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Processing–Structure–Property Relationships in Advanced Manufacturing of Functional Materials

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Abstract

Mechanical processing is very important in modern production since it changes raw materials into usable parts with exact sizes and qualities. This article looks at the basic methods of mechanical processing, such as cutting, shaping, grinding, milling, and joining. It also talks about how important these methods are for getting things done quickly, accurately, and with the least amount of material possible. Recent advancements, including computer numerical control (CNC) machining, automation, sophisticated tooling materials, and smart production systems, are examined, highlighting their effects on productivity, cost efficiency, and product quality. The use of digital technologies and eco-friendly methods in mechanical processing is also looked at. This shows how modern manufacturing deals with problems like energy use, waste reduction, and process reliability. This study gives an overview of what is happening now and what will happen in the future in mechanical processing. It shows how important it is for improving manufacturing performance and making industries more competitive. Predictive control of material behavior during processing is emphasized as being made possible by the integration of digital technologies, such as simulation, sensor-based monitoring, and data-driven optimization. The implementation of energy-efficient and sustainable methods in mechanical processing is being investigated, addressing issues with resource usage, process dependability, and environmental impact. Overall, this study highlights how important mechanical processing is for customizing material characteristics, enhancing manufacturing efficiency, and boosting industrial competitiveness in the creation of cutting-edge functional materials.

Keywords: CNC machining, industrial automation, manufacturing techniques, mechanical processing, process innovation

INTRODUCTION

Mechanical processing takes away or changes the shape of materials to make items out of different types of feedstock. It happens in five steps: choosing, designing, preparing, processing, and showing. Each stage looks at three things: material, technology, and geometrical specification. These things affect each other. The goal is to have the right shape while also meeting size tolerances that make sure pieces fit together and work properly in products. The ability to choose the processing method can save a lot of money and time.

When you remove material, you cut a workpiece into chips or get rid of burrs without making any waste. If the cutting process is finished on time, there will be no overlap, unwanted wear, failure, or damage to either the workpiece or the machine tool. There are many ways to remove material, including as facing, turning, drilling, reaming, carving,

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grinding, sawing, and scraping. Deformation procedures change the shape of a workpiece without making chips. This means that the die must be built to make the exact change that is wanted. Mechanical, thermal, electrical, and chemical methods are all common process alternatives that come from a knowledge tree [1].

FUNDAMENTALS OF MECHANICAL PROCESSING

Mechanical processing is a type of manufacturing that changes the shape of solid materials using machines. Mechanical processing is the process of removing material and changing the shape of solid materials to make pieces with certain forms and physical attributes [2]. Parts then go through other steps of mechanical processing, assembly, or packaging to create finished goods. Different procedures change the price, time, and quality of parts and products [3].

Plastics, metals, and composites are some of the most common materials that are treated. These materials are as strong, cheap, and light as aluminum and steel. Other materials are often used in molds, carpets, and home items. Car engines are often made from a mix of aluminum and magnesium. Selecting the appropriate method is crucial for cost-effectiveness, minimal lead time, and superior quality. Deals generally say what the costs are, when the items will be delivered, and how good they are [4]. When a manufacturer gets a request, they figure out which processes they can use to give accurate quotes or lead times. Also, process selection is done early in the design process to save time and effort.

HOW TO CUT AND MACHINE

The cutting and machining steps employed in mechanical processing determine the shape and strength of goods. Turning is the most prevalent method. It takes material off of a part that is spinning. A stationary workpiece and a spinning cutter are used in milling to cut away material. Drilling makes holes by piercing and controlling their size. Removing material by hand creates certain forms and finishes on the surface. Finishing processes change forms that have already been made in order to get specific geometries and surface finishes. This can mean tighter tolerances or a better look.

When you turn anything, you put it on a spindle that spins and push a cutting tool against it to take off material. The tool goes into the material either radially, axially, or both, and a continuous helical chip formed unless there is a recess. The most important things are the speed of the spindle (n), the feed rate (f), and the depth of the cut (d). To increase the surface polish, tool wear often needs a finishing pass that is three times faster and has a lower feed.

