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Gases – the invisible secret of laser material processing

They may be invisible, but they play an essential role

Growing pressures for productivity, economy and quality demand new solutions and technologies in the area of welding and cutting. One result of these constantly growing demands is laser technology. With its cutting gases Nitrocut® and Oxycut® and the product series MeGaLas® ,Messer Gases for Laser material processing, Messer, the largest privately managed industrial gases specialist, provides all the gases and gas mixes required for laser material processing.

AREAS OF APPLICATION OF PROCESS AND WORKING GASES
Gases used in laser material processing are classified as auxiliary materials and are required in a variety of different process steps depending on the process and the laser source used. In spite of their invisibility, the choice of gases is one of the crucial factors for the optimum success of laser technology. A distinction is made between process gases and working gases. Process gases are required for the function of the CO_2 laser resonator, whereas working gases assist the laser beam as a shielding gas for welding or as a cutting gas.

THE PURITY OF THE GASES
The purity of the working gases for CO_2 lasers is subject to very strict requirements. But purity is also decisive for economy and quality in working gases and gas mixes for welding and cutting. The degree of purity of gases is indicated as a percentage – a number with many places after the decimal point. In order to simplify the designation, an internationally recognised coding system exists. The codes consist of a digit, a point and a second digit. The first digit indicates the number of nines and the digit after the point represents the last digit of the whole value. The code 3.5 thus means that the gas has a minimum purity of 99.95 per cent. Further examples are shown in the table.

Degree of purity of gases	
Code	**Minimum purity in %**
2.5	99.5
3.5	99.95
4.6	99.996
5.0	99.999

PROCESS GASES
Process gases are gas mixes. These are used as a ready-mixed gas or are mixed from their individual components in the laser system before use. The purity, quality and constant composition of these gas mixes play a major role – for good reasons. Even small traces of moisture or hydrocarbons can cause equipment failures. Hydrocarbons may cause damage to the sensitive and costly optical components, while moisture interferes with the excitation discharge, reducing the overall efficiency of the laser. Other faults may occur as a result of dust particles, which can scatter the laser light and disrupt the process. So it is essential for faultless laser operation that the gases used are of high purity and free of troublesome contaminants. The purity requirements mentioned apply equally for the gas supply system.

LASER CUTTING, THE PIONEER IN LASER MATERIAL PROCESSING
Laser cutting, in comparison with other thermal cutting techniques, is known for its high precision, high cutting speeds, low heat input and low component deformation. Possible applications exist in many sectors, such as automobile and aircraft construction, metal and sheet metal working, shipbuilding, the textile industry and medical technology.

Laser cutting techniques are fundamentally classified into three process variants, flame cutting, fusion cutting and sublimation cutting. Which of these processes is employed depends on the material, the quality and economy requirements and the cutting gas used.

Flame cutting with pure oxygen is similar to oxyfuel flame cutting. The material is heated to ignition temperature and then burnt in the jet of pure oxygen. This is conditional on the suitability of the material for flame cutting. In other words, its ignition temperature must be lower than its melting point. This is the case for unalloyed and low alloy steels. But it does not apply for high alloy steels and non-ferrous metals. Here, while flame cutting with oxygen is possible, it is not recommended for reasons of quality and economy.

Materials which are unsuitable for flame cutting are cut using the fusion cutting technique. For this process, the material has to be heated to melting point and then driven out of the kerf by the cutting gas at a pressure of up to 25 bar. The cutting gas used is mostly nitrogen, but argon is also used in special cases. This applies, for example, for titanium, tantalum, zirconium and magnesium, as these materials react chemically with nitrogen. For quality purposes, unalloyed and low-alloy steels may also be cut by the fusion cutting technique using nitrogen. This produces cut surfaces free of oxidation. The cutting speed, however, is significantly slower.

Materials without a melting point, such as wood, plastics, composite materials, perspex, ceramics or paper, are cut by sublimation. Here, the material is directly converted from a solid to a gaseous state. The cutting gas keeps the particles and vapours away from the optical system.

CUTTING GASES

The choice of cutting gases depends on the material to be cut and the quality demands for the cut surfaces produced.

Materials suitable for flame cutting are cut with pure oxygen. Here, the purity of the oxygen has a major influence on the cutting speed (see figure). With high purity, the cutting speed can be increased, according to sheet thickness, by up to 20 per cent. This further reduces the depth of the heat-affected zone, which is anyway low in the case of laser cutting. As a result, the purity 3.5 has become established for flame cutting.

Materials unsuitable for flame cutting are mostly cut with nitrogen. Its inertising effect leads to cut surfaces free of oxide. Here, slight impurities of oxygen or moisture may cause discoloration on cut surfaces due to oxidation. For high quality requirements, the purity 5.0 has proven itself as the standard.

Materials such as titanium, tantalum and magnesium are among the oxide and nitride formers, as they react strongly with oxygen and nitrogen. For cutting these materials without reworking such as milling, grinding or pickling, argon is recommended. Here too, the greater the purity of the argon used, the cleaner the cut surfaces. In the course of further welding, any nitrides and oxides present may be transferred into the weld seam.

THE DIFFERENT TYPES OF WELDING

Thanks to its special characteristics, laser welding solves welding problems like no other technique. Its main feature is the highly concentrated heat input. Laser welding offers high welding speed, a narrow heat-effect zone and low deformation of the component. Another advantage is the low heat input. There is even something special about the joints in comparison with other techniques. The laser is capable of piercing right through a component. This makes welding possible in otherwise inaccessible areas. This is particularly useful in the automobile industry, where weld points on the bodywork, for example, are often concealed. At the same time, the laser fulfils the desire for high welding speeds and low distortion. Laser welding is also suitable for medical technology and micro-electronics.

