means to accommodate eleventh-hour engineering changes. There is a strong trend toward shop floor programming in Europe, especially in the auto industry, mainly driven by pressures to reduce cost and time.

Metrology, Quality awareness and inspection
An essential part of world-class tool making.

Project management
An essential part of world-class tool making.

Robotics

Robotic loading and unloading of machines is the next level of automation that many mould shops are rising to. System 3R, best known for its pioneering integrated tooling systems for EDM, saw more mould shops purchase its Workman robotic systems for mills and EDMs last year than in the three previous years combined. Automation allows increased productivity level to be inherent to the process and not the operator.

Automation is a strong theme in the machining of dies for stamping or forming sheet metal in Europe. There is a clear trend to high speed machines with automatic pallet changers and automatic head changers (but no automatic tool changer).The pre-eminence of mould and die cavity work as a major application for electrical discharge machines is well understood. In fact, "die sinkers" is still a very common name for ram EDMs. Wire EDM-ing is also widely used in die and mould work. Few mould and die shops do not have at least one EDM in the shop. EDM technology has advanced rapidly in the last few years. These changes are altering the strategic value of EDM for mould and die work.

One important change is that both ram and wire machines are considerably faster than they were only a few years ago. "Burn" times have been reduced, although they are still measured in hours. The days of setting up one job and letting it run in the unattended mode overnight are disappearing. In order to achieve extended unattended operation, some means of automating work piece and/or electrode changing must be provided. This is a major incentive for installing automated robotic handling systems on EDM units in mould and die shops. A faster burning EDM with robotic automation will consume electrodes quickly. Meeting this demand creates a bottleneck in electrode fabrication. In the United States, high speed machining of graphite has become an increasingly popular solution. The most significant time savings lie in reducing or eliminating benchwork and polishing. Typically, the time reduction is in the neighbourhood of 50 to 75 percent.

Eliminating most hand work means that the as-machined, CAD-defined geometry will not be lost. High speed machining allows a shop to produce electrodes that are virtually identical to the customer's actual geometry. If more than one electrode must be produced, each "copy" will be exactly alike when benchwork can be reduced or eliminated. Having electrodes that are virtually the same means that virtually identical cavities can be produced at the EDM. This is a major plus for multi-cavity moulds for producing interchangeable injected plastic parts. Highly consistent, as-machined results also mean that EDM time can be reduced. A near-perfect match between electrodes creates optimum conditions for efficient EDMing. Another advantage of high speed

machining appears when producing electrodes with thin walls or ribs, especially in graphite, a very brittle material. With high speed machining, stepovers as fine as 0.001 or 0.002 inch put very little pressure between the cutter and the graphite, whereas conventional machining would almost always cause the rib or wall to break off before being completed. Being able to machine thin walls and ribs allows one-piece electrodes with all ribs in place to be produced. One-piece electrodes eliminate the multiple setups and eliminate the location errors that may have occurred and accumulated between setups. This saves time and improves quality.

Meeting the technical challenges of efficient, high precision, highly automated mould/die machining is within reach. The equipment to do it is available. Proof from the field that this technology works is abundant. Restructuring a shop to exploit this technology is a manageable affair. Many believe however, that achieving a balanced workload is the top priority—a consideration even more important than having the latest equipment dedicated to high end die/mould work. A shop usually has no control of workload. No matter how competitive a shop is technically, it is ultimately dependent on having sufficient volume to return the investment.

International Trends in Skills Development

International trends in skills development follow the technology trends. Tool and Die making has shifted from an occupation requiring primarily artisan skills to one which requires extremely sophisticated skills in areas such as IT and design, inter alia.

Most artisan tool and die makers learn their trade through four or five years of education and training in formal apprenticeships or postsecondary programs. Apprenticeship programs include a mix of classroom instruction and job experience and often require 10,400 hours, or about five years to complete. According to most employers these apprenticeship programs are the best way to learn all aspects of tool and die making. Tool and die maker trainees learn to operate milling machines, lathes, grinders, wire electrical discharge machines, and other machine tools. They also learn to use hand-tools for fitting and assembling gauges, and other mechanical and metal-forming equipment. In addition, they study metalworking processes, such as heat treating and plating. Classroom training usually consists of mechanical drawing, tool designing, tool programming, blueprint reading, and mathematics courses, including algebra, geometry, trigonometry, and basic statistics. Tool and die makers increasingly must have good computer skills to work with CAD technology, CNC machine tools, and computerized measuring machines.

