envirowise
Practical Environmental Advice for Business

GG446

# *Sustainable manufacturing: a signposting guide for metal machining companies*

This Guide has been produced in partnership with the Sustainable Technologies Initiative.

The Sustainable Technologies Initiative (STI) is a programme of collaborative research aimed at improving the sustainability of UK business. The aim is to maintain high levels of economic growth and employment while protecting the environment, making better use of natural resources and working for the good of society as a whole. Companies are encouraged to work with the science base to develop and adopt new sustainable technologies. The programme is sponsored by the Department of Trade and Industry (DTI), the Department for Environment, Food and Rural Affairs (Defra), the Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC).

For further information about the STI Programme please see **www.oakdenehollins.co.uk**

# *Sustainable manufacturing: a signposting guide for metal machining companies*

This Good Practice Guide was produced by Envirowise working with the Sustainable Technologies Initiative

Prepared with assistance from:

Pera Innovation

BBSRC EPSRC dti defra Department for Environment Food and Rural Affairs E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

# Summary


Metal machining companies in the UK are under increasing pressure as a result of overseas competition, stricter environmental legislation, supply chain demand for improved environmental performance and falling skill levels within the industry. Adopting sustainable manufacturing practices offers metal machining companies of all sizes a cost-effective route to improve their economic, environmental and social performance (ie the three pillars of sustainability).

The benefits of implementing the sustainable solutions described in this Good Practice Guide include:

- increased profits from reduced operating costs;
- increased competitiveness;
- reduced material purchase and waste disposal costs;
- reduced water and energy consumption;
- improved environmental performance;
- improved health and safety performance;
- improved public image;
- improved workforce skill levels;
- greater preparedness for future health, safety and environmental legislation.

The Guide describes a range of methods and techniques including lean manufacturing, waste minimisation, alternative machining methods, faster manufacturing, near-net shaping, improved management of metalworking fluids and greater recycling of swarf, spent metals, water, etc. Relevant Envirowise publications and useful websites are signposted as appropriate. All referenced Envirowise publications are available **free** through the Environment and Energy Helpline on freephone **0800 585794** or via the Envirowise website (**www.envirowise.gov.uk**).

# *Contents*

# Introduction



This Good Practice Guide is intended to help metal machining companies of all sizes to save money and improve their environmental performance by implementing sustainable solutions in their business. The Guide describes practical measures that will help companies improve their economic, environmental and social performance (ie the three pillars of sustainability) by:

- minimising waste;
- using resources such as materials, water and energy efficiently;
- improving management of metalworking fluids, swarf, lubricating oils and hydraulic oils;
- adopting lean manufacturing and other sustainable engineering techniques;
- using best practice in machining;
- training all employees about sustainable practices.

Relevant Envirowise publications[1] and useful websites are signposted as appropriate throughout the Guide.

## 1.1 Why do companies need to become sustainable?

The UK engineering industry is a key manufacturing sector, with 75% of the 80 000 companies employing metal machining operations. Metal machining companies have generally been slow to implement new sustainable technologies - largely due to a lack of knowledge, guidance and a clear way forward. In addition, the sector is under increasing pressure from a number of directions, including:

- competition from overseas where labour rates may be significantly cheaper;
- more stringent environmental legislation;
- depletion of raw materials;
- supply chain demand for continuous improvement in environmental performance;
- falling skill levels.

Metal machining companies have traditionally focused on short-term financial considerations, with little thought to the longer-term picture. However, a long-term business strategy is essential to achieve sustainable development and, ultimately, survival. To overcome the challenges facing the sector, it is vital that companies adopt sustainable manufacturing practices. A range of methods and processes for sustainable manufacturing is described in section 3.

## 1.2 What is resource efficiency?

Resource efficiency involves making the most of available resources. It should lead to producing more while using less, and so reduce costs. No company sets out to waste its resources but many do so unwittingly. There are many no-cost and low-cost ways in which a company can get more from its resources.

---

1 All Envirowise publications are available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

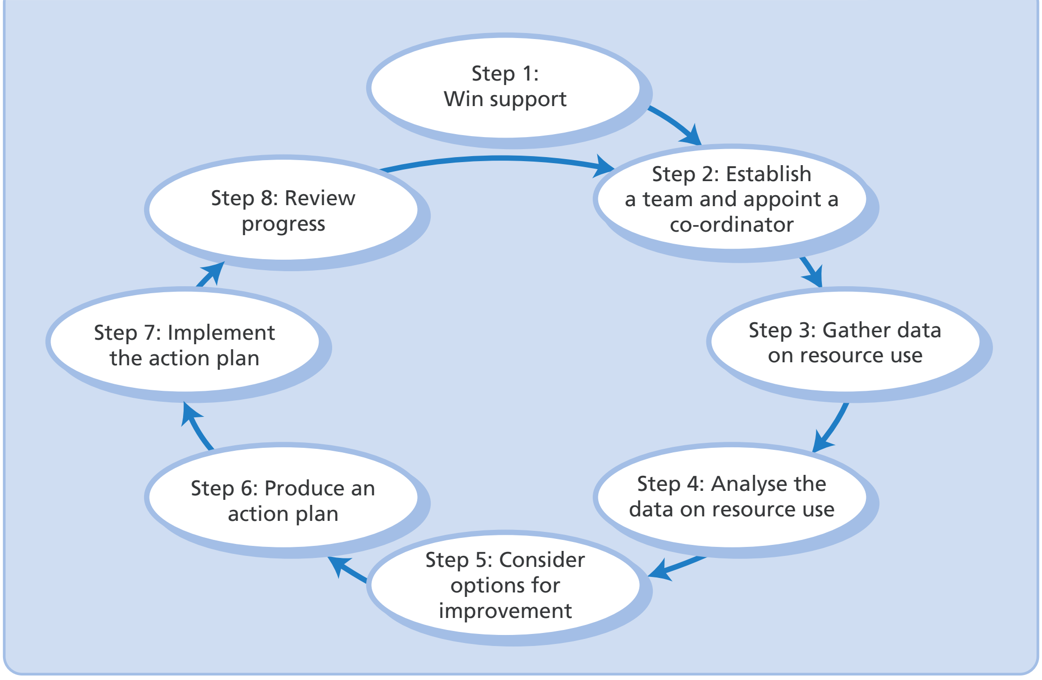
Using resources efficiently means taking action to:

- minimise waste;
- minimise water use and effluent generation;
- reduce energy consumption.

All of these will lead to cost savings that will go straight to the bottom line. Like a sustainability strategy (see section 2), they will also improve your environmental performance and your company's public image.

The best way to increase resource efficiency and reduce waste - and thus improve production efficiency - is to adopt the systematic approach shown in Fig 1. Such an approach also offers a route to the continual improvement demanded by environmental management systems such as ISO 14001 and EMAS.

***Fig 1  A systematic approach to resource efficiency and waste minimisation***




### 1.2.1 What is waste minimisation?

Waste minimisation is a management technique which involves a systematic reduction of waste at source using a method that will identify, cost and reduce waste in an organised manner and which is accountable, robust and repeatable. Waste minimisation is a key element of resource efficiency.

Waste minimisation is not just concerned with material going into a skip. It involves an examination of wasted raw materials, energy, emissions and effort. Raw materials, energy and labour cost 5 - 20 times the direct cost of waste disposal. Skips filled with rejected components may cost £10 000/year to dispose of to landfill, but the real cost of the wasted material could be a further £50 000 - £60 000/year when labour, overheads, wasted raw materials, energy, insurance and other factors are taken into consideration.

Waste minimisation is concerned with reducing:

- raw material consumption;
- water and energy use;

- emissions to air, land and water;
- wasted effort.

A key element of any waste minimisation programme is measuring resource use and waste generation, and then analysing your data to identify opportunities for improvement.

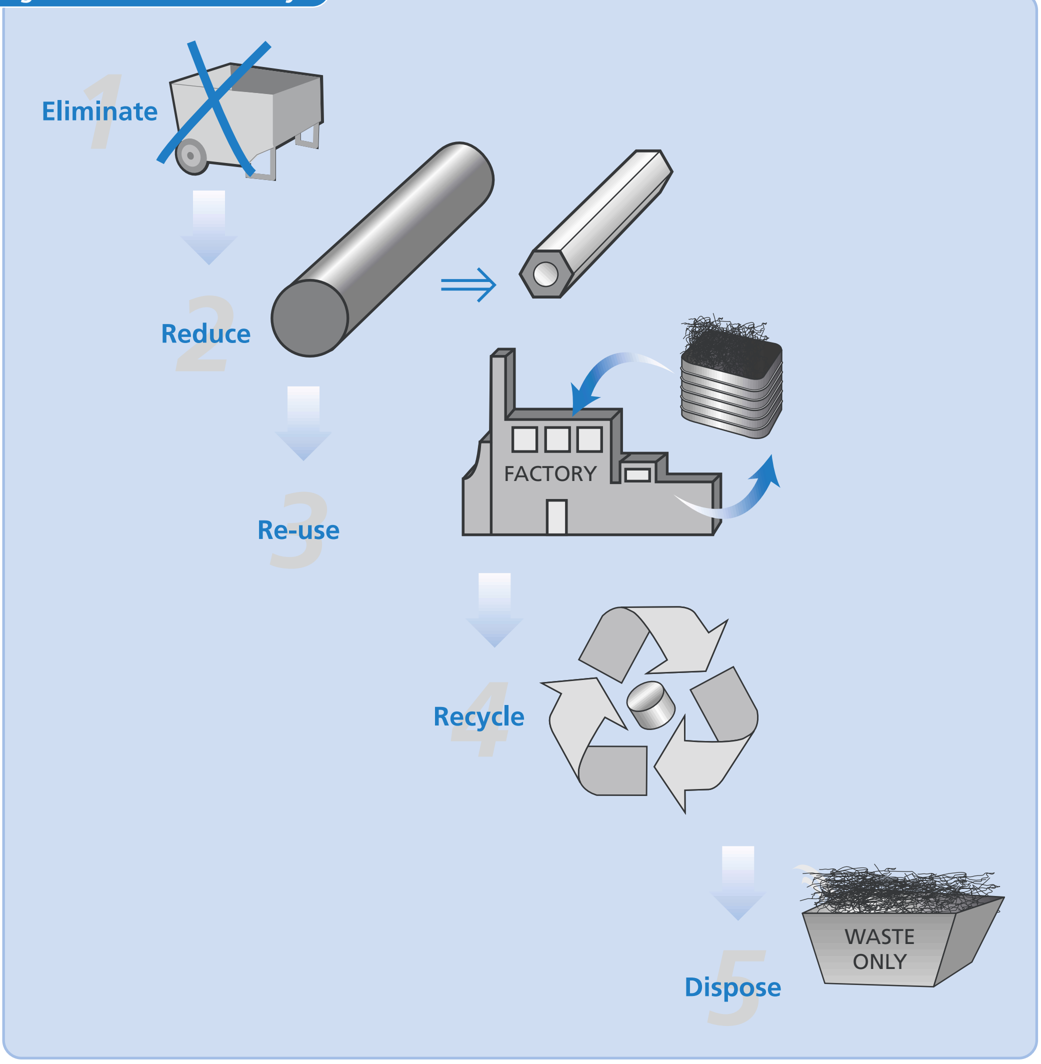
**Remember: if you don't measure it, you can't manage it.**

Waste minimisation makes sound business sense. Your company is probably spending around 4 - 5% of total turnover producing waste. Much of this money could be saved - often quickly and simply - through waste minimisation. The savings could be as much as 1% of turnover or £1 000/employee.

