Machining Technology Developments

What Can Recent Advances in Machining Bring to the Small Manufacturing Enterprise?

An overview of mature and emerging machining processes is presented, with emphasis on the capabilities of established technologies that may be of benefit to small to medium-sized enterprises (SMEs), on either a buy-in or contract-out basis.

A background is provided on general trends in manufacturing industry such as retention of core competencies, contracting out of non-core or specialist activities and the growth of contractors with specialist knowledge of niche technologies.

Case Studies illustrating the impact of developing technologies and the associated competitive advantage gained by some SMEs through their adoption are provided.

Richard Day
Pera Knowledge
Technology Watch titles are written for managers, especially in small and medium-sized manufacturing companies. They offer a practical introduction to cutting-edge developments that affect – or likely soon will affect – the design, development, manufacture and marketing of PRIME products – *products with interdependent* mechanical and electronic (and possibly software) parts.

All Technology Watch titles can be downloaded free of charge from the Prime Faraday Partnership’s Technology Watch website *http://www.primetechnologywatch.org.uk/*. Selected titles can be purchased in paperback from Amazon.co.uk.

In addition to market and technology reviews, the Technology Watch website also provides news cuttings, case studies, an events diary and details of funding opportunities. The service is sponsored by the DTI and managed by the PRIME Faraday Partnership, which marries the academic strengths of Loughborough University and the University of Nottingham to the technology-transfer expertise of Pera.
1.0 Introduction

The act of machining a piece of material is a mechanism for adding value to it through removal of some of its volume. The amount of value that can be added is a function of the complexity of the form remaining, the manner in which the machined component can interact with other components and the design of the form itself.

The development of machining technologies and practices over recent years has meant that designs that were difficult to manufacture can now be produced relatively easily. Also, tolerances and the resultant component alterations that were only a short time ago only achievable by the most highly perfected facilities can now be attained by much more ubiquitous equipment.

The availability of this advanced machining capability brings with it the opportunity for organisations to develop new forms of added value and to bring to the market products that are, to a degree, less constrained by production realities than they are by the design acumen and the capabilities of those involved with product creation.

However, for an organisation that would class itself as being non-specialised in the area of machining technology to fully realise these opportunities, then a greater appreciation of current capabilities, over and above a general understanding of basic machining is required. This report sets out to provide an overview of this area and is intended to be a lead-in to the subject; it will apprise the non-specialist reader of some of the key technologies available and will provide assistance in the selection of appropriate techniques.
2.0 Machining Technology and Industrial Trends

The development of machining technology has been driven by the application of CNC to base processes in conjunction with the high standards of machine-tool build accuracy and reliability that modern machines now possess. These factors, together with advances in the tools used to remove metal, have combined to deliver a range of capable, flexible, machining processes that in the majority of cases can deliver guaranteed results in terms of component quality without the need for primary skills. The trend has been to incorporate particular process parameters and skills into the machine-tool CNC system and this has enabled machining processes to deliver reliable, consistent, results to manufacturing industry. Spin-offs from this core capability have, for example, been the opportunity to run lights-out or twilight shifts, the raising of daily output, and the ability to operate in a more flexible manner and reap the associated benefits such as low work-in-progress and late customisation of products.

SMEs should not view these practices as being the preserve of only large organisations; they may well adopt and adapt these types of strategies to gain competitive advantage themselves.

However, the capital costs of machine tools mean that direct purchase is viable only if a high level of utilisation is achievable. Therefore, for the smaller organisation to gain maximum benefit from these technologies, it is likely they will need to develop a robust outsourcing policy.

Advances in direct point-to-point transfer of CAD and other engineering data from the design function to the production facility provides the technical infrastructure on which these outsourcing policies can be based; other reports in this series will discuss this issue in more detail. The management of such outsourcing arrangements, more specifically increasing customer responsiveness, is also discussed within this report series under the title ‘Fundamental Productivity Improvement Tools and Techniques for SMEs.’

This then brings us to the role of machining itself. Being aware of the main machining processes is only part of the picture for SMEs; the other vitally important aspect is how these processes can impact on the cost of manufacturing SME products through selection of the most cost effective manufacturing method or processing route. The following case studies in this report illustrate some common applications of modern machining technology. Input to specific SME manufacturing methods may be provided by appropriate equipment suppliers or by an impartial third party such as Pera (www.pera.com).