Because tools and dies must meet strict specifications—precision to one ten-thousandth of an inch is common—the work of tool and die makers requires skill with precision measuring devices and a high degree of patience and attention to detail. Good eyesight is essential. Persons entering this occupation also should be mechanically inclined, able to work and solve problems independently, and capable of doing work that requires concentration and physical effort. As well as the artisan skills required, the major additional competencies required in the industry world wide are indicated in the following list:

Table Six: High Order Skills Required

Competency Category	Specific Skills
Product Design	CAD CAM Process Simulation Material Flow Simulation Verification Software
Prototyping	Various
Project Management	Manufacturing environment
Manufacturing Technologies	See trends above and; CAM High Speed Machining
Production Technologies	See above trends and; Automated Quality Control Data Management Robotic Material Handling Production Software Sensor Technology

Source: R. Tinkler (2004) Enterplan

Underpinning these high order skills there is a need to ensure that the level of general artisan training is of a high standard to enable easy progression from one level to the other. When the two major categories of artisan and high order skills required are unpacked, it becomes apparent that skills will vary to some degree as well depending on the type of technology platform in involved, that is, whether press tools, plastics and other moulds, or dies are being made. Variations are in some cases slight, but in other are marked. These too will be influenced by the developments in technology that permeate the industry. The following table offers a summary of the skills required by technology platform,

Table Seven: Skills required: Broad Technology Platform

Technology Platform	Skill
Plastic Moulds & Pressure Die Casting Dies	Estimating Project Management Design Purchasing Blocking Up General Machining Cutter Path Generation CNC Milling Spark Erosion (EDM) Benching Tryout Texturising Sampling & ISIR

Technology Platform	Skill
	Welding Metrology, Inspection, QA and QC
Press Tools	Estimating Design Purchasing Pattern Making Blocking Up Simulation Cutter Path Generation CNC Milling Benching Spark Erosion Fitting Tryout Commissioning Sampling & ISIR Heat Treatment Welding Metrology, Inspection, QA and QC

Source: R. Tinkler (2004) Enterplan & Blueprint International

Skills Required by Job Function

For each major technology platform as outlined in the tables above, specific skills are required. Typically, these skills are organized around easily identifiable job functions which are described below. The table below indicates the skills required for each major job function in the plastic moulds and pressure die casting tool making process:

Table Eight: Skills required: Plastic Moulds and Pressure Die Casting

Job Description & Skills Needed	Job Content
The Estimator Estimators Tasks: to decide the split line of the component how it is removed from the tool once moulded how the tool will open so that the component can be produced and removed how the tool is to be fed (how you get the molten plastic or alloy in most efficiently in order to achieve product quality, economical use of raw material and shortest cycle time) How the tool is to be cooled	The Plastic Mould and pressure die tool making process starts from an enquiry from a customer. The enquiry may be in the form of: A CAD file in 2D or 3D format A CAD file in the form of a solid model A CAD file in the form of a surface model A CAD file in the form of a wire frame A printout of any of the above A 2D or 3D hard copy drawing A freehand sketch A physical sample made from an existing mould

Job Description & Skills Needed	Job Content
The Estimator needs to draw on a wide range of experience in order to envisage how the tool will work. An Estimator will need to be an experienced mould or pressure die tool maker. He/she will need to have spent several years as a Bench Hand, benching, assembling and testing tools.	A stereo lithography sample A set of photographs
The Project Manager It is essential to have a Project Manager to ensure that tool making projects are completed on time and to budget.	Many customers require formal weekly progress reports and this is achieved by the use of Gantt charts or by using computer software such as "MS Project". The Project Manager will design and maintain the Timing Plan. A good working knowledge of tool making is required but it is not necessary for a Project Manager to be a skilled tool maker.
The Designer	Designers often work for a subcontract design company, specialising in tool design. The reasons for this are that, in particular in small tool making companies, there is not enough work to sustain a full time Designer and Designers can generate very high incomes. Tool designs need to be started and completed very quickly after the start of an order and subcontract Designers, whether freelance or company based may be a more flexible resource. Tool Designers need to have good experience of the tools that they design and, traditionally, this will have been obtained by completing a time-served apprenticeship with a number of years experience. The modern day Designer will have good computer skills as well as tool making experience as tools will be designed using CAD techniques. Modern CAD packages, such as VERO International "Visicad", provide sophisticated packages that considerably help the designer. Apart from the mechanical actions of the tool, there are also software packages to