### 1.2.2 The waste hierarchy

The waste hierarchy (see Fig 2) is a systematic approach to waste reduction. The higher up the waste hierarchy that action is taken, the greater the cost savings, as fewer resources and less effort will have been put into the waste. Begin by trying to **eliminate** as much waste as possible at source, next **reduce** the amount of waste that is generated and then **re-use** as many items as possible during the process. Following this, **recycle** what you can only after you have re-used it and, finally, as a last resort, **dispose** of what is left in a responsible way.

*Fig 2 The waste hierarchy*



**Useful Envirowise publications**

- *Resource efficiency - a management guide* (EN320)
- *WasteWise: increased profits at your fingertips* (IT313) - an interactive CD-ROM that brings together all the essential information that companies need to minimise waste and save money
- *Cutting costs by cutting waste: waste minimisation for engineering companies* (ET185)
- *Environmental management systems workbook for engineering manufacturers* (GG205)
- *Measuring to manage: the key to reducing waste costs* (GG414)
- *Support for the engineering industry* (EN335)

# *The benefits of sustainability in metal machining*

A sustainability strategy offers metal machining companies a positive long-term vision that will deliver a more prosperous, cleaner, safer and healthier environment - contributing to a better quality of life for us all, both today and for future generations.

The benefits to a metal machining company of implementing the sustainable solutions described in this Guide include:

- lower operating costs and hence increased bottom line profits;
- improved competitiveness;
- less waste generated;
- more waste re-used or recycled;
- reduced water and energy consumption;
- improved environmental performance;
- improved working conditions;
- improved health and safety performance;
- adoption of best practice in machining;
- improved public profile/image for the company;
- improved workforce skill level;
- greater preparedness for future changes to health, safety and environmental legislation.

Sustainability offers your company the prospect of ensuring economic prosperity while respecting both the environment and its resources, and your employees. This will help to ensure the long-term security of your business.

Many metal machining companies have recently faced difficult periods with declining orders. However, the outlook for the medium-to-long term is better and the companies should take advantage of the benefits offered by sustainable practices to improve their performance and thus their competitiveness.

The UK currently trails in the league of 'manufacturing productivity' behind the USA (55% higher), Germany (29% higher) and France (32% higher). The UK can and must compete; adopting sustainable practices at a local level in metal machining companies is a significant step to achieving this.

**Reducing metal waste brings substantial savings**

An engineering company has reduced metal waste by improving press tools to allow components to be cut from smaller blanks. In addition, off-cuts and stampings are used wherever possible to produce smaller components. The company has achieved cost savings of over £500 000/year from more efficient use of sheet steel. Equipment costs amounted to £70 000, giving a payback period of less than two months. Sheet steel purchases have fallen by around 6%.

For more information about this initiative and others implemented by the company, see *Engineering company saves money by stamping out waste* (CS291)[2].

2 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

# *Implementing sustainable solutions in your company*

**This section describes key methods and processes in sustainable manufacturing. The areas covered in this section should be of benefit to most companies. However, the diverse nature of working practices in the sector means that the Guide cannot cover every possible aspect of manufacturing processes in metal machining.**

Sustainability needs to be integrated into the heart and culture of your company if it is to succeed in bringing change and maintaining progress. The commitment of all levels of staff is necessary to obtain the maximum impact from achieving sustainable working practices.

- Senior managers should set the goals and objectives necessary to implement sustainable manufacturing practices. They should recognise not only the need for and benefits of change, but also the consequences of failing to change.
- Each employee will have a role to play and everyone needs to be aware of where they fit into the line of responsibility.

## 3.1 Lean manufacturing

Lean manufacturing is the cutting edge of modern manufacturing techniques and concepts, and is the single most important manufacturing concept for companies seeking to improve their sustainability performance. The basis of modern lean manufacturing processes originated from a Toyota Production System (TPS), which was first developed in the 1970s and has evolved to become a highly efficient manufacturing programme.

Lean manufacturing also acts as a driver and catalyst for other sustainability pillars such as waste minimisation, right-first-time manufacturing, recycling of materials and economic performance. The systematic approach to waste minimisation advocated by Envirowise (see section 1.2) complements the types of waste targeted by lean manufacturing.

***Sustainability benefits of lean manufacturing***

- Uses less of everything - time, effort, workshop space, tools and raw materials.
- Increases bottom line profits.
- Efficient manufacturing/fewer defects/right first time.
- High skill level requirements.
- Valued employees.

### 3.1.1 What is lean manufacturing?

Lean manufacturing is manufacturing without waste. Material, time, idle equipment, space and inventory are all good examples of potential sources of waste which can result in companies wasting 70 - 90% of their available resources.

Lean manufacturing focuses on the accumulative effects of all the small instances of wasted effort and materials that occur every day in every worker's area. The aim is to pursue continual and small improvements in everyday practices through a self-managing system.

Lean manufacturing adopts a different approach to production processes, where employees' roles, operating systems and rules are all individual. Employees at each stage of the production process are required to operate as independent 'businesses' with ownership of quality levels and delivery deadlines. Lean manufacturing is both an ideal and a set of guiding principles with the aim of achieving continuous improvement.

Lean manufacturing describes an approach to business operations that:

- uses less material/stock;
- produces less waste;
- increases productivity;
- means fewer product defects;
- requires less capital investment;
- takes less human effort;
- requires less floor space.

Forward-thinking organisations understand the benefits and competitive advantages that can be achieved through the technique. Lean manufacturing principles can help to:

- reduce manufacturing cycle time by up to 90%;
- reduce work-in-progress by up to 90%;
- improve quality by up to 50%;
- reduce floor space required by up to 75%.

A team equipped with the concepts and tools for lean manufacturing can improve the bottom line of any manufacturing operation.

### 3.1.2 Getting started in lean manufacturing

To instigate lean manufacturing or 'lean thinking' at your company, consider the five questions posed in the checklist shown in Table 1. By asking these questions, you begin the process of removing valueless operations and eliminating wasteful practices - ie lean thinking.

As the implementation of lean manufacturing can be complex, various tools and concepts have been developed to help companies in their pursuit of lean manufacturing. These are outlined in section 3.1.3.

***Table 1 Checklist: getting started in lean manufacturing***

| Key questions | Key actions |
|---|---|
| What is the value of your product(s) from the viewpoint of your customers? | Specify the value of your product(s). |
| What actions do you carry out that add or do not add value? | Identify the value stream for each product. |
| Do you have a continuous, smooth flow line to minimise cost and improve response and quality? | Make the flow line smooth and continuous. |
| Do you manufacture only to customer demand? | Respond to customer pull. |
| Do you pursue perfection? | Create a permanent circle of value creation and waste elimination. |

**Free site visits from Envirowise to help you get started in lean manufacturing***

An excellent first step towards lean manufacturing is to request a free *Fast*Track and/or a design**track** visit from an independent Envirowise consultant. Such visits can help companies begin to implement a lean manufacturing approach, with all of its benefits, both quickly and cheaply.

A *Fast*Track visit is a confidential, on-site waste review carried out by an environmental advisor that includes up to a day's free advice on resource efficiency. The visit highlights practical opportunities to turn waste into profit by improving resource efficiency and reducing associated costs.

A design**track** visit looks at your product and identifies ways of redesigning it to reduce waste, resource consumption and environmental impact. Remember, 80% of the cost of a product over its life-cycle is in-built at the design phase.

Envirowise can also arrange a counselling visit from one of its experts to discuss a specific environmental issue at your site, eg how to benchmark waste from your process.

For more information, call the Environment and Energy Helpline on freephone 0800 585794 or visit the Envirowise website (www.envirowise.gov.uk).

* Available to companies with fewer than 250 employees.

### 3.1.3 Useful tools for lean manufacturing

This section is not intended to provide an exhaustive description of the various tools and concepts developed to help you implement lean manufacturing. Instead, it gives pointers for you to consider in your pursuit of lean manufacturing and signposts to relevant Envirowise publications and other sources of information.

*Waste in manufacture*

To reduce or eliminate waste, you first need to understand and identify the waste generated. It is broadly recognised that 'only an activity that physically changes the shape or character of a product or assembly can add value'. In other words: any activity that does not change the product or assembly is waste.

Use the checklist given in Table 2 to look at the waste associated with key production considerations. Although these become complex in a typical production environment, a number of techniques and methodologies can help to reduce or eliminate wasted resources, effort and time. These are described overleaf.

**Table 2 Checklist: waste associated with key production considerations**

| Consideration | Issues |
|---|---|
| Over-production or producing too much, too soon | Requires extra storage space, people, equipment, materials and energy.<br>Parts cannot be stored close to where they are required, creating unnecessary motion for operators and unnecessary movement of the parts. |
| Over-processing or doing more than the customer requires | Requires unnecessary operations. |
| Conveyance of components | Is there excessive movement and/or double/triple handling of stock? |
| Inventory | What creates the requirement for inventory levels and how can these be addressed? |
| Motion of people | Can the work sequence or layout be improved to eliminate unnecessary movement of people? |
| Waiting time | What causes people or machines to wait? |
| Rework | The generation of scrap has a much greater impact than its value alone. It causes extra, valueless work through the manufacturing process as a whole (eg through rework, increased lead times, complaints, reduced capacity and increased inventory). |
| Energy | Light, heat and power waste. |
| By-products and waste | Scrap materials, oil, coolant, etc. |
| Resources | Engineering and commercial capabilities are not directed at production requirements and solving problems. |

**Useful Envirowise publications**

- *WasteWise: increased profits at your fingertips* (IT313)
- *Waste mapping: your route to more profit* (ET219)
- *Cutting costs by cutting waste: waste minimisation for engineering companies* (ET185)

***Value stream mapping***

It is important to understand your production process and the elements that create value.

