A comparison of fibre laser and CO₂ laser cutting

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Since the advent of commercial Fibre and Disk laser cutting machines there has been a lot of controversy about the performance of these devices – particularly in comparison to their more established CO₂ counterparts. In the early days the sales staff promoting fibre technology would often declare that the new lasers would very quickly replace CO₂ lasers – but this has not happened. Even taking into account the entrenched position of the older technology, Fibre and Disk lasers have not been as widely accepted as was predicted, although they have been proven to out-perform CO₂ lasers in certain important areas.

Here we present a direct comparison of Fibre laser and CO₂ laser cutting machines from a ‘what laser should you buy next?’ point of view. Both types of machine have their drawbacks and advantages, and a direct comparison needs to compare costs, cutting speeds, cut quality and several other factors including maintenance and safety considerations. A quantitative comparison of the two machines is surprisingly difficult – having given several talks on the subject the best analogy we can give is that it’s like comparing a sports car with a family car.

Terminology

Fibre lasers have been the subject of a lot of jobshop interest for a few of years now – but what are they and what’s the big deal? – and what, for that matter, is a fibre delivered disk laser? In some ways it’s a bit like being back in the 80’s when CO₂ laser sales folk were full of high-tech jargon and the jobshop owners had to sift through all the sales talk nonsense to work out what M² meant, and whether or not it was important.

In fact, as far as a jobshop manager is concerned there is no real difference between a fibre laser and a fibre delivered disk laser. The differences between them are similar to the differences between the technologies of the various batteries you can get for your torch. As long as the torch helps you to avoid stepping in the dish of cat food during a power cut, what do you care if it runs on Lead Zinc batteries or Star Trek DrLithium crystals?

So – for the remainder of this article we will use the term ‘fibre laser’ to mean both fibre and disk lasers (the technical term for both is ‘high brightness 1 micron lasers’).

Background information

CO₂ laser cutting machines have been the main workhorse of the laser cutting world since the 1970’s. A typical high power CO₂ jobshop machine has a power of 4 or 5 kW and is used to cut Stainless steel up to 15 mm thick, aluminium up to 8 mm thick, and mild steel (with oxygen assist) up to 20 mm thick and wood or plastics up to 40 mm. (These are commercially typical figures – higher power machines are available and these are not the maximum thicknesses which can be cut at 5 kW).

Fibre and Disk laser technologies are a direct extension of Nd:YAG lasers – which have enjoyed a niche in the laser cutting world since the 1980’s. Originally Nd:YAG lasers were used either where fine detail (eg Clock hands) needed to be cut, or where the application demanded that the laser be fed to the workpiece by an optical fibre (eg. on an automotive production line where space is at a premium). Fibre and Disk lasers are the more efficient, more powerful big brothers of the early Nd:YAG machines. Multi-kilowatt powers are available and these machines can cut thinner section (3 mm or less) metals considerably faster than CO₂ lasers of the same power. The choice between the two types of machine from a jobshop point of view is not straightforward – both machines have advantages and disadvantages.

In a meeting in the UK in 2012, the world’s leading laser cutting expert – Dr. Dirk Petring - summed up the Fibre laser situation by saying that, ‘If you compare the CO₂ and fibre laser performance for thin section metal cutting, the CO₂ laser is dead’. Within hours I heard a fibre laser cutting salesman misquoting this as ‘The CO₂ laser is dead as far as cutting is concerned – Dirk Petring says so’. But two of the most important words in Dirk’s original statement are ‘thin section’.

Fibre lasers do a great job cutting metals thinner than 3mm – they are faster than their CO₂ counterparts and the edge quality is just as good. If you are a manufacturer of metal cabinets, air ducting components or point of sale display racks, where metal thicknesses are well within this region, the Fibre laser will do the job faster – and will probably be a better choice than a CO₂ machine.

