Handbook to buying a fibre laser

KIMLA

Laser cutting services generate surprisingly high profits, but for many years, despite high maintenance costs and relatively low efficiency, CO_2 lasers have dominated the laser cutting market. This technology reached its limits of development and, due to large numbers of devices on the market, the prices dropped to unattractive levels, at least for possible investors. All this changed, however, in 2010 thanks to the start of the fibre laser revolution.

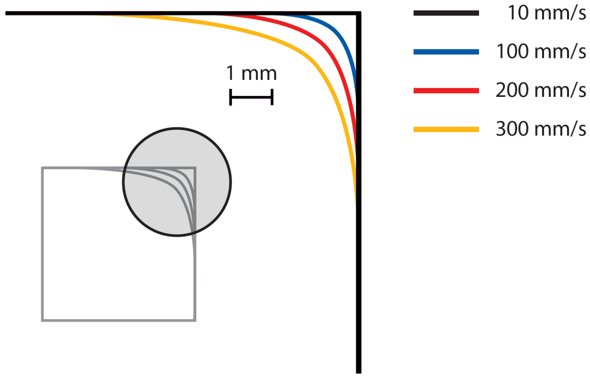
Fibre lasers provided a great opportunity for the sector thanks to much shorter wavelengths and increased cutting speeds when compared to CO_2 lasers – a very attractive proposition for manufacturers. Despite this, the early days of fibre laser technology were challenging; low-powered sources, issues with heads and the restrictions of technical solutions sourced from a previous generation of lasers all held back the capabilities of these machines, which had been manufactured by market tycoons. The result? Early incarnations of fibre lasers were barely more efficient than CO_2 lasers.

One of the biggest advantages of utilising fibre laser technology is demonstrated when thinner sheets of metal require cutting, but at the same time, early models of these machines revealed that they simply didn't have control systems complex enough to implement thin metal cutting efficiently. These systems were originally single-purpose industry computers, which controlled the drives of the cutting head positioning axes. In the era of CO_2 lasers, the systems were implemented from machining tools, which move slower than laser cutting machines, restricting the capabilities of the new wave of fibre lasers.

It became evident that by using slow control systems, manufacturers of fibre cutting machines wasted the potential of the new technology. For example, utilising the control systems from older models of milling machines did not enable fibre machines to operate to their full capabilities.

This meant that, despite the new lasers being equipped with fibre sources reaching cutting speeds five-times faster in comparison to CO_2 lasers, the production efficiency often only rose by 30%.

CONTROL SYSTEM



The reason for the above is the way control systems work; this was invented in the 1950s and, putting it simply, is a control of servo speed on the basis of delay following an interpolator's position. An interpolator is a part of a control system that indicates a position in which a cutting head should be in at any given moment. The difference between the position set by interpolator and the head's actual position is position offset. Offset value after scaling is a set speed value for the servos' driving head. This means that the higher the movement speed, the greater position offset and the better mapping of forms set for cutting. Such a controlled method allows for fast and accurate cutting if the machine is moving slowly. However, attempting to implement this system with fibre laser machines led to manufacturers encountering precision issues up to a few millimetres wide.

This is why manufacturers of lasers equipped with such control systems are compelled to decrease the machining tool speed in order to minimise such errors. Unfortunately, this greatly restricts the dynamics of a machining tool's operation, and thus its efficiency. Such a control method stemmed from the restrictions of microprocessor technology from the 1950s and, in order to create these systems back then, compromises has to be made. In subsequent years microprocessor technology developed rapidly but, the consequent introduction of CNC control systems, manufacturers ended up with contemporary systems operating with the same technology as in the 1950s.

In 1999, Kimla began looking at a new method of operations with CNC controllers. It designed and introduced a concept of offset-less control systems, based on fast DSP processors. The assumption was that all adjustment loops were located in the drive and not scattered between the CNC controller and the servo. With previous technology, the interpolator set the position; with Kimla's solution, the position, speed and acceleration signals were sent concurrently, resulting in an offset value of almost zero, irrespective of the speed.

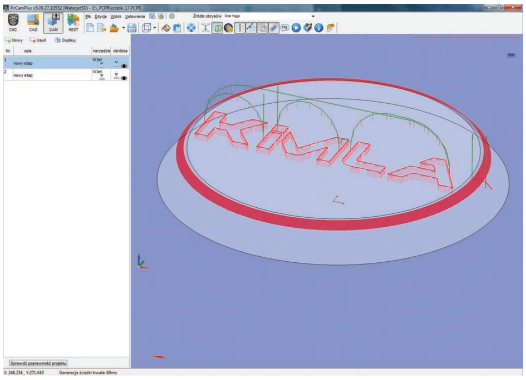
Additionally, the classic systems with scattered regulators operate at frequencies of up to 2 kHz, which means the servo's position is adjusted 2,000 times per second. For relatively slow machining tools this is by all means sufficient, but for modern fibre lasers, which may cut with speed of over 1 m/s, the correction would be effected every 0.5 mm, which is insufficient. Thanks to the regulators in the servo, Kimla avoided the necessity of slow, bidirectional data exchange between the servo and interpolator. Consequently, it became possible to increase the adjustment frequency up to 20 kHz, in turn allowing for precise position control even at great speeds.

G-CODE

Despite these advances, Kimla identified an outstanding operational issue which required attention. The tool's path for the head to follow is stored in the form of coordinates that the head reaches one-by-one, in order to cut the set form. The format was named G-code and is still a standard language of data recording in CNC machines, developed to be compatible with perforated tape. This is a relatively basic and outdated recording method, which stores complex shapes in the form of a polygonal curve consisting of, at times, tens of thousands of short sections that make up a shape.

For fibre lasers with high working speeds, it is often the case that the polygon sections are so short, the system is not able to process single commands fast enough to provide smooth movement. The machine will vibrate, move and slow down unnecessarily, causing further restrictions in the efficiency and deterioration in the cutting quality.

Again, Kimla set out to meet the market demand and developed a unique means of CNC system's vector data processing. The tool's path that the machine follows may be of various shapes, including those which the machine needs to smoothly adjust the feed to to form the cut detail. In such a case, the majority of systems control the speed on the basis of angles between individual sections, changing the set speed in steps. Instead of analysing angles between individual sections, Kimla implemented the concept of calculating centrifugal acceleration values on the basis of shapes the machine follows. This approach allowed for more precise speed calculations, of which the machine may follow a given path, and also, owing to batch data processing the system throughput was greatly increased. The technology was patented as "Dynamiczna Analiza Wektorów™" (Dynamic Vector Analysis).



DRIVES

Each CNC must be equipped with drives, which convert control signals to mechanical axis movement. Most often these are servos operating on a rotational motor with an integrated encoder for measuring of the drive's position. The motor drives the mechanism converting the rotational movement of the motor to the linear movement of a working axis. It may be a circulating ball feeding screw or — more common within lasers — a toothed bar. Between a toothed bar and a motor there is a planetary gear to adjust the speed and torque. This gear is mechanical, and is subject to wear so requires periodic replacement, especially when it comes to the fast and dynamic movements found within a fibre laser. Mechanical drives are combined with return backlash, caused by inaccuracies within gears, friction, tension and wear. The return backlash is impossible to compensate precisely, as the position is affected by the encoder on the motor axis, and axis movement in the range of return backlash may not be measured by encoder.

In recent years, contactless magnetic linear drives have been introduced. Axis movement is evoked directly by magnetic field, which is inexhaustible, and the lack of mechanical gears promotes an increase in the efficiency of the drives. In laser cutting machines, where there's no tool that would put up a resistance during movement, almost all an axis' energy during acceleration may be reclaimed during braking — and this solution was utilised by Kimla in the form of Common DC Bus technology. The reclaimed energy is then transferred to an accelerating axis, resulting in the energy circulating between the drives and minimising consumption. The introduction of this technology created potential energy savings of up to 70%.

ABSOLUTE STRAIGHT-EDGE

In its lasers, Kimla uses linear drives with absolute position reading. Once the machine has started it does not require tracking onto reference points, as the reading is affected on the basis of a micro-barcode engraved on an invar tape along each axis with the resolution of 1 nm. This provides unrivalled accuracy and eliminates the return backlash. The portal drive is affected on both sides via two linear drives with electronic angle correction.