Value stream mapping provides a means of:

- visualising individual value streams;
- reviewing their performance;
- identifying cross-functions and decision-making processes;
- understanding what wastes exist.

Armed with the knowledge provided by value stream mapping, you can draw up improvement plans to tackle significant and/or expensive areas of waste. A value stream map can highlight the difference between, for example, elapsed or lead time, and value adding time.

***Useful website***

Society of Motor Manufacturers and Traders Industry Forum
**www.industryforum.co.uk/products/value.shtml**

***Just-in-time manufacturing***

The key to just-in-time (JIT) manufacturing is to manufacture products/parts 'just in time' for when the consumer needs them, as opposed to producing set amounts of products/parts per machine or product run. This will reduce inventory levels and increase efficiency (inventory levels tend to mask problems in production processes by enabling a fall-back plan).

JIT manufacturing means:

- adjusting production rate to customer demand;
- using the optimum number of people for the required production rate;
- switching off machines when the correct quantity of parts has been produced;
- keeping only sufficient stock to maintain a smooth flow;
- building in quality control to the production process itself.

To be successful, JIT manufacturing requires quality to be built into the flow line system so that faults are addressed quickly and correctly. As a result, a JIT system 'pulls' raw materials/parts from downstream only when needed rather than having large inventories of produced parts continuously pushing further upstream.

***One-piece flow***

An important consideration in JIT manufacturing is 'one-piece flow'. In a traditional production environment, factories are laid out functionally, ie similar machines and processes are grouped and different parts progress together through the various operations required. This leads to:

- long lead times;
- much movement of parts;
- poor labour utilisation;
- limited line balancing;
- high work-in-progress levels;
- poor housekeeping;
- double/triple handling;
- difficulties in detecting defects.

In one-piece flow, parts are made in individual production cells where raw materials are used to produce the finished item in a number of steps. The benefits of one-piece flow include:

- creation of products one by one;
- shorter lead time;
- elimination of inventory between processes;

- multi-tasked operators (potentially decreasing the number required and increasing their flexibility);
- improved teamwork.

***Kanban***

Kanban is a system of regulating the ordering of raw materials and parts from suppliers, based on upstream sales of products. Kanban is a popular pull technique in JIT flow line systems.

Kanban aims to deliver what is required, when it is required, and in the quantity required. It is driven by customer demand and uses the levels of buffer inventories between operations to control production. At set levels of inventory, the upstream process or machine is stopped.

Kanban cards are used to flag machines to pull parts from downstream when the carded part goes upstream. For a machine to operate, a part must be removed from its downstream buffer. This releases the attached card, which moves upstream to the machine and authorises it to produce a new part. Similarly, the machining requirement draws raw materials from the input buffer and this authorises the operation of the upstream process. In this way, the process is driven by removal from the finished goods inventory and the number of circulating cards determines the size of the buffers.

A common practice is to use re-usable packaging containers containing these cards throughout the manufacturing process; best practice extends the use of these containers to suppliers and the customer[3]. This can significantly reduce the cost and environmental impact of packaging while contributing to a lean manufacturing process.

***Benefits of Kanban control***

- Parts are made only on demand.
- Stock buffers are only as large as is required to ensure smooth flow.

***Drawbacks***

- The parts themselves carry the controlling information and therefore parts need to be stored in each buffer to achieve control.
- Kanban is more suited to a high, steady throughput of parts.

A variation on Kanban is CONWIP (Constant Work-in-Progress). In this approach, parts removed from the finished goods inventory authorise the first operation in the process to be carried out. This means that a part can be processed through all stages and intermediate buffers as quickly as possible until it reaches the finished goods buffer. The aim is to keep the intermediate buffers empty and only to provide build-up capacity in the event of a machine breakdown. Compared with Kanban, CONWIP has the advantages of reducing inventory levels and being applicable to multi-stage processes.

By combining their features in a hybrid pull system, overall CONWIP control can be supplemented by Kanban control on individual operations to address specific problems that may be experienced with a particular machine or process and which prevent buffer stocks from building up to a high level.

---

[3] Practical advice on re-usable packaging is given in *Choosing and managing re-usable transit packaging* (GG141), available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

### *Continuous process improvement*

The systems described above provide a means of implementing lean thinking. To continuously improve the production process, consider the areas known as the '5 Ss' (see Table 3). The philosophy behind the 5 Ss is to 'showcase' the production environment so that it can be easily understood and problems identified.

***Table 3 Achieving continuous process improvement: the 5 Ss***

| Action | Benefits |
|---|---|
| Sort | ■ Keeps only what is needed for the job.<br>■ Increases space available.<br>■ Reduces time wasted looking for items. |
| Set location | ■ 'A place for everything and everything in its place.'<br>■ Reduces the time wasted looking for items. |
| Stop contamination | ■ Maintains cleanliness.<br>■ Improves the working environment.<br>■ Unacceptable parts are easily spotted. |
| Standardise | ■ Provides clear, common standards.<br>■ Safety issues stand out.<br>■ A foundation for improvement is generated. |
| Sustain | ■ Maintains the standards set and improvements made.<br>■ The systems become stand-alone. |

### *Kaizan*

'Kaizan' is generally taken to mean a team-based methodology that enables the effective set-up or continuous improvement of an operation or process. An important part of Kaizan philosophy is the continuous improvement of an activity to eliminate waste. Kaizan follows a number of steps (see Table 4 overleaf) and uses the JIT principles outlined above.

One way of supporting Kaizan activities is to run a waste minimisation workshop to maintain the momentum of a manufacturing company following a Kaizan philosophy to reduce waste.

*Table 4 Typical steps in the Kaizan approach to continuous process improvement*

| Step | Actions |
|---|---|
| Initial planning | ■ Set up an evaluation team with representatives from a range of areas within the company.<br>■ Collect information on the part to be manufactured including drawings and samples/prototypes.<br>■ Set clear objectives, eg for production rates, costs (part and capital) and timing. |
| Definition | ■ Develop and evaluate a number of potential manufacturing processes for the part/each production step that follows lean manufacturing/JIT principles to minimise resources (eg tooling, capital, labour, work-in-progress). Quality control should be 'in-built' and the completed part should be defect-free for subsequent processing. One-piece flow should be considered where feasible.<br>■ Produce mock-ups of the potential process options.<br>■ Complete evaluation forms to enable simple comparison between the processes to be made. |
| Selection | ■ Select the best process, based on team consensus. |
| Implementation | ■ Purchase equipment and set up the manufacturing cell. |

***Useful Envirowise publications***

- *Profiting from practical waste minimisation: running a workshop to maintain the momentum* (GG174)
- *Seven practical workshops: helping companies to profit from reducing waste* (IT341)

### *Benchmarking*

Benchmarking performance, both internally and against other engineering companies in your sector, will help to raise the levels of your processes and quality to match those of 'the best in the sector'.

Various methods and tools have been developed within the engineering industry to help companies benchmark their processes and performance, eg:

- World Class Toolmaker Initiative from the Gauge and Toolmakers Association (GTMA). The GTMA World Class Toolmaker Profile offers standards and measures of performance; their adoption allows companies to demonstrate their commitment to continuous improvement in performance.
- The Society of Motor Manufacturers and Traders (SMMT) Industry Forum Master Class. This training programme provides an opportunity to learn about the techniques involved in continuous process improvement while realising the position of leading players in the industry. The aim of this programme is to eliminate wasted effort and activities through continuous process improvement in terms of quality, cost, delivery and partnership (QCDP). However, the SMMT Master Class only touches upon cleaner technology and waste minimisation, both of which offer significant opportunities to save money by reducing the consumption of raw materials, utilities and ancillary materials.

- Lean Processing Programme (LEAP). This programme - part of the Foresight Vehicle Programme - ran from 1998 to 2000 and was designed to extend lean thinking into the automotive/steel industries and their supply chains. It was run by the Lean Enterprise Research Centre at Cardiff University with support from Corus. LEAP built on lean manufacturing techniques to apply them to upstream automotive supply chains; the aim was to minimise waste through continuous process improvement based on QCDP.

  Part of the programme involved opening up communications between downstream and upstream suppliers. This approach allows non-competitors to share information on products and techniques so that the whole supply chain is integrated and waste is minimised, eg sharing material properties, dimensions and tooling requirements for raw materials at an early stage in the design process means fewer problems later on.

- Society of British Aerospace Companies (SBAC) Lean Aerospace Initiative (LAI). This aerospace version of LEAP was launched in April 1998 to:

  - develop consistent performance measures to allow member companies to carry out benchmarking;

  - allow member companies to compare their operating practices with those of lean enterprises.

***Useful websites***

Gauge and Toolmakers Association (GTMA)
**www.gtma.co.uk**

Society of Motor Manufacturers and Traders (SMMT)
**www.smmt.co.uk**

SMMT Industry Forum
**www.industryforum.co.uk/products/master.shtml**

Lean Enterprise Research Centre, Cardiff Business School
**www.cf.ac.uk/uwc/carbs/lerc**

Society of British Aerospace Companies (SBAC) Lean Aerospace Initiative
**www.sbac.co.uk/laihome.htm**

Water Account (an online water benchmarking tool from Envirowise)
**www.envirowise.gov.uk/wateraccount**

***Useful Envirowise publications***

- *Measuring to manage: the key to reducing waste costs* (GG414)
- *Benchmarking the consumption of metal cutting fluids* (EG179)
- *Cleaner technology: an essential guide for industry* (GG288)
- *WasteWise: increased profits at your fingertips* (IT313)
- *Driving down waste puts the brakes on costs* (GC236)
- *Accurate measurement of process waste leads to reduced costs* (CS406)
- *Measuring production helps managers increase profits* (CS356)
- *Support for the engineering industry* (EN335)

*Six Sigma*

The primary emphasis of Six Sigma is process measurement, analysis and improvement. Six Sigma complements lean manufacturing, but differs from it in not seeking to set up a self-managing system and not targeting inventory levels.

Six Sigma attacks specific quality problems with a range of statistically based problem-solving tools such as cause-and-effect diagrams, Pareto charts and flow charts. These tools are used to analyse potential defaults statistically in order to address and solve production problems. The aim is to achieve less than 3.4 defects per million 'production opportunities'. The methodology is rigorous and is implemented by trained personnel known as Six Sigma 'black belts', who work under the guidance of master 'black belts'.

The Six Sigma philosophy ties in well with cleaner design practices where a product's whole life-cycle (including the manufacturing process) is examined. Statistical data on process measurement and analysis can be incorporated into product design to further reduce defects and ultimately reduce resource use and operating costs.

