PMPA EDUCATIONAL FOUNDATION

PRACTICAL PRECISION

helpful information for precision machining students

Student Day 2025

—Conversion Chart—

FRACTION		INCHES		MILLIMETERS	
1/64	33/64	0.0156	0.5156	0.3969	13.0969
1/32	17/32	0.0313	0.5313	0.7938	13.4938
3/64	35/64	0.0469	0.5469	1.1906	13.8906
1/16	9/16	0.0625	0.5625	1.5875	14.2875
5/64	37/64	0.0781	0.5781	1.9844	14.6844
3/32	19/32	0.0938	0.5938	2.3813	15.0813
7/64	39/64	0.1094	0.6094	2.7781	15.4781
1/8	5/8	0.125	0.625	3.175	15.875
9/64	41/64	0.1406	0.6406	3.5719	16.2719
5/32	21/32	0.1563	0.6563	3.9688	16.6688
11/64	43/64	0.1719	0.6719	4.3656	17.0656
3/16	11/16	0.1875	0.6875	4.7625	17.4625
13/64	45/64	0.2031	0.7031	5.1594	17.8594
7/32	23/32	0.2188	0.7188	5.5563	18.2563
15/64	47/64	0.2344	0.7344	5.9531	18.6531
1/4	3/4	0.25	0.75	6.35	19.05
17/64	49/64	0.2656	0.7656	6.7469	19.4469
9/32	25/32	0.2813	0.7813	7.1438	19.8438
19/64	51/64	0.2969	0.7969	7.5406	20.2406
5/16	13/16	0.3125	0.8125	7.9375	20.6375
21/64	53/64	0.3281	0.8281	8.3344	21.0344
11/32	27/32	0.3438	0.8438	8.7313	21.4313
23/64	55/64	0.3594	0.8594	9.1281	21.8281
3/8	7/8	0.375	0.875	9.525	22.225
25/64	57/64	0.3906	0.8906	9.9219	22.6219
13/32	29/32	0.4063	0.9063	10.3188	23.0188
27/64	59/64	0.4219	0.9219	10.7156	23.4156
7/16	15/16	0.4375	0.9375	11.1125	23.8125
29/64	61/64	0.4531	0.9531	11.5094	24.2094
15/32	31/32	0.4688	0.9688	11.9063	24.6063
31/64	63/64	0.4844	0.9844	12.3031	25.0031
1/2	1”	0.5	1	12.7	25.4

Craftsman's Cribsheet

Miles Free - Director of Industry Research and Technology ☒ Technical ☐ Regulatory ☐ Quality ☐ Management

A Quick Guide to the Chemical Elements Found in Steel

This handy quick guide will give you the common chemical elements found in steel, how they affect steel properties and the machining process and a few tips on how to deal with them.

