

## **Basics of Mechanical Engineering-2**

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**Lecture 33**

### **Basics of Machining (Part 1 of 7)**

Welcome to the next segment or sector in this course on Basics of Mechanical Engineering under the heading of manufacturing. We have seen till now casting, metal forming, welding, And now we will try to see machining. The moment you say machining, that means there is some amount of material which is getting removed from the available material. If you look at casting and forming, they were constant volume processes.

That means the starting and ending volumes will be approximately the same. When we moved to welding, it was an addition process where, wherever required, we added material. Now when we move to a subtracting process, we are going to remove material and then generate the shape, size, or dimensions you want. Machining is a very important process. Wherever there is a non-symmetrical shape or a huge amount of material to be removed that cannot be changed through metal forming, we always go for machining operations.

Now, the next basic logical question is: I have a material. Now I have to remove material from the available material. So, how do I do it? Should I use my hands or should I use an aid to remove the material? Now, the aid material is going to be the tool.

So now, by using a tool, I am going to remove material and generate a shape. A simple example: you can try to think of carving out a shape from a given material. Or you can observe the people who work on making statues. Artisans who make statues use a chisel and a hammer. This hammer provides them with an impact load, and the chisel is a sharp edge that helps in controlling the material removal.

So with that basic understanding, let us get into the topic of machining.

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The content of this particular segment on machining will provide a brief introduction. Then we will try to understand its history. Then classifications in machining. There are different classifications.

When you see them, it will be quite interesting. Then you will try to see what tool geometry is. Because when we try to remove material from a stone or a chunk, we have to remove the material in a controlled fashion. So if we have to remove the material in a controlled fashion, we must ensure that the crack or shear generated aligns with our desired outcome. So we will have to understand more about a single-point tool.

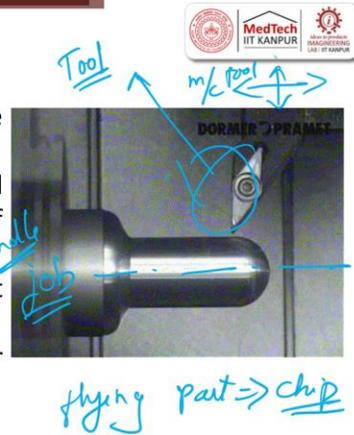
Then we will try to see a single point tool is not only a single point, it has multiple geometries attached with it. So we will try to see tool designation, then we will try to see tool point geometry. When there is two material and the workpiece material, when it touches and moves, there is always a friction. This friction is going to lead to heat. So then let us understand how heat gets dissipated, what is the influence of heat for removal of material.

Then we will try to see chip formation. What is a chip? The material which is removed out of the chunk or the bulk material is called as chip. So chip mechanism we will see. What are the different types of chips and a small recap on this machining.

## Introduction

$$\text{Removal rate} = \frac{\text{volume}}{\text{min}}$$

- Machining is the metal removal process from the work piece to make the finish good. → *Shape/Size/dimension/surface finish*
- In machining process the either tool or workpiece fed toward each other to remove the material in the form of chips/ particles.
- The amount of material removal from the work piece is limit the finish quality of the final finish product.
- Small amount of removal the material provides better surface finish and vice-a-versa.
- The machining operation are:
  - **Conventional:** material removal by a sharp cutting tool, e.g., turning, milling, drilling
  - **Abrasive processes:** material removal by hard, abrasive particles, e.g., grinding
  - **Non-traditional processes:** various energy forms other than sharp cutting tool to remove material.



If you look at the video which is presented here, you will see here there is a tool. So this is a tool. So this which moves here back and forth, this is the tool. The tool is guided by a machine tool. So machine tool tries to control what geometry or the profile the tool has to move.

So this is a tool, and this is the machine tool. Now you can see here; this is the job or the workpiece. Now, on this workpiece, you are trying to create a profile, a shape, a size, or whatever dimension you want. You are trying to create it such that it meets your requirement. Now, this is done by rotating the workpiece.

Why do you want to rotate the workpiece? Because you want to generate an axis-symmetric profile. When you want to generate an axis-symmetric profile, it is always a good idea to rotate the workpiece. The workpiece is held in a spindle. The spindle rotates and holds the workpiece very firmly.

Now, there is a hard material called a tool, which tries to have a relative motion against the workpiece to create the geometry you want. So how is this motion given? It is by the machine tool. So machining is a metal-removal process from the workpiece to get a finished good. So here, we try to talk about shape, size, dimension, and if you want, surface finish also.