**Useful Envirowise publications**

- *Preventing waste in production: industry examples* (GG223)
- *Preventing waste in production: practical methods for process control* (GG224)
- *Cleaner product design: an introduction for industry* (GG294)
- *Cleaner product design: examples from industry* (GG295)
- *Cleaner product design: a practical approach* (GG296)
- *Packaging design for the environment: reducing costs and quantities* (GG360)
- *Product redesign cuts materials and costs* (CS326)

## 3.2 Using resources efficiently

A key element of sustainability is the prudent use of natural resources. This means using non-renewable resources efficiently and developing alternatives to replace them in the future, while using renewable resources in ways that do not endanger the resource or cause serious damage or pollution.

> *"If in 2050 the population of the world consumes natural resources at the levels now enjoyed by the 'rich countries' of the world, it would consume 2 to 7 times the present amount of natural resources. This would multiply the current problems by 2 to 7 times as well, while the goal is an absolute reduction of environmental impacts."*[4]

The main resources of concern to the metal machining sector are:

- metals used in the manufacturing process;
- metalworking fluids (MWFs), lubricating oils and hydraulic oils;
- water;
- energy.

[4] *Towards a sustainable use of natural resources.* H. Muilerman and H. Blonk. January 2001. European Commission for the Environment. The complete report can be downloaded from www.europa.eu.int/comm/environment/pubs/studies.htm.

### 3.2.1 Metals

To maximise your sustainability performance, where practicable you should make use of metals that are both abundant in supply and have potential for recycling/re-use with no significant environmental impact.

Table 5 provides an overview of the sustainability factors to be considered when selecting metal types for manufacturing. Scores from 1 (best) to 5 (worst) have been allocated to various factors.

***Table 5 Sustainability factors affecting metal selection***

| Factor | Steel | Stainless steel | Aluminium | Cast iron | Titanium | Copper alloys |
|---|---|---|---|---|---|---|
| Abundance of raw material | 2 | 3 | 1 | 2 | 5 | 4 |
| Pollution during manufacture | 3 | 4 | 1 | 3 | 3 | 3 |
| Life of metal | 4 | 2 | 3 | 4 | 1 | 3 |
| Ease of recycling | 2 | 3 | 4 | 3 | 5 | 1 |
| Cost of finished product | 2 - 3 | 4 | 2 | 1 - 2 | 5 | 4 |
| Overall score | 13.5 | 16 | 11 | 13.5 | 19 | 15 |

*Key:* 1 = best sustainability score; 5 = worst sustainability score

### 3.2.2 Metalworking fluid formulations

Most MWFs and other industrial lubricants are formulated from virgin mineral oils, which are obtained from non-sustainable crude oil extracts. Although alternative naturally derived feedstocks are available (eg rapeseed, palm, sunflower and other vegetable oils), there has been limited use of these materials - partly due to higher costs and partly due to reduced performance in some applications.

Vegetable-based MWFs utilise sustainable raw materials. They are also considered less toxic than mineral oil-based formulations and may offer improved working conditions for operators.

### 3.2.3 Water

In the past, water was cheap and plentiful, but factors such as the UK's increasing population have made water an increasingly expensive resource. European and UK environmental legislation is also demanding increasingly strict quality standards. Mains water, sewerage and trade effluent charges are thus all increasing steadily.

Water minimisation is one of the easiest ways in which industry can achieve cost savings. Simple and inexpensive measures can typically reduce water consumption by up to **50%**.

To encourage more efficient water use and improvements in water quality, the Government has developed the Water Technology List. This gives details of products and technologies that qualify for an Enhanced Capital Allowance (ECA) (100% tax relief on the cost of the products). By investing in products that use water more sustainably, businesses can expect to enjoy an initial cash boost through the ECA, as well as on-going cost savings on water bills.

**Useful Envirowise publications**

- *Resource efficiency* (EN320)
- *Minimising chemical and water waste in the metal finishing industry* (GG160)
- *Optimising the use of metalworking fluids* (GG199)
- *Cost-effective management of lubricating and hydraulic oils* (GG227)
- *Reducing costs through effective swarf management* (GG264)
- *Cost savings from improved swarf and materials management* (CS375)
- *Packaging design for the environment: reducing costs and quantities* (GG360)
- *Cleaner technology: an essential guide for industry* (GG288)
- *Life-cycle assessment - an introduction for industry* (ET257)
- *Electroplaters plant performance optimisation tool* (IT265)

### 3.2.4 Energy

All metal machining companies can save money and improve their sustainability performance by simply reducing energy consumption. However, many engineering companies (particularly smaller ones) see energy efficiency as a low priority. Although this may be partly due to the relatively low cost of electricity, this is expected to increase significantly in the future and companies should take action now to avoid a 'shock' later. Government measures to tackle global warming, such as the Climate Change Levy, are already affecting energy costs.

Energy is an essential resource for engineering companies. For example, an estimated two-thirds of the electrical energy used by the metal machining industry is for running motors and drives (eg for cutting tools). The cost of this energy is about 100 times more than their initial purchase costs when used typically over a ten-year period. Compressed air is another major use of electricity in metal machining.

In many cases, it is possible to reduce energy consumption by 20 - 30% without major expenditure. Consider the impact this could have on your profits. For example, 2 - 3% of turnover could be directed straight to your bottom line. By how much would sales have to increase to achieve the same impact?

Top energy efficiency tips for metal machining companies:

- Ensure motors/machines are switched off when not in use.
- Inspect and maintain machine tools regularly. Minimise electricity consumption by ensuring that they are in optimum working condition. The frequency of inspection and maintenance will depend upon the type of machine, its age, condition, duration of use, and the type of process.
- Optimise machining conditions for the cutting operation. This will reduce the work input required by the machine.
- Reduce the motor/spindle speed of machine tools where possible. The use of variable speed drives can save an estimated 30 - 40% of energy in some situations.
- Find and fix leaks in your compressed air system. Most users of compressed air can save up to 30% of the energy used by simple measures such as these.
- Consider lowering the operating pressure of your compressed air system. Typically, a reduction of 100 kPa (1 bar) will save around 7% of the energy used.

- Increase employee awareness of measures to reduce energy consumption in all areas of the company's operations.
- Check your consumption of electricity, gas, etc regularly. Check that your bills relate to what you actually use, rather than an estimate.
- Turn off lights in unoccupied areas of the factory - especially at the end of the day.
- Consider heat recovery on-site wherever possible. For example, is it possible to recirculate air from a filtration/abatement system back into the workshop?
- If replacing a motor, ensure it is a higher efficiency motor (Class EFF1). Higher efficiency motors can qualify for tax relief through the Enhanced Capital Allowance scheme.
- Contact Action Energy via the Environment and Energy Helpline (0800 585794) for free advice and information about:
  - energy management;
  - motivating staff to improve performance;
  - compressed air;
  - motors and drives;
  - lighting, heating and ventilation;
  - optimisation and benchmarking of furnace performance;
  - metal melting and holding of molten metal.

  For example, the free Action Energy publication, *Focus on energy: a practical introduction to reducing energy bills* (FOCUS), is an invaluable manual for businesses wanting to save money through energy efficiency.

### *Sustainability benefits of energy efficiency*

- Reduced energy use and thus lower operating costs.
- Reduced environmental impact from energy generation (carbon dioxide emissions).
- Improved employee awareness/skill level of energy saving opportunities.

### *Drawback*

- Some energy saving opportunities may have a longer payback period than is usually acceptable to the company.

### *Useful websites*

WaterNet (information about best practice in water minimisation)
**www.envirowise.gov.uk/waternet**

Sustainable Development
**www.sustainable-development.gov.uk**

Water Account (an online water benchmarking tool from Envirowise)
**www.envirowise.gov.uk/wateraccount**

Action Energy
**www.actionenergy.org.uk**

Enhanced Capital Allowances (Water Technology List and Energy Technology List)
**www.eca.gov.uk**

## 3.3 Minimising metalworking fluid use in metal machining

An estimated 400 000 tonnes of spent water-based metalworking fluids (MWFs) are disposed of in the UK each year. Many of the additives in spent fluids remain untreated and find their way through the sewerage system into the environment where they cause harm. Eliminating or reducing the amount of MWFs used by metal machining companies could have significant economic, environmental and social benefits.

***Sustainability benefits of minimising MWF use in metal machining***

- Saving money on the cost of buying MWFs and disposing of spent MWFs.
- Eliminating or reducing harmful discharges to the environment.
- Improving health and safety in the machine shop.
- Improving the skill level of operators through the use of alternative techniques to wet machining.
- Improving the value of recovered swarf by preventing contamination from MWFs (making it easier to recycle).
- Saving money on the cost of mains water supply.

### 3.3.1 Dry machining

Dry machining offers the potential to reduce or eliminate the use of MWF - and thus the need to buy MWFs and dispose of spent MWFs.

The three commonly used categories of dry machining are:

- 'true' dry machining - with zero cutting lubricant;
- minimum quantity lubrication (MQL) - small quantities of lubricant are applied as a mist to the cutting process;
- air/gas cutting - the gas phase is applied under pressure to cool and remove the swarf from the cutting process.

The applications, advantages and disadvantages of these competing methods are outlined below. Contact your machine and cutting tool supplier for advice on whether any of these methods are acceptable for your process. Table 6 summarises the suitability of the three methods for different materials and operations.

***'True' dry machining***

There is much debate about the feasibility of dry machining technology in some applications. Many engineers are sceptical about the technology, but it is well established in many other industrial sectors and, in the right applications, can provide considerable benefits.

Machining 'dry' eliminates:

- The use of environmentally harmful fluids in the manufacturing process.
- The need for coolant delivery and collection systems on machines. This removes the need for much of the support machinery on each machine tool, significantly reducing capital investment and maintenance costs.

Dry machining also improves the air quality of machine shops because it eliminates MWF mist from the machining process.

### *Sustainability benefits of 'true' dry machining*

- Cleaner manufacturing process.
- No need to buy, manage and dispose of MWFs.
- Reduced environmental impact.
- No MWF mist in the machine shop.
- Increased potential to recycle swarf.
- No need to degrease machined components.

### *Drawbacks*

- Limited application.
- Possibly reduces tool life.

***Minimum quantity lubrication (MQL)***

In this method, MWF is delivered in short pulses (not greater than 3 pulses/second) to the spray nozzle and mixed with low velocity air to deliver micro-droplets of fluid (200 - 600 µm) to the machining operation. MQL is not fully established for all applications, but research is being carried out by a number of machine tool manufacturers to widen its application.

The technology can be effective in applications with lower specific loads, eg lands, flanks or chip flutes on drilling tools. It is also often an excellent technique for solving metal cutting difficulties for dry machining jobs.

