TOOL, DIES AND MOULDS REPORT

1. WHAT IS TOOLING?

The equipment required to convert raw material into a required shape is commonly referred to as tooling.
The process of equipment manufacture that aids in the conversion of a raw material into a required shape is commonly referred to as tool, die and mould making.

Materials converted include:

- Metals
- Aluminium
- Polymers (Plastics)

Tooling is found in almost all manufacturing industries including:

- Automotive
- Aerospace
- Rail & Marine
- Defense
- Mining
- Agro-processing
- Mineral beneficiation
- Leisure
- Packaging (foodstuffs, consumer goods and electronics)

The manufacturing industry is dependant on the availability of a good tool, die and mould making industry.

Tools, dies and moulds directly contribute to:

- Manufacturing output capacity,
- Quality standard of a product produced,
- Price competitiveness of the product produced,
- Lifecycle cost of a product produced.

2. DEFINITION OF INDIVIDUAL AREAS OF TOOL, DIES AND MOULDS.

I. WHAT IS A TOOL?

A machine tool is a powered mechanical device, typically used to fabricate metal components of machines by machining, which is the selective removal of metal. The term machine tool is usually reserved for tools that used a power source other than human movement, but they can be powered by people if appropriately set up. Many historians of technology consider that the true machine tools were born when direct human involvement was removed from the shaping or stamping process of the different kinds of tools.

Machine tools can be powered from a variety of sources. Human and animal power are options, as is energy captured through the use of waterwheels. However, machine tools really began to develop after the development of the steam engine, leading to the Industrial Revolution. Today, most are powered by electricity.

Machine tools can be operated manually, or under automatic control. Early machines used flywheels to stabilize their motion and had complex systems of gears and levers to control the machine and the piece being worked on. Soon after World War II, the NC, or numerical control, machine was developed. NC machines used a series of numbers punched on paper tape or punch cards to control their motion. In the 1960s, computers were added to give even more flexibility to the process. Such machines became known as CNC, or computerized numerical control, machines. NC and CNC machines could precisely repeat sequences over and over, and could produce much more complex pieces than even the most skilled tool operators.

Before long, the machines could automatically change the specific cutting and shaping tools that were being used. For example, a drill machine might contain a magazine with a variety of drill bits for producing holes of various sizes. Previously, either machine operators would usually have to manually change the bit or move the work piece to another station to perform these different operations. The next logical step was to combine several different machine tools together, all under computer control. These are known as machining centers, and have dramatically changed the way parts are made.

From the simplest to the most complex, most machine tools are capable of at least partial self-replication since they are machines, and produce machine parts as their primary function.

Examples of machine tools are:

Broaching machine. A broach is a series of progressively taller chisel points mounted on a single piece of steel, typically used to enlarge a circular hole into a larger noncircular shape such as a square or other desired shape.

Drill press. A drill press (also known as pedestal drill, pillar drill, or bench drill) is a fixed style of drill that may be mounted on a stand or bolted to the floor or workbench. A drill press consists of a base, column (or pillar), table, spindle (or quill), and drill head, usually driven by an induction motor. The head has a set of handles (usually 3) radiating from a central hub that, when turned, move the spindle and chuck vertically, parallel to the axis of the column. The table can be adjusted vertically and is generally moved by a rack and pinion; however, some older models rely on the operator to lift and reclamp the table in position. The table may also be offset from the spindle's axis and in some cases rotated to a position perpendicular to the column. The size of a drill press is typically measured in terms of swing. Swing is defined as twice the throat distance, which is the distance from the center of the spindle to the closest edge of the pillar. For example, a 16-inch drill press will have an 8-inch throat distance.

Gear shaper. A gear shaper is a machine tool for cutting the teeth of internal or external gears. The name shaper relates to the fact that the cutter engages the part on the forward stroke and pulls away from the part on the return stroke, just like the clapper box on a planer shaper. To cut external teeth, a different machine called a hobbing machine can be used.
The cutting tool is also gear shaped having the same pitch as the gear to be cut. However number of cutting teeth must be less than that of the gear to be cut for internal gears. For external gears the number of teeth on the cutter is limited only by the size of the shaping machine

Hobbing machine. A hobbing machine is a special form of milling machine that cuts gears. It is the major industrial process for cutting (as opposed to grinding) spur gears of involute form.
The machine forms the gear via a generating process by rotating the gear blank and the cutter (called a hob) at the same time with a fixed gearing ratio between hob and blank. The hob has a profile given in cross-section by the fundamental rack for the gear tooth profile and is in the form of a helix so that the sides of the teeth on the hob generate the curve on the gear. The helix has a number of cuts parallel to the axis to form the cutting teeth and the profile is suitably relieved to provide cutting clearance.