Turning

Turning changes the contour of a workpiece by taking away material from a part that is moving. The spindle moves the work while it is kept in place on the machine bed. A cutting tool moves in a straight line and cuts at a set feed rate. Chips are made in front of the tip of the tool and then fall off. There are many things that affect the turning process, including as setup, tool choice, geometry, and spindle speed, which defines the size of the cut. The feed rate affects how smooth and deep the cut is [2]. The necessity for finishing is a key thing to think about when designing. Surface roughness is affected by little changes in the tool path, hence it is better to use basic geometric tool paths.

The tool moves in a straight line in one or two directions, while the workpiece rotates around a fixed axis [5]. Standard facing is the most frequent setup. In this case, the tool goes towards the portion first. First, a collar is cut, then a conical lead-in, then a core diameter, and finally a lead-out. Another typical form is turning a valve body blind hole. In this case, the outside is shaped first, and then the inside is sculpted using a bar feeder to bring in long, thin sticks. There are also taper external or internal, spline, groove, thread, and combination settings. The exact dimensions rely on the shape of the part and what the customer needs. Diagnostics may include checking for roughness, play, vibration, and other things.

Milling

One of the most flexible ways to shape materials is by milling. There are two primary forms of milling: horizontal and vertical. The orientation you choose will affect the tool path and the cuts you make. Face milling, slab milling, contour milling, pocket milling, end milling, gang milling, and straddle milling are all common procedures. Because milling is so simple, it is easy to make specialized machines like gang and pallet mills. These machines have various tools or pieces that may be used to manufacture several surfaces at once, which lowers the chance of material shifting and making mistakes [6].

A horizontal milling machine has cylindrical cutters that spin parallel to the spindle axis. Vertical milling machines are better for getting complicated forms without changing the workpieces or equipment. The cutter spins around an axis that is at a right angle to the surface being machined. In vertical milling, different equipment and processes are used to meet different needs, including quickly removing material or getting a better surface polish.

Drilling

When you drill, you make holes of different sizes and shapes in materials. The shape of the hole's cross-section and entry depends on the type of drill. The most common type of drill, the twist drill, makes circular through-holes. Before other drilling operations, spear point drills make holes in materials. Core drills make both through-holes and blind holes, keeping the material in the middle [6]. One of the most important parts of drilling is the quality of the hole, which depends on the workpiece, the tools, and the operating settings. Some common problems are delamination, crater formation, and burr creation. The kind and amount of cutting fluid used also have an effect on the quality of the hole [7].

One of the most typical problems that happens when drilling metallurgical parts is the production of burrs. Two-stage drilling, which includes a pilot hole, makes the burrs less and the hole surface better [8].

Finishing

Finishing activities are the last step in the process of making something. They make the product better and meet the standards that were set before. Finishing narrows down the range of tolerances that were set during design [2]. Common methods include grinding, polishing, and deburring. They can change the shape, geometry, and texture of a part's surface. For this kind of task, you need special tools and extra attention. It takes skill to remove even the smallest bit of material. The hazards go up too. If you do not do it well, you could end up with alterations you do not want, like making things too big or changing the texture. The alterations that happen as a result may potentially make stress-concentration levels higher and degrade mechanical properties [9].

Finishing processes have a few fundamental goals: to improve the look and quality of the surface, lower stress-concentration levels, extend fatigue life and corrosion resistance, and not turn a process into a stage where defects are made. Finding the right balance between the requirement for a better surface finish and the risks that come with it is still a big problem in mechanical processing.

WAYS TO FORM AND SHAPE

Mechanical processing is a group of processes used to change the shape of a product while keeping an eye on its tolerances and surface roughness. The manufacturing business also uses varied schedules to make work cheaper and to make the product surface look better. Forming and shaping operations modify the shape of sheets, bars, and tubes into different shapes without adding any material. Tooling makes it easy to repeat these steps at a low cost.

Forging is the process of using a hammer to put enough power into the work material. There are two main forms of forging: hot forging and cold forging. Hot forging happens at high temperatures, while cold forging happens at room temperature. High strength and low ductility at high temperatures are what make it easier to reduce a workpiece in a cold condition. This is because these properties can cause the work material to fracture and rip. The other difference is whether or not the work material can touch a die while it is being forged. During an open die forging operation, the work material does not touch any die at any point during the deformation process [10]. Forming processes can also change characteristics via thickening, descaling, and softening. Full-clad components are made by stamping thin-walled tubes. Double-sided stamping and differential stamping are two common methods that let you combine hard and ductile materials without needing any extra joining methods.

