

PHOTOCHEMICAL ETCHING:
PRECISION, WITHOUT COMPROMISE

Overcoming the limitations of traditional sheet metal machining technologies



Precision Micro

Everyday issues for design engineers

Engineering is about problem solving. That's why we studied it, why we embarked on this career, and why we come into work every day. We love a challenge. But as our profession develops, the way we solve these challenges can become somewhat overcomplicated – and a simpler solution is needed.

In this context the challenges arise when machining the complex precision components that every industry requires, from automotive and aerospace to electronics and healthcare. The most common ways of shaping and cutting detailed design features into these components are laser cutting and stamping – and, over time, the limitations of these techniques, and the need for others to compensate, have led to a kind of rock-paper-scissors approach to solving three key issues:

- **Thermal and cutting-edge stress**
- **Burring**
- **Material limitations**

Add to this the problem of overcoming process hurdles from R&D to production, and the use of these two techniques show clear limitations. In this paper, we'll take a closer look at them and how we can better overcome them through a lesser-known technique: photochemical etching.

Our aim here is to give you a general view based on simple principles – to equip you with a more rounded understanding of the above problems and help you find a simpler pathway to solving them. After all, as engineers, the only thing we love more than a challenge is a solution...

Thermal and cutting-edge stress

In metal machining, stress is a constant factor limiting effectiveness. It primarily takes two forms: thermal stress and cutting edge, or cutting section, stress – the former a concern for laser cutting, and the latter an enduring issue for stamping. Here, we'll look at both of these types of stress, with a brief primer on overcoming them.

Thermal stress

Heat is always a by-product – particularly when it comes to the laser cutting of sheet metals. The laser cutting of these materials generates a continuous heat source, moving at constant speed along the cutting edge. This can build up to high levels of thermal stress, with the potential to deform the material, potentially at a micron level – but, as is clear given the applications such components are used in, even the slightest imperfection or deformation as a direct result of thermal stress can inhibit the effectiveness of laser-cut components.

Numerous academic studies have attempted to account for thermal stress, model its effects, and propose counteractive methodologies to account for it. As a result, thermal stress fields can, to a large extent, be predicted and accounted for. But as a simple principle of heat transfer – central to laser cutting – thermal stress always presents a significant obstacle.

Cutting edge stress

The limitations and complexities presented by thermal stress for laser cutting often lead engineers to choose stamping, or waterjet cutting, as an alternative. The obstacle of thermal stress here, however, is replaced by physical stress on the cutting edge. Often a result of the shearing process, in which cutting steels are used to cut sheet metal to create the desired components, the physical stress caused can have a detrimental effect on the flatness of the blank and, ultimately, compromise component quality – particularly for parts which require high levels of precision.

While post-machining techniques – including overbending and applying additional force – can reduce the impact on flatness, this adds further time and expense to the production process.

Dealing with stress

All of these techniques showcase the ingenuity applied by engineers to address the shortcomings of stamping as a machining process – just as the in-depth modelling of thermal stress influences and effects show similar efforts for laser cutting. But, returning to our rock-paper-scissors analogy, this is another example of overengineering solutions to challenges when a far simpler one is in evidence.

Photochemical etching removes the heat transfer issue of laser cutting and the physical impact force of mechanical techniques – reducing the risk of deformation and resultant quality control issues. But we'll delve more into this later. First, let's look at some of the other key issues.

Creating a clean finish – at the micron level

Both laser cutting and stamping are capable of machining components in fine detail – but through heat generation and physical impact, as processes, they inevitably cause burring.

Accounting for the impact of the burred edge

While burring is more commonly associated with traditional machining operations, like milling, grinding or turning, it has the potential to compromise the accuracy and dimensions of the most precision-engineered material components. Even the smallest burred edge can have a major impact on the performance of a component – amplified when the component in question needs to be exactly crafted and configured to perform reliably in a critical application.

As a result, both laser cutting and stamping will require greater or lesser degrees of deburring – typically through mechanical processes such as finishing or barrelling, or electrochemical means, depending on the material in question and the nature of the component being created. And this, in itself, can add up to a significant proportion of the overall cost of manufacturing.

