How to Choose the Right Marking Technology for your Application

Choosing the right part marking technology is becoming more and more important in manufacturing, in response to a growing desire among original equipment manufacturers to trace products over their complete lifecycle. The general thinking among manufacturers is that cradle-to-grave traceability will improve product quality, ensure that suppliers meet quality standards, prevent part counterfeiting, and minimize part recalls.

Each of the major marking technologies, which include laser marking, dot peen, electro-chemical etching, and inkjet, comes with its own set of advantages and disadvantages. Manufacturers should select the best technique for a particular part based on such factors as material type, part function, part geometry, surface finish/roughness, mark quality, mark dimension/part size, mark serialization, and coating thickness.

In general, laser marking offers many benefits for direct part marking, because it is faster, more permanent, has a low cost of ownership, uses no consumables, and does not require any further processes to ensure mark durability. Inkjet printing is used as a mark on the fly technology where the part must be moving; typically, mark quality and mark flexibility are poor and the mark is non-permanent. Chemical etching can be excellent for hardened and thin metals. Highly permanent marks made by dot peening can withstand post-plating processes, but mark times are slow and the part must be fixtured, due to the contact of the stylus.

DIRECT PART MARKING BECOMES THE NORM

Many manufacturers have already moved to direct part marking (DPM), which permanently marks the parts with a serial code, having found that the traditional non-direct part marking techniques (like stickers) do not allow for full life cycle tracing. DPM is used widely, most often by medical, automotive, aerospace, and electronics manufacturers to facilitate reliable part identification. The part information may be in the form of human readable alphanumerics and barcode or Data-Matrix™ codes.

Aside from the commercial advantages of part tracking and traceability, another key driver of the movement towards DPM in the above industries is the mandated requirement for unique identification.

Table 1 contains a review of the key factors to consider when comparing the available marking technologies. In addition to these factors, there are also production line implementation considerations to be taken into account, like whether the part is moving or static, what access you have to the part, what to do if there are multiple materials or point of use, and remote operations and programming.

Factor	Notes and thoughts to consider
Material type	• Laser marking produces contrasting marks on metals and plastics • Dot peen cannot mark plastics • Inkjet cannot adhere to some plastics • Chem etch only marks metals
Part function	• Laser, dot peen and chemical etch provide a permanent mark • Laser and dot peen can produce engraved marks for wear resistance • Non-contact marking is preferred if the part is small or mechanically delicate • Non-intrusive marking methods are recommended for parts used in safety-critical applications like aircraft engines or high pressure and high stress systems
Part geometry	• A recessed mark area, and marking on different levels/areas will affect what type of marking system should be used • If a wide mix of parts will be marked with different mark positions, a marking technology with XYZ adjustments is needed
Surface finish/roughness	• Highly polished metal surfaces and rough surfaces provide a difficult surface to read a barcode or Data-Matrix™ code; the laser can roughen the surface (in the case of polished) and smooth the surface (if too rough) to increase mark and code readability
Mark dimensions/ part size	• The laser mark can be easily sized from one part to another instantaneously • The area over which a mark can be made varies for each technology
Mark content (text, graphics, codes)	• Dot peen and inkjet are not suited to marking logos
Integration	• Laser markers can handle barcode serialization, custom text strings, data base connection and remote programming • If space is a concern, a small end and flexible position mark head is beneficial • If the part is moving, ink jet and laser markers can mark parts “on the fly” • Chem etch and dot peen are off line processes
Mark quality	• Laser and chemical etch marks are clear with high resolution • Inkjet and dot peen struggle with mark quality
Environmental profile	• Inkjet and chemical etching both use chemicals • Laser marking has no consumables; in some cases a basic extraction system is needed

Table 1 – Key factors in comparing marking technologies

MARKING TECHNOLOGY PROS AND CONS

Inkjet marking

Inkjet marking is an on-the-fly non-contact marking process, accomplished by forcing pressurized ink through a nozzle. There are two inkjet system types, drop on demand (DOD) and continuous ink jet (CIJ). In either case, the part must be moving to make a mark.

DOD creates a mark with an array of nozzles that simply deposit a dot on the material without steering. The spacing of the nozzles and size of the arrays governs resolution and mark size.