Another way to shape something is by rolling it, which first squeezes the work between two rollers. Once the work is in the rolls, the length-ways centered work starts to roll, which keeps it from escaping from the rollers by making it longer in the axial direction. If the space between the rolls keeps becoming smaller, you can make different rolled shapes, such I shapes and double T shapes, with different cross sections. There are two main types of rolling processes: flat rolling, in which the work material goes between round rollers, and shape rolling, in which the work material goes between shape rolls. When it comes to flat-rolling mills, hot-rolling and cold-rolling mills are usually used as the tools. A hot-rolling mill has two sentry rolls, intermedial rolls, a drive structure, and top turnings. A cold-rolling mill has a sentry roll, a drive, and a turning.

Extrusion is the process of forcing the work material to flow out through a die opening to make the shape of the die. When designing a die, you can group extrusion operations into two groups based on whether or not the work material can get into the die cavity. With the indirect extrusion process, the work material is pushed towards a die without actually going inside the die cavity. The plunger puts tension on the material that is moving to extrude, which shapes the material into a die at the back of the die [11]. Stamping is still possible for large-scale production and can be utilized for both bulging and wrinkling processes, which can be useful for both single and double cavity punches.

Making/Manufacturing

Forging is one of the earliest ways to shape things. When metallic materials are put to compressive forces, they change shape. These pressures get rid of or lessen casting flaws and improve the microstructure. Hot and cold forging are terms used to describe the deformation of structures that happens at temperatures above or below the recrystallization point.

Hot forging makes alloy steel parts better at changing shape. A flow line structure is made, which lowers the rate of fatigue. When cold forging, the die cavity's filling capacity and the metals' ability to change shape both go down. The die is made so that it may be filled with a minimum punch stroke, which makes forging possible. Local forging allows for the most effective use of punch strokes without the risk of not filling the cavity completely. Using flank-oriented tools for complicated local forging can make expensive dies last longer [12, 13].

Rolling

Rolling changes the cross-sectional shapes of workpieces by using compressive forces from rolls that are opposite each other [14]. Today, the most common ways to roll things are bar and sheet rolling [15]. In general, bars are thick, circular, and solid. Rolling sheets, plates, and strips makes shapes that are wider, thinner, and flatter. These shapes can then be turned into corrugated and other shapes. Cold-rolled or hot-rolled, oil-tempered, and hot-dipped galvanized are all common shapes for metal sheets.

Rolling has a big effect on how the material behaves mechanically. Residual stress profiles arise during the procedure because of uneven cooling or forms that are not symmetrical. Bars made using a hot rolling mill get stronger as they work. To get rid of high permanent deformations, you need to reduce the thickness and width by making numerous passes with high pressure. The choice of rolling mill affects these characteristics. For industrial uses, the height of the strips should be between 6 mm and 8 mm.

Extrusion

Extrusion is a common method for making polymer products, as well as food, drugs, metals, and other things. There are two main types of extruders: single-screw and twin-screw. Twin-screw extruders are best for mixing fibers, fillers, masterbatches, and polymer blends. Because of their positive displacement properties, fully intermeshing counter-rotating twin-screw extruders have the largest pumping capacity. There have been numerous new designs for extruders since they first appeared in 1939 as adaptations of continuous kneaders. These new designs have made pumping performance even better. Simulation is an excellent way to learn about, analyze, and improve extrusion processes [16].

There are many different ways to extrude polymers. For example, polyvinyl chloride (PVC), wires, sheets, food-like treats, and compounds can all be made this way. Melting or devolatilization, mixing, and pumping are all parts of all extrusion procedures. Melting, which turns solid particles into a thick mass, is frequently the least understood unit operation, even though it is very important for process control [17].

Stamping

To stamp something, you need a tool and a die to bend it against a hard foundation. Making parts for cars is a common use of stamping. A hydraulic press can handle up to 2000 tonnes, while a mechanical press can handle more than 4000 tonnes. These two types of presses are used to get tonnages between 1500 and 4000 tonnes. In free-cutting, it is theoretically impossible to stamp something over and over. Still, automatic machines are made to reduce the time between multiple pressings, which allows them to reach output rates that are similar to those of lathes or milling machines. Consistent positioning of punched holes is achieved despite the frequency of daily activities. For dies that have bigger calibration variations from daily use than from production cycles that last only a few hours or continuous operation, this kind of flexibility is very important for getting accurate stampings [18].