A broader picture of change exists outside of the field of machining as manufacturing companies demonstrate a trend to concentrate on core competencies and retain their internal capabilities in design, product assembly and niche skills. This strategy retains
a product's competitive and commercial advantage in the market, and maximises the manufacturer's retained added-value in it. This is a simple view of a complex, evolving picture influenced by other factors such as the need to reduce overheads, improve business gearing and retain flexibility and the ability to react to changing markets.

One result of these trends has been the contracting out of non-core and specialist activities to subcontract machining companies, who in turn have built upon these trends by developing themselves into centres of competence for specialist processes or by expanding and offering a wide range of capability in general areas (CNC turning, five-axis milling etc.). Subcontractors have recognised the potential of offering a one-stop manufacturing facility to industry and an emerging trend is for subcontractors to offer a complete sub-assembly or product manufacturing capability, based around their core competency, elevating their position in the supply-chain tier to one of contract manufacturing rather than general subcontracting. Indeed, the knowledge of niche process capabilities that has been developed by some specialist subcontractors enables them now to identify process routes and methodologies yielding cost and design benefits that their OEM partners may not be aware of – for example the reduced need for fixturing in the high-speed machining process due to the ability to snap out the finished component from the original block of raw material or the capability of the laser-cutting process to produce profiled components with scribed score lines for subsequent folding operations.

2.1 Subcontracting

Over the years, the subcontracting industry has assumed greater importance within the industrial manufacturing scene and SMEs can use the following routes, among others, to identify appropriate capacity.

Subcontractors in common areas of activity, such as the turned-parts industry, have formed trade associations and developed them into well organised bodies to promote members’ interests to industry at large and to lobby at ministerial level on issues affecting their members. These associations also publish details of members’ capabilities – a valuable source of information for SMEs wishing to identify subcontract capability. Other sources include business directories such as Kelly’s Industrial Directory, the Machinery Buyer’s Guide and journals with a specific interest in subcontract manufacturing (e.g. Machinery and Production Engineering and Metalworking Production). A spin-off from this is the establishment of a subcontract capacity database (see Metalworking Production) and the emergence of sourcing organisations (e.g. First Index). These options, together with promotional advertisements by subcontractors in the trade press and increasingly on the Internet, all help SMEs to identify subcontract manufacturing capability.

Most capable subcontractors now operate an accredited quality system, such as ISO 9002, providing assurance that their internal quality control, traceability and
manufacturing systems are documented and regulated on a consistent basis, giving a
degree of confidence to any SME making an initial approach. A recognised
accreditation is not, however, mandatory and good business methodology is equally
important. The selection of any subcontractor will depend upon many factors, such as
location, type of machinery, number of skilled heads per machine type, financial
stability/gearing, cleaning and finishing facilities, previous experience, price etc.,
according to the specific requirements of the SME.

Aside from these issues, the usual first stage in identifying subcontract capability is to
concentrate on any basic criteria such as location, turnover, process capability etc. with
specific selection criteria being examined during or following any initial discussion or
visit to a potential subcontractor. A full vendor assessment and comparison exercise is
usually undertaken for high value contracts; Pera have direct experience and expertise
in this area and can offer an impartial view (www.pera.com). The three primary issues
of price, delivery time and quality major in the selection process, although reliability of
delivery and quality, followed by price considerations are emerging as trends in the
decision-making process nowadays.
3.0 Case Studies: Examples of Machining Technology Applications

These examples are intended to illustrate some advantages gained by manufacturers through adoption of machining technology developments.

3.1 Laser Cutting

A SME manufactured a tubular element, fabricated from two annular collars, joined by six welded-on strips. The product was expensive to manufacture due to the numerous operations involved and the fatigue of the welded steel strips resulted in unreliability.

Analysis of the product functionality and awareness of developments in CNC laser profile cutting technology resulted in a more elegant, flexible manufacturing process route being adopted by the SME.

The laser cutting process enabled the entire profile of the product to be cut in its developed form from flat sheet, subsequently being formed to the final shape with one seam joint to finish, reducing fabrication time and lowering product cost. The flexibility of laser profile cutting enabled product variants to be easily accommodated.

3.2 Deburring

Down-hole oilfield manifolds are used to control and direct oil well flows. These components operate at extreme pressures and consist of a multitude of interconnecting gun-drilled holes in a steel slab. Burrs are created where holes intersect, at full depth. Conventional deburring approaches using scrapers and related instruments, did not achieve reliable, consistent results, due to accessibility difficulties.