Hone. A hone is a machine tool used in the manufacture of precision bores to improve the geometry, surface finish and dimensional control of the finished part. This process is called honing.
Typical applications are the finishing of cylinders for internal combustion engines, air bearing spindles and in gear manufacturing. Types of hone are many and various but all consist of one or more abrasive stones that are held under pressure against the surface they are working on.

Lathe. A lathe is a machine tool which spins a block of material to perform various operations such as cutting, sanding, knurling, drilling, or deformation with tools that are applied to the workpiece to create an object which has symmetry about an axis of rotation.

Lathes are used in woodturning, metalworking, metal spinning, and glassworking. Lathes can be used to shape pottery, the best-known design being the potter's wheel. Most suitably equipped metalworking lathes can also be used to produce most solids of revolution, plane surfaces and screw threads or helices. Ornamental lathes can produce three-dimensional solids of incredible complexity. The material is held in place by either one or two centers, at least one of which can be moved horizontally to accommodate varying material lengths. Examples of objects that can be produced on a lathe include candlestick holders, cue sticks, table legs, bowls, baseball bats, crankshafts and camshafts.

Milling machine. A milling machine is a machine tool used for the complex shaping of metal and other solid materials. Its basic form is that of a rotating cutter or endmill which rotates about the spindle axis (similar to a drill), and a movable table to which the workpiece is affixed. That is to say, the cutting tool generally remains stationary (except for its rotation) while the workpiece moves to accomplish the cutting action. Milling machines may be operated manually or under computer numerical control (CNC).
Milling machines can perform a vast number of complex operations, such as slot cutting, planing, drilling, rebating, routing, etc.

Shaper. A shaper is a machine tool used for shaping or surfacing metal and other materials.

Planer. A planer is a type of metalworking machine tool that is analogous to a shaper, but larger, and with the entire workpiece moving beneath the cutter, instead of the cutter moving above a stationary workpiece. The work table is moved back and forth on the bed beneath the cutting head either by mechanical means, such as a rack and pinion gear, or by a hydraulic cylinder.
Planers and shapers were used generally for two types of work: generating accurate flat surfaces and cutting slots (such as keyways). Planers and shapers are now obsolescent, because milling machines have eclipsed them as the machine tools of choice for doing such work. However, they have not yet entirely disappeared from the metalworking world

Stewart platform mills. A Stewart platform is a kind of parallel manipulator using an octahedral assembly of struts. A Stewart platform has six degrees of freedom (x, y, z, pitch, roll, & yaw).

Grinders. A grinding machine is a machine tool used for producing very fine finishes or making very light cuts, using an abrasive wheel as the cutting device. This wheel can be made up of various sizes and types of stones, diamonds or of inorganic materials. For machines used to reduce particle size in materials processing see grinding.

II. WHAT IS A DIE?

A die is a specialized tool used in manufacturing industries to cut, shape and form a wide variety of products and components. Like molds and templates, dies are generally customized and uniquely matched to the product they are used to create. Products made with dies range from simple paper clips to complex pieces used in advanced technology.

Illustration: Progressive die with scrap strip and stampings

Forming dies are typically made by tool and die makers and put into production after mounting into a press. The die is a metal block that is used for forming materials like sheet metal and plastic. For the vacuum forming of plastic sheet only a single form is used, typically to form transparent plastic containers (called blister packs) for merchandise. Vacuum forming is considered a simple molding thermoforming process but uses the same principles as die forming. For the forming of sheet metal, such as automobile body parts, two parts may be used, one, called the punch, performs the stretching, bending, and/or blanking operation, while another part, called the die block, securely clamps the workpiece and provides similar, stretching, bending, and/or blanking operation. The workpiece may pass through several stages using different tools or operations to obtain the final form. In the case of an automotive component there will usually be a shearing operation after the main forming is done and then additional crimping or rolling operations to ensure that all sharp edges are hidden and to add rigidity to the panel.

a) Die operations and types

Die operations are often named after the specific type of die that performs the operation. For example a bending operation is performed by a bending die. Operations are not limited to one specific die as some dies may incorporate multiple operation types.