LINEAR DRIVES WITH HIGH POWER DENSITY

In order to increase the efficiency of cutting, especially of thin metal sheets, it is necessary to provide the highest possible acceleration, in order for the machine to reach the set speed at the shortest distance possible. For this reason, manufacturers attempt to utilise drives with the highest possible powers. At first, when the power of drives is relatively low, their mass is not large enough to affect the moved axis. Increasing the power of the drives causes an increase in the mass, and the mass of the motors is such an important factor that the effect of self-restriction becomes prominent, as the twofold increase in power is levelled by the doubling of drive's mass. There is a limit in efficiency increase, which seemed to be an insurmountable problem. Laser manufacturers purchase linear drives from drive manufacturers, which offer structural solutions that are 10 – 15 years old. Recently, however, modern magnetic materials entered the market, providing a high saturation induction and lighting the way for the creation of a new generation of drives. Kimla started researching such materials in the construction of high-power density drives. As a result, linear drives were designed, implemented and manufactured, in which the power was increased threefold without increasing the motor's mass. This created dynamics untouchable to any other manufacturers of laser cutting machines.

FRAME

The machine should be rigid, accurate and stable. These are general features desirable for CNC machines. However, many manufacturers believe that these requirements for laser cutters are not the most important and allow themselves some simplifications that generate specific problems for the user. Ideally, the laser body would be monolithic, machined in one fixture on a large gate milling machine. Unfortunately, these are not often found and expensive machines, so manufacturers often decide on bodies bolted from several elements. Most often these are two side walls connected by crossbars.

Unfortunately, this solution causes the machine to have a weak stiffness, in particular on the twisting of the body. Therefore, the manufacturers require a foundation for the installation of such a machine. When installing, the cutter is screwed to such a foundation and it is a structural element that stiffens it and is necessary for proper operation. Implementation of the foundation is expensive and time-consuming, and sometimes even impossible when the room in which the device is to be installed is rented.

There are other consequences of this approach. In twisted constructions, it is extremely difficult to ensure parallelism of guides on which the traverse moves. Even small deformations or inaccuracies in machining cause deviations of up to 1 mm which would be disastrous for guides and bearing blocks. Therefore, manufacturers of such constructions use flexible expansion joints, but this in turn reduces the stiffness of the traverse guidance.

Kimla company through investment in dedicated machines for milling frame bodies offers laser cutters, whose entire monolithic bodies are machined in one clamping which ensures parallelism of 0.01mm. Such a solution does not need compensators, it is rigid, stable and requires no foundation. Kimla offers lasers with monolithic bodies up to 3,000 x 12,000mm.

ACCESS TO WORK AREA

There are various ways to ensure access to the interior of the device on the market. In most cases, these are doors on the narrower side wall of the laser. This is the simplest solution, but the area to which the operator can reach with his hand without going inside is very limited. Some manufacturers offer access from the long side of the laser. Access is much wider but the operator must reach through the folding guides and covers before reaching the sheet. It is non-ergonomic and dangerous for shields because it is easy to drop the detail onto the bellows covers and damage them. There are also versions of lasers with side access, which have an inverted traverse that runs along the short side of the machine. This solution causes that the traverse is very long and to ensure the required stiffness is large and heavy. Lasers with such solutions thus have low dynamics and limited efficiency. None of the above solutions, however, allows access to the entire work area and in case of the need to intervene in an inaccessible area it is necessary to enter the laser interior which is very uncomfortable with limited height of the upper covers.

Kimla designing a laser cutting machine put emphasis on the ergonomics of access to the working area ensuring access from all sides of the device through doors placed around the machine. Thanks to this, irrespective of the place of necessary intervention, there is no need to go inside the laser because every place of the working area is available at your fingertips.

LASER PROGRAMMING

In spite of its speed, even a fast machine can't cover all bases. Still, laser manufacturers were using universal control systems to compel users to maintain a team of process engineers, experienced in using programmes for laser cutting machines. This stems from the development of control systems for cutting machines. The first systems were programmed via a primitive keyboard on a machine's panel, and programmes were stored on perforated tapes.

The introduction of the first personal computers facilitated the process of writing and editing programmes beyond the machine, and transferring them on a more convenient data storage means. Nevertheless, the tedious process of typing in thousands of lines of software increased in the 1980s, along with the software for automatic generation of paths for tools of CNC machines. CAM software created by numerous companies poured onto the market in great numbers, and the manufacturers of control systems appeared one-by-one. The issue of compatibility with all pieces of CAM software and control systems emerged, as one standard of data storage was not agreed upon. Additionally, it was hindered by the variety of machines and their configurations, which is why an additional, indispensable module, between the CAM software and the control system was devised — a postprocessor.

POSTPROCESSOR

The design of the right postprocessor is ordered with the supplier of CAM software, by the end user or the dealer of a machine. There is no way to write a good postprocessor in a short timeframe, as this is a process of repeated testing and correcting, which may last for months – after all, the quality of the code of the postprocessor will influence the efficiency and quality of machine's operation. Often, the purchaser concentrates on parameters of the machine, and does not pay attention to the way software is developed, or how smooth the data exchange with the machine is and whether all the laser's functions are implemented in the control software. From time-to-time laser manufacturers change the supplier of CAM software and users of older versions may not receive any assistance, as the laser manufacturer will no longer develop the software. In order to solve this issue, Kimla created a unique solution based on the implementation of all CAD, CAM and nesting functions in one control system.

CAD/CAM/NESTING

This solution developed by Kimla is pioneering, as up to now lasers have been solely programmed by external CAM systems. Any change of shape, detail position and dimension of bores called for the operator to interrupt the machine operation, order a process engineer with a change or a new programme, upload it to the laser and continue work. Often, even the simplest modifications caused long-lasting periods of non-production.

Kimla machines make it possible to work with complete exclusion of a process engineer, as all preparatory work may be conducted in an automatic manner by the operator within a matter of minutes, and any changes or last-minute modifications only take seconds. Of course, for the companies used to working with the participation of a process engineer, it is possible to install the operator's application at the process engineer's stand. Then operators may fulfil all process engineer's tasks and vice versa. Kimla has been developing its system for over 20 years. It is still being extended and implemented with subsequent functional innovations, often on the basis of the needs and direct expectations of the users. There is also the possibility of compiling dedicated custom functionalities, which is not possible in the case of systems delivered by third parties. With the process of development, the clients may be offered software upgrades, adjusting older systems to meet the latest market demands.

CAD is a vector graphics editor, allowing for creation of drawings and loading shapes in .dxf, .dwg, .geo, .taf, .plt, .hpgl formats, etc. Aside from the standard functionalities in this type of software, that is drawing lines, curves, splines, graphic signs, cropping, phasing, rounding, etc., the functions of CAD software are vital for laser cutting machines for automatic cleaning and closure of outlines.

In order to correctly cut details out, the laser beam may not follow the outline of a drawing exactly, as the gap created during cutting — depending on the type and thickness of the metal sheet — amounts to 0.05–0.4 mm, which in turn would cause the cut-out parts to have incorrect dimensions. So, the tool's path must be offset against the outline providing the detail by half of the gap's width. In order for the programme to 'know' which way the offset is to be directed, the outline should be closed, or there is no possibility of establishing whether it is to be an external or internal correction. An additional complication is brought by details with bores, where the external outline should be offset externally, and the internal outline—internally; plus, if there are cases of smaller elements located within larger ones, the situation gets even more troublesome.

This is the reason why cutting details should feature a clearly defined outline — the software must be able to correctly interpret the drawing. Unfortunately, the drawings are often prepared incorrectly. The outlines are not closed; lines are multiplied or sections partially overlap. For a drawing prepared for printing, this is of no particular importance, hence why the rules for setting up correct drawings are often disregarded by construction engineers. This is like a waste of time, as prior to the laser programmes, a process engineer had to manually correct the drawings, which is both tiresome and time consuming. Kimla identified these difficulties and introduced a number of functions which allow for the automatic processing of drawings. Closure of opened outlines, removal of overlapping lines and changing shattered edges with lines and curves are just some of the capabilities, which allow for the automation of a project preparation for laser processing.

CAM generates a tool's path and all commands for head, source and automatics. Ready-made templates for any type and thickness of metal sheets define the way lasers should operate, in order to correctly cut a detail. For each material and thickness, laser manufacturers should, through trial and error, select all parameters, so that the operator or process engineer is able to select one of the readymade process tables and automatically generate a programme.

At times, it happens that the operator, due to atypical material or production requirements, must introduce changes in settings. In most laser cutting machines, technological processes are scattered amongst the control system and CAM software. For example, cutting speed, laser power or punching characteristics are all contained in machine control tables. Alternatively, tie-in points and distances which form the outline and shape of a path are all defined in tables in CAM software. This is the reason for common errors and misunderstadings between process engineers and operators. Quite often, laser tables modified for the sake of one single programme are not restored to default values, therefore cutting with subsequent programmes, and with the use of such a table may give incorrect results. Kimla consolidated all these functions in one system, allowing operators to introduce any given change in cutting parameters as all process tables are copied to a concrete project and are not influenced by modification within the scope of a given project. A saved project with modified settings may be executed again at any given time. Additionally, in companies, where a process engineer prepares programmes for an operator, full interaction and interchangeability between the two posts is possible. A programme prepared by a process engineer may be corrected by an operator, when and if needed. Process engineers may use process samples corrected by operators, so that with subsequent orders the process engineer uses adjusted settings.