For a jobshop the choice is less obvious. “My own firm uses four big CO₂ machines working 24 hours a day. If some new government initiative came along that paid for me to replace all my laser machines for free (I wish), I would not choose to get four Fibre lasers. I would get three CO₂ lasers and one fibre.” (John Powell) So – why is this?

The Choice

First of all we need to establish a level playing field – and the most obvious leveller is purchase price. A 5 kW CO₂ laser cutting machine costs about the same as a 3 kW Fibre one, so we will investigate a comparison between these two types.

There are enough interlinked criteria involved in the direct choice of the two types of machine to drive anyone crazy. Fortunately the big laser cutting machine manufacturers have begun to generate genuine comparative information rather than useless ‘fastest speed’ data and I am grateful for the information supplied to me by both Trumpf and Bystronic in the preparation of this paper.

Although the detailed data can be confusing, there are only two basic considerations for the laser user:

1. How expensive will it be to produce my parts?

2. Is the cut quality good enough?

If we are comparing two machines which require similar capital investment, the expense of the parts is highly dependent on the time it takes to make them – and the costs per hour of running the machine.
a full sheet of steel into two refrigerator doors in 3 minutes, the speed of the sheet changeover mechanism might have a considerable effect on production costs.

For material thicknesses of 4 mm and beyond the cutting speeds of the 5 kW CO₂ laser and the 3 kW Fibre laser start to converge and, because they are cutting slower, the maximum cutting speed is reached more often. At above about 8 mm thick the CO₂ laser is the faster technology – and in this regime, a comparison of highest cutting speeds starts to be useful because the laser cutting process is rate determining rather than the acceleration characteristics of the machine.

One other point to be made here is that piercing times have been much improved by the better manufacturers (like Bystronic and Trumpf) over the past few years. So a new machine will outperform an older machine in terms of acceleration and piercing times irrespective of the laser type it is attached to.

In summary – the fibre laser cuts metal faster at thicknesses below about 4 mm but these speed differences are most advantageous when cutting large, simple shapes.

Running Costs

For a realistic comparison, the running costs of our two machines should be compared per item rather than per hour. If machine ‘A’ costs 10% more to run than machine ‘B’ but produces 20% more products an hour, then it’s part production running costs are lower, not higher than B.

However, to work out the actual costs we need to start from running costs per hour. Running costs can be divided into several different categories, including:

- Electricity
- Laser gas and cutting gas
- Operator salary
- Maintenance costs.

As a general comparison the following points are true:

- Electricity costs of a 3 kW Fibre laser cutting machine are between 25% and 50% that of a 5kW CO₂ machine.
- Fibre lasers don’t use laser gas. However, Fibre laser machines generally use bigger nozzles and therefore more cutting gas than their CO₂ counterparts.

The most important of these considerations is electricity costs. Although the exact figures vary from model to model we can assume that a 3 kW fibre laser cutting machine (including dust extraction etc) consumes approximately 20 kW whereas a 5 kW CO₂ machine consumes about three times this much. In the UK electricity costs approximately £0.10 per kilowatt – so the CO₂ laser will cost approximately £4.00 per hour to run.

If you are trying to reduce costs above all else then you might find that a fibre laser attached to a cheaper (lower acceleration) machine can produce parts more cheaply because the purchase and running costs are minimised. This point has been proved on typical parts by a number of trials carried out by Bystronic. Part production costs will be lower even though your rate of production will also be low. This point is more probably appropriate to a manufacturer rather than a jobshop. In a jobshop situation there should (hopefully) be plenty of work waiting to go on the laser, so high productivity is very important and each cut product has a profit associated with it. A manufacturer might only need the laser to produce goods for a certain part of the week, in which case a cheaper to run (Fibre), less expensive (lower acceleration) machine might be the optimum purchase.