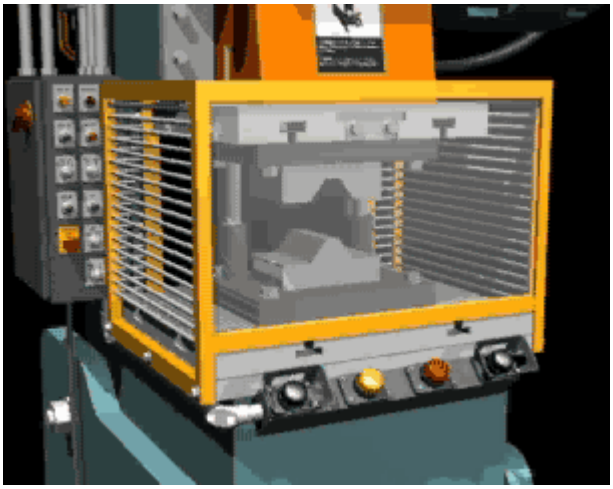

Illustration: Press with bending die

Bending: The bending operation is the act of bending blanks at a predetermined angle. An example would be an "L" bracket which is a straight piece of metal bent at a 90° angle. The main difference between a forming operation and a bending operation is the bending operation creates a straight line bend (such as a corner in a box) as where a form operation may create a curved bend (such as the bottom of a drinks can).
Blanking: A blanking die produces a flat piece of material by cutting the desired shape in one operation. The finish part is referred to as a blank. Generally a blanking die may only cut the outside contour of a part, often used for parts with no internal features.
Broaching: Broaching is the process of removing material through the use of multiple cutting teeth, with each tooth cutting behind the other. A broaching die is often used to remove material from parts that are too thick for shaving.
Bulging: A bulging die expands the closed end of tube through the use of two types of bulging dies. Similar to the way a chef's hat bulges out at the top from the cylindrical band around the chefs head.
Coining: is similar to forming with the main difference being that a coining die may form completely different features on either face of the blank, these features being transferred from the face of the punch or die respectively. The coining die and punch flow the metal by squeezing the blank within a confined area, instead of bending the blank. For example: an Olympic medal that was formed from a coining die may have a flat surface on the back and a raised feature on the front. If the medal was formed (or embossed), the surface on the back would be the reverse image of the front.
Compound operations: Compound dies perform multiple operations on the part. The compound operation is the act of implementing more than one operation during the press cycle.

Compound die: A type of die that has the die block (matrix) mounted on a punch plate with perforators in the upper die with the inner punch mounted in the lower die set. An inverted type of blanking die that punches upwards, leaving the part sitting on the lower punch (after being shed from the upper matrix on the press return stroke) instead of blanking the part through. A compound die allows the cutting of internal and external part features on a single press stroke.
Curling: The curling operation is used to roll the material into a curved shape. A door hinge is an example of a part created by a curling die.
Cut off: Cut off dies are used to cut off excess material from a finished end of a part or to cut off a predetermined length of material strip for additional operations.
Drawing: The drawing operation is very similar to the forming operation except that the drawing operation undergoes severe plastic deformation and the material of the part extends around the sides. A metal cup with a detailed feature at the bottom is an example of the difference between formed and drawn. The bottom of the cup was formed while the sides were drawn.
Extruding: Extruding is the act of severely deforming blanks of metal called slugs into finished parts such as an aluminum I-beam. Extrusion dies use extremely high pressure from the punch to squeeze the metal out into the desired form. The difference between cold forming and extrusion is extruded parts do not take shape of the punch.
Forming: Forming dies bend the blank along a curved surface. An example of a part that has been formed would be the positive end (+) of an AA battery.
Cold forming (cold heading): Cold forming is similar to extruding in that it squeezes the blank material but cold forming uses the punch and the die to create the desired form, extruding does not.
Roll forming: is a continuous bending operation in which sheet or strip metal is gradually formed in tandem sets of rollers until the desired cross-sectional configuration is obtained. Roll forming is ideal for producing parts with long lengths or in large quantities.

Horning: A horning die provides an arbor or horn which the parts are place for secondary operations.
Hydroforming: Forming of tubular part from simpler tubes with high water pressure.
Pancake die: A Pancake die is a simple type of manufacturing die that performs blanking and/or piercing. While many dies perform complex procedures simultaneously, a pancake die may only perform one simple procedure with the finished product being removed by hand.
Piercing: The piercing operation is used to pierce holes in stampings.
Progressive die: Progressive dies provide different stations for operations to be performed. A common practice is to move the material through the die so it is progressively modified at each station until the final operation ejects a finished part.
Shaving: The shaving operation removes a small amount of material from the edges of the part to improve the edges finish or part accuracy. (Compare to Trimming).
Side cam die: Side cams transform vertical motion from the press ram into horizontal or angular motion.
Sub press operation: Sub-press dies blank and/or form small watch, clock, and instrument parts.