Electrochemical deburring, using long electrodes to reach burr sites enabled complete, and consistent removal of intersecting hole burrs, eliminating the possibility of loose burr debris in the manifold system during operation. This gave the SME more confidence in promoting the reliability of their product, consolidating their market position.

3.3 Wire Spark Erosion

The flexibility of this process and its ability to cut hardened blanks and achieve a good surface finish has been exploited by a number of Formula 1 teams to manufacture gear trains on a flexible basis to suit characteristics of individual race circuits. The process permits CNC programming and cutting of involute gears direct from hardened blanks to achieve specific gear ratios on an overnight basis, eliminating the traditional route of
gear hobbing, heat treating and finish grinding, delivering a much quicker response to the demands of Formula 1 practice sessions and hence impacting upon competitiveness.

3.4 CNC Milling

Rotating elements in gas turbines or automotive turbo-chargers have complex geometries and often involve joining of individual blades to central discs. The advent of multi-axis CNC milling has enabled one-piece blade/discs (blisks) to be machined using five-axis machines equipped with high speed spindles, lowering overall production costs by eliminating component parts and increasing the integrity of the finished assembly. One blisk can replace up to 120 separate parts in an equivalent conventional turbine disc.

In the case of turbo-charger impellers, five-axis milling has permitted more complex, efficient blade geometries to be manufactured improving engine efficiencies. CNC has also enabled flexibility in impeller design and geometry to be easily accommodated, thus delivering greater product flexibility in the market.

The above examples demonstrate the type of benefits enjoyed by SMEs through adoption of developments in machining technologies, coupled with their ability to relate process capability to the demands of their products and thus enjoy competitive advantage, product flexibility and higher levels of quality.
4.0 Overview of General Machining Technologies

Having discussed some reasons why organisations may wish to make greater and more diversified use of machining techniques and associated production processes, this report now seeks to provide an overview of the wide range of techniques that are available and can be used as process routes to allow innovative product concepts to be realised.

Process selection is critical to the effective and economic use of machining in manufacturing of the product, either in the product itself or indirectly in the manufacture of moulds, tools or dies used for product manufacture. If good dimensional accuracy is not required for product functionality, then net-shape processes, such as casting, stamping and moulding, may suffice. However, if flatness, roundness or close fits are required, machining will be involved.

It is assumed that the reader of this report will be familiar with fundamental metal cutting processes such as drilling, turning, milling, broaching, tapping, slotting etc., all of which employ some form of cutting tool to shear or shave metal from raw material in a controlled manner. Processes generate or form the desired component shape or feature creating chips of sheared material and generating heat through movement of material over the face of the cutting tool during the machining operation.

As technology has developed, basic manual machine tools have resulted capable of producing the desired workpiece forms by controlling relative movements of workpiece and cutting tool. Developments in numerical control systems, mechanical accuracy, machine tool rigidity, and cutting tools have enabled sophisticated machine tools to evolve capable of guaranteed consistency in the accuracy of the machined product, generating greater confidence for end users.

For most machine tool types, advances in mechanical accuracy have been matched by the application of computer numerical control (CNC) technology, thus removing the need for skilled physical manual manipulation of the cutting tool, and providing the ability to control workpiece dimensions through the CNC system. This in turn has enabled great process flexibility to be achieved, opening up opportunities for just-in-time manufacturing and economical manufacture of batches of one, for example.

The other group of machining processes are those that do not shear metal but use other means to remove metal through electrical, thermal and abrasive-mechanical techniques. These technologies are not as mature as the primary metal cutting processes but certain techniques within this group (i.e. spark erosion, laser cutting) are established and now complement the general metal cutting processes. Again, the integration of CNC has provided process flexibility and widened the scope of application, at the same time removing some of the mystery and ‘black art’ surrounding new processes, through capable process-control systems.
5.0 Established Traditional Machining Processes

5.1 Turning Machines

The lathe is a fundamental machine tool capable of being adapted to many different machining operations in addition to turning (milling, drilling, slotting, gear-cutting) given sufficient skill and ingenuity.

A variety of turning machine types have been developed to address the requirements of industry. Coupled with advances in machine-tool build quality and integration of CNC the following broad categories of capable, reliable turning machine are currently available, in addition to conventional, manually operated centre lathes.