All these things are getting done. In a machining process, either the tool or the workpiece is fed toward each other to remove the material in the form of chips and particles. So what gets removed here? Flying. So the flying part is nothing but the chip.

Depending upon the depth you give in digging, the depth you provide, the chip profile changes or the chip thickness changes. If you go to a small depth, you will get very small chips. When you try to go deeper, you will get large chips. So the unwanted material removed from the workpiece is called the chip. So that is what is told here.

The amount of material removed from the workpiece is limited by the finish quality of the final product. So what is the depth you want? The depth of cut depends on many factors. What is the force you apply from the machine tool? What is the relative motion you apply?

Relative motion you give against the workpiece. And the next one is how do you hold the workpiece? All these things matter. So that's what we say. The amount of material removed.

So material removed will be for a given minute what is the amount of material you take away from that. So it can be the material removal rate. Moment I say rate, there has to be a time component. So now I wanted to play safe. You can try to have what is the volume of material which is removed in a minute is called as material removal rate. So the amount of material removal from the workpiece is limit the finish quality of the final finished product.

Small amount of removal of the material better the surface finish and vice versa. But you should understand, once the material removal rate is very small or very less, the time for machining is going to be large. For example, if I want to remove 1 meter cube of volume in 10 minutes, in 1 minute, you see the time which is involved is reduced. So the production can be very high. So today what we do is we make stiffer or sturdy machine tool.

And then we also try to improve the process parameters like rotating speed, feed rate, and the rate at which the tool advances. All these things are being enhanced today. Very high speeds are achievable. Today, the spindle speed can reach up to 1 lakh RPM. The feed rates can go up to 500 millimeters per minute.

This is very common nowadays. The machining operations are conventional abrasive processes and non-conventional processes. They are classified as conventional.

Conventional means where a tool is used, and the tool is harder and sharper than the workpiece. The immediate jump is to non-conventional or non-traditional machining processes, where the tool need not be in contact with the workpiece.

The tool need not be harder than the workpiece. So, those processes are called non-conventional or non-traditional machining processes. What is an abrasive process? Here, I know a tool wherein I dictate the tool geometry. In an abrasive process, I break the tool into small powder.

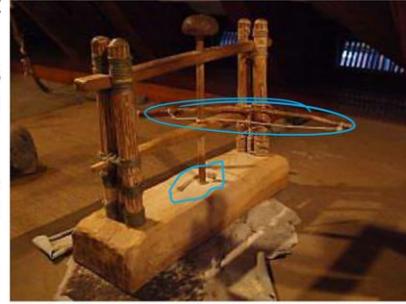
So, the geometry cannot be dictated, but the tool will always be harder; the abrasive will always be harder than the workpiece. Again, there are exceptions. For example, when we try to remove a scratch from glass, right? So, glass is a very hard material. So here, what we do is we try to use soft abrasives to remove the scratch. So that is also possible, but there are exceptions.

Generally, the manufacturing or machining operation will be classified into three in machining. So one is conventional process, two is non-conventional or non-traditional process, and the third one is abrasive process. So whatever I have said, I have written it here. Material removal by sharp cutting tools is conventional process. Then abrasive process where the material is removed by hard abrasives, where the abrasives—the tool—become an abrasive; the size is very small, and geometry control is difficult.

Non-traditional machining process; here, the energy you apply is different, they are not in contact, they do not touch, and the tool need not be harder than the workpiece. So naturally, what comes to your mind now will be: if I compare conventional and abrasive processes, both are different. Where the tool is harder, what will be the material removal rate in abrasive process? Since the tool size is very small and it will not be a single abrasive—multiple abrasives—the amount of material removed will be very small or very less as compared to that of conventional.

## History

- The roots of machining can be traced back to ancient civilizations.
- The Egyptians, Greeks, and Romans developed various tools and techniques for shaping stone, wood, and metal.
- These early craftsmen used handheld tools like chisels, saws, and files to shape materials with precision and skill.
- The lathe, one of the oldest and most fundamental machine tools, was invented in ancient Egypt around 1300 BCE.
- The ancient Egyptians developed a simple lathe known as the “Egyptian Bow Lathe.”



And if you look into history, machining has existed for quite some time. Whenever they wanted to make some design on wood, they have been using machining operations.

When they wanted to drill a hole on a wood, they have been using machining operation. So the machine structure was different, it got evolved. So here they have used impact load, then they have used the control movement of the tool such that they can generate the profile. They started with wood and slowly, slowly, slowly they got the expertise and they got carving it on the metal also. Exhaustive operations have been done by the artisans in the past.