Another functionality that provides more efficient cutting processes is the possibility to automatically generate common lines of cutting. For straight edges, it is greatly favourable to set them so the distance between them is equal to the width of a gap produced during cutting. Then, only one working feed is needed to cut edges of both parts. The savings are by no means trivial, as in some cases time and costs consumed may be decreased by up to 45%, and material consumption by up to 10%. Common cutting lines should be created automatically by algorithms generating a tool's path, and for thicker metal sheets the function of preliminary cutting at branching points is invaluable, as it protects the head against collisions with internal tension forces when cutting metal sheets. In order to fully automatise the process of generating paths with common cutting lines, this function should also be implemented in a nesting module, so that details are distributed within the correct distances automatically.

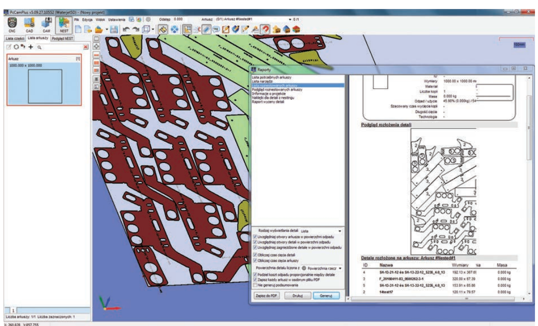
Nesting is the process of automatically arranging designs on a sheet in a way that minimises material waste.
Each detail may be defined with:

- the number of pieces to be cut
- angle of rotation
- direction of rolling or material pattern

For the whole metal sheet with:

- distances between details
- margins and common cutting lines

Modern nesting software allows operational waste to be saved in the form of sheets of which an irregular form was cut out. When the partially cut out sheet is used again, nesting can use such a sheet taking into account the already cut out part when mapping the new cutting paths.

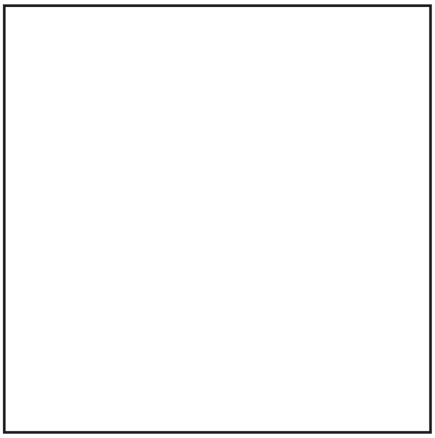


Kimla integrated nesting functionalities within the control system. When practical projects are carried out, cost and the number of forms often do not allow the most effective usage of materials. Large elements cut out of whole sheets are effectively complemented by smaller parts cut out of the empty spaces between the large ones, but this means, final sheets are often not used completely as all parts have been cut out of previous sheets. The predicted number of parts per sheet never allows for all sheets to be filled in exactly by using all the free space. The function of complementing empty spaces with unordered parts may be used, but it is uncertain whether such parts will ever be sellable. This brings another issue to the surface – should manufacturers try to fill the empty spaces between large parts with unordered smaller parts in the hope the order will be repeated, and accepting extended cutting time, or accept the notion of wasting unused material from between larger details? In classic solutions with external CAM systems, there is no possibility to introduce changes in the project when the machining process has started, as the laser does not report progress to the CAM software. In Kimla lasers, when the project is executed, it is possible to interrupt it and introduce another order for a given metal sheet and restart the nesting while considering the already cut-out elements. Thanks to this approach, it is possible to utilise the material even more effectively.

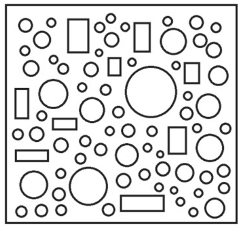
CALCULATION OF CUTTING TIME, PRICING, REPORTING

Quotation for a laser cutting services is the first thing needed, in order to give clients a chance to select it. One of the biggest mistakes providers make is to offer constant rate for a meter of cutting of a given material.

Let's imagine a square with a side of 1m. In order to cut it out, the machine must make 4 meters of cutting through a material. The time needed to cut such a detail with, for example, a 6kW laser and out of a 1.5mm metal sheet amounts to ca. 7 s. Now, let's imagine a square with side of 400mm, but with a large number of bores, so the total distance to be covered over the outline and over edges of bores would also amount to 4m. Incidentally, the detail with the same distance to be covered during cutting requires 38s to be cut, thus it is over five-times longer. If we average cutting costs for different details, it may happen that cutting a detail with a side of 1m will not be attractive in terms of pricing and, in the case of the smaller detail with bores, the expected margin will not be obtained. Of course, it's possible to add an additional charge for one piercing, which — to some extent — will level the difference, though it will never be possible to optimise the process. The only solution to obtain assumed profit per hour is to base the precise cutting quotation on the amount of time needed and costs incurred. But can this be evaluated without actually making the cutting?



1x1 m = 4 m of cutting - Time: 7 s



Also 4 m of cutting - Time: 38 s

Usually clients send files with forms and shapes of details, providing information on the type and thickness of a sheet and ask for a price. The process engineer loads the file to CAM software, loads the parameters table, generates tool's path and runs simulation function. Unfortunately, the amount of time calculated by the CAM software cutting simulator is not precise. The differences may be considerable, increasing with the drop in metal sheet thickness. In some cases, lasers need twice as much time to cut details than the software calculation suggests. This is because external CAM software is not able to precisely mirror the dynamics of laser movements. The matter is complicated even further by the fact that characteristics and time needed for piercing are stored in laser's memory, and CAM software cannot access it directly. If the operator changes them, they are not automatically updated in the process engineer's programme, as a machine's software is one-directional, due to employment of G-code. Data is sent from the CAM software to a machine, but not the other way round.

Through integration of CAM in the control system, Kimla solved the problem of calculating the time and costs needed to make the cutting. Constant access to the simulation algorithm settings of machine's dynamics and process tables allows for precise calculation, considering the cost of electricity, gases, operational parts, operator's own costs and amortization. The operator may also introduce an income amount to be earned per laser working hour, and the system will automatically calculate the price for each detail, considering the cost of materials and nesting data pertaining to wastes from each metal sheet. Such a report may be generated to PDF, resulting in a client-ready quotation. The quotation module may also operate on a separate PC, in order to not burden the process engineer or operator with this task.

EQUIPMENT/SOFTWARE INTERPOLATOR

An important factor, which is worth taking into account, is equipment that constitutes the base for the control system. Currently, almost any control system is based on an industrial PC, facilitating creation of the user interface. However, only professional control systems feature a so-called equipment interpolator, which is used solely for controlling machine's movements. There are control systems, which, in fact, are control system simulators for the PC. Sadly, no PC is a real time machine, as it must handle many tasks queued by operating system. Readings of keyboard, disks, displaying a picture in the screen, network communication — these are only some of the tasks carried out by a PC thousands of times per second. Somewhere between the tasks there are algorithms controlling a machine's movements, which calculate the machine's subsequent position and sends it to the servo.

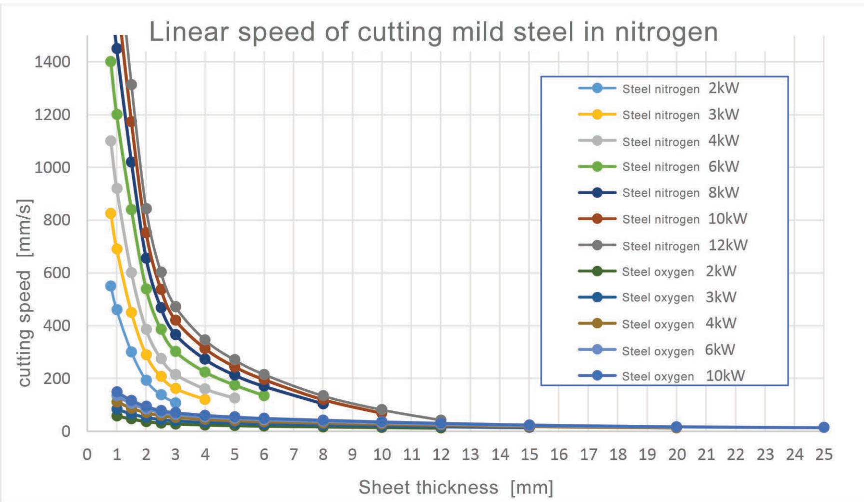
Though the tasks are carried out by a processor, they do not consume the same amount of time, and data is not sent to the servo within the same intervals. This is the so-called 'jitter', and it may deteriorate the quality of movement, causing the machine to skip, vibrate and produce corrugated edges of a detail. That is why professional head movement control systems feature an additional, special processor–interpolator, and its sole task is to control the servo's movements. It must be noted that systems based on a software simulator are very cheap (from EUR 1,000) and often this is as much as 10-times less than the cost of equipment solutions. Professional laser cutting machines are equipped with systems featuring interpolators; nevertheless, there are manufactures which employ cheaper solutions in order to make ill-perceived savings. For 20 years now Kimla has been manufacturing control systems with equipment interpolators, which communicate with servos via Real Time Ethernet industrial communication protocol.