SIMULATION OF FINITE ELEMENTS AND PROCESSES

Tools, equipment, quality control, simulation, and requirements are all parts of mechanical processing in manufacturing. Finite element analysis looks at the design of tools or workpieces by anticipating things like the highest stress, changes in temperature, deformation of the workpiece, and the filling and shaping of hollow portions. Some of the problems that were solved were: extending the life of cutting tools, reducing the path or force of the cutting tool, predicting damaged parts, and preventing parts from bending or warping owing to heat. Analysis gives you the information you need to choose the right cutting tool and machine tool settings to avoid too much cutting force or wear and make sure the surface quality is up to standard [19, 20].

TOOLS AND EQUIPMENT

Tools and machines for processing make mechanical treatment that works every time. Cutting elements take away material as they shape and machine things. Tool wear impacts the quality of the parts and the speed of production. There are ways to measure tool life, set replacement intervals, and guess the condition of the tool. Automation makes parts more uniform, reduces handling mistakes, speeds up production, and makes things safer.

Machining centers usually come with computer numerical control (CNC) systems. Positioning motors and encoders change the location of the cutter and keep track of how far it moves, giving you a lot of information about how long the process takes and how much energy it needs. Part programs encode workpieces as geometric models that show feeds, speeds, and events. An articulated command syntax makes it easy to construct paths and movements that are unique to you.

Highly automated systems load and unload parts without any help. Too much use of tools or fixtures can cause breakdowns and long delays. These systems, on the other hand, keep supplying parts even when things go wrong, which increases runtime and throughput. Reliable observation and control reduce losses from unexpected events like equipment failure.

Tools And How Long They Last

Mechanical processing uses several instruments to change the shape of a raw material into the one you want. There are many different kinds of tools, but most of them may be put into three groups:

cutting, forming, and finishing. Drills, lathes, and mills are examples of cutting tools. Dies are examples of forming tools. Abrasives, brushes, and polishing pads are examples of finishing tools. The tool also interacts with the workpiece. There may be chips or shavings, and direct contact can modify the material by heating it, coating it, hardening it, or changing its shape. Every tool gets old and needs to be replaced.

There are many ways to measure tool wear. Fluted tools with annular edges have two metrics: (i) "flute wear," which is given in units or as a percentage, shows damage near the fluting that is perpendicular to the feed, where contact begins and ends; and (ii) "flute life," which is measured in units or time, shows the cutting length available before reaching a set wear condition. For tools that do not have flutes, such drills or lathes, a length measure of tool wear is the most frequent way to quantify wear. You can reach your quality goals by replacing worn-out tools. Most manufacturing systems keep extra tools on hand for exchange. Comparing wear to usage records tool life, and total cost lets you figure out the cost per part [21, 22].

Automation and CNC

Computer Numerical Control (CNC) systems are very important for making mechanical parts. Because they are accurate and can be repeated, they are quite reliable. CNC is a way to control machine tools with a program. When processing a part, traditional systems need the crucial parameters of tool paths and machine movements to be specified by hand each time. On the other side, CNC systems let you run complicated part programs automatically, so the operator does not have to keep configuring the same settings for multiple parts. More and more machine tools now have CNC technology. Adding automation to CNC systems makes them far more useful than regular systems. Machining systems that are fully automated can run without any human supervision until they are done. Automatic tool attachment, chip transport, and productive machine layouts like parallel machining and twin-spindle operation are further ways to reduce the number of jobs that operators have to do. A chain of lower-priority programs running through simple tasks assigned to helper machines makes it possible to trim continuously.

The control unit, machine tool, and programmed information make up the CNC system. The brain of the CNC system is the control unit. It reads the part program and transmits control signals to the machine tool at the proper time. The precision of contour tracing is directly affected by how well the control works. The CNC control unit usually has three parts: the interpreter, the signal generator, and the machine control unit. You can punch the part program in a strip into an input tape. You can use words or codes to show the geometric and operational information. After that, the program can be put into the CNC unit's core memory, usually by an automated tape controller (ATC), where it will stay in the state it was in when it was first created. In this setup, there is no limit to the length or amount of data, but the first line of the program (initialization commands) must include the tape commands for the ATC's ON/OFF state. To keep the buffer size small, the control unit puts data back into 64-dot blocks. Engineers have made simulation software packages for designing large-scale integrated circuits [23]. This is used to manage the CNC machine.