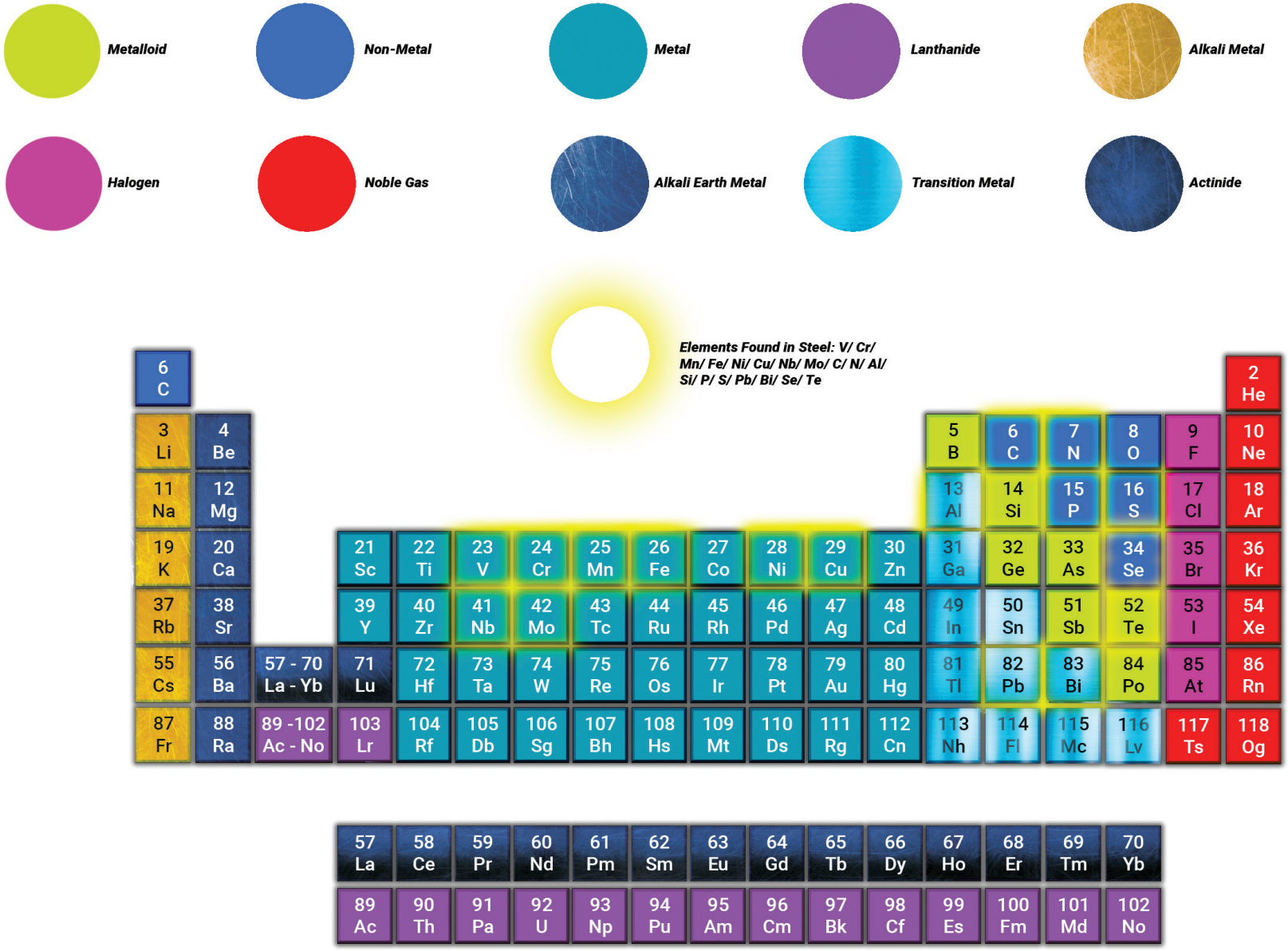
CHEMICAL ELEMENT	SYMBOL	WHAT DOES IT DO FOR THE STEEL PERFORMANCE	WHAT DOES IT DO FOR MACHING	WHAT STEPS TO TAKE WHEN YOU ENCOUNTER THIS
Carbon	C	Strengthens, hardens, makes heat treatable.	Improves up to~0.23%. Gives steel its hardness.	Anneal if over 0.40% and alloy; if carbon steel and over 0.50%.
Manganese	Mn	Strengthens, hardens, enhances heat treatment.	Improves surface and machinability.	No speacial techniques needed. Promotes machining.
Phosphorus	P	Ferrite strengthener. Lowers ductility.	Crisps up chip. Improves surface finish.	Be careful with subsequent cold work on rephosphorized steels.
Sulfur	S	Lowers ductility, toughness, weldability, surface quality.	Controls built up edge (BUE), Improves machinability about 25%	Increase speeds and feeds. Is machinist's friend.*
Silicon	Si	Deoxidizer, makes steel sound. May degrade surface quality.	Abrasive on tools.	Want 0.01-0.02 max silicon in 12XX steels; 0.10 max Si for 11XX for best machinability.
Copper	Cu	Negligible in our applications.	Usually it is a value about how steel is made.	Higher coppers tend to indicate electric furnace steel.
Nickel	Ni	Ferrite strengthener. Aids heat treatment.	Usually makes chips tough to separate.	Avoid dwell. Sharpen tools. Secure workholding.
Chromium	Cr	Corrosion resistance, high temperature strength and heat treatability.	Higher strength makes machining more difficult.	Can be abrasive. Pay attention to tool edges and wear.
Molybdenum	Mo	Increases hardenability, raises tempering temperatures.	Not noticeable.	No special precautions.
Aluminum	Al	Develops fine austenitic grain size. Can combine with nitrogen.	Decreases tool life.	Pay attention to tool edges and wear.
Lead	Pb	No effect on mechanical properties.	Promotes machinability about 25%.	Run at higher productivity. Take advantage of this.
Columbium (Niobium)	Cb / Nb	Grain refiner up to 0.05% in bars. Microalloy strengthener. Similar to Al as grain refiner.	As microalloy, makes material harder and tougher to machine.	Pay attention to tools, understand condition if microalloy.
Vanadium	Va	Grain refiner and strengthener. Microalloy in forging steels.	Decreases tool life. Harder steels more difficult to cut.	Pay attention to tools, understand condition if microalloy.
Bismuth	Bi	No strengthening effects. Possible embrittlement.	Improves machining. Substitute for lead.	Run at higher productivity. Take advantage of this.
Nitrogen	N	Strengthener and lowers ductility (notch toughness). Improves surface finish and promotes chipbreaking.	Crisper chip and Improved surface finish.	Does not like to be cold worked. Avoid dwell, avoid in crimping applications.