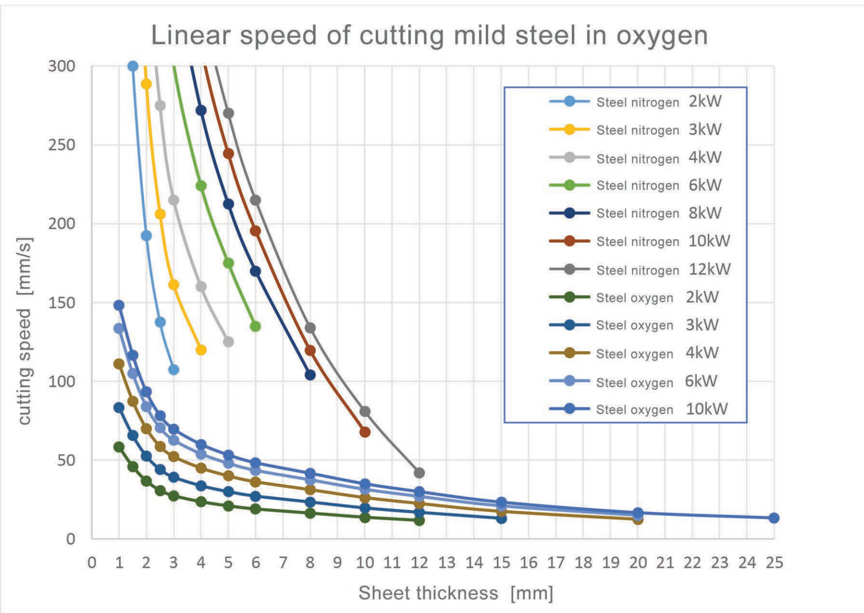
LASER POWER

The power of the first fibre laser for metal cutting reached hundreds of watts and allowed for cutting details in metal sheets with thicknesses of 3mm, with moderate speeds. It was natural to strive to increase power, in order to bolster efficiency and the range of sheets that can be cut. Rapid technological development brought power values counted in kilowatts, but the increase in power output did not translate linearly to improving the efficiency and thickness of cuttable metal sheets.

Early fibre laser machines boasted relatively small power outputs of between 1 and 2kW, meaning the maximum thickness of cutting increased proportionally. When migrating upwards to fibre lasers utilising 2kW or more, the rise starts to collapse and a further increase in power brings a gradually smaller rise in cuttable thickness.

It must be stressed that the thickness of cutting may not be directly connected with a machine's power output. Laboratory tests in optimum conditions are one thing, and instances of cutting various metal sheets in industrial environment are another, thus when deciding upon a laser source, selecting a power reserve should be taken into consideration. Power reserve influences the width of the process window, which is the range of individual parameters for which the cutting quality is acceptable. The lesser the power reserve, the more difficult it is to select correct parameters and cut materials of inferior qualities.





Cutting non-ferrous metals, stainless steels, aluminium, titan or thin black iron sheets is conducted with the use of nitrogen; and thicker black iron sheets and plates are cut with the use of oxygen. When cutting with oxygen, there is a much wider gap produced in comparison to nitrogen cutting, meaning the cutting speed is a lot slower. Therefore, due to the available power, black iron steel is cut more efficiently, at a lower cost, with the addition of nitrogen.

As shown in the above charts, the advantage of cutting thinner metal sheets with nitrogen is enormous and almost five-times as fast as when compared to cutting with oxygen with the same laser power. With thicker sheets and plates this disproportion drops a little, though it is still larger. It must be noted that, due to higher pressures, more gas is used in cutting with nitrogen, but the lower cost of nitrogen and the much greater cutting efficiency compensates for this.

The presented data also confirms the maximum thickness of cutting depending on the laser power. For example, the 3kW laser makes it possible to cut metal sheets and plates with thickness of 15mm, but the maximum cutting thickness with nitrogen is 4mm only. If the power is doubled to reach 6kW, then the limit of cutting with nitrogen is increased to 6mm and this, in turn, makes cutting possible with the speed six-times higher than in the case of 3kW laser.

The above example shows that an increase in power output is very profitable and investments should be directed at the highest laser power outputs. But before making a decision on source power selection, the efficiency of the whole laser cutting process must be considered.

LASER CUTTING MACHINE EFFICIENCY

Machine dynamics is a feature that defines changes in feeding speed depending on outlines the machine follows. It is influenced by speed, acceleration and pick-up.

Cutting speed is restricted by the sort and thickness of a metal sheet, laser power, focal length and height and gas pressure, as well as diameter and distance of a nozzle. Head movement speed is, on the other hand, restricted by the shape of path the head follows and stems mainly from linear and acceleration values and centrifugal ones, exerted at curves. Depending on the sort and thickness of a metal sheet, restrictions in cutting speed and head movement are decisive to various extents when it comes to total machine’s efficiency.

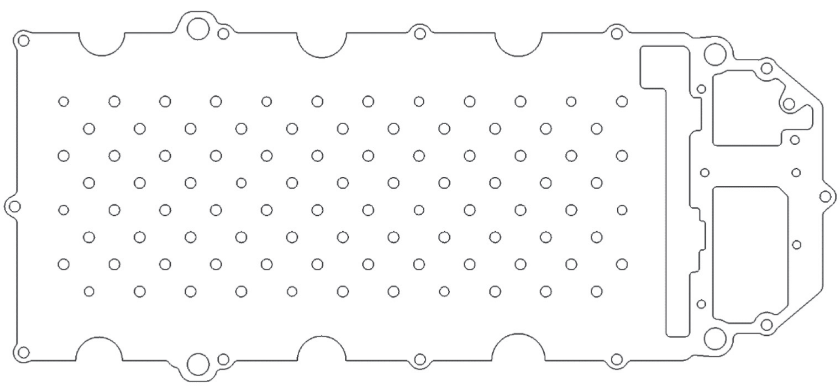
Acceleration is the amount of time a machine needs to reach the set speed, but its

restriction is at times needed at curves, so that the total value of forces stemming from linear and centrifugal acceleration does not exceed forces exerted by drives' power.
In turn, pick-up is a speed in which acceleration increments and is restricted by the rigidity of a machine and powertrain mechanisms, as lack of pick-up would cause sudden jerks and an absence of smooth movement. However, large pick-up restrictions may result in the set speed never being reached, meaning a machine's efficiency would drop considerably.

Acceleration is key to the efficient cutting of thin metal sheets, as the cutting speed stemming from laser power may be so high that detailed sections of metal may be too short to reach the set speed. With small details, it is often the case that a machine's cutting speed is just a fraction of such speed. This means when cutting certain metal sheets, the main factor restricting efficiency is dynamics, with laser power being of secondary importance. With thicker metal sheets and plates the problem is less evident, as cutting speeds are not that high and the acceleration distance is relatively short.

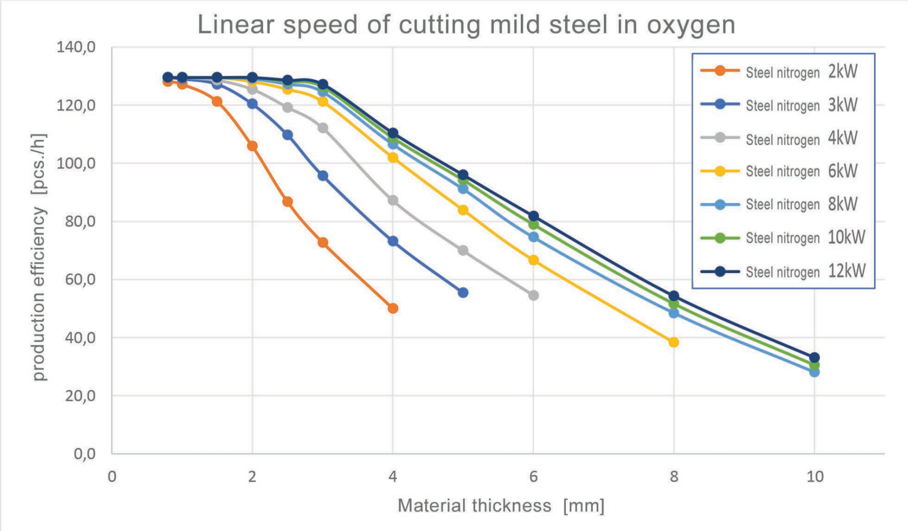
Let's analyse the efficiency of cutting a sample detail with the size of 420 x 180mm, as shown in the picture, depending on sheet thickness and laser power.