5.2 CNC/Manual Conventional Lathes

These machines resemble traditional lathes integrated with basic CNC systems, permitting a reduction in skill levels required to operate the machine through use of canned cycles (pre-programmed sub-routines for common tool movements, such as roughing-out, threading and finishing) and the capability to self-teach the control system by initial manual operation. This lathe type has emerged in recent years and offers a cost-effective, flexible turning capability for one-off and small-batch work.

5.3 CNC Turning Machines

Fully integrated, purpose-built lathes capable of flexible manufacture of turned parts, in low, medium or high volumes, to consistent levels of accuracy. These machines are the mainstay of industrial turning production technology. For this type of machine in particular, powered tooling and the introduction of main and sub-spindles have extended versatility, permitting one-hit machining of components with turned, drilled, tapped and milled features. This has the advantage of eliminating multiple set-ups between different machine tool types and increasing accuracy and functionality of machined components.
Within this category are a wide range of lathe capacities and costs, but like CNC/manual lathes, capable CNC turning equipment can be acquired at reasonable cost with all the associated benefits of flexibility, accuracy and reliability.

5.4 Automatic Lathes – Conventional/CNC

These machines were originally developed to address industrial needs for high volume production of repetition turned parts using single-spindle cam driven machines, followed rapidly by the introduction of multi-spindle lathes capable of enhanced levels of productivity. The advent of CNC turning machines detracted from development of automatic CNC lathes for a few years, although now CNC automatic turning technology is well established, delivering high volume capability with programming flexibility and hence batch flexibility, consolidating the position of this lathe type. A similar effect has occurred with high-precision sliding-head (Swiss) automatic lathes, where CNC has replaced the cam drives traditionally used, achieving flexibility coupled with the extreme precision that this machine type can achieve.

5.5 Vertical Turning Machines

These machine types are designed for machining large rings or discs typical of the needs of the medium- to heavy-engineering sectors. CNC has enabled flexible one-hit machining of complex turned, bored and milled components, although attendant skills levels have not declined significantly due to the heavy nature of the work and the associated high component added value.
Within the turning sector, a degree of overlap often occurs between capability of different machine types. One example is an emerging trend to smaller vertical turning machines which use the spindle to hold the component in the inverted position, in an opposite manner to larger vertical turning machines, achieving optimum swarf clearance, at the same time using the spindle to pick and place components within the machining cycle, thus easing handling.

5.6 Milling Machines

Traditional machines are either horizontal or vertical cutter spindle type and basic machines are capable of a good standard of accuracy when manually operated, with the addition of digital read-outs providing consistent repeatability.

Again, CNC has been extensively applied to this machine tool type and this has enabled a reduction in practical skill level required to achieve acceptable results and enabled flexibility in milling to be achieved, providing the capability to accommodate varying batch quantities and the demands of just-in-time (JIT) production.

Like turning machines, integration of sophisticated software has enabled milling technology to be applied to multi-axis one-hit component machining and permitted the generation of complex surface forms direct from software, eliminating special form tools. ‘Turned’ features can also be produced on static workpieces by interpolation milling, as can helical thread forms. More light metals are being milled, particularly aluminium and titanium, in the aerospace sectors. This has driven the development of high-speed spindles, enabling high surface finishes and metal removal rates to be achieved, eliminating secondary finishing.

For large components, heavy industry has derived benefits from using large, horizontal CNC milling machines to manufacture complex parts (pump bodies, turbine casings etc.) This has minimised the need for re-setting, thus reducing errors and handling, and ultimately easing the manufacturing process.

5.7 Drilling

This is a fundamental machining process using simple cutting tools that belie the demanding nature of metal removal in the region of the drill point itself, due to zero peripheral speed, high pressures and poor flow of cutting fluid, particularly on deeper holes.

Traditional vertical spindle drilling machines remain the mainstay of drilling technology, being manually operated, power fed. CNC has been applied in conjunction with the use of indexing turret-type heads to permit one-hit multi-drilling, tapping, counterboring
and reaming operations to be performed, using lower skill levels. Cutting tools have been subject to considerable development including coolant fed drills, titanium nitride coatings to reduce wear and the use of indexable ‘U’ drills, capable of rapid hole drilling and offset finish boring (on CNC drills) to precise size.

Deep hole (gun) drilling is another variant that has established a firm niche in drilling technology, capable of achieving up to 50:1 depth to diameter ratios, at high feed rates, producing a finish comparable to reaming. The special nature of this process has resulted in a number of contractors offering a deep hole drilling service.