**Sulfur: Plain carbon and alloy steels with sulfur below 0.010 wt % are problematic for machining and surface finish. 0.02 wt % minimum sulfur is optimum in theses steels for machining.*

for more info go to pmpafoundation.org

PERIODIC TABLE

(CHEMICAL ELEMENTS FOUND IN STEEL)



Craftsman's Cribsheet

Miles Free - Director of Industry Research and Technology ☐ Technical ☒ Regulatory ☐ Quality ☐ Management

Helpful Hints for a Successful Career in Precision Machining

1. Never operate any machine or forklift if you are not trained or not familiar with it. Ask your supervisor.
2. Always wear proper PPE to include eye, ear, hand and foot protection.
3. Eliminate entanglement hazards. Always secure or remove loose clothing, tie loose hair and remove jewelry, which can entangle in rotating equipment (especially rings and bracelets) before you operate machinery. Do not wear fabric or leather gloves around rotating equipment.
4. Always maintain a safe distance from machines that are in use.
5. Never operate machinery without all shields and machine guards in place.
6. Always lock out/tag out powered equipment when cleaning, oiling or repairing. Test to assure machine is fully de-energized.
7. Never use compressed air guns to clean clothing and hair and never aim at another person.
8. Never use your hands or a rag to clear chips; never use rags around rotating equipment.
9. Maintain good housekeeping in your work area to eliminate trip, slip and fall hazards.
10. Be sure to lift properly with your legs, not your back. Ask for assistance and use back support when necessary.
11. Always inspect cables, slings and straps and assure they are secure prior to use.
12. Report all injuries, no matter how minor, to your supervisor.

13. Invest in two pair of safety shoes.
14. Invest in any retirement plan.
15. Learn from everyone around you, especially those who will retire in the next five years.
16. Find an area in which you can become your company's expert.

Craftsman's Cribsheet

Miles Free - Director of Industry Research and Technology ☐ Technical ☐ Regulatory ☒ Quality ☐ Management

ACCURACY VS. PRECISION

Your quality assurance manager can put you to sleep explaining the difference between these two terms, but you really need to know the difference.

Accuracy describes "close-to-true value." Precision describes "repeatability."

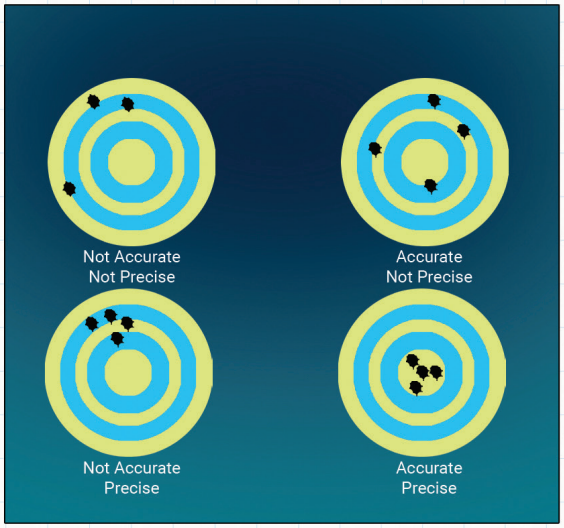
Accuracy in measurement describes how closely the measurement from your system matches the actual or true measurement of the thing being measured. It is the difference between the observed average of measurements and the true average.