Swaging: Swaging (necking) is the process of "necking down" a feature on a part. Swaging is the opposite of bulging as it reduces the size of the part. The end of a shell casing that captures the bullet is an example of swaging.
Trimming: Trimming dies cut away excess or unwanted irregular features from a part, they are usually the last operation performed.

b) Die casting

For the casting of plastic to make components (such as bottle caps or combs) or the forming of low melting point metals (such as zinc alloy pot metal, lead, aluminum, or magnesium), a multipart die is used in a process called injection moulding. For automotive parts such as the cases of automatic transmissions these dies may be quite complex, as they must be dissasembled in specific order to ensure that the workpiece is released freely from the casting die. Parts or products produced by this method are referred to as die cast. Compared to lost wax casting the marginal production can be quite cheap, once the substantial investment in tooling and materials handling equipment is made. Compared to sand casting the die casting method can reproduce fine details on complex parts and yield a smooth surface, greatly reducing machining and polishing requirements. As some small portion of metal may leak between the mating seams of the die this can result in a sharp edge of metal called flash, which must be removed by grinding and buffing. For small metal toys the term die cast is generally considered a mark of quality, especially when compared to the cheaper stamping of lithographed sheet metal, or bare stamped metal possibly later painted.

Products created by forming dies are:

- Metal spoon, fork, and knives
- Aluminum cans
- Car fender, bumper, door, hood, piston, rods, and frame
- Clothing zipper and buttons

c) Thread cutting

Another device also called a die is a nut-like thread cutting device for making screw threads on rod stock. This device may also be used to restore damaged threads - a method called chasing. (Other methods are generally used to produce machine screws and small bolts in quantity — they are formed by a process called rolling.)
For high production a die head may be used. Its operation is very similar but does not require "unthreading" at the end of the cut. The head's construction permits the die head to expand at the required length of thread, disengaging the chasers (cutting tips) and permitting the tools retraction without interfering with the work pieces rotation. Die heads are available and are commonly used for both cut threads and rolled threads. A popular machine that regularly uses a die head is a screw machine.

d) Products created by threading dies.

In contrast to forming dies, threading dies rarely produce a part from start to finish. Many operations are performed on the part in addition to the threading created by the die are:

- Screws, bolts, threaded rod
- Pre-threaded metal plumbing pipe and male fittings.
- Tangs in fencing blades

e) Wire pulling

Wire-making dies have a hole through the middle of them. A wire or rod of Steel, copper, or other metals or alloy, enters into one side and is lubricated and reduced in size. The leading tip of the wire is usually pointed in the process. The tip of the wire is then guided into the die and rolled onto a block on the opposite side. The block provides the power to pull the wire through the die.
The die is logically divided into a few sections. First is an entrance angle that guides the wire into the die. Next is the approach angle which brings the wire to the nib which facilitates the reduction. Next is the bearing and the back relief. Lubrication is added at the entrance angle. The lube can be in powdered soap form. If the lubricant is soap, the friction of the drawing of wire heats the soap to liquid form and coats the wire. The wire should never actually come in contact with the die. A thin coat of lubricant should prevent the metal to metal contact.
For pulling a substantial rod down to a fine wire a series of several dies is used to obtain progressive reduction of diameter in stages.
Standard wire gauges used to refer to the number of dies through which the wire had been pulled. Thus, a higher-numbered wire gauge meant a thinner wire. Typical telephone wires were 22-gauge, while main power cables might be 3- or 4-gauge.

III. WHAT IS MOULDING?

Molding is the process of manufacturing by shaping pliable raw material using a rigid frame or model called a mold.
A mold or mould is a hollowed-out block that is filled with a liquid like plastic, glass, metal, or ceramic raw materials. The liquid hardens or sets inside the mold, adopting its shape. A mold is the opposite of a cast (see casting). The manufacturer who makes the molds is called mold maker. A release agent is typically used to make removal of the hardened/set substance from the mold easier.