Job Description & Skills Needed	Job Content
	simulate the action of the tool and the flow of plastic material within it. The latter aspect is important in determining the feed system and is usually a service provided by the supplier of the feed system. The first objective of the tool Designer is to provide a General Assembly drawing (GA) for approval by the customer. Once approval is given, a Bill of Materials (BOM) can be produced so that all the long lead time materials and those necessary to get started in manufacture can be ordered. Detailing of the tool will follow and drawings will be produced in accordance with the Timing Plan. The Tool Designer works very closely with the Estimator, the customer and the tool making company. Like the Estimator, the Tool Designer will start with any or all of the following, plus a full specification of how the tool will work, what the estimator and customer: have agreed for the specification of the tool including the feed system: o A CAD file in 2D or 3D format o A CAD file in the form of a solid model o A CAD file in the form of a surface model o A CAD file in the form of a wire frame o A 2D or 3D hard copy drawing
Purchasing	Purchasing is carried out once the GA has been approved and the BOM prepared. In small companies, the Designer or the Estimator may order the materials. In larger companies, where strategic purchasing can be more effectively carried out, there may be a separate Purchasing Department.

Job Description & Skills Needed	Job Content
Blocking Up	Blocking Up is the process whereby, blocks of tool steel are prepared for later machining of the cavities or impressions (identical terms for the shape of the finished product in the tool, in effect, a negative image of the final product). These blocks may be to produce the actual body of the tool or slides which fit into the main body. Mould tools will often be made from custom components sourced from suppliers like Hasco. These are pre-prepared and may not require the Blocking Up process, other than to produce any slides.
General Machining	The impression blocks, which form the finished component are held in the tool assembly which is a series of plates, pillars, locking devices etc, which go to make up the mould tool. There is a "Fixed Half" and a "Moving Half" to the tool. The Moving Half, carries the ejector plate and the ejectors. All these components of the tool are produced by conventional or CNC machines, the operation of which requires capable machinists who are able to work from hard copy drawings or by utilising CADCAM techniques. A working knowledge of tool making is required but it is not necessary for the machinists to be skilled tool makers.
Cutter Path Generation	Cutter Path Generation is the process whereby a program (that controls the cutting tools that produce the impressions or cavities using a CNC machine) generates production from either a surface or solid model of the component. The cutter path will take into consideration the contraction of the plastic material when it cools in the mould. Cutter paths will be generated for cutting the impression direct or for machining electrodes for Spark Erosion Machines. In the past, before CNC machines were available, the process was carried out by a copy milling machine, using a model of the component.

Job Description & Skills Needed	Job Content
	Output may be directly to the CNC machine or by media such as CDROM or Floppy Disc. A person who produces Cutter paths will need to be skilled in CADCAM and have a very good working knowledge of the both the machining processes and mould and die tool making
CNC Milling	CNC Milling is now universally used for producing either the electrodes for Spark Erosion or for machining the impressions directly into the tool steel blocks. A rapidly growing CNC Milling process is that of "High Speed" milling, which utilises advances in cutting tool materials and design together with high speed computers. Apart from the reduction in floor to floor time, high speed milling can produce superior surface finishes which require little or no further work by hand. CNC Milling machines may have a Setter and an operator or a Setter/Operator. Once set up, machining times may be quite considerable, on big tools times may be several weeks, and so it is quite normal for one person to look after a number of machines at the same time. It is also normal, to operate the machines 24 hours a day and seven days a week2. CNC Machinists will probably have served an apprenticeship followed by special training , probably provided by the machine supplier or by a specialist CSDCAM company like "DELCAM". CNC Machinists will need a good working knowledge of tool making.
Spark Erosion or Electrical Discharge Machining (EDM) : Solid Electrode	Spark Erosion uses electrodes manufactured by CNC machine, conventional machine or even by hand to erode impressions or cavities into tool steel blocks and slides. Conventional Spark Erosion utilises an electrode that basically replicates the finished component with allowances for spark gap and contraction. In it's simplest form. The process is a simple up and down movement, sometimes with oscillation in the horizontal plane. More recently, with the advance of computer technology, CNC Spark

Job Description & Skills Needed	Job Content
	Erosion machines have made big advances by allowing the use of simpler electrodes and by producing far superior surface finishes. These features also allow for reduced floor to floor times and better quality end products
Spark Erosion or Electrical Discharge Machining (EDM) :Wire	A wire Erosion machine utilise a very fine vertical wire to cut, basically, 2D shapes into tool steel, similar to a band saw but to very fine tolerances. The wire is constantly spooling from one reel to another in the vertical plane with the workpiece moving in the horizontal plane. Because of the ability to incline the vertical axis of the wire, it is also possible to cut tapered holes and slots. A Spark Erosion operator would also be able to set the machine and would likely operate more than one machine at a time. Spark Erosion machines are also run on a 24 hour, seven day a week basis if possible. Operators would likely have served an apprenticeship and would probably have specialist training by the machine producers, such as "Charmilles".
Benching	Bench Hands or Bench Toolmakers will prepare and assemble the components of a mould or die tool ready for try out. They will also make any necessary adjustments after tryout and fully complete the tool ready for production. Benching is an extremely skilled occupation. Bench hands will have served an apprenticeship and will need several years experience to become fully qualified. They may be responsible for tools that may cost many tens of thousands of Pounds Stirling or tools which may be critical for maintaining production schedules. In modern JIT environments, one item missing from an automobile production line can cost thousands an hour in lost output. The Bench Hand will put the final finish on the tool, or prepare the surface of the impression ready for "Texturising". Probably, the highest level of skill for a Bench Hand is to put the finish polish on a Lens or mirror tool. There are machines that can mechanically polish