They who were working in the king's regime or in the kingdom or in the courtyard of the king where they wanted to make artilleries as well as artifacts. The route of machining can be traced back to ancient civilization. The Egyptian, Greek and the Romans developed various tools and techniques for shaping stone, wood and metal. Metal forming was also done. Stamping was also done.

They also did parallelly machining operation. And if you look at the artisans who were making statues, they used to carve stones with a tool which is harder, they use a chisel which is harder than the material stone and then they start carving it in a very controlled fashion. So these early craftsmen used hand held tools like chisel, saw, file to shape material with precision and skill. So in the ancient era, if you go through any of the

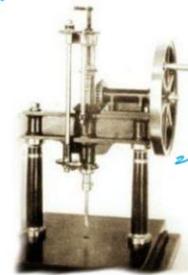
museums, you can see lot of dice made out of elephant tusk. So where they do lot of small features, fragile features, they were all made through precision tools.

They carved; they used files to make it. This has been there. The lathe, one of the oldest and most fundamental machine tools, was invented in ancient Egypt in 1300 BCE. The ancient Egyptians developed a simple lathe known as the Egyptian bow lathe. So this is a bow, and this is a lathe machine.

## History

Lathe  $\Rightarrow$  w/p was rotational  
milling  $\Rightarrow$  tool to rotate w/p constant

- The Industrial Revolution in the 18th century marked a significant milestone in machining history.
- The development of machine tools, such as the lathe and milling machine, revolutionized manufacturing processes.
- These machines introduced mechanization and automation, greatly increasing productivity and precision.
- James Nasmyth, a Scottish engineer, is often credited with developing the first true milling machine around 1829.
- The design incorporated a rotary cutting tool and a table that moved in multiple directions to achieve precision and versatility.
- In the late 19th century, precision machining techniques gained prominence.
- The introduction of grinding machines played a significant role in the industrialization process of precision machining.



18<sup>th</sup> century model



19<sup>th</sup> century model



<https://kaast-usa.com/exploring-the-fascinating-history-of-machining/>

Then, subsequently, when the Industrial Revolution started in the 18th century, a lot of things began developing much faster. And, of course, World War I and II occurred, so they demanded a lot of warfront devices, pistons, and other things. So the Industrial Revolution in the 18th century marked a significant milestone in machining history. The development of machine tools such as lathes and milling machines revolutionized the manufacturing process. These machines introduced mechanization. So, as a mechanical engineer, you will try to read a lot of mechanisms. Three-bar mechanisms, four-bar mechanisms—all these mechanisms aided machine tool development.

So they used to give a drive at one place and have a mechanism that transmitted the drive or the feed—whatever it was—to the tool. So these machines introduced mechanization and automation, greatly increasing productivity and precision. James Nasmyth, a Scottish engineer, is often credited with developing the first true milling machine around 1829.

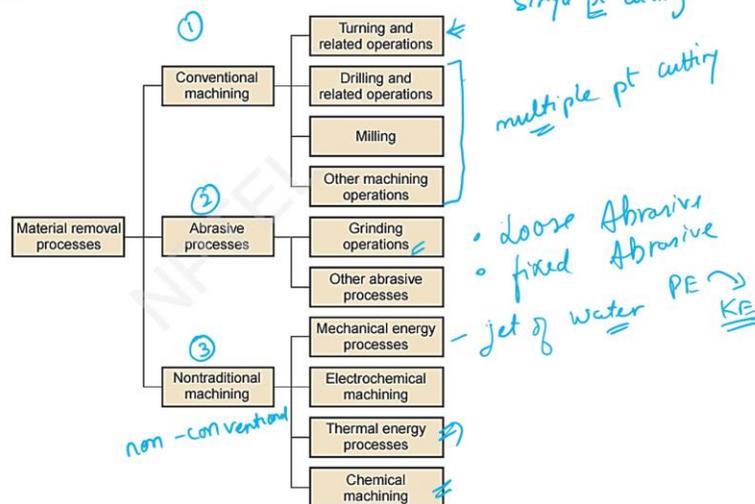
The design incorporated a rotary cutting tool and a table that moved in multiple directions to achieve precision and versatility. So, in the lathe machine, what we saw in the video was the workpiece rotating.

When this gentleman, James, did what he did, he developed a milling machine in which he made the tool rotate and kept the workpiece stationary. Stationary means it can move at a required feed rate. So in a lathe machine, the tool was given the feed rate. In a milling machine, again the tool was given, but the tool was rotated. In the late 19th century, precision machining techniques gained prominence.

