable. Programming is carried out in collaboration with an off-line system by means of a personal computer. More and more systems are requested to be interfaced with various CAD/CAM systems. The most applicable laser robots are laser robot with Nd:YAG Laser and laser robot with CO_2 laser. For Nd:YAG laser, beam guiding is performed from a stationary high-performance Nd:YAG laser with up to 4 kW beam capacity via a flexible light cable in the upper arm of the robot up to the forced air cooled hand axis. The fiber optic cable is mounted here via a connector plug on the hand axis. The diverging laser beam emitted from the fiber optic cable are guided to the outlet opening at the hand axis via two integrated deviation mirrors.

The deviation mirrors are designed as high-reflective coated quartz substrates. The exact position of the beam axis relative to the movement axis is adjusted via adjusting elements on the deviation mirrors. Collimation and focussing of laser beam is performed at the outlet opening of the hand axis via flange-mounted modules that can be flexibly adapted to the processing task. Application fields of Nd:YAG laser robot are: cutting of sheet metal components made of steel, stainless steel, aluminium; welding and soldering of sheet metal components made of steel, stainless steel, aluminium; welding of thermoplastic materials; hardening tool steels; build-up welding with wire and powder filler metal.

***Table 1**: Example of characteristics of laser robots*

Classification:	6-axis robot	Classification:	6-axis robot
Beam source:	Nd:YAG Laser	Beam source:	CO_2 Laser
Beam guidance:	Fiber (300^m)	Beam guidance:	Mirrors
Working area:	4850mmx6250mmx3115mm	Working area:	(|)3260mm
Max. speed:	4.8m/min (depend. on contour)	Max. speed:	Dependent on application
Accuracy:	±0.1mm	Accuracy:	±0.05mm
Positioning sensor:	z-axis (capacitive)	Positioning sensor:	z-axis (capacitive)

The CO2 laser is directly mounted adjustably on the upper arm of the robot with a mounting bracket. The beam exit of the laser is pointing opposite to the hand axis of the robot. Via two adjustable deviation mirrors made of surface-coated silicon the laser beam is coaxially guided into the fourth robot axis. Directly on the hand axis there is rigidly mounted a beam staggering module with two silicon deviation mirrors that guides the beam coming from the fourth axis to the first deviation mirror of the hand axis. Beam guiding in the hand axis is structured similar to the version for the Nd:YAG laser. Instead of the quartz substrates surface-coated silicon mirrors are used. At the outlet end of the hand axis there is mounted the cutting head where exact adjustment of the beam focus position as well as the position of the cutting nozzle via adjusting elements is possible. Application fields of CO_2 laser robot are: cutting of textiles and plastic films; trimming of cloth-lined plastic parts; welding of plastic materials; trimming and cutting of injection molded parts; drilling and perforating of plastic components. Example of characteristics of laser robots with Nd:YAG laser via integrated fiber optic cable and CO_2 laser with integrated laser beam guiding are shown in table 1. Laser-

robot has brought about various improvements in quality, reduced costs and working times. The industries listed above use laser robots for:

- Prototyping, an activity which normally costs a car manufacturer thousands of hours per year (the parts to be produced range from single pieces to a few dozen for experimental pre-production runs).
- Production in small batches, luxury or special cars, trucks and buses or parts for the aerospace industry.
- Production of spare parts where the robot flexibility is especially suited to following the diversified demand.
- For cutting and drawing dies. The process of development that precedes the die forming reaps a major advantage when laser robots are used.
- Cutting of large turbine blade ving contours for rotors and stators.

Flexibility of the systems is often the most important reason for its purchase since in the case of production start-up or small batch production, frequent modifications will be necessary.

4. Conclusion

Laser cutting machines for 3-D thin sheet parts can be conventional laser cutting machines with rotation movements and laser robots. By conventional laser cutting machines rotation movements are realized by rotation of cutting head or by rotation workpiece by added devices on worktable. Laser robots are used for contour cutting 3-D thin sheet parts. Their characteristics is possibility of linear and rotate movement and change in orientation.. Laser robots are characterised by quiet work, precision and possibility of computing and that is decisively they to replace successively conventional cutting machines.

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