Types of molding include:

Powder metallurgy. Powder metallurgy is a forming and fabrication technique consisting of three major processing stages. First, the primary material is physically powdered, divided into many small individual particles. Next, the powder is injected into a mold or passed through a die to produce a weakly cohesive structure (via cold welding) very near the dimensions of the object ultimately to be manufactured. Finally, the end part is formed by applying pressure, high temperature, long setting times (during which self-welding occurs), or any combination thereof.

Ceramics. The term covers inorganic non-metallic materials which are formed by the action of heat. Up until the 1950s or so, the most important of these were the traditional clays, made into pottery, bricks, tiles and the like, along with cements and glass.

Compaction plus sintering is the process of moulding involving either powder metallurgy or ceramics

Plastics. Plastic is the general term for a wide range of synthetic or semi synthetic polymerization products. They are composed of organic condensation or addition polymers and may contain other substances to improve performance or economics. There are many natural polymers generally considered to be "plastics". Plastics can be formed into objects or films or fibers. Their name is derived from the fact that many are malleable, having the property of plasticity. This covers the following areas:

- Injection molding
- Compression molding
- Transfer molding
- Extrusion molding
- Blow molding
- Rotational molding
- Thermoforming
- Vacuum forming, a simplified version of thermoforming
- Reaction Injection Molding
- Laminating
- Expandable bead molding
- Foam molding
- Rotomolding
- Vacuum plug assist molding
- Pressure plug assist molding
- Matched mold

3. GLOBAL OUTLOOK FOR TOOL, DIES AND MOULDS MANUFACTURING

Tool and die/precision machining industry trends are amazingly uniform worldwide. Business is tough almost everywhere, but getting better. The International Tooling & Machining Association represents thousands of companies from around the world where they exchange information and ideas to strengthen the moldmaking industry as a whole and ensure its long-term success.

The tool and die industry conditions in most of the developed and developing countries are surprisingly similar to those in the U.S. and Canada. At the ISTMA (International Special Tooling & Machining Association) 2005 Board Meeting, held in Melbourne, Australia, each country reported the status of its market, focusing primarily on tool and die, and secondarily on precision machining.

The consistent message from almost all of the developed countries and many of the developing countries was:

- Manufacturing is not appreciated.
- A shortage of skilled workers.
- Volume had fallen off and has recovered the last one to two years.
- Profits are down.
- Competition from China.

Separate reports from China also show some similarities, with skilled labor shortages, margin shrinkage and a need to increase prices to cover rising costs.

4. THE TOOL MAKING VALUE CHAIN

Human capital is one of the fundamental building blocks of economic competitiveness. The continued development of human capital is therefore of strategic importance to South African Industry.

The tool making industry provides a unique opportunity for the continued sustainable development of human capital on an expanded skills front. The global competitive development of tools, moulds and dies requires a diverse skills value chain involving highly qualified personal but also lower levels of competencies.

The summary below gives an overview of the extent of the skills value chain:

i) Tool Maker

The Tool and Die Maker remains a central skill within the tool making value chain. Tool and Die Makers are highly skilled workers in the manufacturing industry. Most tool and die makers attend a 4 to 5 year apprenticeship/learnership program to achieve the necessary status qualification. Further experiential training is also required to gain the necessary experience to operate as a Tool Maker. Some of the job functions of a tool and die maker consist of producing jigs, fixtures, form tools, dies, molds, cutting tools, and many other mechanical items used in the manufacturing process.
In modern Tool and Die making techniques the Tool Makers' most important function is during the assembly, finishing and verification of the tool or die.

ii) Project Manager

Timeous delivery of a quality tool or die within the allowed budget is non-negotiable when competing within the global context. The management of the complete value chain to achieve this requires trained and experienced project managers.
Planning, Scheduling and controlling a project also entails managing project financing and constant interaction with suppliers and customers.
Project Managers are either degreed or diploma'd engineers with at least 3 years experience within the tool making environment.

iii) Tool Designer

Up to 80% of the cost and success of a tool is determined during the tool design process. The tool designer therefore plays a critical role in the tool development process.
The tool designer can be either a degreed or diploma'd engineer with a major in design. Sufficient experience in a tool and die field, such as injection moulding, blow moulding, press tooling, die casting or any other tooling field is a necessity. Competency with respect to the effective use of the latest 3D CAD technologies is also a requirement.
The tool designer works in a close relationship with both the Tool Maker as well as the Project manager in the total process of taking the tool to final completion.