So they started making Swiss watches, very small, mechanically activated watches, and mechanically activated systems in which they used springs to store energy. Springs were machined. You could have done it by metal forming, but springs were also machined when very small precision was required because the springback in metal forming was always dominant. The introduction of grinding machines played a significant role in the industrialization process of precision machining. So what was then, and what then was the next stage you can see, and today you can see.

Today it has gone much further, but today you can see machines like this. So here, the drive was still given by hand, but here the motorized drive started coming into existence. Today you have very high-precision machines with multiple axes in control.

## Classification



Now let us get into the classification of machining. So material removal processes are classified into conventional, abrasive processes, and non-traditional machining processes, or they are also called non-conventional machining processes.

It is all the same, conventional or non-conventional. So how are they classified? They are classified as single-point cutting and multiple-point cutting. In single-point cutting, we use a tool that has a single tip. That tip comes in contact with the workpiece and starts machining, and here the workpiece rotates.

It is held in a lathe machine. Most of the time, axis-symmetric parts can be made in this machining process. Next comes drilling. In turning, we had a single point. In drilling, we have two points.

So drilling is always used to make a hole. The relative motion is given between the tool and the workpiece. Here, the tool rotates. When you want to drill a hole, the tool rotates, right? The tool rotates and advances step by step into the workpiece, making a hole.

So, here the drill had to be made two point. Why? Because when the material is removed, as and when you go deeper and deeper and deeper, the material which is removed has to be brought out in a simpler fashion. So when we have to bring the material out, so they used to have a flute. So there will be a flute through which the chip flows out and the material is removed and you drill a hole. What is milling?

Milling is you can have more than two cutting points and they can be used to remove material in a much faster fashion. So instead of two what was there, now I will have a tool where in which there will be multiple cutting edges. Each of the cutting edge will try to remove material. So I can remove lot of materials. If I want to make a flat plate or a stepped slot, then I use milling operation.

Other machining operations are the combination of turning. You can have boring, then you can have many other small, small things, which is a combination of turning, drilling and milling also you can have. Combination or other special type machining process you can have. When I get into abrasive, then in abrasive there are two types. One is called as loose abrasive. The other one is called as fixed abrasive that means to say the abrasive can be fixed at a certain point and that can be used as a tool for machining.

Loose abrasives are where abrasives are spread on top of a surface, and it can occur, for example, if there is mud spread on top of a flat tile. And when you walk, there is friction between your shoe, the sand particles, and the tile. Now, based on your load and the

action you perform, a scratch is created. If many scratches form on the tile, the material is removed. So loose abrasives work in the same phenomenon.

Here, the abrasive size is very small. We talk in terms of microns. So it can be somewhere between 10 microns to 100 microns. That will be the size of the abrasive. The abrasive can be of multiple materials, hard materials.

Those loose abrasives are used. They are spread on top of a workpiece. You have a load applied on top, and then you try to remove it. In a fixed set, there is an abrasive. These abrasives are bonded together by adding a binder to them.

So every abrasive has a fixed location. So when that particular abrasive comes in contact with the workpiece, it removes material and then waits for the next round to come. So generally, what we do is fix the abrasives on top of a wheel. So this wheel is called a grinding wheel. So this is the process which is called a grinding operation.

So suppose you assume there is an abrasive sitting here. When it rotates, this abrasive comes in contact, removes material, and waits for the next rotation to come and remove material again. So those things are called fixed abrasives. So we have discussed that. Then when we get into non-conventional or non-traditional machining processes, we use mechanical energy.

So mechanical energy is when we try to use a high jet of water, okay. Here, the potential energy is converted into kinetic energy, and this kinetic energy tries to remove material. In the jet of water, I also add loose abrasives to remove material. So those operations are called mechanical energy processes. The other one is electrochemical, where I make the positive electrode negative or the positive workpiece a negative electrode.

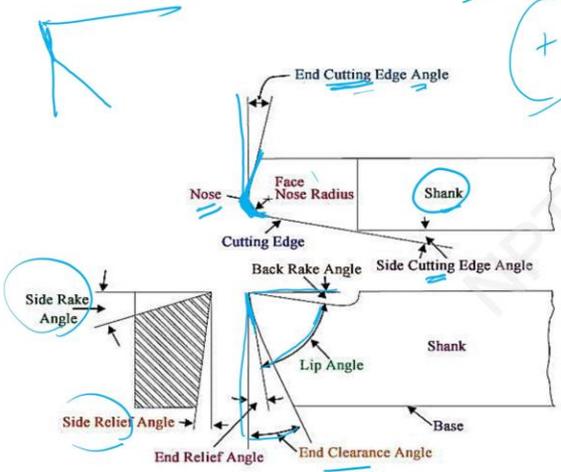
And I apply current along with it. I also have some amount of media, which is an electrolyte, through which an etching operation happens, and I remove material. This is accelerated etching. Along the seashore, you can see material getting eroded in the presence of salt. Here, I use electricity to accelerate it. Thermal is when I use heat or laser.