In remote welding, complex components are welded from distances of up to two metres. The main advantage of this method is the quick positioning of the laser beam. This is carried out from a central unit by means of multiaxially adjustable mirrors. Other advantages are the saving of time and the fact that no complex mechanical components are required for guidance of the beam. The shielding gas is added in this case via the mounting jig. Alternatively, a chamber may also be used.

Heat conduction welding only requires low outputs. The energy of the laser is converted into heat on the surface of the component, forming a molten pool that passes on the heat energy by convection. As in the case of arc welding, this convection can be influenced by the shielding gases and the penetration profile can be adjusted to meet the welding requirements.

Deep welding requires higher outputs, as the metal is not only melted, but is also vaporised. In this case, the laser penetrates deep into the workpiece, cutting a so-called keyhole. In this keyhole a plasma column forms, which absorbs the energy of the laser and passes it on to the material. The result is a continuous welding process. The plasma cloud escaping from the vapour channel (keyhole) must be blown away by the shielding gas, as it would otherwise absorb the laser energy without passing it on to the welding process.

The hybrid technique is a combination of more than one process. An obvious candidate for combination with laser welding is MAG welding. Here, the economy of laser welding is applied to thick plates with the high melting power of the MAG process. The shielding gas chosen must be compatible with both parts of the process. In practice, mixes of argon, helium and an active gas component such as carbon dioxide have proven effective. In addition to the combination with MAG welding, combinations with TIG and plasma welding are also possible.

Laser soldering is similar to heat conduction welding. Here, however, the energy requirement of the solder also has to be taken into account. This technique has established itself, in particular, in automobile construction. In addition to the familiar advantages such as low heat input and low distortion, the corrosion resistance of the solder and its easier mechanibility also play an important role. The security of the joints and their long service life make laser soldering a good alternative.

SHIELDING GASES - AUXILIARY MATERIALS FOR AN OPTIMAL RESULT

As before in cutting technology, the laser is now also becoming firmly established in welding and soldering. A distinction is made here between four variants, heat conduction welding, deep welding, hybrid welding and laser soldering. Welding can be carried out with or without a welding auxiliary material. The welding of different or dissimilar metals and alloys such as aluminium and steel or black and white is also possible.

A shielding gas has a number of functions. One of its main tasks is protection of the hot material from the atmosphere, for this could lead to the absorption of nitrogen or moisture or cause oxidation of the surface. The shielding gas also ensures the continuous removal of the plasma cloud above the workpiece.

Like other shielding gas processes, the laser welding process can also be specifically influenced by the use of optimised shielding gases. The basis of these gas mixes is argon. By the addition of CO_2, oxygen, helium, nitrogen or hydrogen, it is possible to influence the welding process both thermally and metallurgically. Typical gas mixes here are argon/helium, argon/oxygen and argon/hydrogen. The constituents used depend on the material to be joined.

WELDING WITHOUT SHIELDING GAS

Welding without shielding gas is often encountered, especially when solid state lasers are used. It leads to the correct appearance of the weld seam, but that alone is not the crucial factor. Without shielding gas, as in other welding processes, the weld can absorb nitrogen, oxygen and moisture, leading to weld imperfections such as pores and hydrogen cracks. Particularly in the case of unalloyed and low-alloy steels, nitrogen leads to premature ageing and brittleness. In most cases, the consequences are visible after several years, when the component has been subjected to corresponding stresses.

SUCCESSFUL SHIELDING GAS BLANKETING THANKS TO LAMINAR FLOW

When gassing weld or solder points, a laminar flow is a precondition for successful shielding gas blanketing. If the speed of the shielding gas is too high, eddies are created which entrain the atmosphere in the gas jet. This is one of the most frequent reasons for welding faults. Different shielding gas mixes can also influence the laser beam.

For shielding gas blanketing during laser welding, coaxial, lateral, peripheral and annular nozzles are available.

In the case of coaxial shielding gas feed, the whole area of the beam between the nozzle and the lens is filled with the shielding gas. Damage to the lenses can occur here as a result of the formation of a plasma column.

When shielding gases are fed from the side, an injector often forms, resulting in air also being sucked into the weld area. The welding process then takes place in a shielding gas/air mix. The consequences are pores, annealing colours and other welding faults.

If an annular nozzle is used, it is advisable to use small quantities of an additional purge gas, such as nitrogen or helium. This prevents shielding gas reaching the area of the laser optical system. An annular nozzle guarantees uniform shielding gas blanketing of the melt pool.

MESSER GASES – A WIDE-RANGING PRODUCT PORTFOLIO

Messer offers a comprehensive gases programme, which is not always the case. This starts with the right gases for each application with comprehensible, application-oriented naming of the products and extends to the development of new gas mixes to meet customer requirements and wishes.

Smaller quantity requirements, such as the supply of laser gases, are covered by gas cylinders. Single cylinders with a capacity of ten or fifty litres are mostly used for this purpose. For cutting, oxygen or nitrogen is supplied in tanks.

THE GAS SUPPLY – FROM THE CYLINDER TO THE WORKING PLACE

A crucial factor for an optimum gas supply is the transport of the gases to their destination. No contamination must occur during this process. This depends on the correct installation of the hardware, a considered choice of gas valves and a demand-oriented supply of gases of the required purity. Additional insurance is provided by the use of a particle filter. The gas supply to the resonator also demands maximum purity. That applies both for the resonator gases and the feed through pipes and hoses. For the supply line through fixed parts of the system, pipes of copper or CrNi steel are ideal. The pipes must be free of oil and grease and their ends should be sealed with plastic caps during transport. When welding or soldering these pipes, attention should be paid to adequate back shielding.

With hoses, the inward diffusion of nitrogen, oxygen and, in particular, moisture is always a risk. Special materials can reduce this risk.

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