Think of accuracy as the "trustworthiness" of a measurement system.

Precision in measurement describes how well a measurement system will return the same measure; that is its **repeatability.**

As the targets show, it is important to be both accurate and precise if you are to get useable information from your measurement system.

But the repeatability has two components: that of the measurement system (gage) itself and that of the operator(s). The differences resulting from different operators using the same measurement device is called **reproducibility.**



In our shops, we cannot tell if our measurement system has repeatability or reproducibility issues without doing a Long Form Gage R&R study.

Gage repeatability and reproducibility studies (GR&R) use statistical techniques to identify and discern the sources of variation in our measurement system: is it the gage, or is it the operator?

Gage error determined by the GR&R is expressed as a percentage of the tolerance that you are trying to hold.

Typically, 10 percent or less gage error is considered acceptable. Over 30 percent is unacceptable; between 10 and 30 percent gage error may be acceptable depending on the application.

Regardless, any level of gage error is an opportunity for continuous improvement.

GLOSSARY OF PRECISION MACHINING TERMS

Alloy: Substance showing metallic properties made from two or more chemical elements, one of which is a metal.

Annealing: The controlled heating and cooling of metal to change properties or structure by removing stresses to achieve desired properties and make it easier to work with (machine).

Anodizing: Creation of a conversion coating on a metal surface by anodic oxidation. The finish can be decorative, durable, and corrosion resistant, and provides a better surface for paint and adhesion. Typically applied to light metals such as aluminum, titanium, and magnesium.

AS9100: An aerospace standard based on the ISO 9001 quality system requirements and supplements them with additional quality system requirements, in order to satisfy DOD (Department of Defense), NASA (National Aeronautics and Space Administration) and FAA (Federal Aviation Administration) quality requirements.

Bar Feeder: An automated machine that holds and delivers material to the machine tool on demand, without operator supervision.

Bar Stock: Elongated rolled metal product that is thick, narrow and of uniform section down its length. Typically, round, hex, octagonal, square, or rectangular. Sold by weight but specified by dimensions as well as material type and grade.

Bore: Hole or cylindrical cavity around the axis of rotation produced by a single or multi point tool other than a drill.

Boring: Process that is used to enlarge a hole with the use of single or multi- point tool.

Brass: Nonferrous metal consisting mostly of copper and zinc.

Burr: An unwanted, turned over edge of displaced metal resulting from the machining process on a metal or plastic part. See, Deburring.

Caliper: A device to measure inside and outside dimensions on a component. A caliper resembles a compass, with two hinged legs. A Vernier Caliper combines a scaled rule, projecting arm and an attached sliding vernier attached to another projecting arm.

Carbon Steel: A steel with no minimum specified quantity for any element except Carbon, except for incidental amounts of Manganese, silicon, and perhaps other deoxidizers and grain refiners in small quantities. The higher the carbon content, the more difficult it will be to precision machine components from it.

Centerless Grinding: Grinding the outside or inside of a workpiece by means of resting on a knife edge support, with removal taken from a grinding wheel while rotated by feeder wheel.

Chip: In a machine shop, chips are the small pieces of excess material that are removed from the component (plastic or metal) that is being machined.

Chuck: An adjustable device for holding work or tools on a machine so that the workpiece or tool can be rotated for machining or other operations. (collet)

CMM (COORDINATE MEASURING MACHINE): CNC controlled machine used for measuring shapes and dimensions on components, commonly used in precision CNC Swiss machine shops.

CNC (Computer Numerically Controlled): Using the aid of a computer to control and monitor the movements of a machine that was previously run by hand. The machine can have several axes of movements, in either a linear or rotary axis.

CNC Machining: Computer run machining process that removes metal or plastic from bar stock to create a desired shape. It can be used to create a variety of complex shapes with tight tolerances.

CNC Milling: Milling machine that is run by a computer program. Milling machines use rotary cutters to remove material. Learn more about the difference between milling and turning on our blog post, "Turning vs Milling: What's the Difference for precision machining?"

CNC Turning: Similar to a lathe, a computer-controlled machining center that removes metal or plastic from round bar stock. Typically, does turning, boring, drilling and threading. Learn more about CNC Turning.

Cobot: A computer-controlled robotic device designed to assist a person. Also known as a collaborative robot.