QUALITY AND CONTROL

There are many different steps that go into making each part, and each one has a big impact on the quality of the finished result. During the production process, effective quality control generally relies on well-established metrology technologies that make it easy to find leaks, modifications, and faults in parts on time. In general, mechanical operations can be broken down into making changes to a portion or taking material away from it. Each of these mechanisms has its own tolerances and surface polish criteria that tell the cutting or forming machine how to move the tool. Quality standards assist set particular, measurable tolerances and surface finish requirements that must be met in order for a product to be seamlessly integrated into later processes and delivered on time. You can take measurements of unknown tolerances or surface finishes, and if they are discovered to be too high, you can use conventional gauges to look into them further. There are many different shapes that can be used to show surface features clearly. People often use nominal roughness at certain measuring lengths or unique contour characteristics such note breaks, protrusions, and other features to describe surface finishes [24].

There are three main ways to divide mechanical processes: by how the materials interact (process grouping), by whether the process adds or takes away material (process class), and by how it affects the workpiece as a whole (process type). So, the two main types of mechanical processes are metal deformation and material removal [25]. There are five main groupings of processes within these classifications.

Metrology

The science of measurement is called metrology. It entails both direct and indirect measurement of physical quantities for the observation, analysis, and management of diverse quality attributes of products. Metrology is used to set, manage, and check the quality of manufacturing processes and the items made; to make sure that products meet their specifications; and to set up and carry out preventive measures. There are two ways to measure things in metrology: the direct way (with a sensor and a digital output) and the indirect way (where the measurement result comes from signal processing). In the indirect method, the measuring tool might be either a gauge or a machine. Gauges are useful for measuring a small number of things, but machine metrology can provide you information about a lot more things.

In metrology, there is also a method called Decisional Metrology. As part of this technique, an intelligent Post-Machining Metrology System (PMS) has been made. Batch Mode is the most common way to measure things in manufacturing. In this mode, products are measured in batches after they have been made. In general, batches are groups of workpieces that have all gone through the same post-processing procedure in the same assembly. It is suggested that a PMS operating in Stage Mode, which collects Measurable Characteristics (MCs) to help decide how many more operations a workpiece needs, could greatly improve batch mode by providing the necessary and, still, vital information about the geometrical state of the workpieces at earlier stages [25].

Tolerances and Surface Finish

The choice of a traditional mechanical processing method depends on the materials' properties and the needs for geometry, tolerances, and surface polish. The residual dimensions following this kind of machining depend on how precise the part and its features need to be. So, tolerances are very strongly related to assertions about mechanical processes and surface finishes. The illustrations show the tolerances using a system that is acceptable around the world (ISO 286; 1984). Turning, milling, shaping, and slotting are the four most popular ways to do mechanical processing [26]. You can set more than just the fundamental tolerances for diameter on cylindrical and other curved surfaces. For example, you can set run-out. Along with diameters, holes are also specified to make sure they are in the right place and at the right angle [2].

Mechanical processing can make surfaces, such those made with instruments like turners, drills, and mills. The tool life equation can be used to describe how worn out a cutting tool is, no matter what kind it is. Different tools have different wear mechanisms, which gives them different properties. Still, the tool needs to meet the drawing standards in order to make a part that works on time [27].

NEW IDEAS IN MECHANICAL PROCESSING

- *Additive–Subtractive Hybrid Methods:* Hybrid methods are those that build up layers of material and then remove material from the parts that are more intense. This new idea means that you do not need to utilize a high-tech milling machine or grind the item after it has been made, which cuts down on machining time and makes the additively generated portion more accurate and better quality [2].