Job Description & Skills Needed	Job Content
	impressions and these will usually be under the control or direction of the Bench Hand. In the final assembly of a mould or die, a critical operation is "bedding out" the faces of the mould or die that must seal and produce an acceptable split line on the final component. Any error in this process will produce a "Flash" - a thin piece of excess material, which would be unacceptable. The bedding out process is usually carried out on a special press and requires a great deal of skill and patience.
Tryout	Small companies are unlikely to have in house try out facilities and will either have to purchase time at a moulding or casting company offering a try out service or at the customers facility. It is possible to do some basic trying out of a tool by using hot wax on a bedding out press but this process has it's limitations. In small companies, Tryout is generally carried out by the Bench Hand. Large companies, with in house presses, may have people specifically trained to do Tryout. In such cases, the person would need to have had some tool making experience.
Texturising	Texturising is the chemical etching of a surface in order to achieve a cosmetic finish, such as a natural leather look, on a finished component. It is a specialist process usually carried out by a subcontractor but can be done "in-house" if the technology has been purchased. Texturising is a skilled operation and anybody carrying it out would need to have a good working knowledge of mould and die tool making.
Sampling and ISIR	Sampling may be carried out in house, with a subcontract tryout company or at the customers facility. It is very important that the sampling conditions replicate those of production. Apart from maybe overseeing the installation of the

Job Description & Skills Needed	Job Content
	tool on the moulding or casting press, it does not require a skilled toolmaker to be present when sampling a tool. An ISIR or Initial Sample Inspection Report, is the formalised sampling procedure that most customers require when they purchase a mould or die. Basically a Quality Assurance task, the ISIR will call for a full dimension and quality check of the finished, moulded or cast component. The requirements of an ISIR are laid down in a company's Quality System and the skills required are those of metrology. Many tool making companies will have sophisticated measuring equipment such as a Coordinate Measuring Machine, probably with links to the company's CAD CAM system so that measurements can be directly compared with the "native" data (original CAD model). Knowledge and experience of mould and die tool making are not necessary for measuring.
Welding	Welding is not something that you would plan to do when making a tool. However, accidents happen in the manufacture of a tool and in the operation of a tool. Tools also might need minor changes or become worn and some maintenance may be required. Mould and Die impressions can be repaired and modified by welding. This is a very skilled task as it is very easy to cause even more damage. Anyone carrying out the welding process needs to be very well trained and experienced as a welder. It is normally a task carried out by a subcontract specialist welder and unlikely to be a skill that a small or medium sized tool making company would have in house. It is a skill that a moulds and die tool making company would need to be able to access in emergencies.

Job Description & Skills Needed	Job Content
Dimensional Metrologist	Maintenance care and calibration of instruments Calculation of uncertainty budgets Determination of sources of measurement errors Criteria for choosing certain measuring instruments Compiling of calibration procedures Generating and issuing of calibration reports Ensuring traceability to National Standards
Quality Control Inspector	Usage, maintenance and care of measuring equipment Interpretation of engineering drawings including geometrical tolerance Sampling methods Component measurement Use of standard measuring machines including roundness, surface roughness, hardness, profile projectors and co-ordinate measuring machines (3D designing and surface modeling, Reverse engineering, 3D scanning/laser digitizing, Rapid prototyping, creation of machining programs) Statistical process control Liaison with sub-contractors Generating of QC documentation including inspection reports, concessions, acceptance and rejection notes
QA Personnel	Implementation and evaluation of quality management systems eg ISO 9001:2000 Compiling of: Quality policy manuals Procedure manuals Work instructions Audit planning schedules (internal and external) Quality awareness training of staff members Conducting of audits (internal) Maintenance of quality management systems Liaison with certification organizations Quality costing and analysis Reviewing of systems and reporting to top management Machine capability studies

Source: R. Tinkler (2004) Enterplan & Blueprint International / TASA