### *Sustainability benefits of MQL*

- No need to worry about MWF disposal as it is consumed during the machining operation.
- Improved operator safety (no MWF mist is produced).
- The produced swarf is practically dry, thus increasing the potential for recycling without environmental concerns.
- Improved surface integrity due to lower cutting temperatures.
- Faster production by cutting at higher feeds and speeds compared with conventional processes.
- Increased tool life is possible (particularly with high frequency operations).
- No need to degrease machined components.
- MQL can be optimised to ensure that minimal MWF is consumed.
- Wide application range.
- Cost benefits can be achieved.
- High skill levels are achieved as understanding of the process and conditions is important.

### *Drawbacks*

- Requires a specialised controlled pump delivery system for MWF.
- It is not a completely 'clean' technology.
- Some swarf contamination may inhibit the potential for recycling.

*Air/gas cutting*

This technology uses air, nitrogen or an inert gas at high pressures to cool and remove the swarf from the machining process.

**Sustainability benefits of air/gas cutting**

- Clean manufacturing.
- Swarf recovery.
- Reduced environmental impact.
- Lowest overall cost compared with 'true' dry machining and MQL.
- Good skill level required.

**Drawbacks**

- Limited applications.
- Investment in equipment is required.
- Use of compressed air/gas systems incurs relatively high energy costs.

***Which technique to choose?***

The suitability of 'true' dry machining, MQL or air/gas cutting for your process will depend on the type of:

- machine tool;
- metal material;
- cutting operation;
- cutting tool.

Table 6 summarises the potential uses of the three dry machining methods for different materials and machine shop operations.

***Table 6 Potential use of dry machining for different materials and operations***

| Parameter | Dry | MQL | Air/gas |
|---|---|---|---|
| ***Material:*** | | | |
| Low alloy steel | ✓ | ✓ | ✓ |
| Medium alloy steel | ✓ | ✓ | ✓ |
| High alloy steel | # | ✓ | # |
| Stainless steel | × | ✓ | × |
| Cast iron | ✓ | ✓ | ✓ |
| Nodular iron | ✓ | ✓ | ✓ |
| Aluminium | × | ✓ | × |
| Exotic materials | # | # | # |
| ***Operation:*** | | | |
| Turning | ✓ | ✓ | ✓ |
| Milling | ✓ | ✓ | ✓ |
| Drilling | ✓ | ✓ | ✓ |
| Tapping | ✓ | ✓ | ✓ |
| Reaming | × | ✓ | × |

*Key:* Practical: ✓ By application: # Poor: ×

## 3.4 Management of metalworking fluids

The management of water-based metalworking fluids (MWFs) is essential to get the best out of your product. Its importance should not be ignored - it is estimated that 16% of machining costs are attributed to the MWF.

Contamination of water-based MWFs can easily occur from a variety of sources, including:

- airborne bacteria;
- poor hygiene control by the operator;
- tramp oil (eg from slideways oils);
- metal fines from the cutting process;
- re-use of fluid from contaminated swarf.

*Optimising the use of metalworking fluids* (GG199)[5] stresses the benefits of improved MWF management and describes a range of simple low-cost measures to help companies prolong the life of their MWFs and reduce their operating costs. Innovative approaches to help you improve the management of your MWFs are outlined below.

**Sustainability benefits of improved MWF management**

- Extended fluid life.
- Improved cutting performance.
- Reduced purchase costs of new fluids.
- Reduced disposal costs.
- Improved health and safety performance (eg improved working environment for machine tool operators).

**Useful Envirowise publication**

- *Optimising the use of metalworking fluids* (GG199)

**Fluid management programme has major benefits**

An in-house fluid management programme at an engineering company in Birmingham resulted in the following benefits for the company:

- tool life increased by 300%;
- extended fluid life;
- significant reduction in fluid disposal.

### 3.4.1 Phase control MWF technology

Water-based MWFs reject slideways lubricants and hydraulic oils based on mineral oil formulations, thus creating a separated 'tramp oil' phase. Tramp oil is the greatest enemy of water-based MWFs. It is usually the consequence of poor maintenance of the machine tools,

5 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

MWFs, hydraulic systems, etc. Tramp oil is a source of bacterial contamination and encourages the degradation of water-based MWFs. It also contributes to poor surface finishing, increased corrosion of machined components and reduced cutting tool life.

However, recent developments by fluid formulators could significantly reduce the potential for tramp oil in machine tools. The new concept is based on 'phase control' and involves mixing a 'lubricity phase' with a 'biostable/corrosion inhibitor phase' in the appropriate proportions for the machining task. The same 'lubricity phase' is also used as the main component in the slideways oil in the machine tool. If there is any leakage of slideways oil, this mixes readily with the 'phase control' MWF without harming the product or affecting the machining performance (provided the quantity does not significantly alter the concentration of the MWF).

Increasing numbers of fluid formulators are now able to supply phase control technology; consult your supplier for further details. Machine shops with centralised coolant systems will benefit most from this technology.

***Further sustainability benefits: phase control technology***

- Reduced tramp oil in water-based formulations.
- Higher performance machining (oil phase can be varied to optimise tool life).
- Only need to top-up depleted additives.
- Extended fluid life leading to lower MWF purchase and disposal costs.
- Easier fluid maintenance.
- Estimated 30% reduction in running costs compared with single-phase products.
- Applicable to a wide range of machining processes.

### 3.4.2 One-package approach

It is becoming increasingly common for MWF formulators to provide a 'one-package approach' that transfers all aspects of looking after the MWF fluid to the supplier. Such packages cover:

- fluid selection for machining operations;
- fluid management during use;
- disposal of spent MWF.

The time, effort and resources released by such an approach allow companies to concentrate on their core business activities. For more details, contact your MWF supplier.

***Further sustainability benefits: one-package approach***

- Less disruption to machine operators.
- More experienced/higher skilled operators involved in fluid maintenance.
- Could reduce manufacturing costs.

### 3.4.3 Use of a computer expert system

Automated computer 'expert' systems are now being developed to help companies manage their MWFs more effectively. The technology removes the 'subjectivity' from MWF management and provides science-based decisions and actions in an area that can sometimes appear ambiguous. The technology utilises intelligent sensors that can measure fluid concentration, pH and bacterial activity simultaneously using a single probe device. The data are fed into a software package and interpreted to give recommendations for the additions of additives to replenish the MWFs. The technology is expected to become commercially available in the near future.

***Further sustainability benefits: use of expert systems***

- Takes away subjectivity in MWF management.
- Right fluid diagnosis means right corrective action.
- Removes highly skilled task from operators.

### 3.4.4 Biological treatment of spent MWFs

Biological systems now offer a realistic and cost-effective option for treating spent water-based MWFs. They provide an attractive alternative to the traditional separation and concentration process.

The specialised microorganisms used in such systems have the ability to degrade almost all components of MWF effluent, including the synthetic ones. They are also much more resilient than the microorganisms used in sewage treatment works because they are adapted for this polluting and toxic effluent. Many engineering companies are now using biological systems to deal with this problem effluent. Research in this area is also continuing.

The benefits of a biological treatment system include:

- generally lower capital and operating costs than those of alternative systems;
- the capability to treat the soluble synthetic components of modern MWFs that tend to pass through most concentration systems (eg chemical separation and ultrafiltration);
- the fact that the pollutants are destroyed rather than concentrated;
- improved public image (using a 'green' option based on natural processes).

For more information, see the BIO-WISE publication, *A guide to biological treatment for metalworking fluids disposal*[6].

***Useful website***

BIO-WISE
**www.dti.gov.uk/biowise**

## 3.5 Recycling of materials

The concept of recycling is based on the re-use of spent materials, possibly after a cleaning or a conversion process. Traditionally, the metal machining sector has not taken recycling very seriously, but increasing waste disposal costs and stricter environmental legislation (eg the End of Life Vehicles (ELV) directive) have made recycling more advantageous. Environmental legislation may vary between different parts of the UK. For further information on relevant legislation and new legislative developments affecting your company:

- contact the Environment and Energy Helpline on 0800 585794;
- visit the NetRegs website (www.environment-agency.gov.uk/netregs/), developed by the Environment Agency in collaboration with the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service (EHSNI).

6 Available free of charge through the BIO-WISE website (www.dti.gov.uk/biowise) or via the BIO-WISE Helpline (0800 432100).

Areas where recycling opportunities can increase a company's sustainability performance are outlined below.

### 3.5.1 Sending swarf/spent metal for recycling

Swarf can be defined as the unwanted remnants from metal machining processes. Many companies are both gaining revenue and improving their environmental performance by recovering and recycling swarf (particularly that from non-ferrous metals) by selling it to a metal merchant or a foundry.

The main way of increasing the value of swarf is to minimise contamination with other metals, MWFs and/or rainwater. Top tips to increase the value of your swarf/spent metal include:

- segregate different types of spent metal into separate bins and label them with a description of their contents;
- protect the bins from rain or other potential sources of contamination;
- drain or centrifuge the swarf to remove as much MWF drag-out as possible;
- use 'chlorine-free' MWFs (those containing chlorine inhibit the swarf's recycling potential);
- fit a bund to the area where collection bins are stored;
- investigate whether you can sell the swarf/spent metal directly to a recycling company;
- compact materials for ease of transportation.

***Cost savings from improved swarf and materials management***

A company based in Middlesex is a leading manufacturer of aircraft ejection and safety seats for military and commercial applications. New working procedures have allowed it to increase the value of swarf through improved segregation and storage. A centralised system for recycling metalworking fluid has significantly reduced the downtime and materials necessary for optimum machine performance. The benefits of improved swarf management and metalworking fluid recycling at the company included: cost savings of around £58 000/year and an estimated increase of 60 tonnes/year in the amount of metal recovered. In addition, the volume of metalworking fluid sent for disposal was reduced by around 45% and concentrate use by about 40%. The company found that the working environment was cleaner and more efficient as a result of these changes.

For more information, see *Cost savings from improved swarf and materials management* (CS375)[7].

***Sustainability benefits of recycling swarf/spent metal***

- Less waste requiring disposal.
- Revenue obtained for 'waste'.
- Less processing energy and utilisation of raw materials by recycling spent metal compared with using virgin materials.
- Reduced environmental impact from reduced disposal.

7 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

**Useful Envirowise publications**

- *Reducing costs through effective swarf management* (GG264)
- *Cost savings from improved swarf and materials management* (CS375)
- *Waste minimisation pays: five business reasons for reducing waste* (GG125)
- *Cost-effective metal recycling from industrial effluents* (FP94)

### 3.5.2 Replenishing neat oils

Like water-based MWFs, neat oils should be checked for the condition of the product and, where necessary, be topped-up with additives. This will ensure that the fluid is replenished and stays in good condition. The effort is worthwhile as well-managed neat oils can last up to five years in the machine tool. However, oil maintenance requires skilled input.

