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LASER CUTTING OF METAL

Laser cutting is technology of thermal cutting and decomposition of materials, in which a high-power laser is used as a power source [2]. The tool in this process is a laser beam, which is usually invisible, is generated in the laser source and directed to the cutting head by mirrors, where it is concentrated (focused) by a lens to a small spot (Figure 1). Depending on the process, the spot is placed on the surface of the workpiece or on the material to be cut. The intense light beam quickly heats up the workpiece and melts the material. The assist gas (also called cutting gas) is applied to protect and cool the focusing lens and to remove the molten metal from the cut kerf at the same time [5].

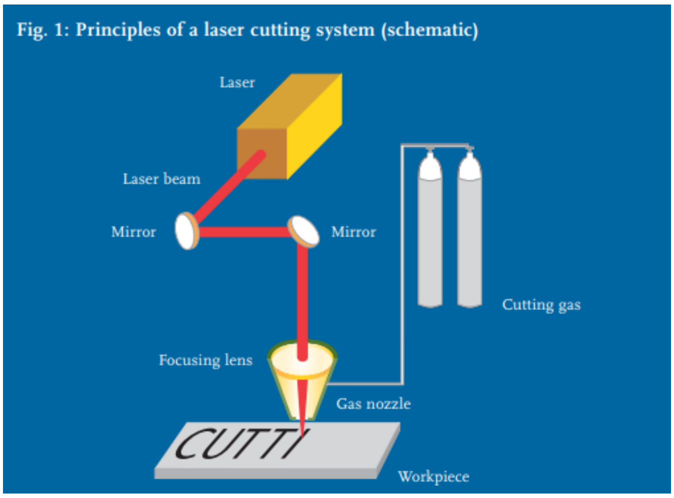

Figure 1. Principles of a laser cutting system

During processing, the focus of the laser beam may be located above the surface of the workpiece, or below the surface, depending on the thickness and properties of the material. Due to its high power density, the laser beam heats, melts and / or evaporates material. In the process of cutting, a gas jet emerges coaxially from the nozzle under pressure, which removes material from the slot formed during cutting. That is why this process was called «gas laser cutting». With the help of such technology it is possible to get narrow notch with a minimum area of thermal influence. Laser cutting is distinguished by the lack of mechanical influence on material during treatment, thus, deformations arising both during the cutting process and the residual after complete cooling are minimal. Therefore, laser cutting, even lightly deformed and non-rigid billets and parts, can be carried out with a high degree of accuracy. Due to the high power of laser radiation, the high performance of the process is ensured in combination with the high quality of the cutting surfaces. Easy control of the movement of the laser radiation source allows laser cutting along the complex contour of flat and bulk details (blanks) for a high degree of automation of the process [1].

There are two cutting processes, depending on the type of assist gas used:

1) when cutting with oxygen, the material is burned and vaporised after being heated up to ignition temperature by the laser beam. The reaction between the oxygen

and the metal actually creates additional energy in the form of heat, which supports the cutting process. These exothermic reactions are the reason why oxygen enables penetration of thick and reflective materials when it is used as a cutting gas;

2) when cutting with non-reactive (inert) gases such as nitrogen or argon, the material is melted solely by the laser power and blown out of the cut kerf by the kinetic energy of the gas jet. As nonreactive gases do not react with the molten metal, and no additional heat is generated, the laser power required is usually much higher than in oxygen cutting of the same thickness. Cutting with nonreactive gases is often referred to as clean cutting or high-pressure cutting.

Vaporisation cutting is another cutting process. In vaporisation cutting, the solid material is converted into vapor without passing through a liquid phase. Gases are used to support the process and remove vapor.

In «cold» cutting, the energy of the laser beam breaks the chemical bonds of the material to be cut, thereby producing powdery residues. Laser beam energy and chemical bond energy must match, and cutting gas is often not needed [5].

Focused laser beam, controlled by the CNC system, provides a high concentration of energy and allows removing almost any material, regardless of it thermophysical properties. Radiation, with energy parameters sufficient for the use of lasers in the process of cutting, has a range of wavelengths from 0.4 to 10.6 microns. In particular, for cutting different materials, the greatest effect is given by a wavelength of 10.6 microns, which is generated by gas CO_2-lasers with an active medium of a mixture of carbon dioxide with nitrogen and helium. Radiation with this wavelength is well absorbed by most nonmetallic materials and, with lesser extent, by metal alloys. Materials with a high reflection coefficient (copper, aluminum) are worse exposed to laser cutting.

In laser cutting of metals, technological installations are used on the basis of solid-state, fiber lasers and carbon dioxide lasers, which can operate in both continuous and pulsed-periodic modes of radiation. The industrial application of gas-laser cutting is constantly increasing, although this process can not completely replace the traditional methods of separating metal blanks. In comparison with other equipment for cutting in production, the cost of laser cutting equipment is quite high, although there has been a tendency to decrease it. In this regard, the laser cutting process becomes effective only with a reasonable choice of application, when the use of traditional methods is labor-consuming or even impossible at all.