Collet: A split sleeve work holding device that secures a single size workpiece during machining-turning, drilling, milling, or grinding.

Computer Aided Design (CAD): Computer software to aid engineers in the drafting, modification, and optimization of a part.

Cutting Oil: A petroleum-based fluid used to lubricate the tool work interface, remove heat, and prevent built up edge while promoting chip removal and preventing rust on steel parts .

Cycle Time: The total time it takes to produce one part on a machine.

Deburring: The process of removing burrs (small, ragged edges/pieces of material creating during the machining process). Deburring processes can be manual, with streams of compressed air or fluids, or rolling the work in a barrel with abrasive media in a fluid. Thermal and electrochemical means can also be employed.

Depth Gage: Device used to measure hole or recess depth.

Diameter: The measurement of the maximum dimension of a round section through the center of the shape.

Die: A tool, typically with a cavity of specific geometry used to create a specific shape reflective of the shape of the tool itself.

Feed Rate: The rate at which the cutting tool or grinding wheel advance into or along the workpiece.

Feed: The act of moving the material relative to the machine cutter. In precision CNC Swiss machine shops, feeding is usually accomplished using automotive bar loading equipment to achieve high efficiencies.

Ferrous: Any metal alloy that has iron as its major ingredient.

First Article Inspection (FAI): A formal reporting process that provides documentation that all measurements from a component design have been verified after production.

Gage: A device for measuring or checking dimensions on a component.

Grinding: Abrasive removal of material with a powered wheel to obtain improved surface finish or tighter dimensional tolerance.

Hardening: Increasing hardness and tensile strength by suitable means that can include cold work, Heating, or cooling processes.

Hardness: The resistance of a material to penetration, measured by one of the following hardness tests: Brinell, Knoop, Mohs, Rockwell, or Vickers. Directly related to tensile strength.

Honing: A low-speed process of finishing a ground surface to a high degree of smoothness and accuracy. Uses abrasive blocks with controlled pressure and rotary or reciprocating motion.

IIoT (Industrial Internet of Things): An evolution of devices that are interconnected with computers' applications. This integration allows for data collection, exchange, and analysis, and potential improvements in overall process.

Insert: A component that is used to join two objects together.

ISO 9001:2015 (International Organization of Standards): A standard that sets out the requirements for a quality management system. It is designed to improve quality and efficiency to improve customer satisfaction. A current version of the standard, ISO 9001:2015 replaced the previous version (ISO 9001:2008).

Knurl: A decorative or gripping surface of a component made by creating uniformly impressed design into the material as a result of pressing hardened rolls into the material. Sometimes cut rather than rolled. Knurls can be straight, diamond cylindrical or other geometries.

Lathe: A machine for shaping metal or plastic material by rotating bar stock and using fixed cutting tools to create the desired geometry. Components made on lathes are also called turned components or Turned parts.

Lead In/Lead Out: How a CNC program approaches and/or leaves the part before cutting. Typically, this is programmed through CAM software.

Milling: Using a rotary cutter with one or more cutting elements which engage the workpiece, removing material as the tool and material move relative to the other. Typically used to create geometries of flat surfaces.

Non-Ferrous: Metal that contains no iron (such as brass or aluminum).

Operator: Or machinist, implements the plans created by a CNC programmer to run a computer-numeric controlled machine. This also may include changing out tools as indicated by the program and overseeing cycle time as well as making designated quality measurements and tests.

Pilot Hole: A small hole drilled as a guide for a larger hole.

Pitch: The axial distance between threads, which will be equal to the lead in a single start screw.

Plating: Process of depositing an adherent layer of a different metal on a component. Plating offers many potential benefits including improved appearance, corrosion resistance, solderability, paint adhesion, wearability. It can also alter surface hardness, conductivity, and reduce friction. Nickel, zinc, and chrome plating are among the most common used for machined parts.

Precision Machining: The process of machining tight tolerance, complex shapes from metal and plastic bar stock as well as forgings, castings, or cold headed blanks. These parts are often human safety critical and employed in applications where failure is not an option.

Print: The human readable output of an electronic file that contains the information traditionally conveyed by blueprints or drawings that define what dimensions and geometric relationships required for a compliant part.

Rockwell Scale: Test methods to compare material hardness based on indentation hardness of a material under specified load and indenters. Several Rockwell Hardness methods and scales cover various ranges of material hardness values.