With a metal sheet thickness of 0.8mm, the source power plays almost an insignificant role – the metal sheet is so thin that the machine is following relatively short sections, and with the given dynamics it is not able to accelerate to a feasible cutting speed. With



metal sheets at a thickness of over 2mm the differences start to be evident, but are not drastic. With thickness of 4mm, the power starts to play an important role, but the largest difference as to the efficiency pertain to the power of 6kW.

Further increases in power provides for better efficiency, but the differences are



minimal. For metal with a thickness of more than 4mm, a laser is not able to employ on-the-fly piercing and must stop with each piercing, pierce the material — depending on the thickness, within 30–600ms — and start cutting the outline. With thick elements featuring a large number of bores, a situation in which the total piercing time is larger than the cutting time is unacceptable. Piercing times, among others, are another reason for a reduction in efficiency chart over 3mm of thickness.

It seems that when comparing 6kW and 12kW we see an increment of up to 80%, but when we analyse the cutting times of a sample detail, taking into account piercing times and restrictions stemming from the machine's dynamics, the differences do not exceed 10%. It should be noted that the cutting efficiency values provided in the chart pertain to a certain sample detail and will differ slightly depending on shapes and number of bores.

Analysis of the differences in efficiency when cutting thick metal sheets and plates — with powers of 6kW and 12kW and with the use of oxygen — shows that over 6kW there is practically no increase in cutting efficiency stemming from feeding speed. A slight increment of efficiency may be expected due to a slightly faster piercing with larger powers, but the total cutting efficiency with transition from 6kW to 12kW does not increase by more than 15%.

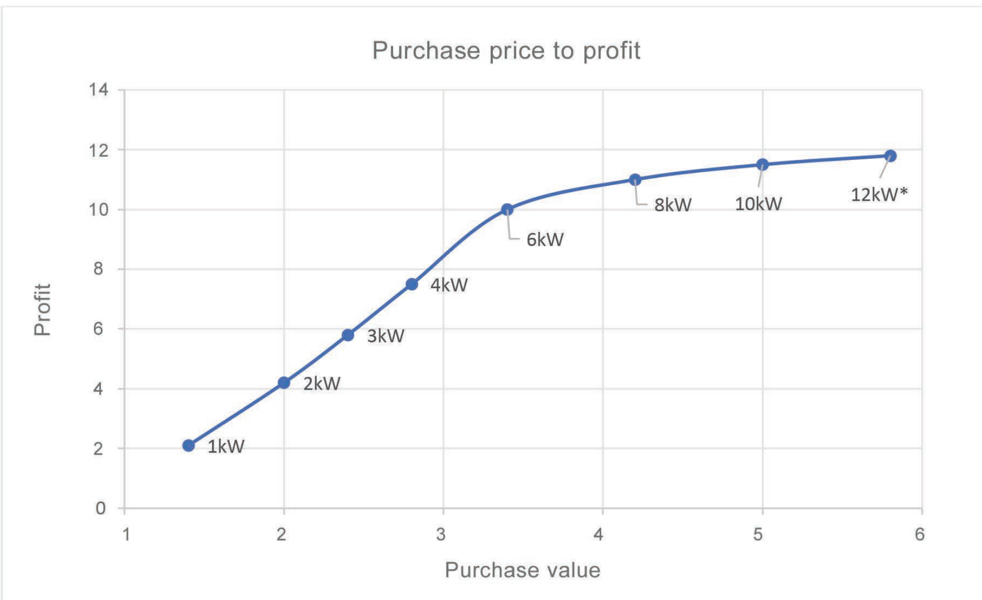
When summing this comparison up it must be noted that the vital difference in efficiency will be evident only with thicknesses, for which a given power allows for cutting with the use of nitrogen, and smaller powers do not allow for this. For example, a 6kW laser may cut, with the use of nitrogen, black iron sheets and plates with thicknesses of up to 6mm, and a 10kW laser — of up to 10mm. This means that the evident difference in efficiency when going from 6kW to 1 kW will be true for metal sheets with thicknesses of 8mm and

10mm. This goes to show that utilising more powerful laser cutting machines is economically viable in the cases when the manufacturer cuts the majority of component parts from metal sheets and plates in this range of thicknesses. On the other hand, if we average the efficiency increment for the whole range of metal sheet and plate thicknesses, then it does not exceed 10–15%.

Standstills are another factor that often go unnoticed, which impacts on the analysis a laser cutting machine's efficiency, as many models don't cut round the clock. The changing of pallets, time needed to run the programmes, head travels over air, exchange of nozzles, pauses in work caused by maintenance works are independent from the source power. When analysing the actual cutting time, it proves that it stays in the range of 60–90% per shift. It should be noted that, with increase in cutting efficiency, the pauses in cutting are not shortened, which in turn means that when calculating efficiency per number of manufactured pieces per shift, the production efficiency increment will be smaller than it is suggested by the increase in laser power.

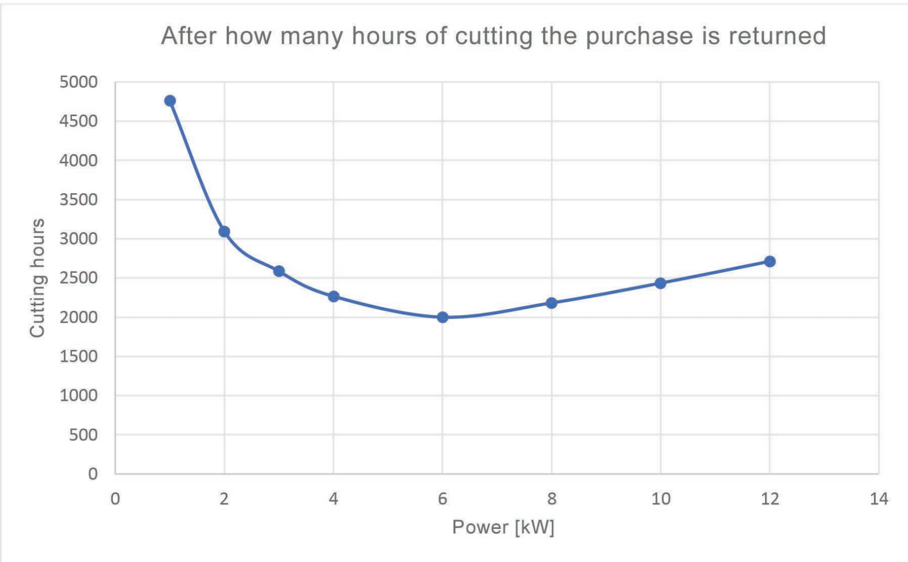
Taking into account the fact that the power offered by a laser cutting machine greatly influences the cost of a system, manufacturers should carefully analyse profits and costs.

For example, a 12kW laser costs almost as much as two 6kW lasers, meaning efficiency will not rise more than by 15%. In the majority of cases it is much more profitable to invest in two 6kW lasers, as manufacturers will receive a 100% increase in efficiency with cutting each metal sheet and each shape.



The above chart demonstrates the estimated possibilities of making a profit from lasers with different power sources, with a view to cutting a machine's purchase price, based on data obtained from companies providing laser cutting services. At the beginning, increase in laser power causes very large increments in profits in relation to increase in purchase price, which is why for purposes of rendering services, purchasing lasers offering lower power is of no use. The minimum power a machine should have if a manufacturer wishes to make a reasonable profit rate is 3kW. A further increase in power causes a subsequent increase in profits, all the way up to machines boasting 6kW — then the curve starts to collapse. Despite considerable increase in investments, the profits start to decline.

It is worth mentioning that the percentage increase in income when comparing powers of 4kW and 6kW laser cutters is higher than when comparing 6kW and 12kW machines. General investment costs may also be presented in the form of time needed to have the laser purchase costs paid-off with relation to power.



The purchase of a laser cutting machine that boasts a smaller amount of power requires ca. 5,000 hours of rendering cutting services in order for the investment to pay off. But with the increase in machinery power, the amount of time is decreased and reaches maximum with 6kW systems. As it has been pointed out earlier, machines with more than 6kW of power reduce the level of profit opportunity and investment costs are rising rapidly, which translates to longer time of pay-off.