I use a laser to heat the material and remove it. Without applying electricity, I only use chemicals to remove material. So what do I do? I try to keep the substrate, then place a mask on top of it. In the mask, I remove material and then perform etching.

Many artists do chemical etching. If they want to create a photo of a legend, like a sportsman, they take a thin copper or brass sheet, apply the mask, and etch it. Then they create it, and this can be used as a great artifact. These are the classifications of machining or material removal processes.

## Cutting Tool Geometry: Single Point





**Side View Of Tool**

Back Rake Angle  $- \rightarrow +$

Lip Angle  $- , 0 , +$

Flank

Base

$P = \frac{F}{A}$

$\delta + 1 \text{ nr}$

mm

Material	Top Rake	Side Clearance
Aluminium	15° - 20°	10° - 15°
Brass	10° - 12°	8° - 10°
Mid Steel	8° - 10°	7° - 9°
Stainless Steel	6° - 7°	6° - 7°
Cast Iron	7° - 9°	7° - 9°



<https://www.magiccuttools.com/toolbits-properties.asp>

Cutting tool geometry: Single Point. Since the next couple of slides are very important, we will focus only on the slides and give them higher priority. I request all of you to focus on the slides. Now that you know we have a cuboidal tool, we also know its property: it must be harder than the workpiece. You also know that if I have line contact, I will have to apply a lot of force.

Basically, pressure is nothing but force per unit area. So now, I have to reduce the pressure. To reduce the pressure, I must convert this line contact into point contact. I must convert this line contact into point contact. So, to convert this into point contact, I must modify the face.

So, I must make changes on the top face and also on the side face. So, I will try to say that on the top face, I must make a change. On the side face, I must make a change. And on the front face, I must make a change. Why?

When I make all these things, I would convert them into a single point. Now, when the workpiece is in contact with the tool, it is going to create a chip. Now, the chip, whatever

is there, has to flow through the rake face or has to flow through the face of the tool. So when it has to flow through the face, I have to make sure that I give an angle such that the chip can easily flow on the face and get out. So, I will now try to focus on the angles.

So if you see the side view of the tool, you can see that there is a rake face. The rake face is the face where the chip moves. And here, we have said back rake face. So just hold on for a minute. When we go through the other views, you will understand where this back comes from.

So there is a rake face. On this rake face, the chip will move out. The other phase is when the tool is moving toward the workpiece; there will now be on the top where the chip moves. Now, there should be a clearance or a relief such that this phase of the tool will not come in contact with the workpiece. So, that angle is called the relief angle.

The angle which is in between the relief angle and the rake angle is called as the lip angle. So, back rake and end rake. So, now we will try to see what is this back and end. From the side view, let us go to this view. In this view, you are trying to keep the tool and see from the top.

This is the top. When we see from the top, you see here there is a shank and then you see there is a cutting edge and there is a end cutting edge. This cutting edge will be in contact with the workpiece as and when the feed rate is moving. So between the shank and the tip, now the tip is converted into a nose radius because a tip which is there over a period of time gets blunt. So I am making a radius so that I have a larger area through which the tool is coming in contact with the workpiece.

So you have a nose radius and then you have a cutting edge. You have a cutting edge which comes in contact with the workpiece and you have a nose radius where the point is converted into a nose. So there you will have a radius. The other end of this, because when you see here, this is the cutting edge and now this edge is also there. So that edge will try to form an angle which is called as end cutting edge angle, this portion.

So this portion will also have an angle, now this portion will also have an angle, this portion will also have an angle. So, now you see there are three angles. Now, let us try to see the side view of this. So, in the side view, you try to see the side cutting rake angle. The plane whatever is there is never perpendicular.

It is inclined at an angle. This plane is inclined at an angle. So you will have a side rake angle and then in the relief whatever we saw here we will have a side relief angle. So

when we try to note down please see this is end relief and this is side relief. And here you see a back rake angle and you see a side rake angle.

Back rake and side rake. So these are two different rake angles. Back rake angle and side rake angle. Now what is left? You have already seen the nose radius.

So now what is pending is the clearance angle. So the end clearance angle and side cutting angle are also what you saw. So it is only the end clearance angle. So the end clearance angle is not a straight line as we get. It is after a certain point that we also try to maintain an angle.