iv) CAM/CNC Programmers

3 axis and 5 axis Computer Aided Manufacturing (CAM) technologies are widely utilised in the tool making process. Computer Numerical Control (CNC) Programming of these machines is another specialisation skill essential to the successful manufacture of tools and dies. The CNC programmer must be competent in the principles of tool making as CNC programming requires knowledge of programming language, tool materials, cutting

operations and process accuracies. Staying abreast with latest CNC technologies is also important.

v) Milling and Turning Operators

Conventional milling and turning is still a skill required within the modern skills value chain. For the purposes of tool making precision milling and turning is often required. Milling and turning qualifications can be obtained as part of a tool making apprenticeship or as a stand alone apprenticeship.

vi) Wire EDM and Electro sparking operators

Electrical discharge machining (or EDM) is a machining method primarily used for hard metals or those that would be impossible to machine with traditional techniques. One critical limitation, however, is that EDM only works with materials that are electrically conductive. EDM can cut small or odd-shaped angles, intricate contours or cavities in extremely hard steel and exotic metals such as titanium, hastelloy, kovar, inconel and carbide.
The EDM operator must be competent in the principles of tool making as EDM operation also requires CNC programming, knowledge of tool materials and process accuracies.

vi) Tool Room Managers

The Tool Room Manager has a strong line management function to co-ordinate tool room activities. A competent manager will ensure that all resources, human and infrastructure, are optimally and efficiently utilised. This contributes to work quality and short turn-around times.
The Tool Room Manager will himself be a trained and experienced Tool Maker. He works closely with the Project Manager to ensure tight control on project progress.
Good Tool Room Managers have strong leadership skills, have good organizational skills and must have adequate tool making experience.

vii) Metallurgists

Tool making challenges often require the use of special materials and material heat treatment techniques. Metallurgists with knowledge and experience in tool making have become an essential competency in the tool making skills value chain.

viii) Metrologists

Metrology is the science of measurement, measurement techniques and measurement analysis. In tool and die making dimension tolerances and accuracies are measured in micrometers (microns). Sophisticated methods and equipment are used to validate and verify manufactured component dimensions to design data.

Metrology is a specialization field that contributes directly to successful tool and product development. Tool Makers, Tool Designers and Metrologists work in a close relationship to accomplish geometrical accuracies required in quality tool making.

ix) Engineering Analysts

Simulation of the material conversion process through computer aided simulation tools have become common place in the tool making process. The analysis of material behaviour from a molten state through the solidifying process with the accompanying effect on final product integrity is an important input toward tool design. Also the behaviour of metals when being deformed through a pressing process can be simulated beforehand and results are used to optimize press tool design.
Such simulations are executed by Engineering Analysts with both a proper understanding of the process being analysed as well as a thorough understanding of the underlying programming and numerical principles used in the simulation software.
Good results from a thorough conducted simulation is invaluable during the tool development process.

x) Cost Estimators

A major challenge in tool and die development is the estimation of costs, for quotation purposes, before the tool design has been finalized. Cost Estimators have to address this challenge by relying on their experience in the tool making industry as well as relying on the input of tool makers and tool designers.

xi) Heat Treatment Operators

In tool making the technique of heat treatment is almost always used to modify the mechanical hardness of tool metals. This process is normally one of the last activities that takes place before a tool is completed. It is also a very sophisticated and sensitive process. A mistake at this stage impacts on timely completion of the tool. Heat treatment operators therefore have a great responsibility in making sure that the process is executed successfully.

xii) Polishers

Polishing is the process of creating a smooth and shiny surface by using rubbing or a chemical action.
Tool surfaces that define product surface finish are normally polished. Accurate and intricate tool interfaces often also require polishing for proper tool functionality.
Tool polishing is a skill that requires hand skills as well as a knowledge and ability to utilise the available machining and chemical technologies to achieve the required result.

5. IN THE FINAL ANALYSIS

The supply of manufactured products depends on tool, die and mould (TDM) manufacturing. The TDM industry provides the machines, tools and equipment necessary to produce most manufactured components. The TDM industry is a high value-adding constituent in the supply of manufactured products by being at the heart of component manufacturing and by forming the backbone of the manufacturing sector. Unfortunately, the South African TDM industry experienced a steady economic decline during the last decade. This decline resulted in a negative effect on the domestic manufacturing industry. The South African government realised the evident need to restructure and develop the TDM industry. There is a need to increase Research and Development activities in order for government to increase global competitiveness of the South African TDM industry and also to incentivise the SMME sector start-ups. The South African TDM industry lacks the capacity to supply in the local demand. The shortfalls and the need for improvement can be done by comparing the South African industry against its global counterparts.