FOR MANUFACTURING PURPOSES OR TO RENDER SERVICES

In order to choose the most appropriate laser, a manufacturer needs to consider the purpose of purchasing the machinery. Different considerations should be taken into account depending on whether a laser cutting machine is being purchased for a manufacturer's own purposes or for subcontracting services. Let's consider the differences in cutting a sheet of metal on a manufacturer's own laser cutting machine, compared to outsourcing the project to a subcontracting company. If the metal sheet is cut by a company offering such services, the cost will amount to an example price of EUR 25. However, if the metal is cut on a manufacturer's own machine, the cutting cost will amount to an example price EUR 1,25 on a 2kW machine, EUR 1 on a 3kW machine and EUR 0,75 on a 4kW machine.

It's clear that, since the difference in the cost for cutting the metal sheet on 2kW and 4kW machines is only EUR 0,50, the differing purchase prices for these lasers will not be paid off quickly. Let's look at another angle: if a manufacturer plans to implement a cutting project on his or her own laser cutting machine, using a 2kW laser will be able to process, for example, five metal sheets per hour, earning EUR 125 per hour. With a 3kW laser, 7.5 piece of metal will be cut per hour, earning EUR 185 per hour and a4kW laser will cut 10 pieces of metal per hour and generate EUR 250 per hour. Therefore, purchasing a higher powered laser translates to greater profit generating capabilities.

COSTS OF LASER MAINTENANCE

A key, influential factor when purchasing a laser cutting system is the operational costs of running a machine.
These include the costs of parts, gases and electricity. The average operational costs of running a fibre laser cutting system are estimated to be between EUR 7,50 and 17,50 per hour, depending on the source power and gas type.

While evidence about the low operational costs of fibre lasers are, of course, well--grounded when compared to CO_2 lasers, this evidence shouldn't be misinterpreted.

Operational elements like nozzles, safety windows and ceramic insulators can be replaced by the operator in a matter of minutes. The nozzles are replaced manually with the replacement of metal sheets, although automatic nozzle exchange systems are employed in some cases. Manual exchange is not troublesome and takes just a few seconds. A ceramic nozzle chuck is basically wear-resistant, but at the same time functions as a safety fuse that protects the head from serious damages in the event of a malfunction. The safety window protects the focusing lens and prohibits gas from entering the top head compartment.

Elements of a laser cutting machine that are replaced automatically often include lenses, fibre optic connections and convoluted screens, although some laser manufacturers provide warranty on other operational elements too.

The frequency of having to replace optics within a laser cutting system is heavily influenced by how powerful the laser cutting system is, however, other factors play a part too. Based on statistical data, optics aren't usually replaced on 2kW laser cutting machines for around two years. With machines over 6kW, the operational life of optics reduces dramatically, with the highest power machines needing replacement optics every few weeks.
The development in advanced optic technology has led to a longer life of these operational elements, with the life expectancy of these parts expected to continue to increase.

HEAD

The laser head is one of the most important components of a laser cutting machine. It plays an integral role regarding cutting quality, piercing speed and the range of material thicknesses that can be cut with the machine.

When fibre optic lasers emerged in the market, the first heads compatible with this technology were quite primitive, not featuring automatic elements or safety equipment. Heads we're eventually developed featuring these functions, but only on 2kW fibre laser systems. However, the rapid development in this technology identified a new set of requirements for these laser heads – the laser head had quickly become the weakest link in a fibre laser cutting system.

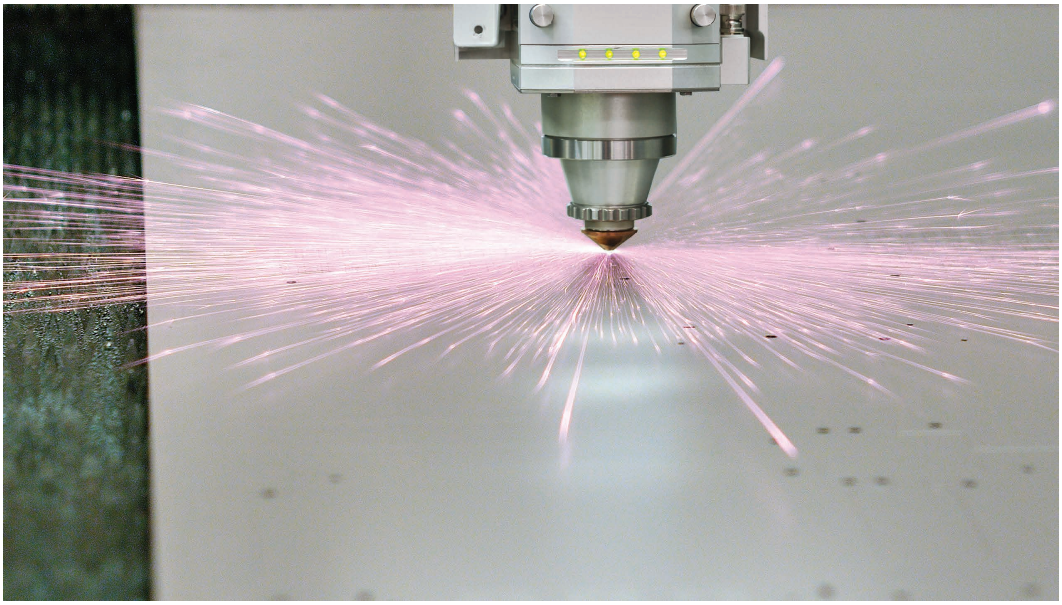
Laser manufacturers attempted to deliver heads compatible with higher-powered machines, but a lack of designed standards in this area resulted in a number of challenges. For example, with early fibre laser heads, the operator was not aware of anything going wrong with this component until catastrophic damage to a lens had already occurred.

The focusing lens may heat to a point at which its glass surface melts. This melted glass, of which the lens is made, evaporates and the liquefied material can come into contact with the neighbouring collimator lens, which can also become damaged.

The damaged collimator lens may damage quartz tip of fibre wire connection, leading to the operator — who, at this point, has not noticed deterioration in cutting quality, so has not switched off the machine in time to avert the problem — needs to replace the whole optics component.
To tackle the above, attempts were made to develop new generations of heads that were equipped with the means to measure the temperature of lenses. However, these temperature gauges only measured the lens casing temperature.

Since the glass that lenses are made of features relatively low thermal conductivity and in the case of lens surface overheating, a certain amount of time must pass in order for the temperature of the lens to be read through the casing, in order for a safety mechanism to be triggered. Unfortunately, this mechanism is often triggered too late and, subsequently, optical elements are subjects of damage.

Kimla has developed a contactless method for measuring lens surface temperature, based on micro-bolometric matrices. This allows for temperature monitoring to take place directly at the point of its origin – the lens itself – enabling an instant halt of the machine's operation when the alarm temperature is exceeded.



MEASURING DISTANCE FROM MATERIAL

Measurement is another key factor a laser head must taken into consideration when cutting. The head must follow a material's surface no matter how uneven, and travel with sufficient, high speed in spite of a material's rough surface.

A laser head uses a radio waves generator to measure the changing space between the nozzle and a sheet of metal. The closer the nozzle is to the metal's surface, the higher the capacity becomes and the frequency decreases. On the basis of this decrease, the distance is determined and the laser head height corrected.

In majority of lasers the distance measurement and height correction are carried out with frequency of 1 kHz, that is 1,000 times per second. Despite this, such a frequency can be insufficient with high-speed machines. For example, when the head is travelling at a speed of 1m/s, the head height correction will be executed every 1mm. In order to avoid collision, it is of key importance for the head to react as fast as possible. That is why Kimla has designed a new generation measurement unit, utilising DSP processor signals, which enables frequency increase for measurements and head height correction to 20kHz. This system is capable of faster reactions and the precise adjustment of the head position.

The measurement range of the distance from a metal sheet/plate is very important when piercing thicker materials. During piercing sparks and melted material may escape with such a speed that they may counterforce the resistance of gas momentum and enter the head, destroying the safety window. That is why, when piercing thicker metal sheets and plates – especially the ones cut with the use of oxygen – the nozzle should be retracted from the material even at the height of a dozen or so millimetres. This is a height beyond a standard working range for height regulators, and this is why the majority of lasers pierce with heights amounting to maximum of 10 mm. In turn, this often results in the faster wear of safety windows. Measurement systems featured in Kimla lasers have been designed in a way that makes it possible for the measuring range to reach 20mm, which considerably shortens piercing time and extends an optics operational life.

In order to facilitate piercing from such a large distance, the head must feature automatic functionality, enabling it to lower the focal height towards the metal sheet surface. When piercing, the head must be raised, but the focal point should remain at the material surface.

The safety window separates high-pressure and low-pressure sections. Window sealing requires control and verification, otherwise it may result in damage to lenses. That is why pressure measurement is so important in both cases: of the high-pressure section — for nozzle pressure control; and of the low-pressure section — for control of possible leaks.