5.8 Sawing

This is a similar scenario to that of drilling in that developments in cutting tools (bandsaw blades, tungsten and diamond-tipped circular saws) have extended process capability and productivity, whilst the application of CNC has opened up process flexibility in terms of quick length setting, batch size mixing and optimum cutting conditions. For high output installations, raw material handling systems permit minimally manned operation, and the accuracy of sawn lengths and narrow kerf widths have minimised material waste and reduced stock removal requirements for subsequent machining operations.

5.9 Grinding

Generally speaking this is a precision metal removal process, usually for low stock removal but applications do exist in the area of high stock (bulk) metal removal, using high efficiency/creep feed grinding techniques.

Grinding produces small size chips and a process feature is that the cutting tool (grinding wheel) is self-sharpening during the process, given correct grinding parameters. Traditional process types are surface, cylindrical and tool grinding. Within these primary process groups are variants such as surface and cylindrical form grinding, centreless through-feed (continuous) and plunge grinding, thread grinding and complex cutter geometry grinding.

The grinding process has traditionally been regarded as something of a black art with process variables being able to be tuned to achieve different modes of stock removal, wheel characteristics and grinding performance. There have been considerable developments in the quality of grinding machine build leading to greater accuracy and consistency of ground products, linked to the application of CNC, which, as in the case of other processes, has simplified process control, thus raising the consistency of quality results and reducing the level of skills required.
Grinding wheel technology has been subject to ongoing developments, with super-abrasive wheels (cubic boron nitride (CBN), polycrystalline diamond) capable of high volumes of metal removal at minimal wear rates for certain applications. This reduces the need for re-dressing of form, and permits greater consistency in long-running process capability, improving productivity and raising quality levels.

An emerging trend has been the application of hard turning, using CBN cutting tools and precision turning machines. This technique produces high surface finishes and levels of accuracy, eliminating the need to use grinding in certain applications. For certain applications, this trend is likely to continue although ongoing developments in grinding-wheel technology and intelligent machine control systems will ensure the grinding process remains a very important primary metal removal process.

5.10 Gear Cutting, Slotting, Broaching

These techniques are well established and tend to be regarded as specialist within the metal cutting processes group as the components machined usually have a complex, precise geometry (i.e. gears and bevel gears)

A number of techniques have been developed to generate or form the desired component profile (gear hobbing, shaping, grinding) and the application of CNC has greatly improved ease of set-up and control of process parameters, again delivering process flexibility, accuracy and consistency. Gear cutting technology is a complex area and a number of process types for specific gear forms (i.e. bevel gears) have emerged, underlining the industry perception of gear cutting as being a specialist process area.

5.11 Deburring

Traditionally, sharp edges were treated, when necessary, during the manufacturing/assembly process by using manual files, brushes, emery cloth, chisels etc. This activity became known as deburring, de-frazing, and edge-breaking, and was regarded as a necessary evil within the metal cutting industry.

A number of solutions to this problem area were adopted, based mainly upon rotating/vibrating drums that tumbled or vibrated components against abrasive stones in order to diminish the effects of sharp edges. For simple, mass produced parts, with fairly consistent external burrs (such as auto turned parts), these basic technologies enabled a degree of consistency to be achieved and reduced some of the tedium in manual deburring.
The last few decades have witnessed great advances in burr-removal techniques, which have been driven by the demands of product design, functionality, integrity, safety and quality.

The general trend is towards more control over product quality and hence, where appropriate, non-manual deburring processes are preferred due to their consistency and reliability both in terms of burr removal and quality of the resulting surface. It should be noted that consistency of the initial burr is of paramount importance to the capability of any deburring process, hence the need for emphasis on controlling metal cutting processes to achieve a consistent start-point for subsequent burr removal.

5.12 Vibratory Deburring

In the basic process, a rubber-lined tub mounted on helical support springs is vibrated by an electrical unit attached to it. Parts are loaded into the tub with ceramic media. Water and abrasive is dispensed into the tub and vibration rubs abrasive, media and parts together. All accessible component surfaces are dulled and sharp edges are removed, blunted or smoothed.

5.13 Tumbling/Barrelling

This is one of the oldest methods of removing burrs and/or brightening surfaces. Components and/or media are enclosed in a rotating drum, either wet or dry, and the tumbling action, over what could be a protracted period of time, improves the surface condition of components by deburring/polishing.