Screw Machine: An automatic lathe that will run production parts with minimal human intervention throughout the production run. Screw machines can be single or multi-spindle and will run small and medium size parts in medium and high volumes. A screw machine is used to make bolts, fittings, couplings, hose fittings, shafts, screws, and pins, as well as a wide variety of other types of fasteners and components.

Spindle: The rotating torque providing part of a machine which may hold the bar or workpiece, or the tool or grinding wheel doing the work, depending on type of machine. A multi spindle machine can do machining operations on multiple pieces at the same time, thus reducing cost per piece, due to reduced cycle time from the parallel processing .

Stainless Steel: Steels in this category of steel have had chromium, nickel and perhaps other elements added to prevent corrosion. The added chromium provides a more lustrous finish and makes the parts more suitable for food service medical, dental, and other critical applications. Stainless steels are considered more difficult to machine.

Steel: An iron-based alloy, malleable in some temperature ranges as initially cast, containing Carbon, Manganese, and other chemical elements. It can be produced from molten iron in a basic Oxygen furnace supplied by a blast furnace using Iron Ore, limestone and Coke made from coal as initial feedstock, or , more commonly in the USA, made from recycled preexisting scrap steel in an electric furnace. Steel is initially solidified in to blooms or billets from a continuous caster, which are then rolled into bars for subsequent processing prior to machining. There are over one thousand variations of steel in four basic categories (carbon steel, alloy steel, stainless steel, and tool steel).

Surface Finish: The measure of the overall texture of a surface that is characterized by the lay, surface roughness, and waviness of the surface of the workpiece, usually described in units of microinches.

Swiss Screw Machining: (Also known as Swiss lathes, or Swiss automatic lathe). The holding mechanism (collet) for the bar stock is recessed behind the guide bushing. This offers additional support to the material as it is being machined providing better tolerances for the finishing operations. These are also particularly effective at turning small diameter parts. The name Swiss screw machine comes from the fact that the first types of these machines were created

in Switzerland. Adding CNC to the Swiss screw machines came about in the 1990s.

Tapping: The process of cutting screw threads inside of a hole by using a tool with one or more cutting elements arranged such as to generate the desired thread size and form on the periphery as the tool moves both axially into the part and radially inside the hole.

Tensile Strength: (TS) The property of a metal which resists force applied to pull it apart. It is the ratio of maximum load applied to the original cross-sectional area. It is also called Ultimate Tensile Strength (UTS) relating to the ultimate load it withstood while remaining in one piece. Typical US units are KSI or thousands (Kilo) of pounds per square inch.

Thread Gage: Device used to measure the threads on a machined component.

Thread Rolling: A secondary finishing process that produces a screw thread by passing the material through a set of hardened dies under great pressure to move it to conform with the geometry of the rolls. Thread rolling can be employed on the machine tool and can be performed as a secondary finishing process.

Tolerance: The allowable amount that the finished component can differ from the original specified dimensions or relative location. Usually expressed at +/- a certain number of thousandths of an inch on parts, often specified as + .000/- .00X" on cold drawn steel bars.

Torque: The rotational force (or turning force) a spindle drive motor generates to ensure cutting action when the workpiece material and tool engage.

Turning: Machining process that rotates a workpiece material against a cutting tool in a lathe to create desired geometry, dimensions, and features about a central axis.

Workholding: Any implement that is used to hold a workpiece in place while it is being machined. Examples include collets, three jaw chucks, four jaw chucks. In milling pallets, tombstones, and multiple collets fixturing can be used to hold single or multiple parts for machining.

PRECISION MACHINING CAREERS

ENTRY LEVEL JOBS

(start with on-the-job training)

- Machine Operator
- Setup Technician
- Millwright
- Machinist

TECHNICAL LEVEL JOBS

(with certification, associate's degree, or apprenticeship)

- Robotics Programmer
- CNC Programmer
- Industrial Sales
- Industrial Machinery Mechanic
- Quality Technician

PROFESSIONAL LEVEL JOBS

(with bachelor's degree, master's degree, or specialized training & experience)

- Mechanical Engineer
- Systems Engineer
- Electrical Engineer
- Industrial Engineer
- Operations Manager

No Degree? No Problem! Earn Big in Precision Machining

STUDENT DAY 2025

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