Of similar importance is the guarantee that no humidity enters the head along with gas, or that the cooling system is unsealed. In order to provide maximum control of the head condition, Kimla has installed the following sensors in its laser heads:

- Temperature of the top safety window
- Temperature of the collimator lens itself
- Temperature of the collimator lens housing
- Temperature of the Focusing lens itself
- Temperature of the Focusing lens housing

- Temperature of the safety window
- Temperature of the housing
- Temperature of the head height controller
- Presser at the nozzle
- Pressure in lens compartment
- Humidity in lens chamber
- Total loss power at the head
- Total loss power at the fibre optics connection
- Beam reflection from the material

One of the actions an operator handles with the laser head is replacement of the safety window. It is a relatively simple and quick thing to do, but many mistakes can be made. The basic rule is not to leave the window compartment open, as tiny impurities from the air may get inside the head.

An operator should also always remember to never turn the used window upside down, or to replace a window that is even slightly damaged. It should also be noted that, prior to fitting the window, an operator should check the Teflon window sealing, as even the slightest lack of tightness can lead to further problems.

In order to increase safety when replacing a window on a Kimla machine, an additional safety window is mounted on top of the original window, so that an operator would not result in serious damage to the optics.

RULES TO FOLLOW WHEN PURCHASING A LASER

A client who wants to invest in a laser cutting machine should take serious consideration when doing so, especially if the manufacturer is purchasing its first laser cutting system.

Laser cutting machines are one of the most expensive CNC machines a manufacturer can purchase, and making the wrong decision could be catastrophic for a business.

A client should start by understanding the basics of lasers and their practical applications. Although this can be a time-consuming process, it could prevent an investor wasting millions.

Below is a set of advice and recommendations covering what should be taking into account when purchasing a laser cutting machine, and what to ask a potential dealer when making a decision about purchasing a machine.

When gathering knowledge about lasers, manufacturers often visit various suppliers or contact them by phone to obtain information on the systems they offer.
Where possible, it's advisable to obtain this information in writing, via email for example. Dealers will often try and tempt potential customers with jargon rather than fact, so where possible, obtaining information on a laser cutting system in writing so it can be referred back to is sensible.

Additionally, an email may be opened and read again in order to refresh memory, as well as proving that a dealer provided assurance of a machine's characteristics, should a purchased system be lacking.

Generally, all laser cutting machines offered on the market can be divided into two categories: machines that are reliable and machines that are of slightly higher value.

It is hard to tell one machine from another in terms of their group affiliation; the reliability of a machine doesn't always guarantee a high capacity, and a high capacity is not a guarantee of reliability. It may be assumed that lasers by well-known trade names will work well and will simply do their job. They might not be the most efficient machines on the market, but they will cut what they are supposed to cut.

A client should also remember that large companies have great costs to cover, meaning they must earn a lot. Increasing prices is not an option in a competitive market, so a quality after-sales service is a viable source of income.

Ever wondered why one company offers safety windows for EUR 40 a piece and another one for EUR 200? They are made of the same glass, feature the same anti-reflex layers and may even be manufactured in the same factory. But it turns out that the more expensive ones also feature a patented phase, meaning no other company is eligible to manufacture the product.

A different example of actions that are evidently not aimed at quality and functionality improvement, but at generating a steady flow of money is software, which checks serial numbers on individual components of the control system. If a number is not on a list purchased by a laser's manufacturer, then the element will not work.

So, while a component might be produced by a reputable manufacturer for an example cost of EUR 4,000, since it doesn't feature the required serial number, it will not work. In comparison, a component that does include the necessary serial number could cost EUR 14,000, as an example.

Another way in which manufacturers increase their income is by offering after sales services. If a laser source malfunctions, the user must contact the supplier and, while the supplier will not repair the laser, it will contact the machine's manufacturer to arrange the repair.

The machine's manufacturer may then quote for the repair, which can increase costs dramatically. This is why, prior to purchasing a laser, it is important to verify the prices of services and main spare parts, like laser modules.

Kimla has been following the rule of not making profit on after-sale technical services for many years now. The after-sales technical service is by all means paid, however, the pricing for these services is to cover the costs of their time, not generating income. Thanks to this approach, it is often found that, when a malfunction occurs, the cost of repairing it will be a lot cheaper than other manufacturers.

Large companies utilise a complex decision-making process, and R&I departments are scattered all over the world, meaning new products are developed relatively slowly. With a product like a laser cutting system, which is a very advanced piece of machinery, it can take up to 10 years to develop a new product – from the commencement of a project to its introduction to the market.

This is the time during which many technological solutions undergo changes, meaning a new machine is already obsolete when it enters the market.

On the other hand, machines produced in Asia or, in broader sense, outside the European Union tempt potential customers with low prices. However, potential investors need to remember that there is no such thing as a free meal.

So, what is the best way for an investor to evaluate a machine effectively? The questions below should be asked to manufacturers, before considering the responses in order to make an informed decision:

- Is the laser manufactured in the EU and is there a manufacturer's service available in that area?
- Is the source manufactured in the EU and is there a manufacturer's service availa ble in the area?
- Is the head manufactured in the EU and is there a manufacturer's service available in the area?
- Is the control system manufactured in the EU and is there a manufacturer's service available in the area?
- Has the supplier has been operating in the area for over 10 years?
- Does the supplier have a laser showroom?
- Does the supplier have a warehouse with spare parts?
- Does the supplier boast clients, who are in possession of a number of its lasers?
- Does it feature the Declaration of Conformity issued by a party from the EU?
- Does the control system feature an equipment interpolator?
- Can the laser be installed without foundation works necessary?
- Does the laser feature the whole housing with certified infrared filters?
- Is the laser feature CAD/CAM software developed by the laser’s manufacturer?
- Do the all axes feature magnetic linear drives?

CONTRACT AGREEMENT

- Check if there is a warranty for the machine. (Check if it is not excluded in the sales agreement, as if it is excluded, return of a machine to the supplier will not be possible even in the case of a defect).
- If the supplier runs an LLC company, check the date of its establishment, share capital and assets (financial accounts should be available on the Internet). If share capital is low, and there are no assets, it's worth baring in mind that a warranty will be of no help in the case of supplier's insolvency.
- Check if the dealer is a company registered in EU or just an intermediary and the purchase is made via the dealer, e.g., directly in a country outside the European Union.
- Check if the company is insured for at least the amount equal to the purchase price of a laser system; it is a good idea to ask for the copy of an insurance policy.
- Check if the supplier has already traded similar lasers in the past. If not, it's likely the supplier has no means to provide after-sales support. If yes, more of such machines should be operating in the area. It is recommended to visit at least three companies using such a laser; it is best to schedule a visit without the seller's assistance and it is advisable to talk to an operator, as owners rarely the finer details about their machines. Remember, the seller will never send a client to a dissatisfied existing customer, which is why searching for such a machine and getting opinions about it independently is so important.
- Check the manufacturer of the laser source. If it is not manufactured in Europe, it is not worth taking the risk. Most likely, there will not be any after-sales support in Europe, let alone, for example, in your country. When there is no after-sales support offered by a laser source's manufacturer, problems can arise with transportation and the need to salvage an expensive device. In such a case even warranty repair may be connected with high costs and months of standstill.
- Check the way the after-sales support is provided – a service coming directly from the supplier is a must. The supplier should bear the responsibility for after-sales support, as it is the supplier who is responsible for dismounting fibre cable prior to repair and then for mounting it after the repair. If this is done incorrectly, the responsibility should be borne by the supplier (a necessary contractual provision).
- Check the way the laser head is going to be mounted. If a head is manufactured in Asia, the chances for professional after-sales support is practically equal to zero. If the optics are damaged, check who is going to repair such a head, and check working conditions and skills of those responsible for the repair. Check if the supplier has a head for replacement. Check the conditions in the laboratory for servicing heads. Check the supplier's experience in their

replacement and whether the supplier assumes responsibility for the outcomes of incorrectly conducted replacement.
- Never purchase a laser from a company which does not have a demonstration laser; if a dealer shows only machines in a catalogue, it means he or she will have no idea whatsoever about the service operation of a machine, nor about the sourcing of spare parts. In the event of any problems, there will be nothing to compare with, nor the source of components.
- It is a must to visit the company where a laser is to be purchased from; never order a laser on the basis of supplier's sales representative's visit only.
- Make your own judgment on whether or not a company exemplifies proper potential for selling such machines.