A modern variant of the process is centrifugal barrel finishing, where the process time is significantly reduced by employing small rotating barrels fixed to a rotating turret; the arrangement produces high centrifugal forces that accelerate deburring. Other variants
of the barrel theme use rotating vertical drums filled with media and parts, having a special internal contour that creates an internal tumbling action.

### 5.14 Abrasive Jet

The larger, industrial installations use mechanically- or air-driven blast systems to remove burrs/scale from components in blast chambers or in tumbling chambers. Liquid abrasive blasting systems use blast guns or manually manipulated components in enclosed blast cabinets to deburr and smooth component surfaces. Miniature pencil systems are used to manually treat selected areas of components for precise treatment of surfaces (PCB boards, electrical connector’s and intricate parts).

![Figure 4 - Abrasive Jet Machining - Grand State University. 1999.](image)

### 5.15 Brushing, Sanding, Mechanical

These processes can be used individually or in conjunction with each other to abrade away burrs and refine the burr site. Brushing can use rotary steel or other metal brushes, or non-metallic brushes or abrasive impregnated nylon brushes, all designed to address specific burr removal requirements in terms of burr size, removal rates and residual finish. Sanding uses a variety of abrasive types, sizes and bonds to achieve a similar effect.

Abrasives can be in the form of rotary wheels, flexible strips and large linishing belts or miniature finishing heads based on abrasive strips. Mechanical processes use high-speed rotary carbide files or chamfering cutters to remove burrs, leaving a chamfered edge.

All of the above techniques require a controlled manipulation of the deburring brush, disc or cutter around the edges to be deburred. Due to this, considerable effort has
been expended in the application of robotics in this area, by manipulating the component or the deburring head as appropriate.

5.16 Electrochemical (ECD)

The erosive action of a low voltage current flowing through a simple salt electrolyte is used to erode burrs from selected sites due to the close proximity of an electrode. Unlike the other processes described so far, ECD is able to remove specific burrs from any site. Therefore, it is ideal for inaccessible internal burrs (i.e. deep cross-drilled holes). The process is fast (10 sec cycle times) and given suitably controlled burrs, will produce consistent, rounded edges. ECD is extensively used in high volume automatic systems in the automotive industry. The process can be controlled to edge-break, edge radius or edge round, as desired. Specific electrode tooling is required; post ECD parts require water wash and/or de-watering and drying.

5.17 Abrasive Flow (AFM)

This process consists of pumping an abrasive-laden polymer medium through or over the component to be deburred. Tooling is used to direct the abrasive polymer and where the flow is constricted, or where the media is forced to change direction, maximum abrasion of the product material occurs.

The medium is pumped by means of two hydraulic cylinders, positioned above and below the tooling, flowing from the top cylinder, through the tooling into the bottom cylinder, and then returning (one cycle). Medium type, pressure, cycle time and temperature can all be varied to edge round, polish and smooth components. After AFM, parts require a cleaning cycle to remove residual particles of the medium. The process is not capable of heavy burr removal but it is very effective on consistent small burrs, and for parts with complex internal passages

5.18 Thermal Energy – Explosive (TEM)

Components are fixtured or placed in rigid wire baskets in a gas-filled enclosed chamber. The gas is spark ignited and the resulting thermal energy vaporises thin sections with large surface areas (i.e. burrs) without affecting the component bulk itself. The process is capable of fast processing of many parts and can access internal burrs to achieve a degree of internal deburring. Delicate components are not suitable for this process and lightweight parts are usually fixtured. Parts require a post TEM clean or a pickling treatment. Extensively used in the automotive/hydraulics industry for carburettor/manifold parts.
6.0 Emerging/Non Traditional Technologies

There are wide ranges of technologies which use mechanical/abrasive, electrical, thermal or chemical action to remove metal. A lot of these technologies can be regarded as fringe or still developing from the point of view of being of practical use for general small manufacturing enterprise’s and some have already been described in the deburring section of this report; therefore, only primary or commonly used techniques are described.

6.1 Laser Cutting

A well-established thermal cutting process usually applied to profile cutting of complex shapes from sheet or plate, but also well established in multi-axis mode to profiling of three-dimensional forms. There are numerous applications of laser cutting and the technology has consolidated its position in industry and is still being improved to deliver higher levels of performance in terms of cutting speed, accuracy and productivity.