Ultimately, however, the oil will need to be replaced. Provided the spent oil is kept separate from other wastes, you may be able to sell it for reprocessing into 'lower grade' lubricants or for use as burner/support fuels. Spent neat metalworking oils are classed as special/hazardous waste and should be disposed of through a specialist waste treatment company.

**Sustainability benefits of replenishing neat oils**

- Reduced purchase costs of new neat oils.
- Reduced oil disposal and disposal costs.
- Improved environmental performance.

**Useful Envirowise publication**

- *Optimising the use of metalworking fluids* (GG199)

### 3.5.3 Re-using water on-site

Water is a precious and essential raw material for manufacturing, but most end-users do not re-use their spent water on-site. One barrier for its re-use is the difficulty in controlling the quality of spent water from a process. However, there are often potential applications (eg washing/cleaning processes or re-use into similar production processes with some carryover of 'raw material/finished product') that could be implemented without harm to the process. However, minimising the amount of water used in the first place will give the most savings (in water supply and effluent treatment/disposal costs).

**Recycling spent water-based MWFs**

An automotive manufacturing company producing around 7 000 engines per day uses water-based MWFs for its cutting processes. When these fluids are ready to be replaced, they are processed in an evaporator and the recovered water phase is used to prepare new fluid dilutions. This approach eliminates the need to dispose of the recovered water phase. The recovered oil phase is sold to oil recycling companies.

There are a number of options for treating industrial wastewater on-site. The most suitable technology will depend on factors such as degree of contamination, volumes to be treated, required quality of 'cleaned water', payback period of treatment equipment, etc. Table 7 summarises the advantages and disadvantages of proven wastewater treatment options. Membrane technology is the most commonly used method and payback periods of around 18 months can be achieved in many industrial applications.

***Table 7 Advantages and disadvantages of wastewater treatment options***

| Method | Advantages | Disadvantages |
|---|---|---|
| Ultrafiltration | Excellent at treating emulsified oil phases. | Unable to treat water-soluble components. |
| Reverse osmosis | Possible to remove some water-soluble components. Often used as a polishing technology for the recovered water phase from ultrafiltration. | Technology can be expensive. Membrane tubes may need to be replaced frequently if they are not maintained properly. |
| Ion exchange | Good at removing water-soluble contaminants. | Harmful by-products are formed during the regeneration of the ion exchange resins. |
| Chemical treatment | Good at removing water-soluble contaminants. | Harmful 'sludge' by-product. |
| Evaporation/ vacuum distillation | Very good treatment performance (including removal of water-soluble contaminants). | Capital cost can be more expensive. |

***Sustainability benefits of re-using water***

- Conserves fresh water supplies.
- Reduces/eliminates wastewater disposal costs.
- Reduces cost of buying fresh mains water.
- Improved environmental impact.

***Useful Envirowise publications***

- *Optimising the use of metalworking fluids* (GG199)
- *Automatic recycling of metalworking fluid* (GC197)
- *Cost-effective membrane technologies for minimising wastes and effluents* (GG54)
- *Minimising chemical and water waste in the metal finishing industry* (GG160)
- *Cost-effective treatment of waste oily water* (CS92)

### 3.5.4 Manufacturing parts with equal lives

Manufacturing products from components of equal or similar operational lives means that, once the product becomes spent, the components can be segregated (if the materials are of different composition) and potentially recycled. This approach offers the benefit of utilising all components in a product to the maximum before recycling or disposal. Many components with residual usefulness are typically disposed of because they are attached to/combined with to part of a product/process that has become spent.

***Sustainability benefits of manufacturing parts with equal lives***

- Only spent components are recycled.
- Components are designed with recycling in mind.

***Useful Envirowise publications***

- *Cleaner product design: an introduction for industry* (GG294)
- *Cleaner product design: examples from industry* (GG295)
- *Cleaner product design: a practical approach* (GG296)

## 3.6 Faster manufacturing

Most companies give a high priority to faster manufacturing in order to become more economically competitive, especially in the face of competition from overseas where labour rates may be significantly cheaper than in the UK.

Companies are demanding more and more from machine tool manufacturers, tool producers and MWF formulators to deliver technology that can significantly increase the rate of production output. This can be achieved through:

- faster spindle rates;
- harder cutting tools;
- advanced lubrication technology.

Although the cost and effort involved in high-speed machining may be higher, it can offer significant sustainability benefits.

Various methods/approaches to achieve faster metal machining are considered overleaf.

***Sustainability benefits of faster manufacturing***

- Shorter production cycles mean lower costs to produce the finished product.
- Enhanced productivity due to higher output in any given time.
- Potentially lower investment costs due to the reduction in the number of machines required.
- Improved manufacturing flexibility due to reduced production times and high output.
- Improved product quality/accuracy of shape and surface finish due to reduced cutting forces.
- Good utilisation of staff resources.

### 3.6.1 High technology cutting tools

Manufacturers work constantly to develop tools capable of removing metal at faster and faster rates using increasingly higher spindle and feed rates. The benefits of faster cutting tools should not be achieved at the expense of reduced tool life, otherwise the gain will be minimised or eliminated.

A number of advanced cutting tool technologies have now been developed for high-speed metal removal work. Contact a reputable tool supplier to ask about the potential benefits of using these state-of-the-art products.

- **Polycrystalline diamond.** The popularity of polycrystalline diamond (PCD) as tipped inserts in cutting tools has increased significantly due to their effective use in fast metal machining tasks. Typical applications include:

  - the machining of a wide range of aluminium/silicon alloys, eg engine blocks and manifolds;
  - rough-milling aluminium castings, eg cylinder heads.

  Swarf can be produced rapidly with PCD cutting tools and it is important to remove this material effectively from the work area to maximise cutting tool life.

  With effective swarf removal and a rigid operating machine set-up, cutting speeds using PCD can be as high as 10 000 surface feet per minute (sfpm). The required spindle speeds to achieve these rates are generated by the latest computerised numerical control (CNC) machining and turning centres.

- **Cubic boron nitride.** Cubic boron nitride (CBN or cBN) is of great interest for a wide range of machining applications and, like PCD, is increasing in popularity. It is expected to eventually rival diamond cutting tools in status. CBN tools combine a number of extreme properties such as rigidity and hardness, chemical resistance and high thermal conductivity.

- **Ceramics.** The interest in the use of ceramic materials in high-speed cutting tools is based mainly on their material properties (excellent hardness, good wear resistance, chemical stability), which are unaffected at high cutting speeds. Ceramic cutting tools represent a different class of cutting tool material with unique chemical and mechanical properties.

  In terms of the cutting tool itself, development of more wear-resistant tool materials for application in high-speed machining has had a profound impact on productivity. This increase in cutting speed has been made possible through the progressive evolution of ceramic tool materials. To realise the full potential of ceramics, it is necessary to have a clear understanding of all the variables that affect the performance of these tools.

- **Whisker ceramics.** Silicon carbide (SiC) whisker-reinforced ceramic composites offer a significant improvement in mechanical properties compared with monolithic materials. The incorporation of SiC whiskers into alumina ceramics results in increases in strength, fracture toughness, thermal conductivity, thermal shock resistance and high temperature creep resistance.

### 3.6.2 High-pressure lubrication

This technology involves rapid machining in a closed environment/chamber. MWF is dispensed at high pressure at the machining operation to deliver the required cooling and lubrication under these arduous conditions. The MWF is circulated at typically 200 - 800 kPa (2 - 8 bar) within the system; additional pumps can be added to deliver the MWF at up to 10 MPa (100 bar). High-pressure lubrication is typically used in arduous machining/grinding applications such as 'creep feed grinding'. Special 'high performance' lubricants are required for this technology.

Contact a reputable machine tool supplier for further advice and information.

**Sustainability benefits of high-pressure lubrication**

- Fast production.
- Improved health and safety conditions (due to the enclosed machining environment).
- High skill level task.

**Drawback**

- Capital investment for new technology.

### 3.6.3 Good MWF performance

Selecting the correct MWF technology for your metal cutting process is vital to get the best out of your metal machining operation. It will enable the metal cutting process to be carried out more efficiently.

It is also important to ensure that water-based MWFs are used at the correct dilution concentration. Failure to do so could result in poor surface finishing, reduced tool life and increased corrosion of the component and cutting tools.

Contact a reputable MWF supplier with details about your specific metal machining operations for advice on the most suitable technology. Ask for test data to quantify any machining performance claims and for test samples for trials in your workshop.

**Sustainability benefits of ensuring good MWF performance**

- Improved quality of machining, eg surface finishing, and improved accuracy/ tolerances.
- Improved cutting tool life.
- Lower operating/metal machining costs.
- Improved health and safety in the workshop.
- Reduced energy consumption in metal machining.

**Drawback**

- Identifying the best MWF technology will involve time and effort to ascertain the most suitable MWF technology.

**Useful Envirowise publication**

- *Optimising the use of metalworking fluids* (GG199)

### 3.6.4 Knowledge of optimum cutting conditions

Machining at the optimum cutting conditions is paramount. Even small deviations from the 'optimum' can affect the:

- performance of the machining task;
- surface integrity of the component;
- cutting tool life;
- energy consumption of the machine tool.

Identifying the 'optimum' machining conditions for a specific task involves identifying the feed and speed rates that will maximise tool life. These rates have to be determined for specific metal machining operations with specific MWF technologies, as any of these different variables are likely to affect machining performance.

The best approach to identify the 'optimum' machining conditions is to first contact your cutting tool supplier for advice. Then contact your MWF supplier for advice on the most suitable product for the task. The next step is to spend some time altering the feed and speed rates for the process (eg ±5% or ±10% from the suggested optimum) to find out if the machining performance can be improved further.

Contact the supplier of your machine tools and cutting tools for specific advice about your machining applications. Then carry out in-house validation machining trials.

***Sustainability benefits of optimum cutting conditions***

- Improved quality of machining, eg surface finishing, and improved accuracy/ tolerances.
- Improved cutting tool life.
- Lower operating/metal machining costs.
- Reduced energy consumption in metal machining.

***Drawback***

- Identifying the 'optimum' conditions may involve some time and effort initially.

### 3.6.5 Metalworking using through-drills

Through-drills allow the MWF easier access to the point of contact between the cutting tool and the machined surface. This results in improved lubrication in the machining task compared with conventional drills. A further advantage of through-drills is that they are able to remove the swarf from the cutting process much more effectively.

For advice about using through-drills, contact your cutting tool supplier with specific details about your drilling applications.