So this is called the end clearance angle. This is called the end clearance angle. So we have the end cutting edge angle. Then we have the end clearance angle, side relief angle, end relief angle, back rake angle, and side rake angle. So if you see there, there are six angles and one nose radius to define a tool, a single-point cutting tool.

So if you see a single-point cutting tool, these were all two-dimensional, wherein we had orthogonal projections. If you see, a tool looks like this. So this will give you more clarity. This figure will give you more clarity. So you see here, here is a shank, right?

From a shank which is cuboidal, you have to cut these angles to the tool. This is a straightforward nose radius, right? Now, when this is the cutting edge, this is the cutting edge. The angle towards this is the back rake angle through which the chip moves. Then we have a side relief.

So here, if you see from here to here, whatever is called the side relief angle. And when we try to give a cuboid an angle, then it is called the side cutting edge angle. Then we have this: the end cutting edge angle and this is the side rake angle. So these are the six angles with the nose radius for a single-point cutting tool.

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## Cutting Tool Geometry: Single Point



- **Shank:** It is a single point cutting tool consists of a neck which is known as operating end, and the shank or body. It is used to hold the tool in the tool post or tool holder. *tool → tool post → m/c tool*
- **Face:** it is the surface on which the chip impinges and along which it flows as it is separated from the work.
- **Flanks:** the flanks are two surfaces of the tool facing the work. They are called the side or main flank and the end or auxiliary flank. *←*
- **Cutting Edge:** they are formed by intersections of the face and the flanks. They are called the side or main cutting edge and end cutting edge.
- **Nose:** The nose is the element formed at the junction of the side and end cutting edges. This junction or the nose has a curve of small radius, known as nose radius.



So I have explained about it. The shank is used for holding the tool. The face is the surface on which the chip impinges, the rake face. The chip impinges and flows along with it. The flanks are two surfaces of the tool facing the work. They are called the side or main flank and the end or auxiliary flank.

The cutting edge is the intersection of the flank face, the face, and the flank. They are called the side and main cutting edges. Main cutting edge and the end cutting edge angle. These are all the side cutting edge angles. The last one is the nose radius.

So shank, face, flank, cutting edge, and nose radius. These are the angles generally used for a single-point cutting tool.

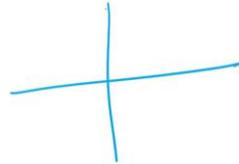
## NRS System of Tool Designation $\Rightarrow \delta, n, r$



Normal Rake System (NRS) utilizes three planes as reference for measuring various tool angles.

These three planes are enlisted below.

1. **Reference Plane ( $\pi_R$ )**—It is a plane perpendicular to the cutting velocity vector ( $V_c$ ).
2. **Cutting Plane ( $\pi_C$ )**—It is a plane perpendicular to reference plane ( $\pi_R$ ) and contains the principal cutting edge of the tool.



## NRS System of Tool Designation



3. **Normal Plane ( $\pi_N$ )**—It is a plane perpendicular to the principal cutting edge of the tool. Normal plane may not be perpendicular to the reference plane ( $\pi_R$ ) and Cutting Plane ( $\pi_C$ ).

However, normal plane is always perpendicular to the principal cutting edge.

- Unlike ASA and ORS systems of tool designation where all three planes of reference are mutually perpendicular, in NRS system three planes of reference may not be mutually perpendicular.
- They will become mutually perpendicular only when the cutting tool has zero inclination angle ( $\lambda$ ).  
In such case, NRS system and ORS system will become same.



In single-point cutting tool designation, there are three major things people generally talk about. They are the ASA system, ORS system, and NRS system. There are three different types of systems because every country had its own convention.

We will focus only on NRS so that you can understand how the NRS angles are derived. Then, by parallel analogy, you can do the same for ASA and ORS. This will also give you a clear example of your understanding of engineering drawing, which we studied in

the first year, where you cut a section, rotate it, and then find the angles. In the NRS system, the tool you have is cuboidal, and from there, you are supposed to make 6 angles and 1 nose radius. So if that is the case, you must have references.

So the NRS system will have 3 reference planes. With these three reference planes, you try to figure out the angle deviation from these planes and then you try to figure out the end cutting, side cutting, edge cutting, all the angles. So in the NRS system utilizes three phases, all the three, ASA and ORS also uses the same. The only thing is what is the angle between the planes? So, based on that then we try to keep the tool as reference and then we try to understand. So, normal rake system utilizes three planes as reference for measuring various tool angles.