CIJ creates marks using charged ink droplets that are deflected perpendicular to the part movement direction in order to create characters. Rows of ink droplets are applied to the product, forming a dot-matrix character as the part moves past the nozzle. Character height (top to bottom) is determined by applying a voltage to each individual drop, which deflects drops to the appropriate position along the Y-axis. The printer's stroke rate and the line speed of the moving product determine the character's width (X-axis).

Table 2 lists the method's key pros and cons. **Figure 1** shows a schematic of the equipment along with a photo.

Pros
∞ Capable of marking fast moving parts
∞ Can create color marks, UV only readable marks
∞ Cheap capital equipment costs
Cons
∞ Quality of marks is low, graphics and 2D data codes are difficult to mark
∞ High running costs (ink cost)
∞ Solvent bases, ink consumables and cleaning fluids create environmental and health issues for both usage and disposal – specifically solvents such as methyl ethyl ketones (MEK's)
∞ Part must be moving to mark
∞ Printing head needs to be close to part
∞ Marks are not permanent (fade under UV, or rub off)
∞ Materials limited by ink adhesion
∞ Print heads require regular cleaning
∞ Equipment is generally not reliable

Table 2 – Pros and cons if inkjet marking

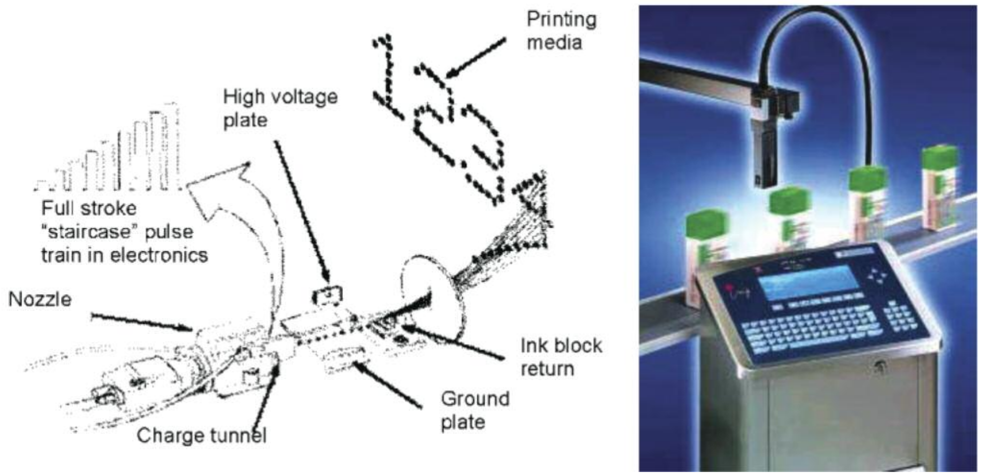

Figure 1 – Schematic of continuous inkjet (CIJ) method and picture of equipment

Dot peening

Dot peening or pin stamping is a contact marking process in which pneumatically or electro-mechanically driven single or multiple carbide styluses create a mark by physically indenting the surface of the material by impact. The stylus is mounted on XY stepper motors to create the mark pattern. Critical to the readability of a dot peen mark are the indent's shape, size and where relevant, spacing. The indented line or dot created should trap or reflect light and be large enough to be distinguished from the part's surface roughness. Therefore, mark contrast is created by ambient light, and will only be viewable from certain angles. For Data-Matrix™ codes, the lighting is key to being able to read the code. **Figure 2** illustrates the dot peen mark and equipment. **Table 3** details the method's pros and cons.