***Sustainability benefits of using through-drills***

- Faster machining potential.
- Longer tool life.
- Reduced energy consumption during machining.

***Drawback***

- Increased costs for the purchase of through-drills compared with conventional drills.

### 3.6.6 Maintenance of your cutting machines

Many companies do not have a maintenance programme for their machine tools, but instead rely on a reactive approach to repair a machine after it has broken down. A planned maintenance programme has the advantages of improved reliability, integrity and safety of machinery.

A maintenance programme can be introduced progressively, starting with the machinery that is most important to the business. You can then extend it to other plant and machinery over time.

Once complete maintenance cover has been achieved, any subsequent breakdowns are likely to be unforeseen ones and the chance of this occurring will be significantly reduced.

- Carry out regular inspections to help minimise disruption to production. Inspections can be either visual or more sophisticated depending on the type of machinery or plant.
- Keep records of maintenance and inspection activities. This will help you to keep track of progress, while such records may be necessary to comply with health and safety legislation.
- Regularly inspect and maintain the following machinery and plant:
  - metal cutting machines;
  - grinding machines;
  - power presses;
  - pressure vessels;
  - lifting equipment;
  - cranes;
  - compressed air equipment.
- Contact the supplier of your machinery/plant or consult the operating/maintenance manuals supplied with the equipment for details of required preventative maintenance.
- Consult relevant health and safety legislation (regulations, codes of practice, etc) as these can contain comprehensive details of maintenance requirements for certain equipment.

***Preventative maintenance to reduce hydraulic oil consumption***

Hydraulic oil tanks used for CNC machining, at a company that supplies the automotive industry, were previously topped up on a regular basis. However, maintenance staff noticed that some machines seemed to use much more oil than others of a similar size and workload. A monitoring programme and a three-tier maintenance system were implemented so that now tanks are topped up only when necessary. A systematic maintenance investigation and repair work are carried out if the machines are not reaching their standard benchmark figure. Even though there was an increase in the number of parts produced, these measures reduced hydraulic oil consumption by 70% between 1991 and 1998.

For more information about this and other sustainability initiatives at the company, see *Driving down waste puts the brakes on costs* (GC236)[8].

***Sustainability benefits of regular maintenance for cutting machines***

- It is cost-effective.
- Less interruption to business.
- Reduced energy costs.
- Better quality finished products.
- Longer machine life.
- Longer cutting tool life.
- Compliance with health and safety legislation.

***Drawback***

- Initial expenditure of money and time.

---

8 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise website (www.envirowise.gov.uk).

***Useful websites***

HMSO
**www.hmso.gov.uk**

Health and Safety Executive (HSE)
**www.hse.gov.uk**

### 3.6.7 Use of softer materials

Machining softer materials such as aluminium can be significantly faster compared with stainless steel and other metal alloys.

When manufacturing a metal product using metal removal machinery, consider if aluminium or any other softer metal could be used, as these offer significant sustainability benefits.

***Sustainability benefits of using softer materials***

- Faster machining.
- Improved manufacturing efficiency.
- Lighter materials (improved health and safety aspects).
- Potential to recycle the metals (eg aluminium).
- Materials could cost less (eg aluminium).
- Lower energy consumption for machining compared with 'hard' materials.

***Drawback***

- Applications may be limited.

## 3.7 Near-net shaping

An estimated 50% of production costs in metal machining are spent on geometric shaping. Implementing near-net shaping techniques could allow standard mechanical components to be manufactured at substantially lower costs due to:

- reduced machining and finishing operations;
- reduced material use.

Major advances in near-net practices have allowed the limitations (eg selective wear-resistant surfaces) of traditional techniques, such as sand casting, to be addressed. Design engineers now have an array of new techniques that provide versatile and adaptable engineering practices covering a wide variety of applications.

The various processes associated with near-net shaping - from traditional methods to more specialist concepts - are explained below. The advantages of these techniques are highlighted.

### 3.7.1 Casting

Casting is a general term used in the engineering industry. It encompasses numerous techniques covering a range of metals, properties, and surface finish and volume requirements. Other considerations, such as weight of the component and complexity of the geometry, are all influential in selecting the correct casting process.

To cast a component, you require a pattern that is used to produce the mould profile. These can be made of various materials and are associated with the particular type of casting process being used.

### *Sand casting*

Sand casting is a common process for producing parts with complex geometries and is often regarded as the cheapest method of producing a three-dimensional component.

The most common sand used in this process is silica and the grade of sand dictates the surface finish that can be achieved. The mould usually consists of sand particles approximately 200 - 300 μm in diameter. Zirconium sand is often used if a high-quality surface finish is required.

The sand is mixed with the binder and packed around the pattern. Once the two halves are connected, the void produced can be filled with molten metal via a sprue. Following cooling, the sand mould is removed mechanically leaving a raw casting for future machining.

#### *Sustainability benefits of sand casting*

- Relatively inexpensive.
- Mass production runs.
- Good for prototyping.

#### *Drawbacks*

- Generally poor dimensional control and surface finish.
- The process is limited in terms of minimum section thickness and thus is not suitable for thin sections or components with large section changes.
- Components may have a hard surface layer due to cooling and interaction between the sand. This can reduce cutting tool life.

#### *Useful Envirowise publication*

- *Optimising sand use in foundries* (GG119)

### *Investment casting*

Investment casting is used to produce relatively high tolerance cast components in various steels and other metals. A wax pattern is produced by injection moulding and attached to a sprue for multi-component runs. The sprue is then dipped into a slurry and sand mix. This is repeated several times and allowed to dry. The pattern assembly is then heated to remove the wax creating a negative impression of the desired component. The moulds are then filled with molten metal and allowed to cool. Following cooling, the shell is broken away and the sprue removed.

### *Sustainability benefits of investment casting*

- Minimal finishing operations are required following casting.
- The dimensional accuracy remains constant as the wax patterns are produced in an injection mould.
- Very good surface finish is achievable and it is possible to produce thin-walled components.
- This technique can be used on various metal alloys.

### *Drawbacks*

- Process is limited in terms of size and weight.
- The process is relatively expensive due to the high cost of wax mould tooling and ceramic production.
- The process is not suited to small batch runs. Although the process has good tolerances, further machining is required on most components.

### *Lost foam casting*

A lost foam casting is created by moulding desired shapes in polystyrene foam. These foam segments are then glued together to form a pattern. The pattern is then glued to a sprue and dipped into a ceramic slurry. The coated cluster is placed into a flask, which is then filled with sand. While the flask is being filled, it is vibrated so the sand fills all the voids in the coated pattern. Molten aluminium is then poured into a pouring cup, evaporating the foam cluster and filling the space which the foam occupied. After the metal has solidified, the metal cluster is pulled from the flask, the coating is flashed off in a quench tank, and the sprue is removed.

Typical applications for foam cast parts include cylinder heads, engine blocks and manifolds; other complex parts are potential candidates for this process.

### *Sustainability benefits of lost foam casting*

- Very complex geometries can be cast.
- The parts have good dimensional accuracy and do not require a sand core.
- The parts have fewer gasket surfaces as many of the pieces are cast together.

### *Drawbacks*

- Tooling costs are high making it unsuitable for small runs.
- Not all metal alloys can be cast in this manner and there is a limit on web thickness of 3 mm.

### *Useful websites*

Cast Metals Federation (CMF)
**www.castmetalsfederation.com**

Institute of Cast Metal Engineers (ICMF)
**www.ibf.org.uk**

British Foundry Association (BFA)
**www.castmetalsfederation.com/bfa.asp**

## 3.7.2 Powder metallurgy

Powder metallurgy components are manufactured by initially compacting lubricated metal powders in a die. The compacted 'green' part is ejected from the die and sintered in an oven under controlled conditions and atmosphere, such that the particles become metallurgically joined to produce a high integrity metal part at, or close to, the final component dimensions. The part may then be hardened (through or case) and finished (eg by grinding and polishing), depending on its end use.

Powder metallurgy is applicable to many metals and engineering steels, enabling components of varying requirements to be produced. It offers significant potential advantages to the engineering sector.

***Sustainability benefits of powder metallurgy***

- Material utilisation of over 90 - 95% can be achieved. This is up to a factor of two more than when machining from block, bar stock or forged/cast blanks.
- Machining requirements are reduced; the component often requiring just a final grinding operation.
- Energy consumption is less due to the reduction in heat treatment and machining operations.
- Manufacture time is reduced due to the fewer steps.
- Part cost can typically be reduced by up to 5 - 10%, compared with traditional routes.
- Parts are produced with close, reproducible tolerances.
- Component properties can be tailored to suit particular requirements, eg hardness and porosity.

***Drawbacks***

- Powder metallurgy is a specialist process and not typically carried out in-house. Companies are therefore reliant on an outside supplier.
- Buying in powder metallurgy blanks costs more than alternative routes. This extra cost has to be outweighed by the savings from the reduced machining and subsequent processing steps.
- Powder metallurgy is not suited to one-off or low production runs due to the initial die manufacture and process requirements. Typical production runs of 5 000 - 10 000 components/year may be required.

***Useful websites***

European Powder Metallurgy Association (EPMA)
**www.epma.com**

Institute of Materials, Minerals and Mining (IOM$^3$)
**www.iom3.org**

## 3.7.3 Metal injection moulding

Metal injection moulding combines powder metallurgy with plastic injection moulding to enable near-net metallic parts with a complex shape to be produced. Metal powders are mixed with a thermoplastic binder, typically to a 50 - 70% loading. The mix can then be moulded in conventional injection moulding machines to give the 'green' part, which is slightly larger than final requirements. The binder is partially removed, typically using heat or solvent, and the part is sintered as with powder metallurgy. During this process, the part shrinks in all dimensions. The part may then be heat-treated and, if required, machine-finished.

*Sustainability benefits of metal injection moulding*

- Complex metal shapes can be produced, similar to plastic moulded components. This overcomes the limit with powder metallurgy parts, which calls for no undercuts or projecting parts that make removal from the die impossible.
- There is little or no requirement for machining.
- It is a rapidly expanding technology due to its flexibility and the complexity of parts attainable.
- As with powder metallurgy, energy costs and machining requirements are low and material utilisation is very high (>95%).

*Drawbacks*

- The requirement for an injection moulding tool means the technique is not suited to low production runs. Precision casting may be a better choice for low to medium runs.
- Part size is typically less than 100 gms and wall thickness is 0.5 - 5 mm.
- Although increasing in use, the technique is still at a relatively early stage of development and commercialisation. There may be limitations in its cost-effectiveness.
- As with powder metallurgy, specialist suppliers are required.