Eliminating burring through photochemical etching

In a similar way to how photochemical etching navigates around the potential for thermal and cutting-edge stress, this technique effectively eliminates the possibility of burring in an etched component.

This is because no heat or force is used when etching. There's no opportunity for stress or deformation, and no possibility of creating burred edges. In chemically etched stainless steel components, there remain no unaltered physical properties and characteristics; just a component made to precise specifications, simply and accurately.

And when these components may, for example, be used as mission-critical springs in satellites or safety-critical ABS braking systems, for fuel injection solutions or even for corrosion resistant microfilters, this accuracy in staying 100% true to specifications and within tolerances without the possibility of burrs or stresses, can be invaluable.

Working within the parameters of different metals

At the design stage of any manufacturing project, it is absolutely imperative to know the materials you are working with – and the physical properties and limitations of those materials.

The difficulty in the difference

Across the spectrum of metals, from stainless steel to aluminium, titanium and more specialist materials, there's a huge variance in hardness and integrity. Any machining process needs to account for these, so that the resulting components adhere to all relevant standards of quality and performance.

Stainless steel is, as expected, something of an industry standard, used across applications thanks to its versatility and durability.

But what of aluminium? Lighter, more flexible and more desirable for aerospace and heat-exchange applications, it's also significantly more difficult to machine than sheet metal staples. Aluminium and its alloys, for example, tend to work-harden when punched or stamped, while its high heat reflectivity properties make it extremely challenging to laser cut.

At the other end of the scale, titanium carries its own complexities. Desirable for many medical applications from cranial and dental implants to pacemaker battery collector grids, titanium raises issues when it comes to profiling complex, highly accurate components. With the highest strength-to-density ratio of any metallic element, as well as its low thermal conductivity and chemical reactivity, it's exceptionally tricky to manipulate without potential damage to tools and equipment.

This is just a quick snapshot of the range of material limitations that show the boundaries of traditional machining techniques. It is clear that a different methodology needs to be used.

Etching the impossible

Combining sheet metal with a photoresist mask printed with a CAD image of the required components, then selectively etched with chemical etchants, photochemical etching presents a less intrusive, more accurate and repeatable option for creating intricate components.

Whereas conventional machining, laser cutting and stamping face sizeable difficulties in machining a broad range of metals, photochemical etching presents a more economical and efficient way to produce custom parts with complex designs and strict tolerances. This is especially valuable given the use of inexpensive and easily reworked photo-tools that ensure high accuracy and repeatability in production.

Applying this thinking to the particular parameters and limitations of metals like aluminium and titanium, it becomes clear that achieving a finer finish – critical to precision-engineered components – requires us to go beyond traditional techniques. In particular, this is true of the cost and feasibility factor. With OEMs requiring critical components within short lead times and at best cost, photochemical etching provides another key advantage in overcoming process hurdles.

Cutting lead times, costs and complexity – without compromise

In manufacturing, there's a clear thread from R&D to production; from concept to completion. This is where business and manufacturing intersect – and, as we enter an age where cost pressures are ever greater, how does the machining of complex products impact the two typical hurdles of a project: uncertainty and cost?

Lead time uncertainty

The biggest factor affecting supply chain performance is uncertainty – and, in the manufacturing context, this is firmly embedded within lead time uncertainty. This can, itself, lead to increased inventory costs and inconsistent service – and, while the adoption of just-in-time logistics and ordering processes can mitigate this, the etching process itself can play a part.

Everything we've covered thus far is categorically in the physical processes of machining, and the material factors of the metal used.

But all of these play a part not just in the performance of components and applications, but in the wider business and supply chain.

Additional processes like deburring, unforeseen consequences of stresses, inadequate consideration of material imitations: all of these are potent sources of uncertainty. The easiest way to combat this uncertainty is through simplicity – such as that presented through photochemical etching, which, by eliminating stress and burring, and being tailored to each material in question, can be an integral part of a more concrete supply chain, with absolute certainty in lead times, often measured in hours rather than weeks or months.

Cost versus complexity

In all kinds of traditional machining and sheet metalworking, complexity is often a byword for cost. The use of non-standard materials, thicknesses and grades, as well as additional tooling and process needs, have made this an accepted fact of life.

But it doesn't need to be.