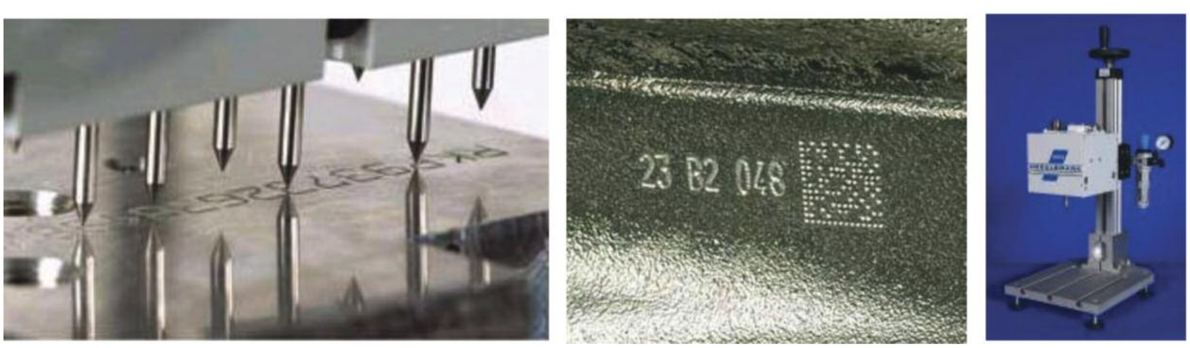

Figure 1 – Multiple stylus engraver, typical mark in aluminum and dot peen equipment

Pros	
•	Cheap equipment costs
•	Highly permanent marks that can withstand post plating processes
Cons	
•	Low mark quality
•	Part must be physically robust to avoid deformation due to marking process
•	Part must be clamped for marking
•	Carbide stylus requires regular replacement
•	Only metals under Rockwell hardness 60 can be marked
•	Limited "hard" plastics can be marked as most show spring back of indentation
•	Unable to mark barcodes
•	Marking speed is slow

Table 3 – Pros and cons of dot peen marking

Electro-chemical etch

This contact marking process requires a mask, an electrolyte solution, and an electrode marking head. The mark is created as material is removed by "forced corrosion" according to the mask in various degrees to produce an "oxide" black surface effect, or an "etched" mark where the image is engraved into the material. The area to be marked must be cleaned, the pre-produced mask is then fixed onto the part, the mask is then coated with the electrolytic solution, and finally the electrode contact is made. Marking time may be seconds or hours depending upon the mark's penetration. The multi-step process required slows down the marking speed to a certain extent.

This process is an excellent way to mark hardened and thin metals. Although contact is required to form a closed circuit, negligible force is applied during the process. The method etches material to a depth of 0.0001-inch in around one second and up to depths of around 0.01-inch. Dark marks on stainless steel are created in seconds.

Chemical etching requires proper disposal of the used chemicals, either by using wastewater treatment equipment or contracting with a certified third party disposal company, which adds to its cost. Although the equipment can be low cost, actual implementation at a facility can be quite high throughout the life of the product, due to the need for a wastewater filtration system or certified third party disposal, and the solutions and stencils used to create the markings. The filtration system will need upkeep and the liabilities are far greater, because you are dumping chemicals through a filtration system into public water systems.

Table 4 notes the key pros and cons of this process. **Figure 3** shows the method in action.

Pros	
∞	Cheap equipment costs
∞	Creates excellent contrast on stainless steels
∞	Close control of engrave depth
∞	Negligible mechanical force exerted on part
∞	Equipment is portable
Cons	
∞	Lack of mark flexibility, new mask required for each different mark
∞	Cost of masks
∞	"Messy" process requires application of mask and liquid electrolytic on part
∞	Only conductive materials can be marked
∞	Need for wastewater equipment or certified third party disposal adds to costs

Table 4 – Pros and cons of electrochemical etching

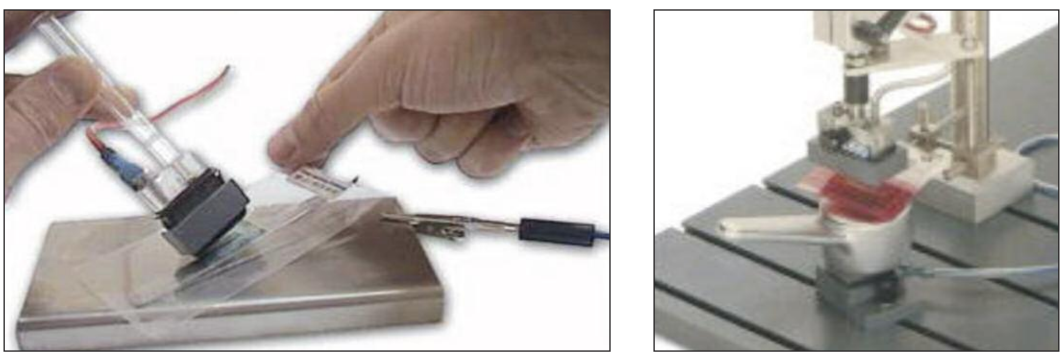

Figure 3 – Electro-chemical etching with electrode, mask and applied electrolyte

Laser markers

Laser marking, a fast and clean marking technology, is rapidly displacing and replacing older product marking technology. Easy and flexible automation, improved environmental profile, and low cost of ownership add to the benefits of the technology.