*Useful website*

Institute of Materials, Minerals and Mining (IOM$^3$)
**www.iom3.org**

## 3.8 Alternative machining methods

Traditional machining processes such as turning and milling are becoming faster at metal removal and can profile very complicated geometries. However, various ‘new’ machining methods are now accepted as viable in certain applications and especially in machining hardened materials. These techniques are summarised below.

- **Electro discharge machining (EDM).** This process is based on the melting point of the material and not the hardness. An electrode is placed in a dielectric fluid near the metal surface and the component is oppositely charged. When the two conductors are close enough, a spark arcs across the dielectric fluid causing the metal to ‘burn’. This process is repeated until the component takes on the shape of the electrode.

  This process is ideal for tool-making applications where hardened materials are used. However, following the EDM ‘machining’ process, it may be necessary to hand finish the surfaces as the roughness value may not be to the desired specification.

- **Wire EDM.** A thin wire is used as an electrode and is held taught between two adjustable guides. The dielectric fluid in this case is deionised water and the component to be machined is totally submerged in the fluid. This process is similar to EDM, but the profile is generated by the X-Y-Z axis being moved. The process is also considered much faster than EDM. As with the standard EDM process, wire EDM is best suited to the production of dies and moulds, where pre-hardening of the materials is general practice.

- **Electrochemical machining (ECM).** The workpiece in this process forms the anode and the preformed electrode is the cathode. The surface of the material to be machined is therefore attracted to the electrode on which the chemically dissolved metal is deposited. As with the other EDM processes, ECM is machined independent of the material hardness and is therefore suited to hardened materials. Complicated profiles can be achieved on materials with a low machinability.
- **Electron beam machining.** An electron beam is generated and aimed, using magnetic fields, at the workpiece. When the electrons collide with the metal, heat is generated and the metallic surface is vaporised. This process is used in applications such as annealing, welding and metal removal. This technique is good for machining narrow slots and drilling small holes of around 100 μm.
- **Ultrasonic machining (USM).** A ductile and tough tool is pressed against the workpiece with constant force while a stream of abrasive slurry passes between the tool and the workpiece. This has two functions. The first is to offer up an abrasive particulate to the metal surface and thus remove material in its path. The second function is to carry away any metal particles and spent abrasive from the machining site. The majority of the cutting action comes from an ultrasonic (cyclic) force applied in addition to the other forces; the abrasive is therefore 'driven' into the metal. Materials that are difficult to machine, such as tungsten, can benefit from this type of metal removal. However, USM has limited applications.

***Useful websites***

Department of Mechanical Engineering, Bath University (student project)
**www.bath.ac.uk/~en9smd/intro.htm**

TWI World Centre for Materials Joining Technology (TWI Ltd is the operating arm of The Welding Institute)
**www.twi.co.uk/j32k/index.xtp**

### 3.8.1 Use of lasers

Although lasers have been used in industry for the last 20 years, the technology is still regarded as 'new'. However, applications have increased in recent years and the technology has also developed. Industrial lasers generally operate outside the 'visible spectrum', ie over 750 nm (infrared) or below 400 nm (ultraviolet).

A laser[9] is a beam of high energy collimated light, which is focused into a small area and thus can produce very high power densities. Many different types of laser are currently used in industry and the power can range from milliwatts to kilowatts.

The many types of laser (see Table 8 overleaf) are all designed to operate in a certain wavelength, power and, in some cases, application. These lasers fall into various classes depending on their potential to cause biological damage. All industrial lasers generally fall into Class IV and particular safety precautions are required before operating such equipment.

9 Laser = light amplification by stimulated emission of radiation.

**Table 8 Different types of laser**

| Type | Description | Main applications |
|---|---|---|
| ***Solid-state lasers*** | | |
| Ruby laser | Synthetic 'ruby' (or sapphire) is doped with chromium ions. Can range from milliwatts to hundreds of watts of energy. | Non-contact surface measurement. Distance measurement. Other meteorological applications. Extensive use in medicine. |
| NdYAG | A crystal of yttrium-aluminium-garnate is doped with neodymium ions. Can deliver over 5 kW of energy to the workpiece. | Welding sheet metals. Profile cutting of sheet materials. |
| ***Gas lasers*** | | |
| Carbon dioxide | Very high power lasers with 25 kW achievable at the workpiece. | Welding plate materials. Cutting plate materials. |
| HeNe | Helium and neon gases excited by electrical discharge. Relatively low power: 0.5 - 50 mW. | Alignment. Levelling systems. Positioning systems. |
| Argon ion laser | Uses a plasma of excited ions surrounded by a magnetic field to maintain the density of the beam. Power of approximately 1 - 25 W. | Semiconductor processing. Optical image processing. |

### *Sustainability benefits of lasers in engineering*

- Lasers allow materials to be heated up rapidly, leading to fast melting of the material being processed. Lasers can be utilised for various processing tasks, making them extremely versatile and relatively easy to adapt for different operations.
- With these processes, important advantages are achieved compared with conventional tools (eg high processing speed) due to the high concentration of energy and the high quality of the processed workpiece. Due to the intensity of the beam, deformations caused by excessive heating are minimal as the heat-affected zone is relatively small. This particular attribute minimises further processing or machining of the material's surface. All of these advantages result in reduced production costs, minimal material use and higher production rates.

### *Drawbacks*

- Not all materials lend themselves to laser welding or cutting and this can be a major hindrance to versatility. The initial capital expenditure is high and auxiliary items (eg delivery optics and fibre optics) are expensive to replace. The internal components have to be kept extremely clean to avoid absorption on mirrors and rods. Incorrect handling and dust can damage the delivery components, thus reducing their life significantly. Certain materials reflect the laser energy back into the machine, causing damage to the rods (which are also expensive).

**Useful websites**

Association of Industrial Laser Users (AILU)
**www.ailu.org.uk**

European Laser Applications Network (ELAN)
**www.ailu.org.uk/elan**

TWI World Centre for Materials Joining Technology (TWI Ltd is the operating arm of The Welding Institute)
**www.twi.co.uk/j32k/index.xtp**

UK Laser and Electro-Optics Trade Association (UKLEO)
**www.ukleo.org**

## 3.9 Training

The role of apprentices in the metal machining sector is critical to its sustainability. 'Hands-on' engineers are on the front line of manufacturing processes and it is important that they are trained adequately for their work tasks. Competent employees are essential to any successful business and without 'know-how' the functionality of a company can be seriously affected.

Today's apprentices need to be multi-disciplined; they need not only to be competent to use a range of machine tools but also to be equipped with IT skills. They should be capable of working with mechanised/automated equipment and have the ability to adapt rapidly to new technological developments.

Training of apprentices should be considered an investment with tangible returns in terms of:

- improved productivity;
- better quality work;
- increased efficiency;
- greater versatility.

It is important for apprentices to understand the underlying principles of their actions and not just 'how' to operate a piece of machinery. A thorough understanding of the principles will result in better decision-making capabilities in production activities and contribute to continuous improvement and development programmes.

Training also gives people the feeling of being valued and respected; this is important for all employees.

- Identify your current training needs:
  - Ask staff if they understand how to get the best out of their machines.
  - Check product quality performance.
  - Check for the number of defects generated.
  - Compare the gap in competence between your 'best' employee and 'worst' employee and consider if training could bridge this gap.
  - Compare your skill levels with those in similar industrial sectors. How does your company measure up?

- Identify suitable training courses. Machine tool suppliers often run external courses for operators. Training courses can also be identified through sources such as local colleges, higher education, the Internet and the local press.
- Monitor performance. After receiving training, check that the knowledge/skill gap has been addressed.
- Consider refresher training. This can be beneficial when:
  - there have been technological developments affecting a machining process;
  - lack of familiarity means that some aspects of a machining task are being given greater priority;
  - there are signs of reduced/poor operator performance, eg reduced quality performance and an increase in the number of health and safety incidents.

The subject of salaries should not be overlooked. Some companies are reluctant to send staff on external training programmes since they perceive that their 'market potential' could increase and they may take these skills and join a competitor. However, it makes business sense to pay the going rate for your staff as this can help to reduce the temptation to move to a similar job at another company. Fear of losing staff should not be considered a barrier to equipping staff with the right skills. Competitive salaries will also help to attract new apprentices into the sector and address the chronic skill shortage.

Any business is only as good as its employees and these are ultimately a company's most important asset. Look after them and equip them sufficiently so in return they can give their best to the business.

### *Sustainability benefits of effective training*

- Skilled and competent workforce that does the job properly.
- Improved business efficiency.
- Improved employee satisfaction.
- Improved health and safety standards.

### *Drawback*

- Initial outlay of money/time for training.

# Next steps



- Obtain senior management commitment to adopt sustainable manufacturing.
- Increase employee awareness of the need to become sustainable and the part they can play.
- If you have not already done so, implement a systematic waste minimisation programme.
- Analyse data on resource use and waste generation to identify opportunities for improvement.
- Think about how you could implement lean manufacturing techniques in your company. Could you adopt faster manufacturing or near-net shaping? Or use alternative machining methods?
- Optimise your use of metalworking fluids, lubricating oils, hydraulic oils, etc.
- Take action to boost your recycling of swarf, metalworking fluids and other materials.
- Consider training needs for all employees.
- Develop an action plan for implementing sustainable manufacturing that includes a statement of your objectives, realistic targets and a date for reviewing progress.
- Contact the Environment and Energy Helpline on 0800 585794 to:
  - order any of the free publications signposted in this Guide;
  - seek free advice from an Envirowise or an Action Energy consultant;
  - request a free *Fast*Track or design**track** visit.

Envirowise - Practical Environmental Advice for Business - is a Government programme that offers free, independent and practical advice to UK businesses to reduce waste at source and increase profits. It is managed by Momenta, an operating division of AEA Technology plc, and Technology Transfer and Innovation Ltd.

Envirowise offers a range of free services including:

- Free advice from Envirowise experts through the Environment and Energy Helpline.
- A variety of publications that provide up-to-date information on waste minimisation issues, methods and successes.
- Free, on-site waste reviews from Envirowise advisors, called *Fast*Track visits, that help businesses identify and realise savings.
- Guidance on waste minimisation clubs across the UK that provide a chance for local companies to meet regularly and share best practices in waste minimisation.
- Best practice seminars and practical workshops that offer an ideal way to examine waste minimisation issues and discuss opportunities and methodologies.

*For further information please contact the*

**Environment and Energy Helpline 0800 585794**

envirowise
Practical Environmental Advice for Business

Harwell International Business Centre | Didcot | Oxfordshire | OX11 0QJ
E-mail: helpline@envirowise.gov.uk Internet: www.envirowise.gov.uk