SAFETY

- Is the laser equipped with housing and certified infrared filters? If not, the operation of such a laser is prohibited in Europe.
- Does the laser feature CE markings and details on whether or not the certification body is from Europe? If not, it may mean that the machine doesn't adhere to the CE Declaration of Conformity.
- An investor should note that CE markings are the responsibility of the importing party, which is why it is the importer who is obliged to issue the CE marking. More often than not, such an importer has no resources to prepare such a certification on one's own and that is why such certification must be ordered with a notified body. Documentation of the risk assessment procedure should be requested from the certification body. It is prohibited to operate a machine without CE markings.

WARRANTY

- The purchaser should be aware that component parts of the laser cutting system, the operational life of which cannot be predicted, are not subject of a warranty. So, in order to avoid any surprises, the dealer should deliver a list of parts that are not covered within the machine's warranty, together with counterpart price list of the parts. The contract should feature a provision that all parts that are not included in the warranty exclusion list are considered as covered with the warranty.
- One should check requirements pertaining to preparation for installation and conditions of the machine's foundation. It may come to prominence that, for example, a laser must be installed on a foundation; but when the user rents premises, interference with the floor and the preparation of foundations is impossible. (Kimla machines do not require preparation of foundations). There are cases, when dealers refuse to provide warranty repairs for malfunctions due to the installation of the laser without prior preparation of appropriate foundations.
- The following should also be verified:
  - What is the operating temperature of a laser?
  - What is its storage temperature?
  - Whether abrupt power failure or cut-off will damage the machine?

LASER POTENTIAL

- The contract agreement should specify the dimensions of the metal sheets/plates the laser is to cut. The sorts of sheets/plates and their thicknesses should be specifically stated. Do not follow tables in catalogues as there can be exceptions. Also, offers may contain information about thicknesses of cutting, but subsequent descriptions may contain the condition: "All parameters indicated in this offer are for reference purposes only and the supplier does not guarantee them." Read offers and contract agreements very thoroughly.
- At times, there is no contract agreement and the purchase is made on the basis of General Terms and Conditions for Sales. Thoroughly read and keep such General Terms and Conditions. If the provisions set forth in them are not clear, consult with a lawyer.
- When commissioning a machine make sure all specified metal sheets/plates are really cuttable. To not sign commissioning protocols unless the laser operator is not able to cut all

sorts of specified metal sheets/plates on his or her own. It will also be a test for the quality of training.

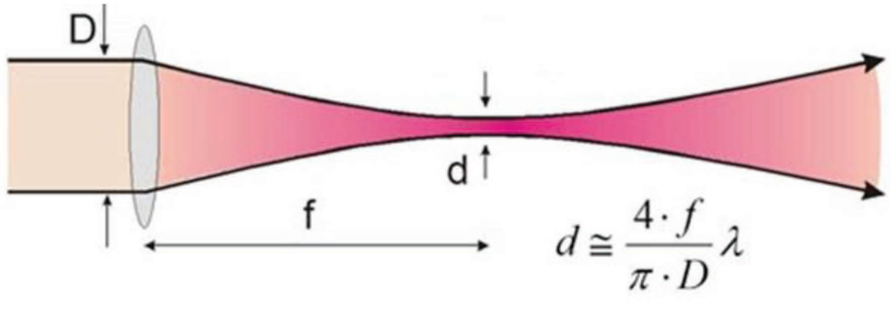
- Check the software for the preparation of the tool's path and who is responsible for writing postprocessor and whether all laser functions are compatible with postprocessor; many surprises are possible in this respect.
- Make sure to also establish the rules for updating software in the case of errors. Check who and on what grounds will amend the software and the postprocessor.
- Check the control system, its name and model and whether it is a professional system or merely a software simulator.
- Check if there are full versions of operation and service manuals available.
- Check manufacturers of individual components: servos, gears, guides, pressure regulator, motors, inverters, electromagnetic valves, PLC.
- Check if the manufacturer delivers the machine with a copy of the control system software, in case the system gets damaged and requires replacement — without manufacturer's software there are no means to repair the machine.
- It is recommended to physically check spare parts stock at the supplier's warehouse. Lasers are complex machines, and in order to be able to count on prompt assistance of the supplier, the supplier should maintain a stock of practically all components that constitute a laser.
- Be sure to check the actual laser efficiency, as differences between individual cutting machines may be multiple. Provide the supplier with .dxf files with sample details for cutting in various thicknesses and sorts of metal sheets/plates. The supplier should cut them out and return together with information on cutting time. Keep them for future reference during commissioning. It is good to indicate in the contract agreement that during commissioning the amounts of time for sample cutting will be verified.
- It is recommended to send similar details to other service providers for quotation. The best solution is to divide the final charge onto the costs of materials and cost of cutting. On the basis of cutting time it is possible to calculate the possible number of such details per hour and estimate whether cutting with the use of a given machine is profitable or not.

FIBRE OR CO_2

Laser Fibre is the abbreviated name of a laser with a fibre optic resonator. From CO_2 lasers, it differs from the fact that the active medium is the fibre of the fibre doped with ytterbium. The whole resonator is based on a solid body, it has no exchangeable elements and regulatory elements, such as mirrors. Lasers for cutting steel were used already in the sixties. CO_2 technology has been developed for many years, but in recent years no significant changes have been introduced in the technology of CO_2 laser cutting. Their limited efficiency results directly from physical phenomena, not technological limitations in their production.

Fibre optic technology is currently the most modern method of sheet metal cutting. It is characterized by extraordinary efficiency and effectiveness. Fibre lasers have many times more efficiency than CO_2 lasers, therefore they consume much less energy.
The energy efficiency of fibre optic lasers is around 35%. This value is much higher than in the case of CO_2 lasers whose efficiency is around 5%. For example: a 4kW CO_2 laser needs 80kW power, and a 2kW fibre laser that fits its capabilities consumes only 6kW. Taking into account the above-mentioned factors, the costs of fibre laser operation related to electricity can be up to ten times lower than
in the case of a CO_2 laser.

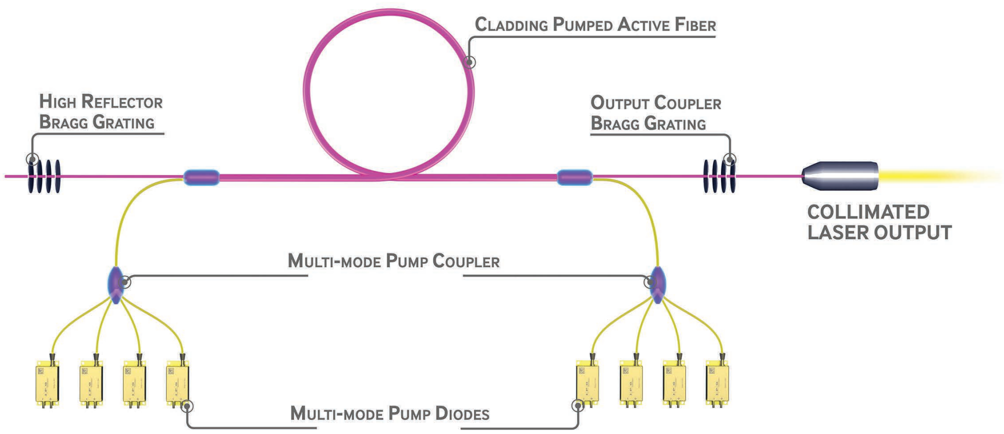
Another advantage of Fibre lasers is the much shorter wavelength of light, allowing a greater concentration of energy in the focused beam. This higher energy density enables faster laser cutting with less power.



$$d \cong \frac{4 \cdot f}{\pi \cdot D} \lambda$$

The figure shows a formula for determining the diameter of a focused radius. As you can see it is proportional to the wavelength, so for a CO_2 laser with a wavelength of 10.6um, the diameter of the focused beam will be ten times greater than for a fibre laser with a wavelength of 1.06um. Thus, the fibre laser can cut a much more concentrated laser beam and melts the much narrower gap to separate the material. Smelting a narrower gap requires less energy and therefore the specific laser power allows for much faster cutting. Therefore, with thin sheets, the fibre laser cutting speed can be up to 5 times higher than with the CO_2 laser. The effect of increasing the cutting speed is also possible due to the fact that the absorption of the wave length 1.06um by metals is much higher than at 10.6um. For this reason, fibre lasers can cut highly reflective metals such as copper, which was not possible using CO_2 lasers.

Before the high-power fibre lasers were created, laser discs appeared on CO_2 lasers. They generate the same wavelength as fibre lasers but the resonator is of the "open cavity" type. In this solution, the active medium is also glass doped with Ytterbium but in the form of a thin disc. In this case, the light must leave the active medium before it bounces off the mirror and returns to it. Each passage through the boundary of glass-air centres causes some losses, which does not allow to obtain such high efficiency as fibre lasers that are all in fibre lasers, where light does not leave the glass until it reaches the head. Thanks to this, higher efficiency and lower maintenance costs are possible.

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