These three planes are listed below. One is reference plane  $\pi_r$ . The other one is cutting plane  $\pi_c$  and the third one is a normal plane  $\pi_n$ . What is  $\pi_r$ ?  $\pi_r$  is the plane perpendicular to the cutting velocity vector. With cutting velocity vector is  $v_c$ , we will see in the figure in the next slide.

The cutting plane, it is a plane perpendicular to reference plane. So reference plane and it is perpendicular. So this is plane and perpendicular. So cutting plane, it is a plane perpendicular to the reference plane and contains the principal cutting edge of the tool. It contains the principal cutting edge of the tool.

So now what we are trying to do is, first we said everything is perpendicular. Now we try to maintain the perpendicularity but try to have a small angle so that matches with the principal cutting edge. The next one is the normal plane. It is a plane perpendicular to the principal cutting edge of the tool. The normal plane may not be perpendicular to the reference plane.

So reference plane and cutting plane are perpendicular. The normal plane need not be perpendicular to the reference plane, but it is perpendicular to the reference plane. However, the normal plane is always perpendicular to the principal cutting edge. So, first we saw reference plane, then we saw cutting plane, then we saw normal plane. So,  $\pi_r$  and  $\pi_c$  and then  $\pi_c$  and  $\pi_n$ . So,  $\pi_c$  is perpendicular to  $\pi_r$  and contains principal cutting edge.

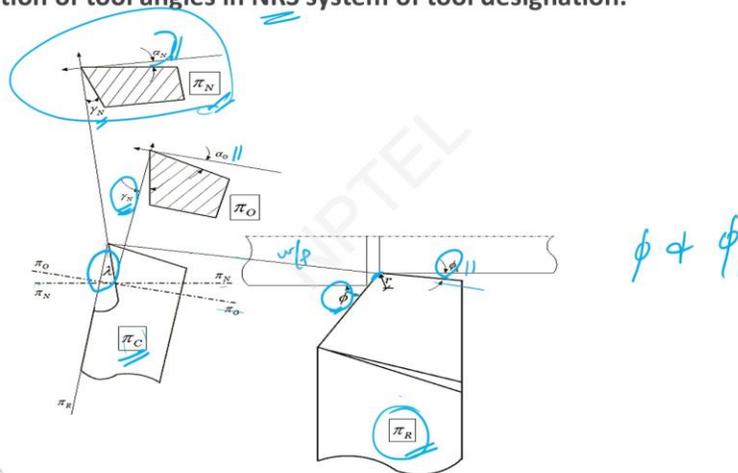
$\pi_n$  is perpendicular to the principal cutting edge. Unlike ASA and ORS system of tool designation, where all three planes of reference are mutually perpendicular in NRS system, right, all perpendicular, in NRS system, the three planes of reference may not be mutually perpendicular. In ASA and ORS, they are perpendicular to each other. So they

will become mutually perpendicular only when the cutting tool has zero inclination, then in that case NRS system and ORS system will be the same. So this point is only to make sure that how can you transfer from here to here, here to here, ASA to ORS, ORS to NRS, you can transfer it.

All the three reference systems are followed and when we try to buy a tool, we should try to ask them does it follow ASA system, ORS system or NRS system.

## NRS System of Tool Designation

Representation of tool angles in NRS system of tool designation.



<https://www.minaprem.com/machining/cutter/>

## NRS System of Tool Designation

### Various features displayed in NRS system of tool designation

- Similar to ORS system, NRS system of tool designation also specifies two different rake angles, two different clearance angles, two different cutting edge angles, and the nose radius value in mm.
- Various features of the single point turning tool (SPTT) that NRS system specify are

**Normal Rake Angle ( $\gamma_N$ )**—It is the angle of orientation of tool's rake surface from the reference plane ( $\pi_R$ ) and measured on normal plane ( $\pi_N$ ).

**Inclination Angle ( $\lambda$ )**—It is the angle of inclination of tool's principal cutting edge from the reference plane ( $\pi_R$ ) and measured on cutting plane ( $\pi_C$ ).

**Normal Clearance Angle ( $\alpha_N$ )**—It is the angle of orientation of tool's principal flank surface from the cutting plane ( $\pi_C$ ) and measured on normal plane ( $\pi_N$ ).



Now this is the plane which we are talking about. So there are three reference planes. One is  $\pi_c$  which you can see along the cutting plane. The other one is  $\pi_r$  reference plane and the next one is  $\pi_n$  which is normal to it.

If you can see both the figures like this is one plane, one. This is the other plane and this is the third plane which is at an angle. So now when we try to take a tool and we try to section the tool, so let us try to take section AA. So this is AA, right? So when we try to section AA and we try to project it, you try to see here  $\alpha_O$  and  $\gamma_O$  is present.