- *Advanced Materials and Coatings:* New alloys such cobalt–chromium alloys, high-speed steel, and metal matrix composites have come out in the machining area. Pioneering the usage of sophisticated coatings like TiN and diamond. These materials make tools last longer, wear down less quickly, cut faster, work better at higher temperatures, and stick less to the work material. To better machine composite materials, new die materials like tc–pd, tc–wc, tc–aln, tc–al2o3, tc–co, and tc–mg have been made [4].
- *Sustainable Manufacturing Practices:* Using a gear box instead of a variable drive unit can help you use less energy. Recycling cutting oils, switching to biodegradable lubricants, using minimal quantity lubrication (MQL) oils with a water-soluble basis, and recycling shavings and trash are all crucial. These actions lower emissions and expenses in the long run.
- *Hybrid Methods for Adding and Subtracting:* To satisfy the rising needs of manufacturing, hybrid machine tools that use both additive and subtractive processes have been developed. These tools take advantage of the strengths of each method while minimizing their weaknesses. These techniques make it easier to make complex shapes that would be hard or too expensive to make using only one method. Their use is still growing as people try to make better use of resources and meet strict quality standards. Hybrid configurations make it easier to automate process planning, use resources more efficiently, and create complicated forms. However, there are still problems with smoothly combining the two methods, keeping an eye on and reviewing many activities, and handling a lot of post-processing. Also, even when additive manufacturing makes a part that is almost the right shape, it often still needs a lot of extra machining [28].
- *Advanced Coatings and Materials:* The classical research on mechanical processing emphasizes on the creation of new metallic materials to improve life and lower costs, especially for purposes that have to deal with complicated loading circumstances [29]. Low-density ultralight materials, Ti-based materials, and wear-resistant materials are the most promising modern engineering alloys [30]. Using them should lead to less wear on tools and longer lifespans for mechanical parts. The ongoing study and constant flow of novel materials for mechanical processing still make it a good area for developing new generations of processing itself.
- *Practices for Making Things That are Good for the Environment:* Manufacturing has an impact on both people and society. Sustainable manufacturing is when the benefits to the environment, economy, and society outweigh the costs at every stage of the product's life cycle. Machinery is very important for making things, yet it uses a lot of energy and water. It is the second most energy-intensive manufacturing industry after petroleum refining. It makes waste like noise, vibration, and chips. Sustainability factors in machining encompass material selection, the process, tools, parameters, and cutting fluids [31].

SAFETY AND UPKEEP

In mechanical processing, safety is the most important thing. Operators and machinery will be safe if they follow safety rules and instructions. To make sure that equipment is made to avoid dangers, several manufacturers have put in place mechanisms for safety and risk assessment. There are a lot of rules in this area. Lockout/Tagout techniques [32] are often used to lower the dangers that come with releasing energy and starting up a system without warning while maintenance is going on. Good training and tool design make it less likely that people will accidentally get into dangerous areas. Emergency shutdown mechanisms are very important for keeping workers safe.

Automation technology makes it possible to provide equipment in new ways. Changes to the program or the equipment that are not controlled could cause harm or put safety at risk. There are many standards that cover general safety, the process of assessing risk, machine-related requirements, and the analysis of injury data.

To keep people safe and accurate, equipment needs to be serviced on a regular basis [33]. Maintenance done right can cut down on breakdowns and make equipment last longer. Regular checks for defects or wear that could lead to faults, as well as examining important gauges, assist find problems early. Regular calibration will make sure that equipment and processes work as they should.

CONCLUSION

Mechanical processing is an important part of making things since it involves modifying the shape or removing material to make parts from raw materials. The main goals are to make sure the right tolerances are met, get the right surface finishes, and make the end product's mechanical qualities better.

Some Important Ideas Are

Removing material: Cutting or changing the shape of most of the workpiece, which is usually a solid form. This method makes machined pieces with certain shapes, for example. Deformation without removal is also frequent in manufacturing. Deformations: The process of changing the size and shape of a part, such as bending it, that is desirable during forming operations. These methods can also make surfaces that are quite complicated without removing any material. Tolerances: The acceptable differences in length, angles, surfaces, and other things that happen during the making of parts. Controlling tolerances is very important for mechanical assembly, and it naturally limits the procedures that may be used. Surface finish: The quality of the surface of the finished object. It is frequently depicted in terms of roughness (in microns) or certain criteria.

You need to know the basics of how mechanical processing works to understand these ideas. When material is being removed, cutting forces move from the cutter to the workpiece. The machine tool gives the cutter mechanical energy, which makes it move and cuts chips. The other part goes through a mechanical process that tests its strength and elasticity. The service life of a cutter is also affected by how much wear and tear there is between the material layer and the cutter. This depends on the material's qualities, the cutting circumstances, and the design of the tool.

The most common way to shape materials in modern manufacturing is through mechanical processing. It is thought to be worth about 15% of the total value of all produced parts in the world. The use of both hand tools and machines, as well as the right cutting processes and tools, has made it possible to make parts with complex shapes at a low cost [4].

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