![Figure 5 – Mechanics of Laser Cutting – University of California, Berkley.](image)

OEM companies account for many laser-cutting applications, whilst numerous laser cutting subcontractors offer process capability to general industry.

This is a versatile process and the integration of CNC has enabled rapid programming, economical use of material through nesting routines and process optimisation during cutting. High power lasers are enabling thicker sections to be cut and faster cutting speeds to be achieved, creating further competitiveness in the subcontract laser cutting sector, impacting on bottom line cutting costs.

6.2 Water/Abrasive Water Jet Cutting

This technology has emerged as a serious cutting process in the last decade or so. For most intents and purposes, it is capable of cutting material at any hardness level, without damaging the workpiece or imparting residual stresses. The usual application
areas are profiling of simple or contoured forms from flat sheet or plate. The integration of robotics has widened the application of water-jet cutting to complex forms, such as the trimming of moulded composite automotive components. In terms of development, the process lags that of laser profiling and, on average, is slower. Along with plasma profiling, water-jet and laser cutting techniques complement and overlap each other and their selection depends upon specific profiling applications.

6.3 Spark Erosion (EDM)

A thermal process that removes metal by the action of spark discharges in a dielectric fluid. The process has matured over the last 40 years and is extensively used in the toolmaking industry to either plunge-form cavities using shaped tools or to precisely profile-cut intricate forms in pre-hardened blanks using a reel-to-reel cutting wire (extrusion dies etc.), all under CNC. The process is traditionally slow but precise, and advances in spark discharge control circuitry have achieved a flexible, accurate process capable of reliable lights-out (unmanned, overnight) operation producing components that in many cases require no finishing or bench work.

Advances in speed of cutting and the integration of automatic electrode changing are widening the application of EDM techniques to volume production work, encroaching on milling and grinding technologies.

6.4 Photochemical Etching

This process uses a combination of photographic and etching technologies to selectively etch through thin sheet and blank out profiled forms.

The technique could be regarded as a niche area from the general engineering industry point of view, but is widely applied in the electronics industry and capable of economical manufacture of thin sheet components with complex forms, in both prototype and production quantities, eliminating the need for expensive press-tools.

Variants of the process have been used to produce lightweight aerospace structures by removing unwanted metal, yet retaining functional strength where it is needed.

6.5 Electrochemical Machining (ECM)

Deburring techniques are the most common electrochemical process available to SMEs, as described previously. Unlike thermal techniques of metal removal (EDM, lasers), ECM does not heat components and is capable of removing metal ten times
faster than EDM can, although at more commercial levels of precision compared to the more accurate capabilities of EDM.

However, the nature of the process has not lent itself to easy refinement as has been the case with EDM techniques and serious production applications have focussed on volume forming of components such as gas turbine blades in difficult-to-machine alloys by niche subcontractors.
7.0 Summary

Machining technologies are continually developing and there will always be fringe applications of emerging technologies that will benefit niche SME applications.

The sector however is underpinned by mature, robust technologies that through a more general appreciation of their capabilities can bring benefits to SME users, delivering bottom-line benefits in productivity, quality and market response, as illustrated by this brief report.

Options for SME technology users are to buy-in capable machine tools or to make use of the established subcontract-machining sector for component or complete sub-assembly manufacture, increasing productivity and quality, or quickening their market response capabilities, as illustrated by this brief report.

The decision to use subcontractors will involve a matrix of factors, such as the processes involved, volumes, and retention of SME core skills, long-term product trends, quality, and confidence in the ability of the subcontractors to contribute to the core SME business.
8.0 References:

Machining Data Handbook, Volumes 1 and 2
Pera Deburring Report
Metals Handbook, Volume 16
Machinery and Production Engineering (journal)
Metalworking Production (journal)
Advanced Manufacturing (magazine), January 2001

9.0 Other Sources of Advice and Information

Gauge and Toolmakers Association (GTMA)
3 Forge House
Summerleys Road
Princes Risborough
Buckinghamshire
HP27 9DT
Tel: 01844 274 222

British Turned Parts Manufacturers Association (BTMA)
136 Hagley Road
Edgbaston
Birmingham
B16 9PN
Tel: 0121 454 4141

Advanced Manufacturing Technology Research Institute (AMTRI)
Hulley Road
Macclesfield
Cheshire
SK10 2NE
Tel: 01625 425 421

Machine Tool Technologies Association (MTTA)
62 Bayswater Road
London
W2 3PS
Tel: 0207 402 6671