Now we try to incline at an angle and then we try to cut it. So that is BB. We try to project BB. We try to get  $\alpha_N$  and  $\gamma_N$ . So now you can see there are three planes. Where are the three planes?

You can see here there is a orthogonal plane  $\gamma_O$ . So this is orthogonal reference. So you try to take a section along it which is represented as BB. So when we try to cut and then project the section you get a BB section here where in which we can get two angles the  $\alpha_n$  and  $\gamma_N$ . Then when we try to take a section which is normal reference,  $\gamma_N$  which is a normal reference plane, we try to take a section AA. When we try to project it it comes as you try to get  $\alpha_N$  and  $\gamma_N$ , ok.

These are the two things one is  $\alpha_n$   $\gamma_N$  then  $\alpha_O$ ,  $\gamma_O$ , right? And then you try to have an inclined angle  $\lambda$ , which is nothing but the angle between the orthogonal and the normal is  $\lambda$ . And along the cutting edge, what you have is the reference plane  $\pi_R$ . So now you can see  $\pi_N$ ,  $\pi_R$ ,  $\pi_O$  is there. And then this  $\pi_R$ , when we try to draw it, you can try to see the other angles will be seen. Now, various features displayed in NRS system of tool designation. Similar to ORS system, NRS tool designation also signifies two different rake angles, two different clearance angles, two different cutting angles and one nose radius.

So, that is how it is. You will have angle that is rake will be 2. Then you will have clearance will be 2. Then you will have cutting will be 2. And then you will try to have a nose radius.

That will be 1. The various features of a single-point cutting tool that the NRS system specifies are the normal rake angle. You have an inclination angle,  $\lambda$ . Then you have a normal clearance angle,  $\alpha_n$ . So, the normal rake angle is the angle of orientation of the tool's rake surface from the reference plane and measured on a normal plane.

Please go back to these figures, wherein there is a plane and an axis. Please understand that, and only then can you interpret this. The normal rake angle,  $\gamma_N$ , is the angle of orientation of the tool's rake surface from the reference plane  $\pi_R$ . Where is  $\pi_R$ ?  $\pi_R$  is here.  $\pi_R$  and measured on the normal plane  $\pi_N$ . Where is  $\pi_N$ ?  $\pi_N$  is the normal plane, which you can see here.

$\pi_R$  is the reference plane;  $\pi_N$  is the normal plane. So, that is called  $\gamma_N$ . What is the inclination angle? It is the angle of inclination of the tool's principal cutting edge from the reference plane  $\pi_R$ , measured on the cutting plane  $\pi_C$ . This is the inclination angle. So, this is the angle which is given here.  $Z$  orthogonal and  $Z$  normal, the angle inclined is  $\lambda$ .

Normal clearance angle which is seen in this plane, you can see that is an angle of orientation of the tool's principal flank surface from the cutting plane to measured on the normal plane.

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## NRS System of Tool Designation



**Auxiliary Normal Clearance Angle ( $\alpha_N'$ )**—It is the angle of orientation of tool's auxiliary flank surface from the auxiliary cutting plane ( $\pi_C'$ ) and measured on auxiliary normal plane ( $\pi_N'$ ).

**Principal Cutting Edge Angle ( $\Phi$ )**—It is the angle between cutting plane ( $\pi_C$ ) (which contains principal cutting edge) and the longitudinal feed direction, measured on reference plane ( $\pi_R$ ).

**Auxiliary Cutting Edge Angle ( $\Phi_1$ )**—It is the angle between auxiliary cutting plane ( $\pi_C'$ ) (which contains auxiliary cutting edge) and the longitudinal feed line, measured on reference plane ( $\pi_R$ ).

**Nose Radius ( $r$ )**—This is nothing but the curvature at the tool tip. Similar to ORS system, in NRS system, nose radius value is expressed in mm



The auxiliary normal clearance angle, it is the angle orientation of the tool's auxiliary flank surface from the auxiliary cutting plane measured on the auxiliary normal plane is  $\gamma_N$  prime. So the principal cutting angle is  $\Phi$  and this will be  $\Phi_1$ . So which again we can see from here,  $\gamma_N$  and  $\Phi_1$ .

So the principal cutting edge angle is  $\phi$ . It is the angle between the cutting plane which contains the principal cutting edge and the longitudinal feed direction measured on the reference plane. The auxiliary cutting edge will be  $\Phi_1$  and the nose radius is  $r$ .

Thank you very much.