Several major laser marking choices are available, each one with specific marking characteristics that align best with particular materials and applications. Laser choices include Ytterbium:fiber (Yb:fiber); Neodymium: vanadate (Nd:YVO_4); green (532 nanometers (nm)); ultraviolet (UV); and carbon dioxide (CO_2). In addition, Neodymium-doped yttrium aluminum garnet (Nd:YAG) is an older technology that is still being used in the high power market, but has largely been superseded by one of the others listed.

Each marking system has the same basic design – the laser is steered by mirrors mounted onto galvo motors to produce the mark. Each mirror moves along a single axis. These galvos move extremely quickly with very little inertia, and so can write marks at high speeds. The beam is focused using an f-theta lens that produces a focus across the mark plane. **Table 5** examines the method's general pros and cons and **Figure 4** is an illustration of the key components of a laser marking system.

Pros	• Best mark quality
	• Non-contact process with good standoff distance
	• Highly flexible mark; text, graphics, data codes
	• High speed
	• Permanent marks
	• Mark can be dynamically sized
	• Wide range of markable materials
	• Easy integration
	• No mark consumables
	• No post processing
Cons	• High capital cost of marking equipment
	• Safety shielding required

Table 5 – Pros and cons of laser marking technology

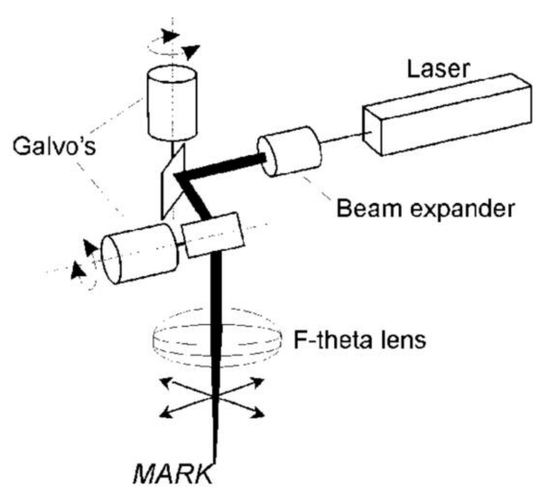

Figure 4 – Schematic of general laser marking system

Each method discussed has a variety of pros and cons, and **Table 6** provides a general side-by-side comparison. On balance, laser marking is the most versatile of the DPM methods, with benefits including superior permanent mark quality; highly flexible marks that can incorporate text, graphics, logos and data codes; and a wide range of markable materials. In addition, laser marking is a high speed process that is easily integrated into the manufacturing line. Safety is enhanced because laser marking is a non-contact process with good standoff distance, and the lack of chemicals makes it environmentally preferable.

Parameter	Laser	Ink jet	Dot peen	Chemical etching
Best for	Most applications	High speed moving parts	Large/thick metal parts	Thin metals with repeated marks
Mark quality	Excellent	Average	Poor	Excellent
Materials	Most materials	Most materials	Metals	Metals only
Mark permanence	Permanent	Markings can be rubbed off in time	Permanent	Permanent
Speed	Fast	Fast	Slow	Slow
Integration	Highly flexible system for production line and also programming and remote operation	Basic mark control	Basic mark control	NA
Process Consumables	None Runs off a standard 110v outlet	Inks Cleaning fluids Ink disposal poses additional environmental costs and impacts	Stylus	Process chemicals Masks
Maintenance	Maintenance free	Daily maintenance needed to ensure inks are flowing properly, are full, and machine is free from residual build–up during marking.	Daily maintenance needed to ensure stylus pens are working well	Daily maintenance needed to ensure mask is working well
Capital cost	$$$$	$$	$$	$$
Running costs	$	$$$$	$$$	$$$

Table 6 – Marking systems comparison