When cutting in a pulsed mode, a continuous cut is obtained as a result of successive overlaps one after another. The impulse character of the processing provides the minimum depth of material warming up.

The lasers of continuous action on carbon dioxide, from a few hundred watts to several kilowatts, are used for gas-laser cutting, in which a jet of gas is fed into the laser beam. The gas is chosen depending on the type of material being processed. During cutting wood, plywood, plastics, paper, cardboard, textile materials into the processing area, air or inert gas is fed to the area that cools the edges of the cut and prevents the material from burning and expanding the slit. When cutting most metals, glass, ceramics, a gas jet blows from the zone of action of the beam molten material, which allows obtaining surfaces with a low roughness and provides high accuracy of cutting. During cutting low-carbon or alloy steels and titanium, a stream of oxygen is fed into the heating zone. As a result of the exothermic reaction of metal oxidation extra heat is released, which can significantly increase the cutting speed.

Carbon dioxide lasers are used to cut brittle materials (glass, ceramics) by controlled thermal decomposition. At local heating of the material along the trajectory of the ray motion, a thermal stress exceeds the material strength limit. The resulting fracture develops following a beam whose trajectory may have a complex form. The cutting speed reaches several m / min. Controlled thermal cracking is used when cutting glass tubes in the production of electric vacuum devices, ceramic substrates of integrated circuits, for cutting sheet and shaped glass [3].

There are three technological processes of laser cutting: sublimation, fusion cutting and gas-oxygen cutting.

In sublimation cutting, the material is evaporated in the cut zone under the action of laser radiation. To ensure the minimum width of the slot, the radiation power must be high to reduce heat conduction losses. This process uses inert or chemically passive gases, for example, nitrogen (N_2), helium (He), argon (Ar). The result of sublimation cutting are: smooth edges of the cut, the minimum thermal effect on the material, the absence of oxidation of the cut. The disadvantage is the low cutting speed and limiting the thickness of the material to 1 mm. The described process is applicable both to metal processing and to materials that melt slightly or have no molten state at all, for example, wood, paper, ceramics and plastics.

Laser fusion cutting is used for machining high-alloy steels and non-ferrous metals. It is characterized by the transition of the metal to the molten state in the region of the formed slot, after which the melt is removed by a stream of inert gas (argon, nitrogen). This method allows the use of higher cutting speeds, since no evaporation of the material is required. The choice of gas used can prevent oxidation of the edges of the cut. Laser fusion cutting with gas supply under pressure over 6 bar allows to increase the speed of removal of molten material from the slot, which prevents the formation of burrs and slag sticking to the edges of the cut. Nitrogen is used to prevent oxidation of the edges. High pressure gas laser fusion cutting is mainly used for stainless steel and alloys of aluminum.

Gas-oxygen cutting differs from laser fusion cutting. The melted material is removed from the cutting zone with an oxygen jet. As a result of the interaction of oxygen with melted and partially evaporated metal several times increases the supply of energy to the zone of interaction of the laser beam and the workpiece. The advantages of gas-oxygen cutting include the possibility of separating sheets of metal with a large thickness, high processing speed. There are also disadvantages of this method – the cutting edge has significant irregularities and is oxidized, which creates the need for further processing. This process is used to separate metals only [2].

There are many different methods in cutting using lasers, with different types used to cut different material. Some of the methods are vaporization, melt and blow, melt blow and burn, thermal stress cracking, scribing, cold cutting and burning stabilized laser cutting [4].

The advanced equipment has a number of settings. For example, a cutting operator can specify the depth of penetration of the laser beam, as well as its power. And this extends the area of the use of machine tools, allowing them to use not only cutting, but also engraving the material. In addition, you can make products of the desired configuration, after which the equipment to carry out their marking in the minimum terms.

Over the past decade, laser cutting has developed into state-of-the-art technology. It is estimated that more than 25,000 cutting systems are used for the high-power cutting of metals and non-metals worldwide. When including e.g. low power applications, such as plastics cutting and paper cutting, the numbers are even higher.

Impressive examples of modern laser cutting applications are: 1) cutting of hydro-formed parts and tubes; 2) high speed cutting of thin-sheet metal; 3) cutting of thick section-material.

Developing lasers with higher output powers without sacrificing beam quality has been one important goal in the past. Other efforts focused on improving the drive technology of the motion system and enhancing material handling around the cutting table.

Predictions are that laser cutting based on improved cutting speeds, little tool wear and unlimited flexibility will further replace competing technologies. There are market surveys suggesting that the number of flatbed laser cutter installations will double over the next ten years. In addition, laser manufacturers will address new markets such as cutting tubes and pipes. The gases used to generate the laser beam and expel the molten metal out of the cut kerf are important consumables during laser operations. They can prolong the lifetime of the optical component, increase the cutting speed and improve the cutting quality. All the above contribute to more profitable laser operation [5].

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