On a day-to-day basis, Fibre lasers cost less than CO₂ lasers to maintain. However, whereas the maintenance costs of a CO₂ laser over ten years (including large item failures) are well known, Fibre lasers are not yet old enough for large item replacement costs to be known. A typical large item failure on a CO₂ laser would be a turbo/blower, at a cost of about £12,000. The large items on a fibre laser could involve con
CO2 laser. Fibre laser salesmen will point fibre laser cutting is inferior to that of the remains true that the cut edge quality for or 8 mm. However, beyond this point it roughness with material thickness – par-\text{ticularly} towards the bottom of the cut edge.

Over the range of thickness shown here the CO2 laser cut edge retains its low roughness, but the Fibre laser cut edge experiences a steady increase of edge roughness, but the Fibre laser cut edge quality CO2 and Fibre laser cuts up to 6 cutting and we have seen equivalent similar for both types of laser for fusion view, below 4 mm the cut edges are unhappy taking a reduced cut quality to the one they are used to. Typical cut edge quality for 10 mm stainless steel for the two types of laser are shown in figures 3. There is a clear increase in roughness of the cut edge towards the bottom of the cut edge in the case of the CO2 laser cut edge retains its low roughness with material thickness – particularly towards the bottom of the cut edge.

From a general engineering point of view, below 4 mm the cut edges are similar for both types of laser for fusion cutting and we have seen equivalent quality CO2 and Fibre laser cuts up to 6 or 8 mm. However, beyond this point it remains true that the cut edge quality for fibre laser cutting is inferior to that of the CO2 laser. Fibre laser salesmen will point out that the edge quality is still pretty good – but some customers would be unhappy taking a reduced cut quality to the one they are used to. Typical cut edge quality for 10 mm stainless steel for the two types of laser are shown in figures 3. There is a clear increase in roughness of the cut edge towards the bottom of the cut edge in the case of the fibre laser cut.

For Oxygen-assisted cutting of mild steel the cut quality for fibre laser cutting at all thicknesses has been much improved over the past few years, and is nowadays comparable to CO2 laser cutting.

Range of materials
Fibre lasers are better than CO2 machines at cutting copper and aluminium alloys but cannot cut most non-metals such as polymers (plastics) or wood based products.
Most jobshops cut only a small amount of non-metals so this inability to cut plastics should have been only a minor concern. However, there is one area where plastics cutting is important to jobshop laser cutting. A great deal of the stainless steel which is cut by laser is supplied with a covering of protective plastic. The CO2 laser beam is readily absorbed by both the plastic and the steel beneath and so the two materials are cut in one pass. In the case of Fibre lasers the plastics used are usually transparent as far as the laser beam is concerned and, if this is the case, the cutting machine needs to carry out the cut in two operations;
1. Run over the shape to be cut with a defocused beam – to melt the plastic out of the way, and
2. Cut the steel with the focussed beam.
This double process has two disadvantages: it wastes production time, and it leaves a residue of melted plastic on the top face of the cut component along the cut line. The residue is fairly easy to remove. Recently the steel suppliers have introduced some new plastic protective coatings that absorb the Fibre laser beam and which therefore can be cut with the steel in the one pass – but these coatings are not easily available in the very short lead times demanded of, and by, jobshops.

Safety
Both CO2 and Fibre laser machines are adequately enclosed to protect the operators and are classified as completely safe. The only safety-related difference between the two types of laser concerns the transparent panels which are used to view the cutting operation.
In the case of CO2 lasers these panels are made of cheap, readily available polycarbonate, and it is standard practice for a jobshop to cut their own replacement panels as the old ones get scratched and damaged. The panels used on fibre laser machines are much more high-tech and must not be replaced by polycarbonate – as polycarbonate and most other plastics are transparent to a fibre laser beam.

The verdict
If you are a jobshop boss with the usual wide spread of cutting requirements then you should buy CO2 machines until you have enough suitable work to fill the capacity of a fibre laser. This will usually mean that you will have approximately three CO2 machines for every fibre machine.

But in either case it’s a good idea to get the potential suppliers of the equipment to carry out actual cutting trials on typical jobs and don’t forget to include the sheet changeover times in your assessment.

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