Photochemical etching offers near-infinite geometric customisability and complexity, with precision tolerances, accuracy and repeatability, that render it suitable for even the most extreme applications.

And yet, this complexity can be achieved without the cost of additional tooling or processes – so that, as well as lead time certainty, design engineers can strip out the cost of complexity from projects.

Chemical versus conventional: How does it stack up?

Laser cutting and stamping are the two most commonly used machining processes available – but there is a range of other options, from water jet cutting to electroforming. All have their uses and applications, but how does photochemical etching compare for flexibility, usage and performance? Here’s an at-a-glance guide for your reference.

	PHOTO ETCHING	LASER CUTTING	STAMPING	WIRE EDM	WATER JET CUTTING	ELECTROFORMING
Sampling	Low cost	Low cost	High cost	Low cost	Low cost	Medium cost
Metals	Nearly all metals	Nearly all metals	Nearly all metals	Conductive metals	Nearly all metals	Nickel and copper
Hardness	No restriction	No restriction	Problems with soft, hard or brittle metals	Hardness is a consideration	Hardness is a consideration	Typically 200-670 HV
Stress	No stress	Thermal stress on cutting edge	Stress at cutting edge	Deformation, tempering and structural changes may occur	Limited stress on cutting edge	Low-stress
Burrs	No burring	Micro burring	Partial burring	Micro burring	Micro burring	No burring
Tooling and design changes	Quick, easy and cost-effective	Quick, easy and cost-effective	Expensive and time consuming	Quick, easy and cost-effective	Quick, easy and cost-effective	Quick, easy and cost-effective
Typical lead times	Seven days	Seven days	Six weeks - six months	Seven days	Seven days	Seven days
Tolerance as a percentage of metal thickness	±10%	±5%	±10%	±10%	±15%	±5%
Can parts be supplied in sheets for easy counting/handling?	Yes	Yes	Not easily	Yes	Yes	Yes

A commercially and operationally desirable alternative

Photochemical etching – often shortened to chemical etching or photo etching – is a subtractive machining process for sheet metals, using safe and sustainable chemical etchants to create complex designs for high-precision components. Suitable for almost any metal, it's a highly accurate and cost-effective way to manufacture intricate parts for a huge range of applications.

How does it work?

The chemical etching process sees a photoresist applied to the sheet before the component design is printed through UV exposure. The non-printed photoresist areas are then removed, exposing the metal, which is then etched away.

As has been pointed out, almost any metal can be etched in this way – thousands of types, in sizes as thin as 0.010mm and sheets up to 1500mm in length. Through a nine-step process, these metal sheets can be transformed into any kind of precision component.



This process ensures that accuracy and tolerances are absolutely fit for purpose – over and above traditional metal machining, laser cutting or stamping – while offering the depth and engraved features needed for specialist components, such as bipolar fuel cells and heat exchanger plates.

Why choose photochemical etching?

In this white paper, we've explored some of the critical limitations of laser cutting and stamping – shortcomings that can cause significant problems downstream. We've also highlighted how chemical etching can overcome these:

- **Stress:** With no heat application or physical impact on the etching process, the issues of thermal and cutting-edge stress are completely eliminated through photochemical etching.
- **Burring:** Similarly, the lack of impact force or harsh cutting totally prevents the possibility of burred edges.
- **Material limitations:** The range of metals available for chemical etching is testament to its ability to work flawlessly across the spectrum of hardness, density and strength – with no impact on the finished component.

Beyond these advantages, chemical etching maximises value for money. For example, unique characteristics can be added at no extra cost, as all of the process features are machined at the same time. It's also low-cost to set up and modify – whereas, in sheet metalworking, complexity means cost, chemical etching and digital tooling can create feature-rich, complex and precise parts of the most flexible geometries without the traditionally associated costs.

Chemical etching offers a more economical prototyping approach, with engineers paying by the sheet – unlike other machining methods. So, components with different geometries and almost limitless complexity can be processed from a single tool, producing many part types in one production run – faster, simpler and smarter.

Finally, linked to this, chemical etching is inherently quicker – reducing lead times and supply chain uncertainty thanks to tooling taking hours, on average, rather than the weeks or months required of traditional processes. Which, coupled with its advantages over the limitations of traditional metalworking techniques, is a fitting explanation for why more design engineers than ever are now adopting it as their preferred methodology – and why Precision Micro is stretching the boundaries of what can be achieved...

Pioneering new possibilities in etching and component design

For over 50 years, Precision Micro has been one of the world's foremost specialists in photochemical etching, every year producing more than 60,000,000 precision-etched components for customers in over 30 countries worldwide.

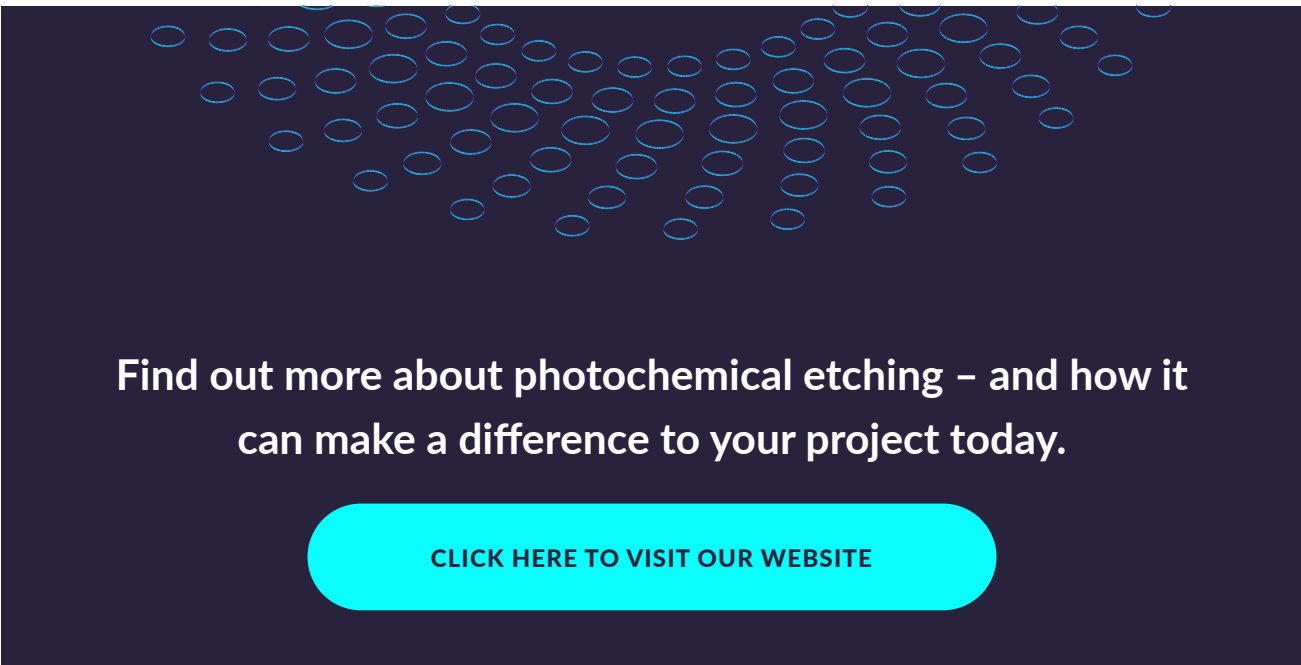
From high-spec, high-performance alloys for aerospace and automotive applications to medical-grade titanium components within life-saving equipment, every part is designed to specification, free from stresses and burrs.

This relies on the advantages of photochemical etching – but it also relies on a unique fusion of art and science; combining creativity and imagination with scientific focus to deliver ever-more safe, reliable, comfortable and efficient components that make a better today for everyone.

Proven capability, unrivalled knowhow

As the only chemical etching company accredited to ISO 9001, ISO 14001, IATF 16949, ISO 13485 and AS 9100, Precision Micro sets the standard for quality, accuracy, repeatability and continuous improvement – particularly when working with hard-to-machine metals and proprietary super-alloys.

A reliable partner with global technical support and constant investment in added-value technologies, we have Europe's largest sheet etching capacity: a 44,000ft² / 4100m² facility working with over 2,000 material variants, to reduce lead times and deliver dependable, high-integrity components to exact, and exacting, specifications.



Find out more about photochemical etching – and how it can make a difference to your project today.

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